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CLIMATIZATION OF INDOOR SPEED SKATING RINK

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SUMMARY

An indoor speed skating arena (400 m) is now being built at Hamar for the 1994 Winter Olympics hosted by the city of Lillehammer, Norway. The volume enclosing this 22.000 m² arena is approximately 350.000 m³. The concept of creating such an enormous volume, and still being able to keep control of the climate conditions, represents a significant challenge. Today, only 2-3 other arenas of similar size exist, and the main goal for a new rink must be to offer the best conditions available, both for spectators and not the least for the athletes. This task is both demanding and interesting. The inspiring part is that this challenge can to a large extent be solved by the HVAC-discipline.

The paper describes the numerical simulations which have been performed in order to optimize the climate in the skating rink during the competition - and planning phase. The work performed has aimed at three main targets:

- Climatization for maximum athletic performance.
- Climatization for best possible thermal comfort.
- Climatization/energy control for an environmentally and economically acceptable post-olympic period.

So far, the results obtained from the simulations have proven successful. Combined with engineering calculations, decision making has been vastly improved.

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INTRODUCTION

An indoor speed skating arena (400 m) is now being built at Hamar for the 1994 Winter Olympics hosted by the city of Lillehammer, Norway. The volume enclosing this 22.000 m^2 arena is approximately 350.000 m^3. The concept of creating such an enormous volume, and still being able to keep control of the climate conditions, represents a significant challenge. Today, only 2-3 other arenas of similar size exist, and the main goal for a new rink must be to offer the best conditions available, both for spectators and not the least for the athletes. This task is both demanding and interesting. The inspiring part is that this challenge can to a large extent be solved by the HVAC-discipline.

THE PROBLEM

By constructing a protective building envelope over the entire ice surface, the cornerstone has been laid for optimum athletic performances. Thus, the distance between success and failure is marginal. When shielding an ice rink from environmental loads, you will simultaneously enclose a number of unwanted internal loads in the arena. These are:

- Heat load from persons, lighting and other technical equipment.
- Moisture from persons and clothing.
- Insufficient and/or Inadequate ventilation.

As seen at other large international championships, this may give problems related to fog and condensation. Simplified, the problems are two-fold: [1]

1. In speed skating where the classification is absolute in time and related to skaters in other heats, a marginal change in the conditions can be severe. One could state that climate control must focus on ATHLETIC PERFORMANCE.

2. The climate conditions will also have a great influence on the running costs of the arena, both on a long - and short term. An unwanted scenario will consist of:

- Condensation and mould/rot on surfaces and structural elements.
- Harsh working conditions for the employees.
- High energy consumption.
- Low comfort level for the spectators.

Summarized, the climatic control must also focus on ENERGY MEASURES and THERMAL COMFORT.

THE GOAL

The major goals of all the engineering hours and simulation hours that have been spent on designing and planning the climate control system for the so called Hamar Olympic Hall - The Viking Ship, can be summarized to: Keeping a low temperature, low velocity and low humidity in the vicinity of the ice-surface. This is to reduce ice growth and riming on the speed skating slab.

At the same time, we wish to keep a relatively high temperature from the skaters knee-height and upwards. The reason for this is that the reduction in air density will lower the total drag on the skater. We sort of create an artificial high altitude arena. Calculations performed indicate a possible lowering of 20 seconds on a 10.000 m, provided that the skater is able to produce the same power output in the Olympic Hall as he or she would have done at a comparative outdoor track with the ambient temperature 20K lower; see table 1:

THEORETICAL IMPROVEMENT IN FINISHING-TIMES DUE TO HIGHER AIR-TEMPERATURE		
DISTANCE	OUTDOOR TRACKS	INDOOR TRACKS
500 m	38:00 sec.	37:12 sec.
1500 m	1,58:00	1,55:26
5000 m	7,00:00	6,50:24
10000 m	15,00:00	14,39:00

Table 1: Theoretical calculated improvement due to higher air temperature. Assumed zero air velocity and 20 K higher indoor temperature.

CLIMATIC CONTROL AND ENERGY MANAGEMENT WAS FOCUSED IN THE PLANNING PHASE COMPETITION

During the pre planning phase, before the design and planning team was chosen, a complete Computerized Fluid Dynamics ("CFD") simulation was carried out. The code we used was the PHOENICS, version 1.5, as described in reference [2].

The main objective with these simulations was to establish an understanding of how different ventilation principles would effect high load conditions, both regarding athletic performance and thermal comfort for the spectators.

The results from the comprehensive simulations can be presented by 5 runs: [3]

#1: Wide spread supply-mixing:

Large air supply nozzles 12 m apart, air supply from the ceiling, isothermal. This scattered placing shows distinct 3-dimensional effects, low mixing at the ice-slab vicinity, high air velocities at the stands.

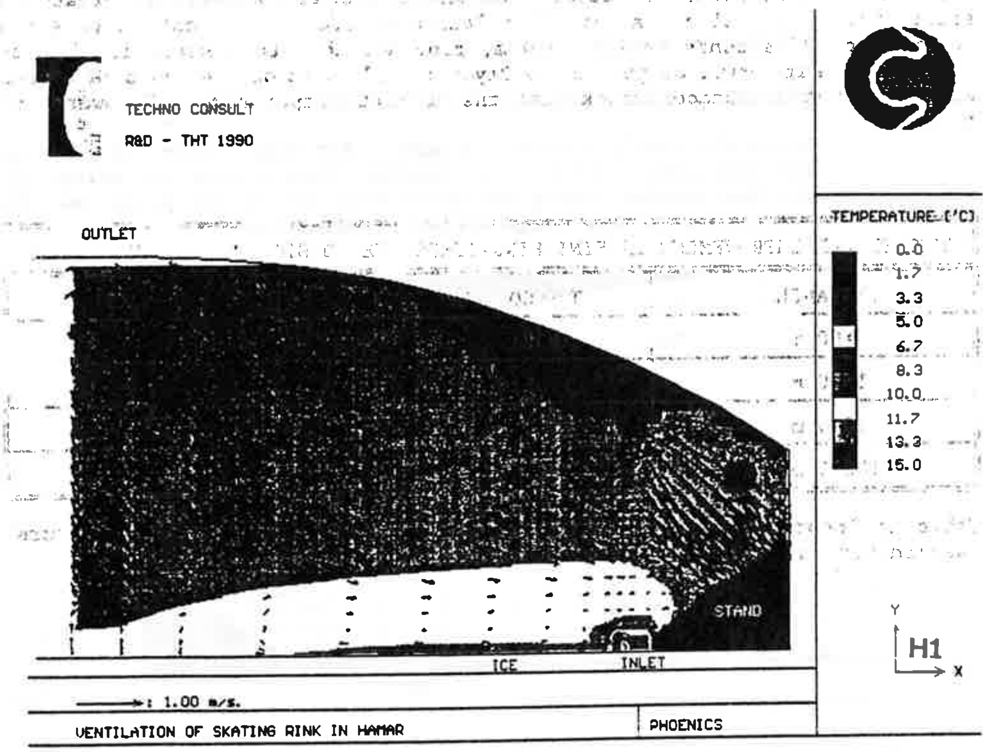

Fig. 1. Wide spread supply - mixing.

#2: <u>Adjacent supply - mixing:</u>

Large air supply nozzles 6 m apart, air supply from the ceiling, isothermal. 2-dimensional ventilation effects, the mixing creates a vortex which impacts directly onto the ice. Large cooling effect in the spectator area.

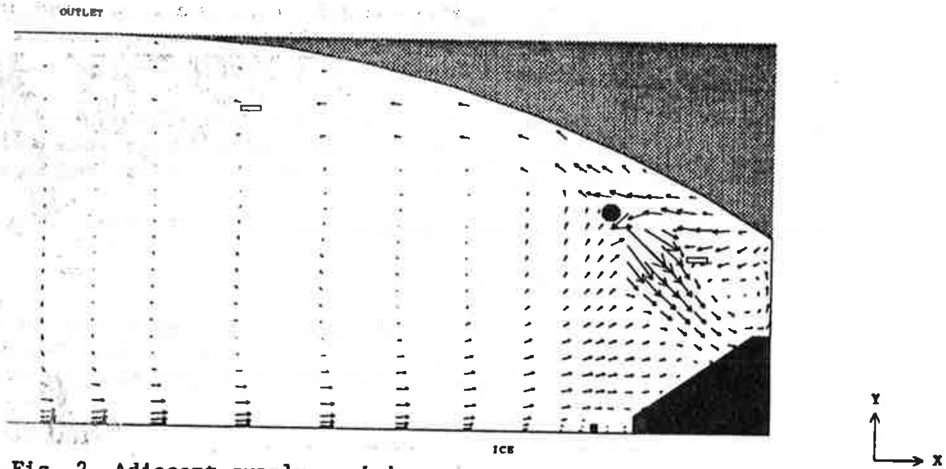

Fig. 2. Adjacent supply - mixing. ⟶ : 2.00 m/s.

#3: <u>Adjacent supply, low air velocity-mixing</u>

Large air supply nozzles 6 m apart. Air supply from the ceiling, low temperature (7°C), low impulse. (Low supply air velocity). The low impulse supply air mixes with the rising plume over the spectators and the large vortex is maintained.

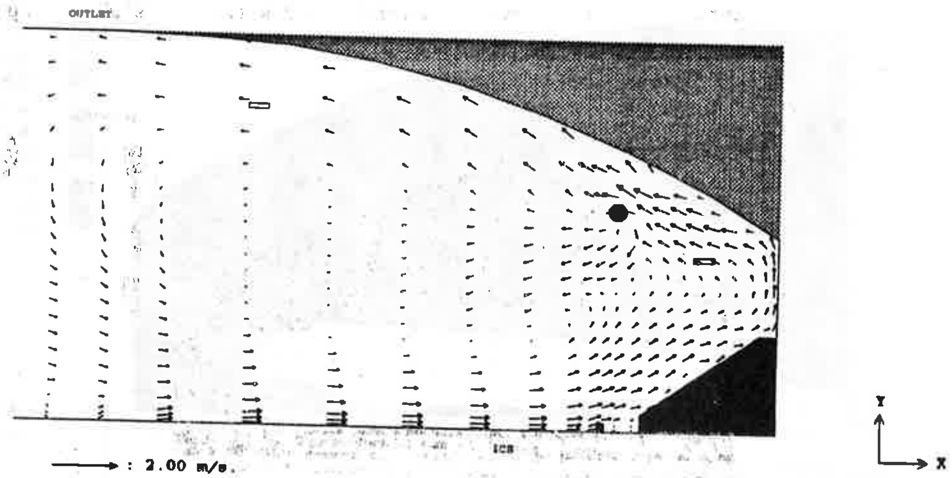

Fig. 3. Adjacent supply, low air velocity - mixing.

#4: <u>Displacement ventilation, low temperature at ice level</u>

The air supply is low in impulse, with a temperature below ambient. Distinct stratification is achieved, very low velocities in the entire arena. Dry, cool air covers the ice slab before turning and entering the stands. The possibility of extracting moist air over the stands using a modified extract hood-principle was also investigated. This solution was not successful.

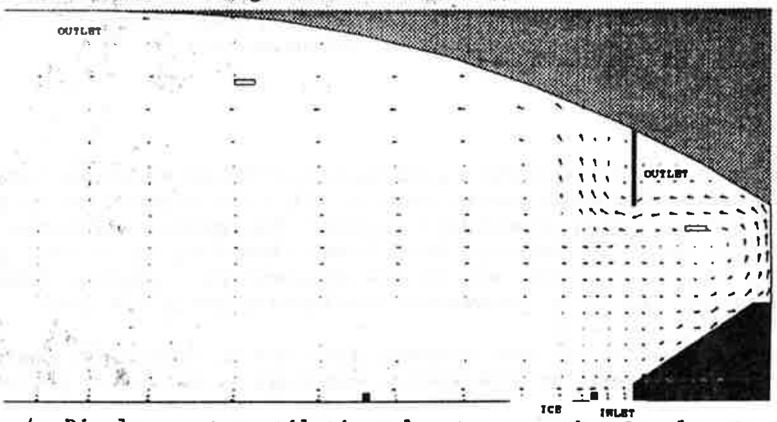

Fig. 4. Displacement ventilation, low temp. at ice level.

#5: <u>Displacement ventilation, higher temperature at ice level</u>

The solution is the same as #4, except that the air supply is kept at 15°C. Stratification tends to last, while the dry supply air moves directly upwards along the stands. A significant increase in moisture transport towards the ice slab is expected.

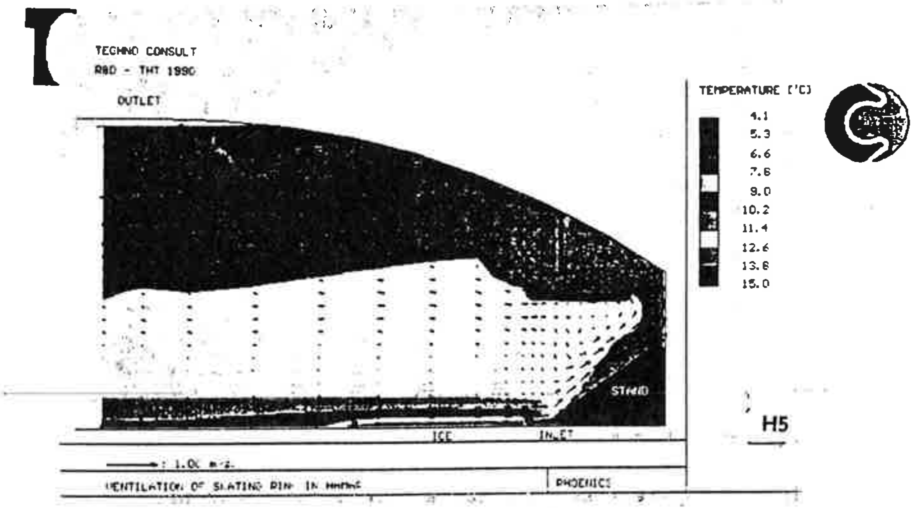

Fig. 5. Displacement ventilation, higher temperature.

After the pre-planning phase, it was decided that the Hamar Olympic Hall was to be put out for a project-/price-competition under a turn-key contract. Taking the need for a high level of technical skill into consideration, the competition was made very special. Focus was put on

- Architectural design.
- Adaptability in the landscape.
- Environmentally acceptable materials and technical solutions.
- Energy management and HVAC systems which will give optimum flexibility as well as low annual costs.

PHASE 1

During phase 1, 6 competitors gave their individual solutions based on a tight description. The scope stated clearly that a low temperature water based heat distribution system should be installed. The energy source was to be waste heat from the ice-machinery. Water-based floor heating is used in the shower rooms, in the wardrobes and in the adjacent fire station. Elsewhere, low-temperature radiators, convectors and heating coils are used.

In order to optimize heat recovery from the machinery, outdoor temperature compensation and water-side series couplings is extensively used.

After an intense scrutiny of the 6 very high quality proposals, 3 finalists were chosen. The evaluation was based on the comprehensive solution, encompassing all engineering aspects as well as economy. The 3 finalists were given individual comments and critics.

PHASE 2

In phase 2 of the competition, more quantitative demands were given for the climate in the large volume. Table 2 gives the exact numbers.

Maximum outdoor temperature	:	+ 10°C
Maximum outdoor rel. humidity	:	80 %
Maximum number of spectators	:	6500

Part of the volume (zone)	TEMPERATURE [°C]		HUMIDITY [g/kg]		AIR VELOCITY [m/s]	
	Normal	Minimum	Normal	Maximum	Normal	Maximum
0.2 to 1.0 m over the speed skating track	10	6	3	4	< 0.1	0.2
1.0 to 2.0 m over the speed skating track	12	8	3	5	< 0.1	0.3
0.2 to 2.0 m over the bandy ice	8	5	3	5	< 0.1	0.3
Over the stands, shoulder height. (60 cm over the seats).	14	12	Functional demands	Functional demands	0.3	

Table 2. The quantitative climate demands given.

In addition, functional demands regarding the indoor climate were made active:

- Fog is not to exist at any place. The local air humidity must therefore be kept lower than the local dew-point temperature.

  Possible measures: De-humidification and/or local heating.

- Condensation and/or drip from the ceiling and walls shall not be found during normal conditions after the ice slab has been prepared for the season.

  Possible measures: De-humidification, local heating, low emissivity materials.

The competitors were also informed that a verification simulation using CFD would have to be performed during the detail project phase. During an intensive evaluation period, all three finalists reached a very high level of technical optimization. During the construction phase, the winning proposal from Ole K. Karlsen, the so-called Viking Ship, has been developed further.

INSTALLATIONS

The technical installations which in December '92 will be operative and ready for creating the best possible ice-and skating conditions, consist of:

- Screw compressors with a maximum freezing capacity of 2,300 kW. This gives a relative freezing capacity of 255 W/m² on the additional bandy surface.

- Refrigerant R717, i.e. NH_3

- A high pressure step (heat pump) with a condenser capacity of approximately 750 kW. This gives the required temperature rise for utilization of the waste heat from the cooling process. The maximum supply temperature for the heating system is 50°C during the winter.

- Total supply-air to the arena: 200,000 m³/h.
  130,000 m³/h is supplied as displacement ventilation with the possibility of dehumidifying the air to x = 4 g/kg. The rest, 70,000 m³/h can be supplied as mixing ventilation.

- De-humidifying capacity of 650 kW, which is supplied from the ice machinery.

- Additional supply air for the wardrobes, technical rooms and office-rooms: 53,000 m³/h.

VERIFICATION SIMULATIONS

As mentioned, the proposed HVAC-design had to pass through a verification simulation. Our CFD-Phoenics version 1.5.3 was also used for this purpose, and the final geometry with revised air-supply principles was established as a new model. [4]. An interesting new aspect in the simulations was the bandy-ice-surface which enlarged the total ice area from approximately 5,000 m² to 10,000 m².

The main circulation in the Viking Ship was found to be dominated by three large, but relatively weak vortexes, the main driving forces being:

- Supply of cold air at the ice level.
- Heat supply from spectators and the lighting system over the stands.

- The lighting system in the middle of the arena.

The main vortexes, as seen in figure 6 are:

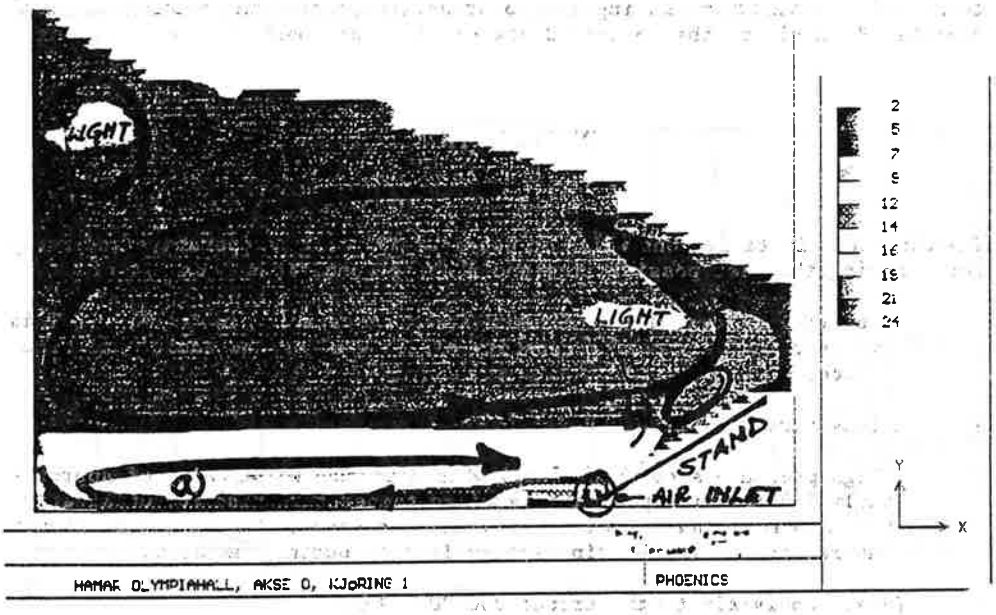

Fig. 6. Main air circulation in the Viking ship.

a) Cold supply air which skims along the ice surface towards the middle, thereafter returning to the stands.

b) The return air passes over the stands and is then accelerated due to the heat rejection from the spectators and lighting.

c) A free standing, small vortex is established over the lighting equipment near the centerline of the Hamar Olympic Hall.

The air volume involved in the vortexes is considerably larger than the total air supply. This explains the marked equalization of moisture over the entire volume, as seen in figure 7:

Fig. 7. Moisture concentration.

Summarized, the air flow-pattern and the moisture distribution show very promising results. As shown in figure 8 , the air velocities will be very low, and the moisture content will always be lower than the dew point temperature. These are factors that will positively affect the individual skaters maximum ability.

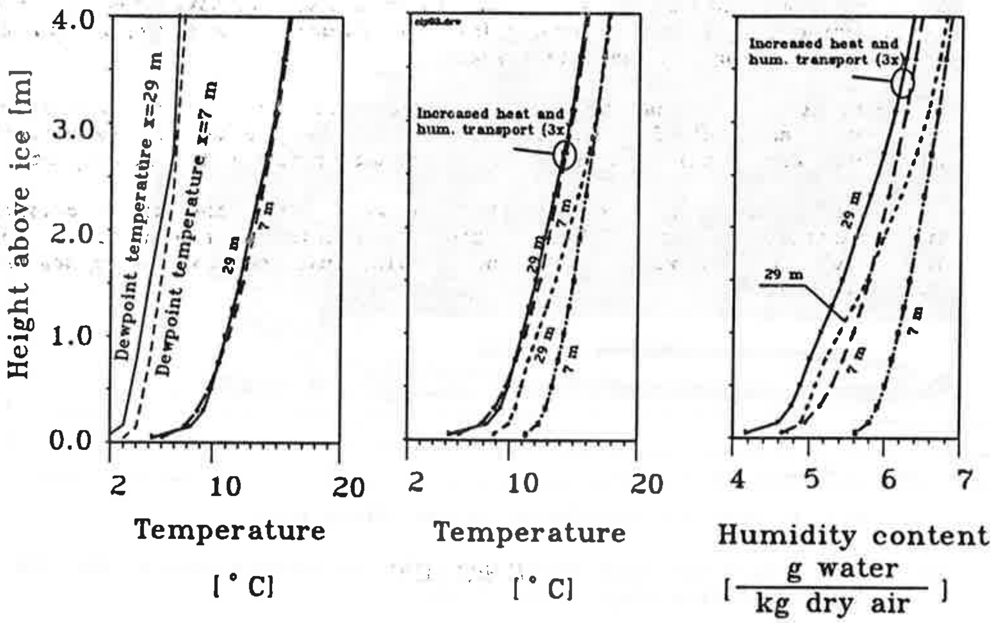

Fig. 8. Air humidity (including dew point temperature) and air temperature is shown versus height above ice surface. Distance from arena center is indicated, x = 7 m and 29 m, represents bandy respectively speed skating surface.

CONCLUSION

For large enclosures, for instance concert halls, industrial halls, sports arenas and shopping malls, the use of advanced flow simulation tools is becoming a powerful advantage in the design phases. We have, however, seen large engineering companies jumping into the CFD market and giving it up after 2 years, accepting considerable losses.

Our experience is, that this tool must be used in a group with strong engineering and fluid flow knowhow. CFD programs have a need for experienced personnel, and therefore a rather large amount of flow oriented projects.

For Hamar Olympic Hall - The Viking Ship, as well as for other of our offshore and industrial projects, CFD-simulations have this far proven costly, but successful. Combined with engineering calculations, decision-making has been vastly improved.

LITERATURE

[1] Madsen, C.N., "Climate conditions in ice rinks". KULDE 5/89.

[2] CHAM, Wimledon Village, England 1990.

[3] Børresen, B.A., et.al. "Hamar Skating arena - prephase ventilation simulation". Sandvika (1990)

[4] Børresen, B.A., et.al. "Hamar Olympic Hall - Numeric simulations of h climatic conditions", Sandvika (1991)