SEOUL SYMPOSIUM ON UNDERGROUND SPACE AND CONSTRUCTION TECHNOLOGY/October, 1993/SEOUL/KOREA

GJOEVIK MOUNTAIN HALL - OLYMPIC ICE HOCKEY RINK PLANNING AND DESIGN

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Introduction

The Gjoevik Mountain Hall was officially opened May 6th '93, by H. M. King Harald, with more than 5000 guests invited, after 27 months of planning and construction.

The Mountain Hall, 61 metres wide, 91 metres long and 25 metres high, is by far the largest rock cavern in the world made on purpose, open for public on a permanent basis.

The Mountain Hall is a demonstration of the leading role of Norwegian rock technology, and the successful cooperation between design, research and construction expertise.

HISTORY

Norway shall host the XVII Olympic Winter Games in Lillehammer in February 1994.

When it was decided that one of the icehockey arenas should be located in Gjoevik, a small city 45 kilometres south of Lillehammer, Fortifikasjon A/S launched the idea of constructing the ice-hockey arena in rock.

Already a swimming pool, a telecommunication trunk station and a civil defence headquarter had been built in the area, all planned by Fortifikasjon A/S.

The knowledge of the rock conditions were already very good.

And, the owner, the City of Gjoevik, had very good experience with their installations in rock, concerning energy and maintenance costs. But the story starts more than 10 years before.

In 1970's The Norwegian Energy Corporation was studying the feasibility of construction of a nuclear power plant in Norway. One of the alternatives was to install the power plant in a rock cavern. However, a span of 40-60 m was needed, far more than over made before.

FORTIFIKASJON A/S, NGI, NIT AND DYNO INDUSTRIES started to carry out a feasibility study for a cavern, 60 metres wide, 127 metres long and 20 metres high. The final plan was to construct a full scale pilot cavern, to study the problems connected to a span of such enormous dimensions.

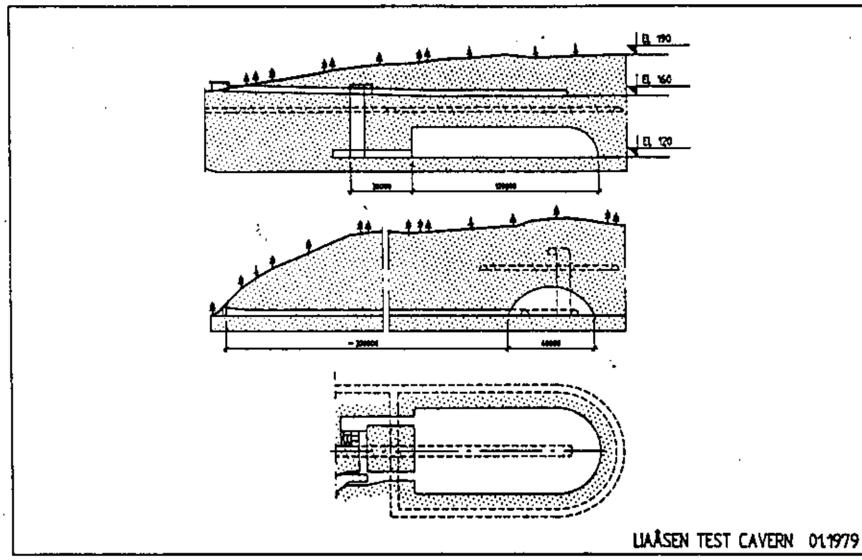

Fig. 1 Liasen Pilot Cavern

Not to leave a large cavern in the mountain unused after excavation, Fortifikasjon was presenting a proposal to the City of Oslo, to use the space for sport activities, as sport halls, swimming pool and ice-hockey rink.

When the Norwegian Parliament later on completely scrapped the plans for a nuclear power plant, the plans for the test cavern was also abandoned and put in the bottom of a drawer.
So, when the Olympic Icehockey Rink on Gjoevik came up, the idea for a giant rock cavern was reborn.

The City of Gjoevik showed their interest in the idea of a rock stadium as an alternative to a conventional aboveground ice hockey hall.

On its own initiative, Fortifikasjon A/S was making a first lay-out for an ice rink in rock, which was presented to the City of Gjoevik.

And a long debate followed:
The public, the local politicans, the local construction industry and the Olympic Steering Commitee were mixed into a hot debate.

The arguments **against**, were:

* Risk, because of never performed before
* Safety
* Impression
* Construction time
* Exclusion of local construction industry in a very hard labor market

The arguments **for**, where:

* Location of the arena in the middle of the city with easy access
* All infrastructure (roads, water, sewage, electricity, telephone etc) already existing at the site
* No extra land for site needed
* No disruption of the environment due to a giant structure in an area with small, traditional buildings
* Low energy costs
* Low maintenance costs
* Low lifetime costs

And of course, in addition an unique opportunity to
* Present Norwegian Rock Techonology to all the world
* Do fullscale research on large spans
* Develope methods for ecxavation

and securing of large spans
* Show the possibilities for utilization of the underground in the future for all types of installations
* Show the value of the underground as a development resource

FORTIFIKASJON A/S' rock alternative was therefore backed up by
- NGI (Norwegian Geotechnical Institute)
- NOTEBY A/S (Norsk Teknisk Byggekontroll A/S)
- SINTEF (Foundation for Industrial and Scientific Research at the Norwegian Institute of Technology)
- NTC (Norwegian Trade Council) and
- private consulting companies

So, at last, the final approval of the rock alternative came in January '91.

The excavation started 3 months later in April '91, and the whole installation was finished in April '93, 3 months ahead of schedule.

DESIGN

Location

The Gjoevik Mountain Hall is located in the heart of the City of Gjoevik.

In the same mountain are located several other rock installations:
- Telecommunication trunk station
- Dual purpose air raid shelter/public swimming pool
- Civil defence headquarter

The basic knowledge of the rock conditions was therefore very good.

Layout

The layout for the ice rink is based on:

- LOOC's (Lillehammer Olympic Committee): Specifications and demands for an Olympic Ice Rink
    * Internationional measures of ice rink, locker rooms etc
    * Number of public seatings
    * Completely separated safety zones for
        - VIP
        - Media
        - Players
        - Public
    * Separate VIP entrance
    * Medical centre
    * Restaurants
- Specifications from Broadcasting Systems:
    * Illumination level
    * Distances and horizontal and vertical sightlines from cameras to ice surface
- Location of main entrance
- Location of emergency exits
- Geological conditions
- Coordination with existing installations
- Economical excavation
- Future use after the Olympic Games :
    * Ice hockey rink
    * Exhibitions
    * Concerts
    * Civil defence air raid shelter etc.

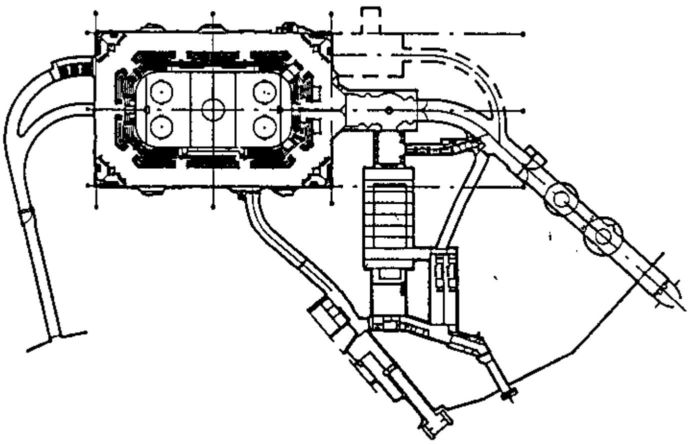

Fig. 2 Overall wiev

The main entrance is from Roeverdalen, almost in center of Gjoevik.

The main entrance tunnel is 115 m long and contains the ticket control system.

85 m from the entrance, public and staff are diverted from the public and are entering the stadium on Plan 1.

The public are entering on Plan 2.

The press are entering on Plan 3 through a separate tunnel from Roeverdalen.

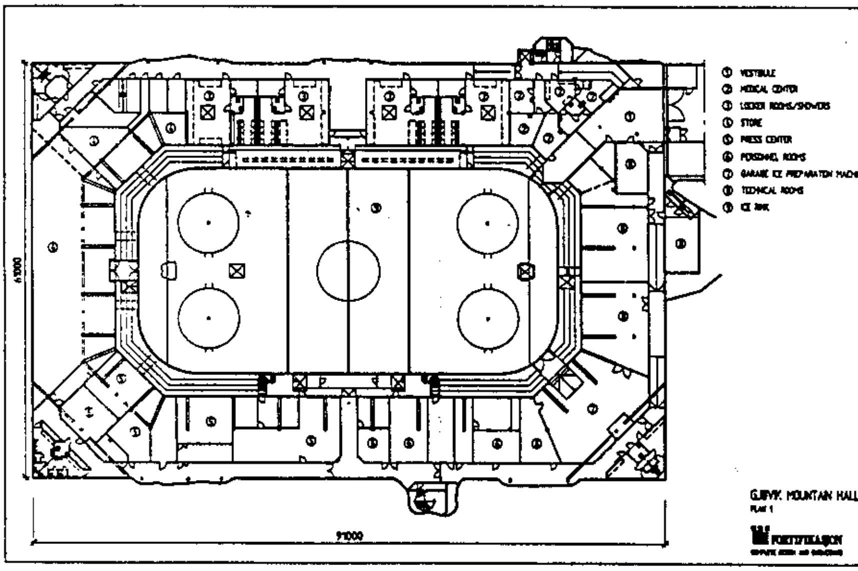

Fig. 3 Plan 1

On Plan 1 are located

- VIP Lifts to VIP Lounge on Plan
- Press center
- Locker rooms and showers for players
- Medical center
- Staff rooms
- Technical rooms
- Ice rinks

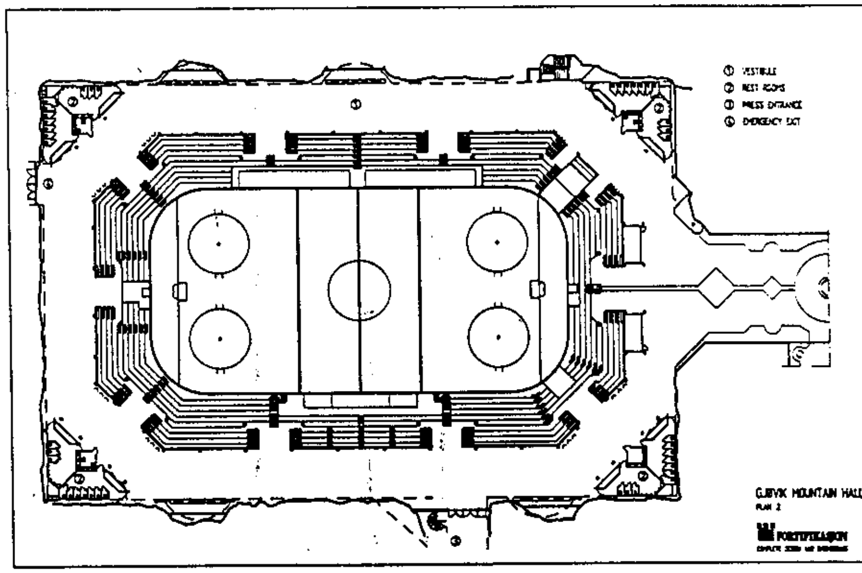

Fig. 4 Plan 2

On Plan 2 are located

- Restaurants
- Vestibule under the tribunes with access to the seats
- Rest rooms
- Tribunes (between Plan 2 and Plan 3)

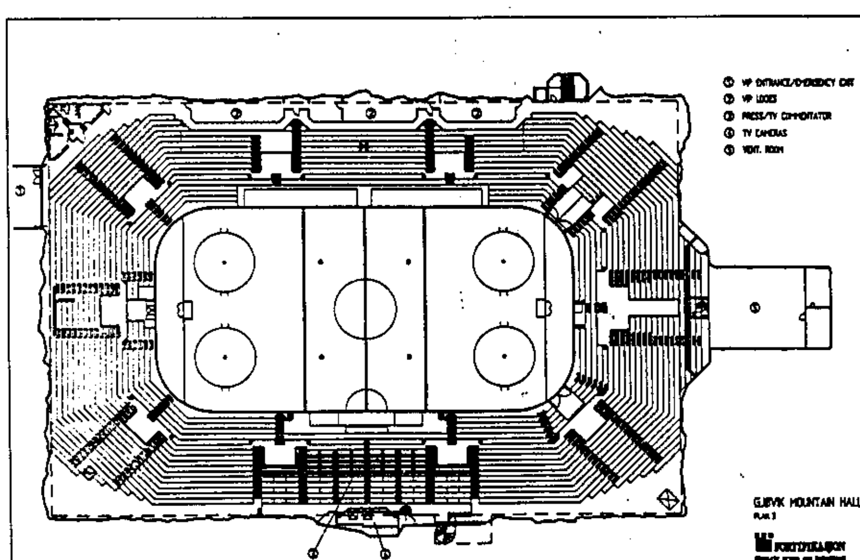

Fig. 5 Plan 3

On Plan 3 are located

- VIP entrance through separate tunnel
- VIP loges
- TV cameras
- TV commentator boxes
- Press tribunes
- Main ventilation room

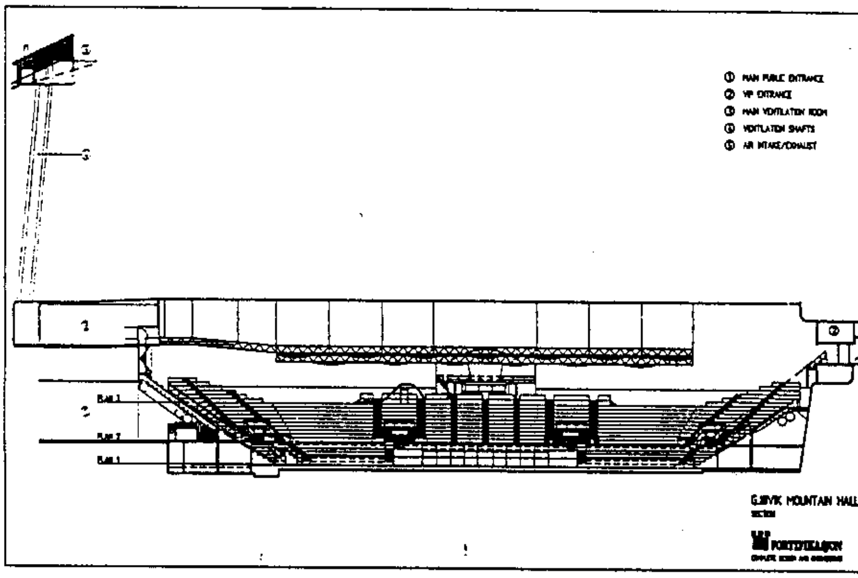

Fig. 6 Longitudal section

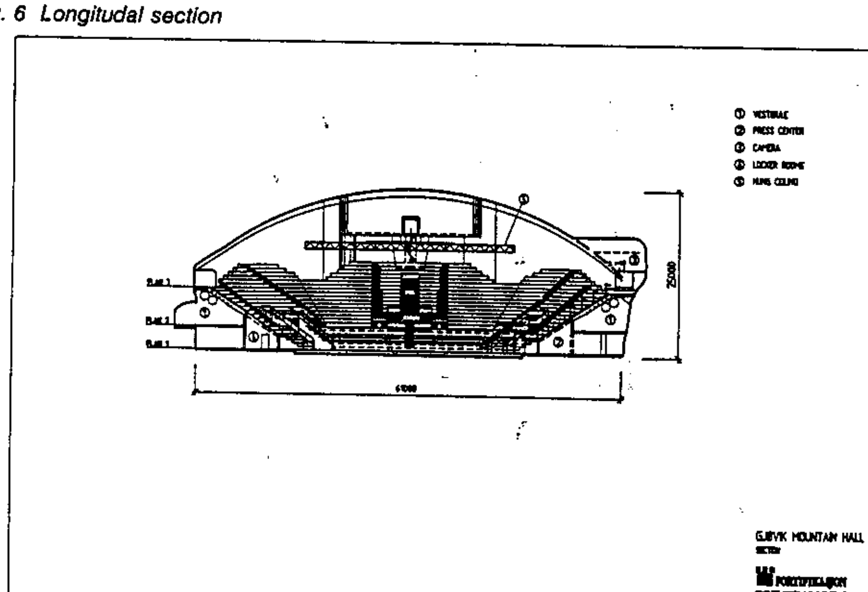

Fig. 7 Cross section

CIVIL WORKS

Excavation and securing

The excavation and securing of the cavern will be presented in detail in other lectures of the symposium.

But just a brief summary of the main points:

- Several attack points was necessary to be able to excavate the cavern rationally:

  * The main part of the rock is transported out through a tunnel, starting 10 m below roof level.
  This transport tunnel is functioning as VIP entrance and emergency exit.
  The blasting of the roof part was made in sections. The securing was made consecutively. The whole roof part was blasted and secured before the lower part was excavated.

  * The rest of the rock was transported out the main entrance tunnel

- The conditions for the vibrations were very strict due to

  * Telecommunication installitions with sensitive computer installations located very close in the same mountain.

  * Swimming pool in a directly connected cavern.

  * Surrounding residental and business area

The vibrations were continously monitored.

The influence on the overlaying rock was monitored in deformation measuring instruments in boreholes and precision nivillement on the surface and inside the cavern

Materials

General

All materials and all parts of the building satisfy the specifications in the Norwegian building code, as for building regulations, fire regulations, other offical regulations and Norwegian Standards.

Special emphasis has been put on economical constructions regarding erection and maintenance.

Very strict specifications are put on the choice of materials regarding fire risk.

Rock walls and roof

* In the main hall steel fibre reinforced concrete is used.
On the walls an extra layer of conventional shotcrete is applied to cover the steel fibres and to make a more smoth surface.

* In the tunnels, generally conventional shotcrete is used.

* In the main entrance tunnel and in the winter garden, a special drained roof system is used:

The system gives
- Excellent water leakage control
- Accoustical attunication
- Rock resembling surface

Main hall ceiling

In the main hall a ceiling of corrugated, galvanized steel is installed.
The main purpose of the ceiling is to protect against dripping from the rock roof down on the ice surface and on the spectators.

Hung ceiling

Under the steel ceiling is installated a hang ceiling made of plaster boards on a steel frame. The ceiling is covering the air exhaust ducts cable ladders and walk-ways for maintenance of the flood-lights, installed under the ceiling.

Floors on rock

The floors are generally made of reinforced concrete on a layer of crushed stone with a diffusion barriere.

Ice rink floor

The ice rink floor is made of, in direction from rock surface

- Levelling with on site materials
- Double diffusion barriere
- Styrofoam insulation
- Reinforced concrete with the freezing coils imbedded

Walls

Fire barriers:
Walls acting as fire barriers are made of on site cast concrete.

Partition walls

Partition walls are made of plaster boards on a galvanized steel frame.

Prefabricated concrete

In the main hall tribunes and floor slabs are supported on prefabricated column and beams. The tribunes are made of precast modules of prestressed concrete.
The floor slabs between the floors are made of precast concrete.

Acoustical treatment

To control the acoustics in the main hall, a very extensive computer calculation were carried out.

Parts of the steel ceiling is covered by acoustical boards (installed in a artistic, olympic pattern).

The acoustics in the main hall is considered to be exellent.

Public shelter

The main entrance can be closed by heavy concrete gates for converting the mountain hall to a public air-raid shelter for 2000 people.

MAIN TECHNICAL SPECIFICATIONS

CIVIL ENGINEERING

SIZE OF STADIUM

Width	61 m
Length	91 m
Heigth	25 m
Volume stadium	114,000 m3
Volume winter garden + main entrenance	10,000 m3
Gross floor area	10,010 m2
Net floor area	14,910 m2
Ice rink (gross)	160 m2
Seating for public	5200
Max number public + participants	5800
Rock volume excavated	165,000 m3
Public shelter for	2000

MECHANICAL INSTALLATIONS

Ventilation

The ventilation system shall

- provide sufficient fresh air for an hygienic air charge in the main hall, offices, wardrobes etc.

- control the relative air humidity in the main hall to prevent while frost on the ice surface

- control the temperature in the hall lduring all conditions of use

- provide smoke-free escape routes in case of fire

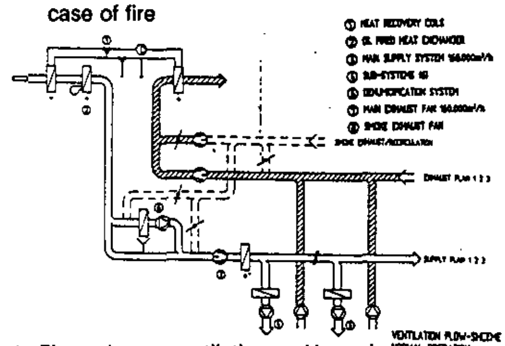

Fig. 8 Flowscheme ventilation - Normal operation

The total capacity of the ventilation system is 160.000 m3/h, based on a seating of spectators of 5200 in additon to sport participants and official, an illumination level at the ice surface of 1600 lux. The ideal temperature in the hall is 10°C - 16°C.

The ventilation system is divided in two main system:

- ventilation system for main hall
- ventilation system for offices, wardrobes, restaurant etc, divided in 6 subsystems

<u>Main hall system</u>

The capacity of the main hall system can be steplessly adjusted between 160.000 m3/h and 25.000 m3/h in accordance to the use and number of players and spectators.

The system can operate in a recirculation mode for humidity control when the hall is not in use.

The system can also be reversed and speeded up to provide adequate smoke exhaust in case of fire. This will be more discussed in a following lecture.

The air intake and air exhaust is located on the top of the mountain, and 4 shafts each with a diametre of 1.80 metres are bored 32 metres vertically down to ventilation room located at the roof level in the main hall.

In the mechanical room on the top of the shaft, the fresh air is preheated in a heat recovery coil and in a direct oilfired heat exchanger, before supplied to the main ventilation system.

The conditioned air is supplied to the corridor on first floor under the tribunes and flowing through the entrances into the hall. The used air is exhausted through a duct system under the ceiling. It is a deplacement ventilation system, ensuring dry air to be supplied at the icelevel to prevent white frost forming on the ice surface and obtaining an airflow in the hall where the heat from the spectators and illumination is the driving force.

The system is therefore also a part of the safety system, ensuring smoke free lower part of the main hall and escapeways.

<u>Ice-making system</u>

For making the ice, a freezing system with two screw compressors are installed.

The freezer machinery is installed on first floor at the end of the ice rink.

Brine with a temperature of approximatly -10°C is circulated in a PVC-pipe system cast into the concrete floor.

The condensers are water cooled. The total freezing capacity is 500 kW. The full capacity is only used for ice-making. To maintain the ice only 75ákW are needed.

The total heat rejection from the condensers is 795 kW, which is mainly used for heating purpose.

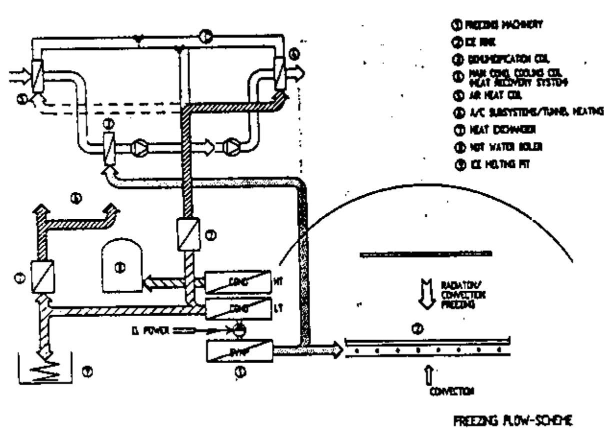

Fig. 9 Flowscheme freezing system

Two special features should be mentioned:

* A reflecting ceiling is installed above the ice rink.
This is reducing the cooling capacity for maintaining the ice by 50 %.

* Due to the location of the ice rink on a rock floor, no heating system under the rink is needed to prevent frost-heaval of the ground.
This means more condenser heat is available for heating.

Heating system

The heating system consists of following main components:

- Direct oil-fired heat exchange for preheating of fresh supply air

- Electrical boiler for heating of airconditioning subsystems

- Electric heaters installed in offices etc.

- Heat pipes in shower room floors

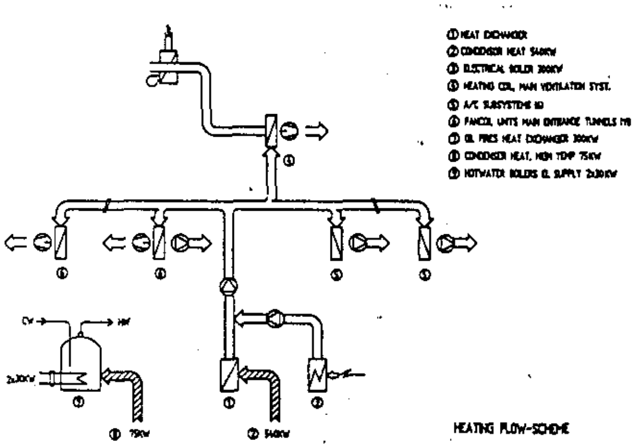

Fig. 10 Flowscheme heating system

The heating system is integrated with the freezing systems condenser cooling system, for maximum utilization of waste heat.

The capacity of the heating system can raise the temperature in the hall from 10_C to 18_C in 24 hours when the hall is converted from ice rink to f.i. concert hall.

Energy conservation

Much emphesize is put on the energy conservation.

The technical installations are integrated and heat recovery devices are installad to reduce the energy consumption:

- In the ventilation system is installed a recouperating system with an effeciency better than 60 %.

Coils are installed respectively in the intake and the exhaust air openings and non-freeze liqued is ciculated between the coils.

The system is also connected to the freezing plants condenser cooling system. The surplus condenser heat can be vasted in the exhaust coil, but can be utilized for preheat of fresh air in cold periods.

The condenser heat from the freezing plant is used for

- heating of the entrance tunnels

- heating of

- preheating of tap water for the showers and sanitary systems

- melting of ice removed from the ice rink by the ice preparation machine

MAIN TECHNICAL SPECIFICATIONS

Mechanical Installations

VENTILATION SYSTEM

Air volume, stepless variable	25.000 - 160.000 m3/h
Max smoke exhaust capacity (Emergency)	300.000 m3/h
Heat recouperation from exhaust air, efficiency	> 65 %

HEATING SYSTEM

Direct oil fired heat exchanger (Intake air heating at low temperatures)	700 kW
Electrical boiler	300 kW

FREEZING SYSTEM

Max freezing capacity (Icemaking)	500 kW
Normal " "	75 kW
Condenser heat max	695 kW

UTILIZATION OF CONDENSER HEAT

For heating purpose (normal winter)	100 %

ELECTRICAL INSTALLATIONS

Power supply

The power is supplied from the municipal power grid in a 11 kV high tension cable to the tranformer room located on 1st floor. In case of power break-down, a diesel powered emergency generator is installed. The emergency generator is starting automatically and is supplying power to priority load, as

- emergency illumination
- fire exhaust ventilation etc

The capacity of the emergency power plant is 200 kVA.

(For use during the Olympic Games a provinsional standby power plant will be installed outside the cavern. The capacity is 1600 kVA).

Illumination

The illumination is generally fluoresent. The illumination level is general 150 lux.

For the ice rink 100 high capacity floodlights, each 2.0 kW are installed. The illumination level at the ice is 1600 lux at TV trans-missions. The illumination level is stepwise adjustable down to 600 lux.

Emergency illumination

Marker fixtures for the escape routes are autmatically turned on by main power breakdown. The fixtures is powered from 24 Volt accumulators.

The system has a 72 hours battery back-up.

Heating

For heating is installed:

* Electric heaters in locker rooms, offices etc.

* Heating cables in shower room floors

* Electric boiler for airconditioning system - 300 kW

* Hot water boilers for hot water production, for sanitary systems 2 x 60 kW

Included in the electrical system are:

* Telecommunication system

* Automatization system

* Alarm and signal system for
  - Mechanical systems
  - Burglar detection and alarm
  - Fire detection and alarm

* Internal TV (ITV)

* Audio and video systems

The complete installation can be monitored from the "Operation and Control Center" located on second floor.

MAIN TECHNICAL SPECIFICATIONS

Electrical installations

POWER

Main power supply	1 900 kW
Emergency power	200 kVA

ILLUMINATION

Ice rink max (CTV camera)	1 600 lux
Ice rink normal	600 lux
General	150 lux

TELECOMMUNICATION SYSTEMS

ALARM & SIGNAL SYSTEMS

- Interlock system
- Time system
- Admission control / Door signal system
- Fire detection and alarm

AUDIO AND VIDEO SYSTEMS

- Amplifier and loudspeaking systems
- Internal TV (ITV) systems

AUTOMATIZATION

- A/C automatization system
- Control monitoring system

COSTS

	USD x 1000
CIVIL ENGINEERING	
- Blasting, mucking, transport	
- Securing (bolting, shotcreeting)	
- Concrete works	
- Interior works	
- Furniture and equipment	
- Steel and aluminium works	9,110.3
MECHANICAL INSTALLATIONS	
- Ventilation	
- Heating/cooling	
- Freezing	
- Sanitary	
- Sprinkler	1,660.5
ELECTROTECHNICAL INSTALLATIONS	
- Power	
- Communcation/automatation	
- Emergency power	
- Lifts	
- Outdoor installations	
- Provinsional installations	2,191.9
Miscellanous	1,479.4
Preliminaries	2,315.3
Total exclusive V.A.T. Usd x 1000	16,757.4

CONCLUSION

Today, the Gjoevik Mountain Hall is successfully finished and operating to everybodys satisfaction.

With the combination of science, experise and experience, what was considered to be impossible has become possible.

The international interest has been enormous, because this project has opened a new underground world.

The possibilities are legio:

- Sport facilities
- Concert halls
- Nuclear power plants
- Precision industry
- Librarys
- Military installations
  and so fort

And through the research program, new information on the underground development will continue to flow in the years to come.

Fortifikasjon A/S has through this project strengthened the company's competence on underground installations and will be at your service on any kind of underground projects.