

## Pore Ventilation (Sometimes Called Dynamic Insulation)

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This paper will give an introduction to Pore-ventilation, with a brief history of its development, and an outline of the potential benefits to be gained by client and user. The principles behind the technique and both theoretical and built case studies are presented with illustrations.

### What is Dynamic Insulation?

A building which is built to allow gases to pass through the whole fabric is termed a "breathing construction". The extremes run from no wall (roof / floor) at all, through to a completely air and moisture tight element (only theoretically achievable). The gradations between the two extremes are illustrated in Figure 1, which indicates how building constructions range from very tight - through moisture transfusive - to air transfusive, or "open".

The motivation behind the use of Pore-ventilation is multifold. It is concerned with:-

- improving insulation performance
- improving indoor climate
- controlling interstitial condensation
- reducing quantity of mechanical systems

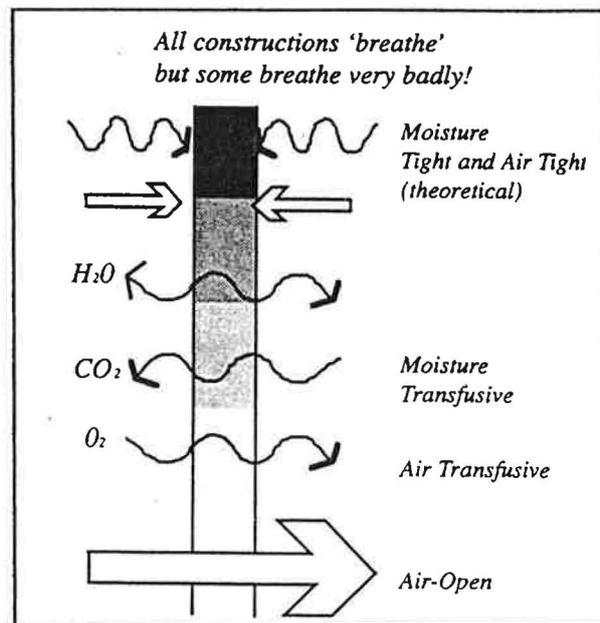


Fig 1 degrees of transfusion

Over the past 20 years energy conservation measures have resulted in buildings which are becoming increasingly tightly sealed, and often this has resulted in the use of constructions which do not breathe well.

There is increasing concern over the potential health hazards resulting from occupying a tightly sealed space, where the air is polluted by toxic emissions from synthetic materials - the use of which has seen a dramatic increase over this same period<sup>1</sup>. These emissions - together with micro bacterial activity - increase with higher relative humidity (>60% RH) and become more aggressive with low relative humidity (<40% RH).

There is evidence that mechanical ventilation is a significant contributing factor to the pollution of the indoor air, because of the concentration of pollutant particles in the ductwork and the ability of other particles to pass in the opposite direction to the extracted air. Meanwhile external air quality is known to be deteriorating, particularly in urban locations and adjacent to busy roads.

<sup>1</sup> Leif Øye NTNU Trondheim

Concern regarding health is particularly the case with timber construction where the use of plastic vapour barriers is standard practice. The plastic vapour barrier reduces the potential for vapour storage (buffer) and this can result in wide swings in the indoor relative humidity which encourages the activity of mould, mites, bacteria and viruses (at high RH) and distributes it widely (at low RH)<sup>2</sup>. The Europe-wide tendency for building standards to be introduced which will require buildings to be more sealed than at present, could be setting the context for future health risks.

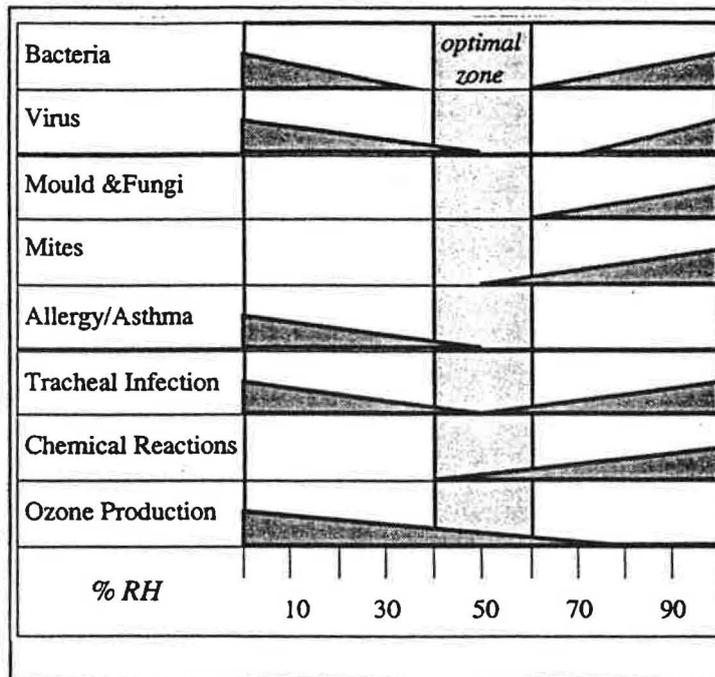


Fig 2 Relative Humidity and Health

Breathing walls differ from conventional timber frame construction by not using a plastic vapour barrier whereby moisture is prevented from entering the construction. Instead there is controlled and continuous moisture migration through the structure allowing moisture vapour to escape slowly without condensation occurring. This is achieved by specifying hygroscopic materials. All materials should be as vapour open as possible, and the vapour resistance should be a little higher on the inside than the outside. It is important to avoid uncontrolled air leakage from the warm side to the cold side as this might cause condensation. This is most simply done by creating a small negative pressure inside the building. Ventilation to the cool outside of the construction allows natural moisture migration to occur, thus complying with the Building Regulations<sup>3</sup>

#### Why use it, and who benefits? - the Client and user

The Scottish Sports Council, have commissioned three studies from the Gaia Group to investigate the use of Pore-ventilation in sports buildings:-

*"One of the many benefits of taking part in sport is that of improved health. In order to encourage more people to participate in sport or those participating to do so more frequently, the Scottish Sports Council, inter alia, promotes and assists the development of sports facilities which are user and environmentally friendly. That is healthy buildings for healthy pursuits.*

*For a number of years now there has been a move to provide comfort levels to meet customer expectations eg higher water temperatures in swimming pools, increased heating and ventilation in sports halls and air conditioning in fitness suites. This has resulted in increased energy usage but not necessarily a good quality internal climate.*

<sup>2</sup> Torsten Andersen

<sup>3</sup> via BS 5250 1989 (Control of Condensation in Buildings).

*Most sports facilities operate at a loss, therefore running costs have to be controlled if operating costs are to be kept within acceptable limits. As energy costs are second only to staff costs, the Scottish Sports Council has developed a programme of demonstration projects aimed at reducing these while ensuring that the internal climate is suitable for the activities taking place. Part of this programme has been the research into pore-ventilation carried out by Gaia.*

*Results are published in Research Report N° 43<sup>4</sup> and a further publication due out soon, which show that pore-ventilation:*

- *can provide a good quality internal environment;*
- *is likely to reduce capital costs;*
- *can reduce energy consumption and therefore reduce operating costs; and*
- *is environmentally sound.*

*We are now developing a project with Gaia to demonstrate the cost-effectiveness of pore-ventilation in creating a sports facility which is user and environmentally friendly."*

*Ian McKemzie, Scottish Sports Council*

### **When is it appropriate? - History and background, present and potential situation**

The use of dynamically insulated construction dates far back in history in Norway from primitive shelters and huts through to modern buildings. In particular dynamically insulated ceilings have a long tradition in Norwegian animal buildings.

After valuable preliminary work by Pattie in Canada in the early 1960's<sup>5</sup>, Trygve Graee at the Norwegian University of Agriculture (Ås) started to develop Pore-ventilation in ceilings in farm buildings (mid 60's)<sup>6</sup>. This sprouted a number of smaller groups all over Europe developing different aspects of Pore-ventilation. As well as much work undertaken by both the Norwegian and Swedish Building Research Institutes one of the key figures investigating the detailed physics was Helmut Bartussek from Austria<sup>7</sup>. This was still primarily in agricultural buildings where the interest centred around the extreme moisture conditions. Slowly it was also introduced into housing, schools and office buildings and to great effect in sports halls.

The principle was originally developed using conventional building materials in agricultural buildings, however the system is now developing with environmentally benign materials and not just in animal buildings but also for storage and industrial buildings. In particular it has achieved good results in potato and vegetable stores, where the requisite high relative humidity has been maintained by the use of wet capillary cloth hanging inside the walls. Some of these buildings are designed for temperature differences of >40° C and relative humidity inside of 95-100%. They have also introduced the system into aquaculture buildings to good effect.

All these buildings incorporate a very porous ceiling with a low pressure drop, but with extract fans as the control rather than pressurising fans in the cold loft. Moisture is not allowed to enter the loft space from the interior, as this is part of the climatisation of the indoor climate. As the building gets rid of moisture through the construction the ventilation rate can be reduced. It is important that the loft space is well ventilated.

<sup>4</sup> Gaia for Scottish Sports Council 1995 Research Report N° 43

<sup>5</sup> Pattie (see bibliog)

<sup>6</sup> Graee (see bibliog)

<sup>7</sup> Bartussek (see bibliog)

In the 1970s the Norwegian Institute of Technology at the University of Trondheim developed a dynamically insulated ceiling with a built-in heat store. Their latest report<sup>8</sup> indicates that "The extra benefits from this system in addition to the energy saving are:

- filtration of the ventilation air
- well distributed and preheated ventilation air and no draught
- a system that easily dries out moisture that might enter the wall."

NBRI have developed standard 'deemed to satisfy' details for their Building Detail Catalogue, and have developed a rig to monitor any indoor and outdoor climatic conditions.

In Sweden Skanska ab and others have developed the "Optima ceiling system" - a prefabricated dynamic construction system. In principle it is the same as the system used in the Baerum Nursing Home and Solvik housing for elderly people<sup>9</sup> - where a false ceiling and grilles distribute air below the porous membrane between the rooms and the loft.

What is interesting now is the debate between the simple, low technology solutions in the dynamic/ diffusive insulated agricultural buildings (Graee, NTH, Bartussek, Gaia, etc.) and the high / complex technology schemes of the services engineers (NBRI, AIS, etc.)<sup>10</sup>.

### How does it work? - principles

The process of drawing external air into the inside through a layer of porous insulation material within the roof or wall construction is called pore-ventilation.

The flow of air is controlled by a slight pressure differential, either an increased pressure on the outside, a reduced pressure on the inside or a combination of these. This can be created either mechanically or naturally by means of stack effect.

The air transmission operates through a large area and the velocity required to ventilate the internal space ( less than 10m/hr) is well below that when a draught becomes noticeable .

The ventilation heat losses in swimming pools can be more significant than the fabric heat losses. Nevertheless, there are reasons to believe that the requisite airflow for the control of humidity is less than in conventional ventilation systems. This is due to the characteristics of the internal airflow in a pore-ventilated building.<sup>11</sup>

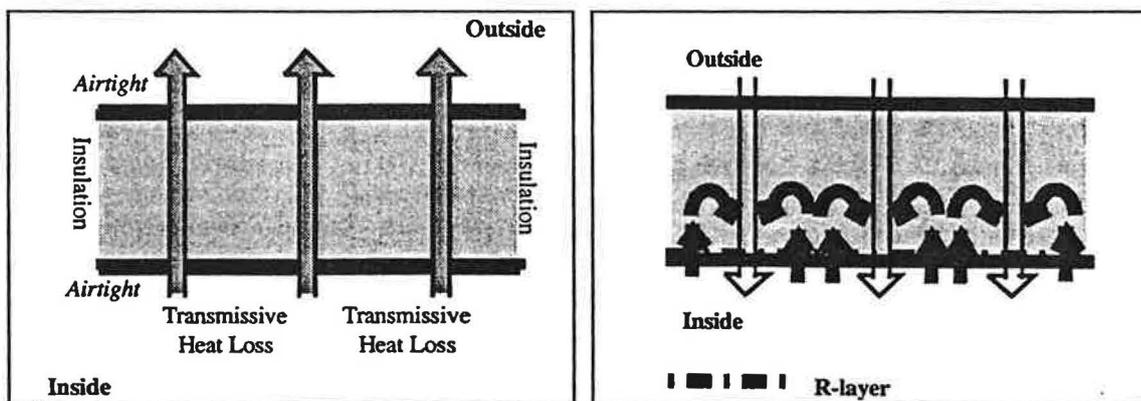


Fig 3 heat exchange in a dynamic wall

<sup>8</sup> "Dynamic Insulation in a Wall" (Arvid Dalehaug 1993)

<sup>9</sup> see SSC Research Report no.43

<sup>10</sup> Jon Brunsell NBRI, Oslo, 1994

The incoming air is warmed by the heat escaping through the construction and the entire insulation acts as a large heat exchanger. In theory the U-value in such a construction, called the dynamic U-Value ( $U_{dyn}$ ) can be reduced towards zero.  $U_{dyn}$  depends on air velocity. With the velocities operating within swimming pool halls heat recovery of 75% - 99% can be anticipated. This indicates that a reduced thickness of insulation could be used in a pore-ventilation construction. Further heat can still be recovered from the extracted air.

Due to the low velocity and the large area through which the air flows this system is a much more efficient filter than a conventional mechanical ventilation system where regular maintenance is essential to the performance. There would appear to be no problem with the insulation material becoming clogged with particles. Tests have shown that the lifetime of the insulation should be many times that of the building. However the quality of the external air is a factor.

The constant air stream from the cold to the warm side of the construction effectively ventilates the the construction and prevents water vapour from creating a hazard.

### **Materials**

In principle any open-porous material is suitable for a pore-ventilation system and information on the porosity levels are available for most materials. If the porosity is sufficiently fine, air transmission - at these air velocities - is directly proportional to the pressure difference across the material from one side to another.

Control of the air flow in a pore-ventilation system is achieved by creating an even resistance in the dynamic insulation layer, normally by the inclusion of a cloth (polyester) or perforated cellulose paper, plastic or unwoven cellulose.

Following early design and build single houses by the Gaia Group in Norway (1984/5) it was discovered that a number of product and material properties provided by manufacturers were not sufficiently accurate. For example porosity values could be incorrect by a factor of three, and moisture absorption figures were also imprecise. Both these pieces of information can be crucial at the design stage, if the system is to operate optimally.

Tests have been carried out by the Norwegian Building Research Institute into the performance of various insulation materials when used in a ceiling construction. The most suitable materials have been found to be fibre mats, cellulose fibre, Leca (block and bulk), or porous concrete blocks (but not aerated blocks). However particular attention must be given to design and installation of the joints between individual panels or mats and the supporting structure.

It is most important that design and site supervision of all details of the system is carried out by one organisation who accepts responsibility for the proper functioning. Otherwise simple mistakes can be made due to operatives misunderstanding the system, e.g. fans installed to extract air from loft spaces instead of pressurising the loft.

### **Other Developments**

The heat storage capacity of solid walls which are pervious to air can be used during the summer to condition the incoming air and this can effectively dampen the diurnal temperature variation of the incoming external air.

A further development called the Solpor system involves addition of a layer of glazing to the outside of solid walls and the use of solar energy to heat the air to be transmitted into the inside. The available heat depends upon the location and orientation but experiments have shown that this could amount to 200 to 300kWh/m<sup>2</sup> per heating season<sup>12</sup>.

### Where does it work best? - Case studies

Beyond these domestic projects a series of buildings were constructed by Oslo Engineers Projekt Arbeit a/s and these were visited by the Gaia Group in preparation for their research for the Scottish Sports Council in three projects.

The following are the summaries of the case studies

#### Rykkinnhallen Sports Hall Baerum

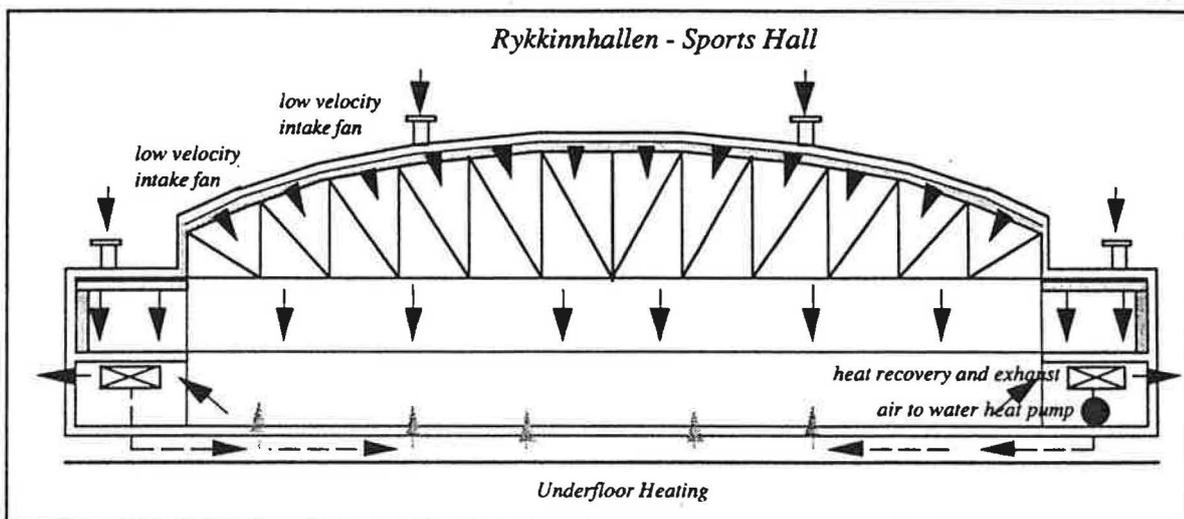


Fig 4 section through Rykkinnhallen hall

This 4500 m<sup>2</sup> facility opened in 1992 comprises an existing sports hall with a new basketball hall with 35m-span curved roof.

The basketball hall and associated fitness studio are ventilated through a dynamic-insulation roof, pressurised by low velocity roof-mounted fans. Air enters and is preheated through a 200mm thick cellulose fibre insulation layer held in place by an open-weave matting giving fine-tuning of the porosity level of the overall roof construction. The air is exhausted via grilles at approximately 2.5 m above floor level and the heat is taken from this via an air-to-water heat pump which feeds to three calorifiers which in turn feed the under floor water-borne heating system. In summer conditions the under floor system can be used for cooling.

Due to the minimum amount of technical systems required for this building the total area of the Plant room is about 25 m<sup>2</sup> (0.6%).

<sup>12</sup> AIS Utvikling a/s has developed a Solpor (passive solar) technique patented as the AIS System. They have further developed the system into a combined ventilation, heating and cooling system.

The CO<sub>2</sub> levels have been monitored over the past two years and findings confirm that at the low pressures being operated for this building the CO<sub>2</sub> is able to exhaust through the permeable roof membrane in the opposite direction to the flow of the incoming air.

Other monitoring on the project thus far indicates energy savings of up to 50% over a conventional Norwegian construction.<sup>13</sup>

### Baerum Nursing Home

This project is based on the same principles as Rykkinnhallen - but at a very much reduced scale and as a refurbishment to an existing building. It also uses a false ceiling and grilles for its air distribution below the porous membrane between the rooms and the pressurised loft. Extract is from the bed sitting room via the en suite bathroom so that moisture-laden air is removed at the last point, and does not percolate into the living area.

The most significant aspect to this project was the (subjective) sense of freshness of the indoor air, which is very unusual in a building where there is a high degree of medical support to residents in need of constant care.

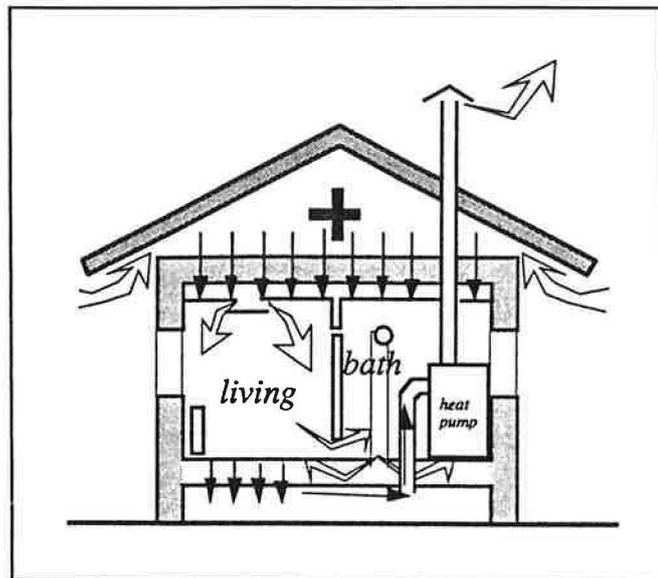


Fig 5 section through single storey building

### Gullhaug Sheltered Housing

The principle in this scheme is one of bringing the air in through the walls rather than the ceilings. This is an appropriate solution for a two storey building where a cold loft is not an option. Extended eaves at high level act as intake points and the air is drawn down through the cavity of the external wall, preheated and precleansed through the insulation and brought into the room itself below the window cill, over a convection heater. The exhaust air is taken out through the wet areas (kitchens, bathrooms).

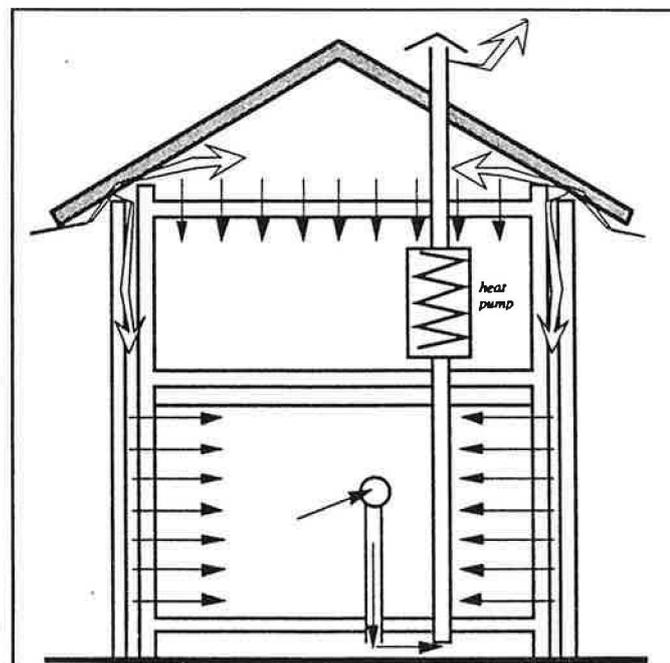


Fig 6 section through two storey building

<sup>13</sup> Harald Netti (private monitoring '94-'96) and Lars Myhre A/s (project commencing 1996)

## Research Projects

The following projects comprise a series of research studies investigating the feasibility of Pore ventilation for sports facilities in the Scottish context.

### DESEC (Drumchapel Ecological Sports and Environment Centre)

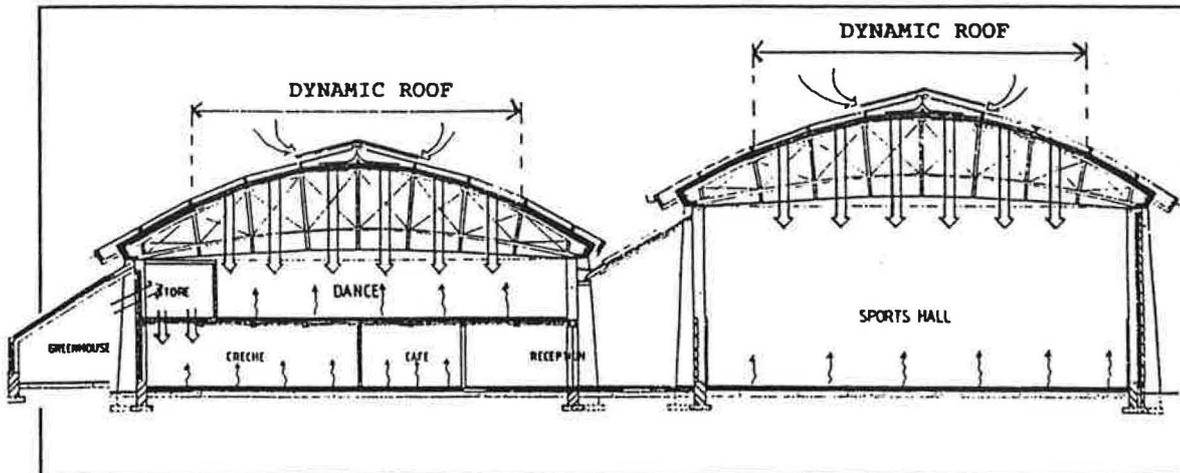


Fig 7 section through DESEC Building

The whole of the building at Drumchapel is proposed as a prime example of the use of dynamic insulation principles - in combination with carefully selected natural materials, which will complement the design for the indoor climate. The project includes breathing roof, wall and Solpor (Trombe wall) systems, and includes a large amount of porous surfaces to assist in the control of indoor humidity.

### Craighalbert Swimming Pool

The Centre for Children with motor neurone disease has a stringent indoor climate requirement - involving an air temperature of 36°C and a water temperature of 35°C, which - together with a high chlorine air environment - gives a hostile wet-side environment. It was considered therefore that if it was feasible to use pore-ventilation in this context then it would be even more viable for a conventional wet centre facility. The computer studies indicated a net saving in energy over an equivalent contemporary pool, and a measured improvement in indoor climate. The report concluded with a recommendation that the Scottish Sports Council proceed to a demonstration project.

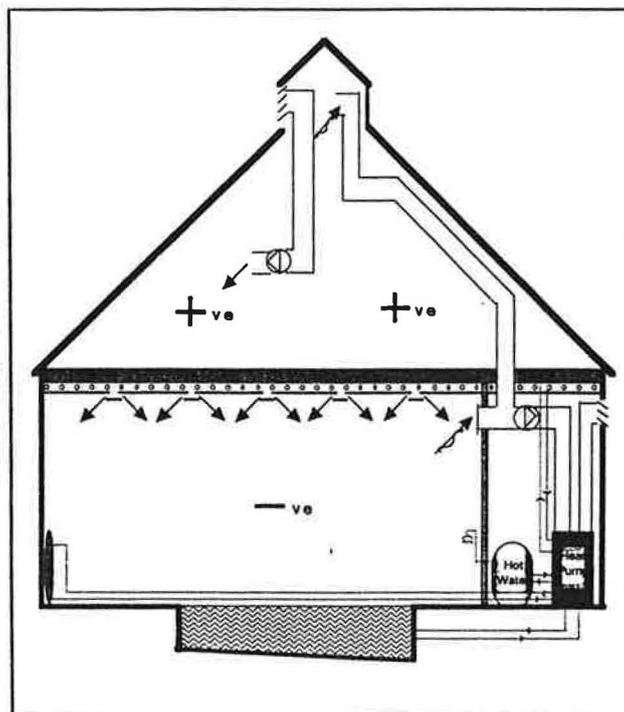
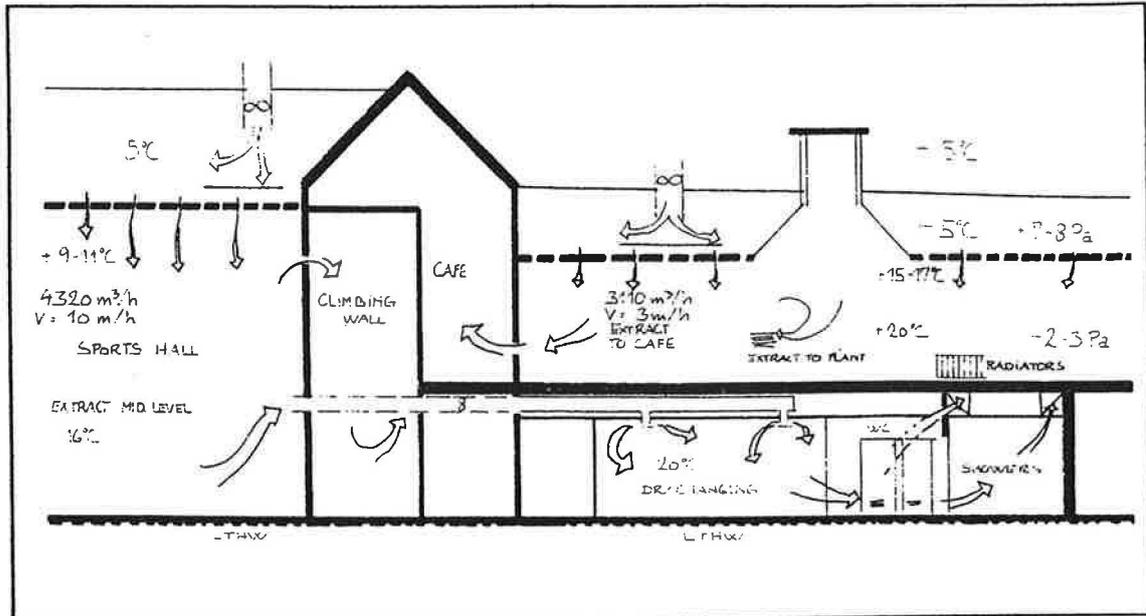


Fig 8 Craighalbert Pool Section

**McLaren Community Leisure Centre****Fig 9 McLaren Centre Section**

Following the recommendation of the Craighalbert Report it became possible for the recommendations to be developed in a project in Callander, where both wet and dry side facilities were being proposed. The project is due for completion in 1997, and will be monitored for its effectiveness in achieving the intended goals.

**Conclusions**

Evidence from existing (monitored) projects would indicate the potential benefits from the use of Pore-ventilation are real. These include: a reduction in energy consumption ranging from dramatic to significant; an improvement in indoor air quality due to control of relative humidity; filtering of incoming air in a passive manner; reduction in ambient toxic gases; control of interstitial condensation and reduction in M & E Plant.

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## Bibliography

Åström T: "Skolhus & Miljø" (Schools & Environment) 3 - 1992

Austin Jane "Survey of Asthma in Children in the Highland area" (Daily Mail 26/4/95)

Bartussek, H: "Luftdurchlässige Konstruktionen" (Airtransfusive construction) SchweizIngenieur &Architekt 30-31/86

Brunsell Jorn T: "The performance of Dynamic Insulation in two residential buildings" Air Infiltration Review, Vol. 16 N° 4 1995.

Graee Trygve: "Pustende bygningskonstruksjoner", (Breathing building Construction) Plan & Bygg 1979 - Graee Trygve: Paper ASEA Stillwater, Oklahoma 1974

Guhl, A&Nicander-Brederg, H: **Två Förstudier av luftkvalitet i byggnader med dynamisk isolering**".(Study of Air Quality in 2 Dynamic Insulation Buildings) Stockholms Universitet 1988

Hines J: "Breathing Walls" Architects Journal 26/1/95

Jansson A: "Mätningar av dynamisk isolerings filtrerande förmåga" (Measurement of porosity in Dynamic Insulation) Arbetarskyddstyrelsens arbetsmedicinska avd. 1981

Liddell H: "What the Breathing Wall is it all about?" ACTAC Conference, Leeds 4/95

Liddell H. Roalkvam R: "Pore ventilation in Sports Halls" Research Report no 43 Scottish Sports Council '95.

Sällvik K: "The influence of clogging on the air penetrability in porous materials used for air inlets". Internationales Symposium über Porenlüftung 1988, "Porenlüftung 1988" BAL Gumpenstein, Irnding, Austria.