Friendly Heating: a holistic study of synergism between microclimate, air pollution and cultural heritage

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Cultural heritage is preserved in many places, at different levels of environmental safety. Air pollution, microclimate and human impact are determined by the location and the use and their synergisms increase the deterioration rate. The consequences are even worse in the case of periodic microclimate unbalances. Museums and archives are in a fortunate situation, being used under the supervision of specialists in conservation. In most cases, however, temperature and relative humidity undergo dangerous daily synergistic cycles whose consequences are still quantitatively unknown. The consequences are even more dramatic in the case of more enhanced weekly cycles, as it happens in churches that are at the same time place of worship and exhibition rooms for many artworks. In many cases, especially in the Art Cities, people pay to visit a Church, which is transformed into a museum in business days, and in worship place in holidays.

In practice, Churches are museums differently managed and in the borderline case they behave as ageing chambers for artworks. The study of the extreme conditions found in such cases is beneficial for museum and archives conservators. To this aim, the FRIENDLY-HEATING project studies the indoor air quality (both chemical and physical) in terms of causes and effects in a relevant case study and proposes an innovative heating system to minimize the impact on artworks. The global approach will be evident from the whole set of related presentations.

Churches have been utilised for centuries in the cold, and when they have been heated, artworks suffered or were dramatically damaged. The Temperature rise during services causes Relative Humidity to drop, and paintings on canvas and other artefacts with low thermal inertia, dehydrate and shrink. As opposed, frescoes, which have high thermal inertia likely remain below the Dew Point raised by people breathing in crowed conditions suffer from moisture condensation. The ideal solution is to utilise the church as if people were not in, keeping churchgoers comfortable, but leaving the church in the cold, as it was before the use. FRIENDLY-HEATING is based on some low-temperature (50°C) heating elements (based on Joule effect on graphite granules or glass doped with metal oxides) that emit infrared radiation at 8.6 mm peak wavelength. The maximum temperature is self-regulated. Should T exceed an upper physical limit, the expansion of the graphite coating offers a natural cut-out of the system. A thermostat is added for further regulation. All the elements have been tested in the laboratory (CNR-ISAC, Padova) and simulated (FAGO, Eindhoven, The Netherlands).

FRIENDLY-HEATING mainly uses low-temperature sources of radiant heat: most infrared and only a very minor heat supplied to air. More than one heat sources are strategically located on each pew in order to respond to the physiological demand of heat in different parts of the body (foot, legs and hands) and reach the highest comfort level, while other commercially available pew heating systems are based on one underseat element only, obtaining a minimum level of comfort. The altar area is solved with a heating carpet on the floor, and a heating altar-cloth on the altar.

The combination of the above underseat radiant elements, heating strips (underkneeler strips and hand-warmer panels) and heating carpets may solve many situations. For instance, a Mosque can be made comfortable with the use of heating carpets. An Orthodox church may take advantage of radiant elements on the seats placed around walls and heating carpets on the floor in the central part of the church. An application is underway for the Stavropoleos Basilica, Bucarest.

The church in Rocca Pietore (Italy) was chosen for the study, on the Alps at 1150 m a.s.l., for two reasons: (i) the local climate is very cold, and represents a severe test, (ii) the church has many artworks of different types, i.e. a good test for conservation. After the success of the first church, another installation was made at S. Stefano di Cadore, also on the Alps.

Continuous monitoring of both the indoor microclimate and the response of wooden statues and frames (ICSC, Kraków, and *Zajaczkowska – Kloda* Lodz, Poland) has shown that the novel systems keeps heat concentrated in the manned area, avoiding any impact on artworks, either located on walls or the ceiling. With the novel heating system also the internal air motions, the deposition of suspended particles and the surface soiling were reduced. Air pollution and deposition were carefully monitored both inside and outside (UIA, Antwerp, Belgium). Air motions and difference in temperature between air and surfaces are highly relevant for soiling of frescoes or murals. In addition to air motions, the ceiling temperature was measured with remote sensing in order to investigate the overheating generated by heat escaping from the seated area during the time of a normal service (CNR-ISAC, Padova). With the old hot air system, the ceiling was overheated by some 10°C after a 1 hour operation. On the other hand, with the early prototype of the novel heating system, the increase in ceiling temperature was very modest <0.5°C. A comparison of the daily range of air temperature and relative humidity measured near the altar in the days in which the old hot air, or the novel heating system were operated during liturgical services, showed two distinct clouds of scattered data. The popular hot air heating system falls within a risky area; the novel system in absolutely safe conditions. The first key goal, i.e. artwork conservation, has been successfully reached.

Comfort is the second key goal. The equilibrium temperature measured on a blackbody strip situated in the middle of each row of pews to represent the effective temperature felt by a standing person (CNR-ISAC, Padova). Even when the indoor natural temperature was near to zero, the seated area was mild on average, with warm feet and legs (i.e. 15-20°C), and moderately cool head, as desired. Comfort has also been measured from the skin temperature of some volunteers (FIOH, Oulu, Finland). Internal temperature and turbulence profiles are under study to assess a comfortable balance between air speed and up-draught temperature level in a cold environment. The problem is open and under study because the threshold for air motion discomfort is known only for room temperature T around 20°C (NEN-EN-ISO 7730 standard), not for T close to 0°C. At low temperature and appropriate speed, mild updrafts might provide a positive sensation; the appropriate balance is still unknown.

Energy saving is the third goal. The vertical profiles demonstrated that with the popular, old hot air heating system, less than 7% of the heat was kept in the manned area warming the churchgoers up, and more than 93% of the heat was lost, being dispersed in the church. On the other hand, with the early FRIENDLY-HEATING prototype (Milanoprogetti, Milano; FH Padova), up to 70-80% of the heat remains concentrated in the pew area warming people up. The bulk warming up efficiency is some ten times greater than the hot air heating system and constitutes a very efficient way to save energy.

Another key feature is the problem of moisture, ignored by other systems.

In conclusion, the novel system leaves church and artworks in their natural, unaffected microclimate and keeps heat, as far as possible, concentrated in the area where people stay. It avoids temperature and moisture cycles and microclimate perturbations. Briefly, it allows utilising the building as it were unmanned. It is the first heating system that takes into consideration not only temperature, but also the excess moisture released by churchgoers, removing moisture too. A further advantage is that it needs only a wire for power supply, so that its installation does not cause damage for adaptation works to historical buildings.