FLOWNEX®
SIMULATION ENVIRONMENT

CHILLED WATER DISTRIBUTION

This case study demonstrates Flownex's ability to predict the temperature rise in chilled water networks due to gravitational effects and heat transfer from the environment.

MINING INDUSTRY

CHALLENGE:

A common method used to condition the working environment in deep mines is to chill water on the surface and then pipe it down the mine where it is used to cool the air in the working areas through water/air heat exchangers.

The following two factors impact the efficiency of such systems:

- The temperature rise of the chilled water due to gravitational effects;
- The heat transfer from the often hot environment to the chilled water.

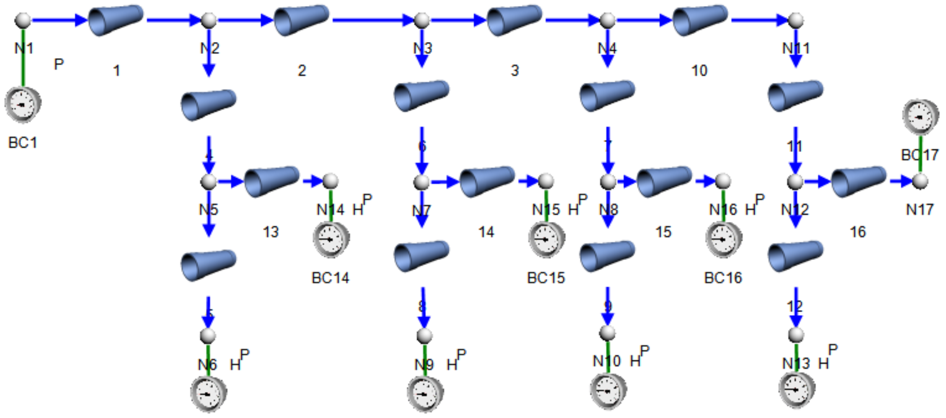
This case study demonstrates Flownex's ability to predict the temperature rise in chilled water networks due to (1) gravitational effects and (2) heat transfer from the environment.

BENEFITS:

- Flownex takes into account temperature rise due to gravitational effects.
- Flownex can simulate heat transfer due to the temperature difference between the fluid and ambient conditions.

SOLUTION:

Flownex was used to calculate the flow and temperature distribution in a chilled water reticulation network for a deep mine. This case study demonstrates Flownex's ability to predict the temperature rise due to gravitational effects as well the code's ability to calculate heat transfer due to the temperature difference between the fluid and ambient conditions.



Flownex was used to calculate the flow and temperature distribution in a chilled water reticulation network for a deep mine.

CHILLED WATER DISTRIBUTION NETWORK FOR A DEEP MINE

SYSTEM DESCRIPTION

Figure 1 shows the lay-out of the system that is considered in this case study.

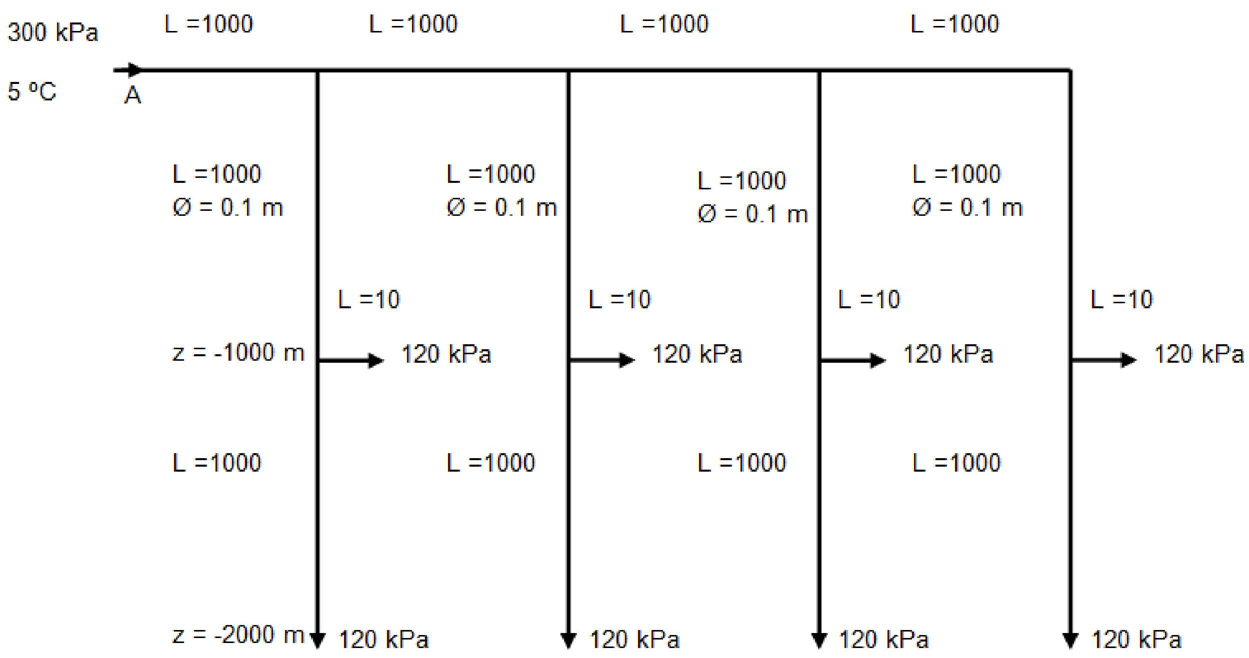


Figure 1: Layout of the chilled water distribution system.

Chilled water is supplied into a header at point A at a pressure of 300 kPa and a temperature of 5 °C. The header supplies four pipelines that go down the mine with draw-off points at depths of 1000 m and 2000 m.

OBJECTIVE OF SIMULATION

The objective of the simulation is (1) to predict the temperatures rise due to the gravitational effects and (2) to investigate the impact of applying insulation to one of the pipes (pipe 2).

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FLOWNEX MODEL

The Flownex model of the system is shown in Figure 2.

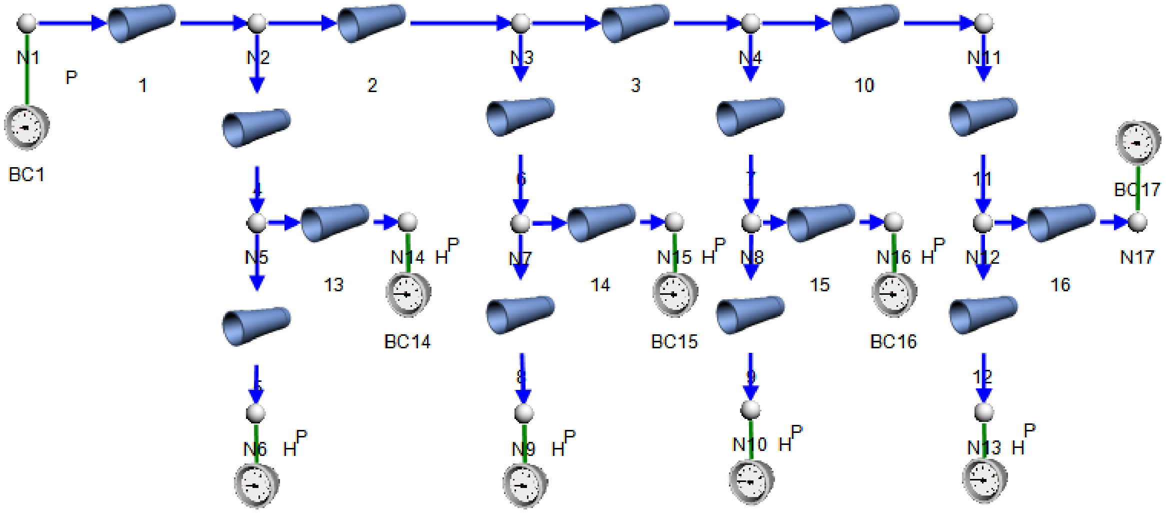

Figure 2: Flownex network of the chilled water distribution system.

DESCRIPTION OF SIMULATION

A fixed pressure of 300 kPa is specified at Node1 while a fixed pressure boundary condition of 120 kPa is specified at all the draw-off points (Nodes 6, 9, 10, 13, 14, 15, 16 and17). In addition to this a fixed temperature boundary condition of 5 ºC is specified at Node1.

Predict the temperatures rise due to the gravitational effects and investigate the impact of applying insulation to one of the pipes.

RESULTS

Three simulations were done. In the first one adiabatic flow was assumed for all pipe sections. The temperatures at the draw-off points for this case are as follows:

Node # (at 2000 m)	Temperature [ºC]	Node # (at 1000 m)	Temperature [ºC]
6	9.73	14	7.38
9	9.73	15	7.38
10	9.73	16	7.38
13	9.73	17	7.38

As can be seen from the above table the temperatures at a depth of 1000 m are approximately 2.38 °C higher than the supply temperature of 5 °C while the temperatures at a depth of 2000 m are approximately 4.73 °C higher than the supply temperature. At a total mass flow of 350 kg/s this translates to a cooling loss of about 6.9 MW!

A quick check with the following analytical expression based on the energy equation confirms the validity of the results:

$$\text{At depth of 1000m:}\ \ \Delta T = \frac{g\Delta z}{c_p} = \frac{9.81\times 1000}{4189[J/kg.K]} = 2.34\,°C \tag{0.1}$$

$$\text{At depth of 2000m:}\ \ \Delta T = \frac{g\Delta z}{c_p} = \frac{9.81\times 2000}{4189[J/kg.K]} = 4.68\,°C \tag{0.2}$$

The small differences between the Flownex results and the analytical results are due to the kinetic energy that is not taken into account in the analytical expression.

In the second case a wall thickness of 5 mm is specified for pipe 2 together with a convective heat transfer coefficient of 20 $W/m^2.K$ and an ambient temperature of 30 °C. A thermal conductivity value 20 W/m.K is assumed for the pipe wall. The Flownex results for this case are as follows:

Node # (at 2000 m)	Temperature [°C]	Node # (at 1000 m)	Temperature [°C]
6	9.73	14	7.38
9	10.44	15	8.09
10	10.44	16	8.09
13	10.44	17	8.09

The heat transfer to pipe 2 is 779 kW, which is about 11 percent of the total cooling loss due to gravitational effects. Remember this is only in one pipe section.

In the third case insulation with a thickness of 50 mm and thermal conductivity of 0.8 W/m.K is applied to pipe 2. This reduces the heat transfer to pipe 2 by about 49 percent to 400 kW.

CONCLUSION

Flownex was used to calculate the flow and temperature distribution in a chilled water reticulation network for a deep mine. This case study demonstrates Flownex's ability to predict the temperature rise due to gravitational effects as well the code's ability to calculate heat transfer due to the temperature difference between the fluid and ambient conditions.