# Horizontal Cooling Water Tank in Frederiksberg, Denmark

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Frederiksberg Forsyning

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# Horizontal Cooling Water tank

- Who is Frederiksberg Forsyning?
- District Cooling in Denmark
- Background on the Carlsberg Byen Plant and contract.
- Horizontal Thermal Energy Storage tank
- Design considerations
- Pictures
- Results

# Frederiksberg Forsyning

- Municipal Utility company
- We offer domestic gas, potable water, sewage, district heating
- Approximately 100.000 inhabitants in Frederiksberg.
- 99,5% receive district heating, 4300 meters
- 100% receive potable water, 5000 meters
- 17.500 gas meters.

# District cooling in Denmark

Frederiksberg Forsyning

- Danish Climate!
- District Cooling is a non regulated commercial field
- Frederiksberg is one of 2 major developers of district cooling in Copenhagen
- District cooling is not limited to the municipality (everything else we do is limited to Frederiksberg).
- Started in 2013, we now have 2 separate plants running in Copenhagen.


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**The Development Company Carlsberg Byen P/S**

The Carlsberg City District is owned and developed by the development company Carlsberg Byen P/S, which is owned by a consortium consisting of Realdania, Carlsberg Breweries, pension groups PFA Pension and PenSam, and the insurance firm Topdanmark.

10-15 years development period.

500.000 square meters.

Carlsberg Byen expect 45% residential, 45% Shops and 10% culture facilities.

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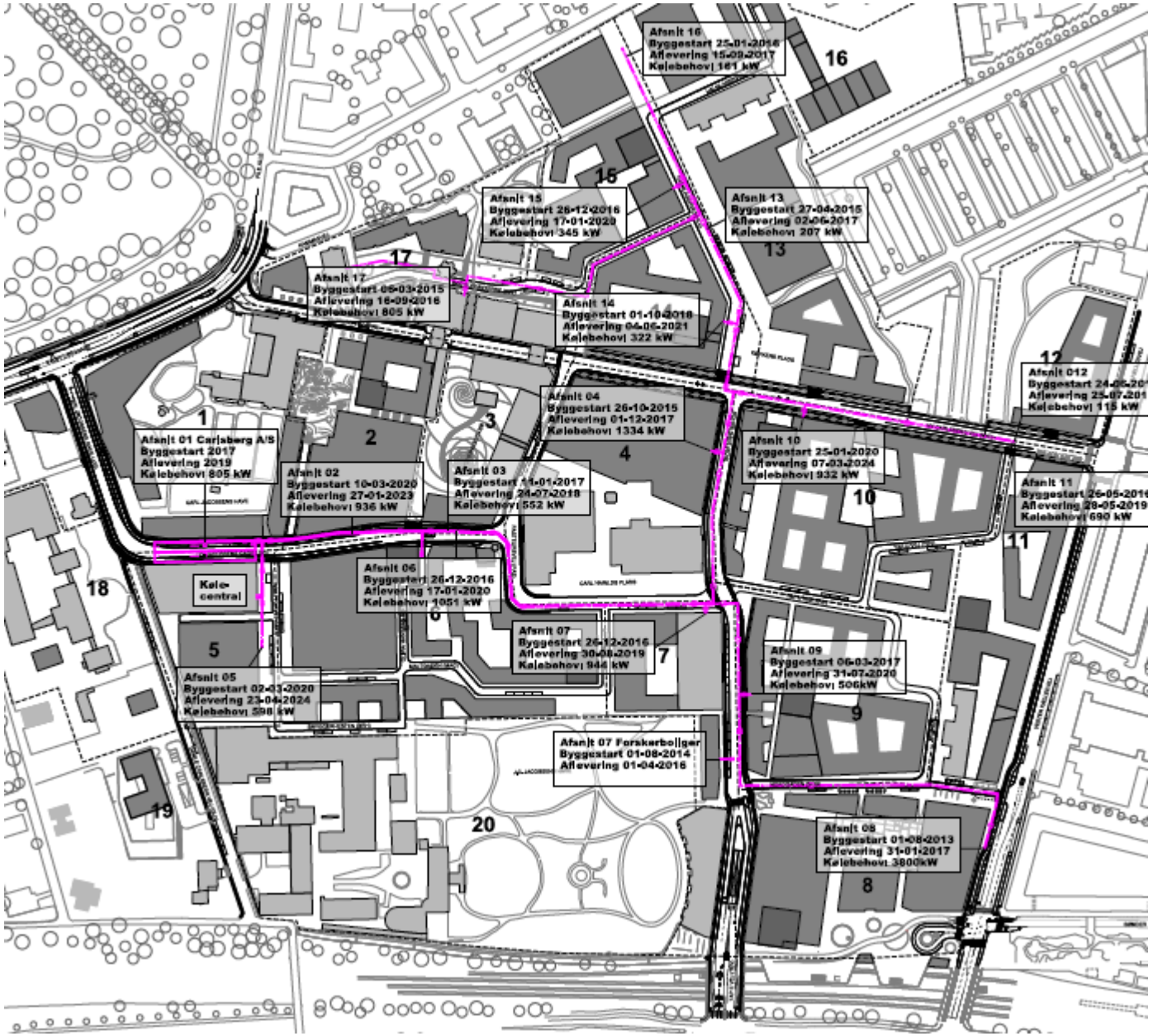

# Our Contract With Carlsberg Byen

- 25 Years running time
- Carlsberg Byen garantee a yearly use of cooling and expansion rate
- First delivery of cooling water to the first client is 1st April 2016
- 90 % for air conditioning (expected)
- 10 % for process clients (expected)

# Technical Description

- Ammonia based chillers (cooling machines) electrically driven to produce the cooling energy.
- Dry coolers to remove heat energy and to deliver ‘free cooling’ in the spring and autuum.
- Cooling water delivery temperature 9°C, Return temperature 17°C
- Storage tank contributes with 4 MW peak cooling power during the day when it has been cooled down during the night.
- Cooling pipes in the ground are uninsulated PE (Polyerythan) pipes.

# Technical Key Figures

- 10,4 MW (3000 RT) cooling power expected
- 4 km Cooling pipes in the ground.
- Storage tank is 4.000 $m^3$
- Installed chiller capacity is 4,3 MW (1200 RT) cooling power.
- Storage tank will deliver 4 MW (1140 RT) cooling power.
- The concurrency is set at 0.8.
- 2 MW (570 RT) ‘free cooling’ heat exchanger.

# Cellar

# Storage Tank

- 4.000 m3, installed in the ground under a new road in the area.
- The tank consists of a warm section and a cold section.
- Each section 66 m long, 5,8 m tall, 6 m wide
- Built of concrete tunnel elements which are sealed together.
- Access to the tank from shafts from the road that runs above the tank.
- Regulations say that the storage tanks must be inspected every 5 years by divers.
- The costs of filling are so large that we hope we never have to empty them.

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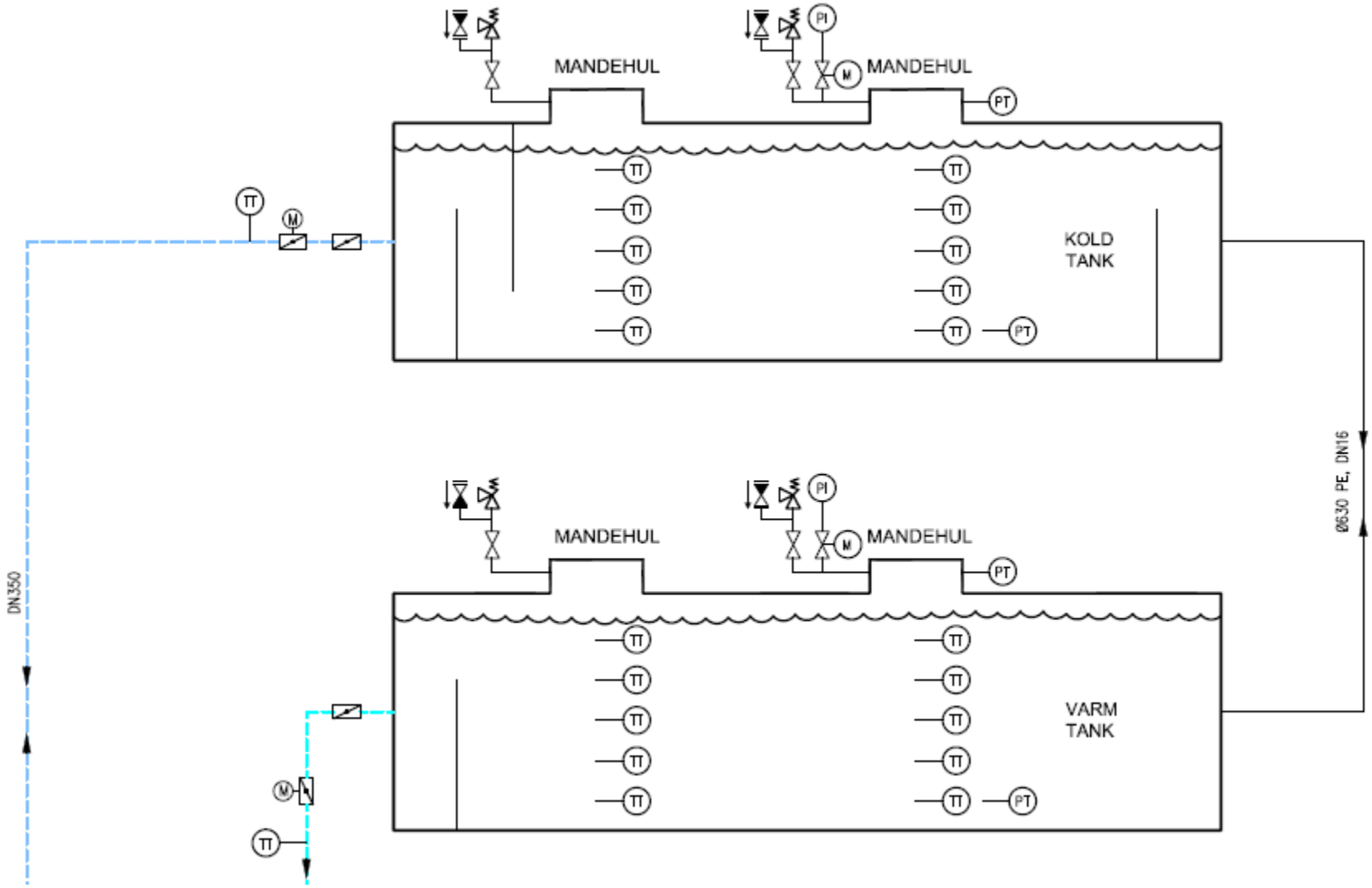
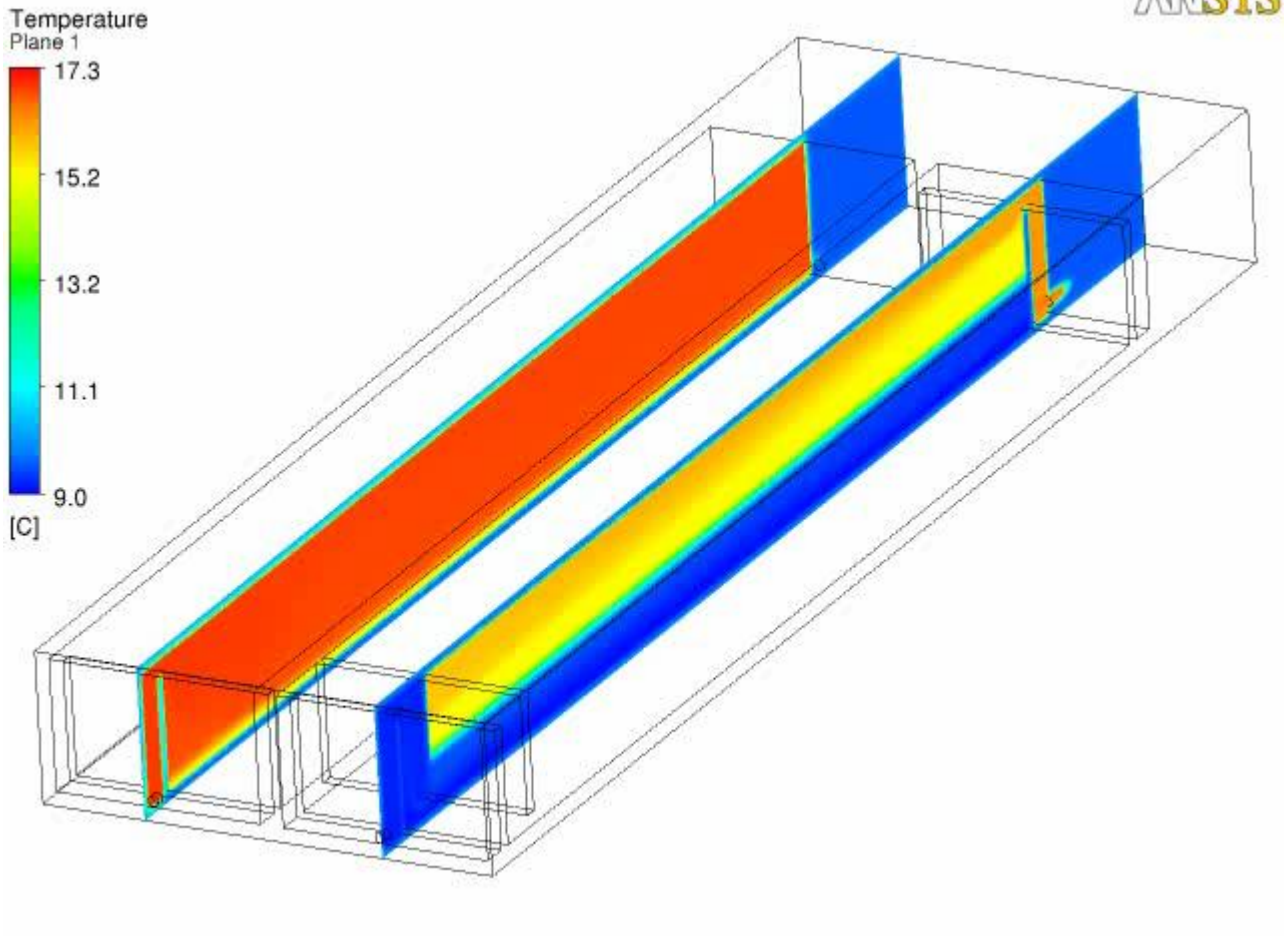
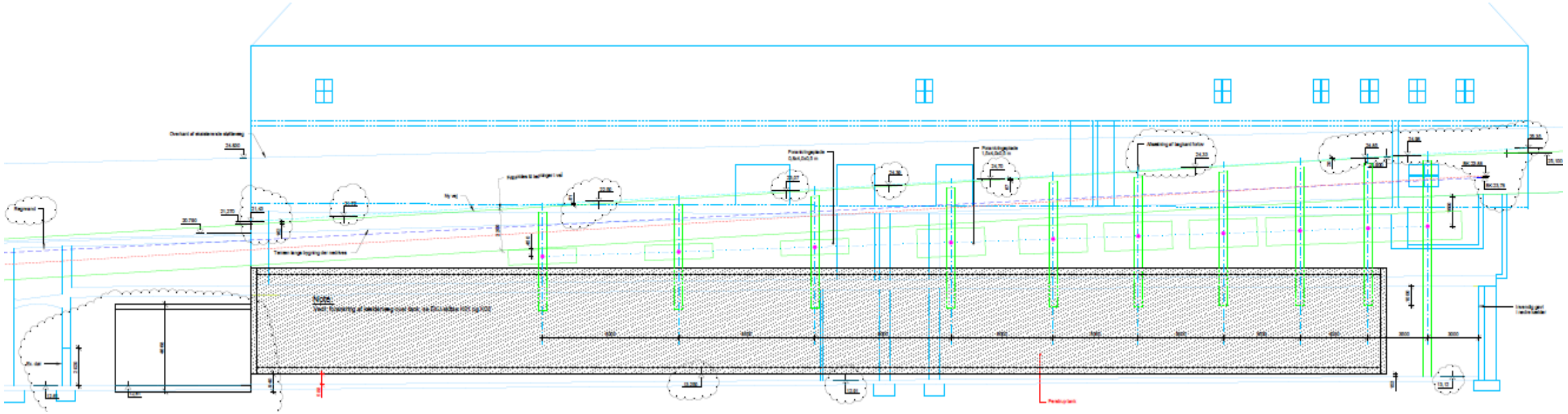


# Storage Simulation



# Storage tank section



# Storage tank

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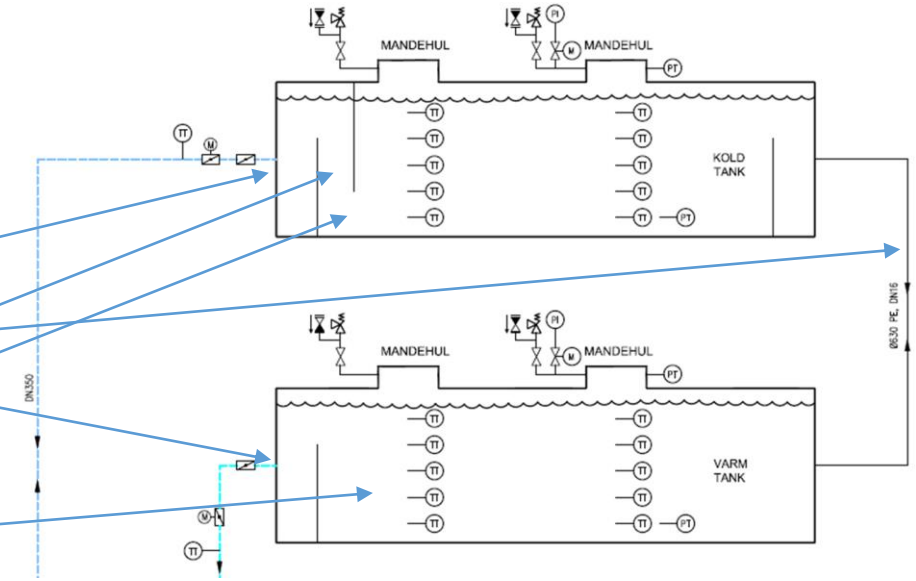
# Storage tank

# Storage Tank Design Considerations

- Size of the tank 4.000 $m^3$
- 5-6 hours of operation at 4 MW cooling power (1140 tons of refrigeration).
- Physical restraints of the building site.
- Flow at 430 $m^3/h$

| Flow speeds | $m^2$ | m/s |
|---|---|---|
| Inlet and outlet pipes SS 350 | 0,06 | 1,865 |
| Connecting pipe DN 630 | 0,21 | 0,572 |
| | | |
| Area between section walls | 9,00 | 0,013 |
| Area under section wall | 6,00 | 0,020 |
| Main cross section | 28,20 | 0,004 |



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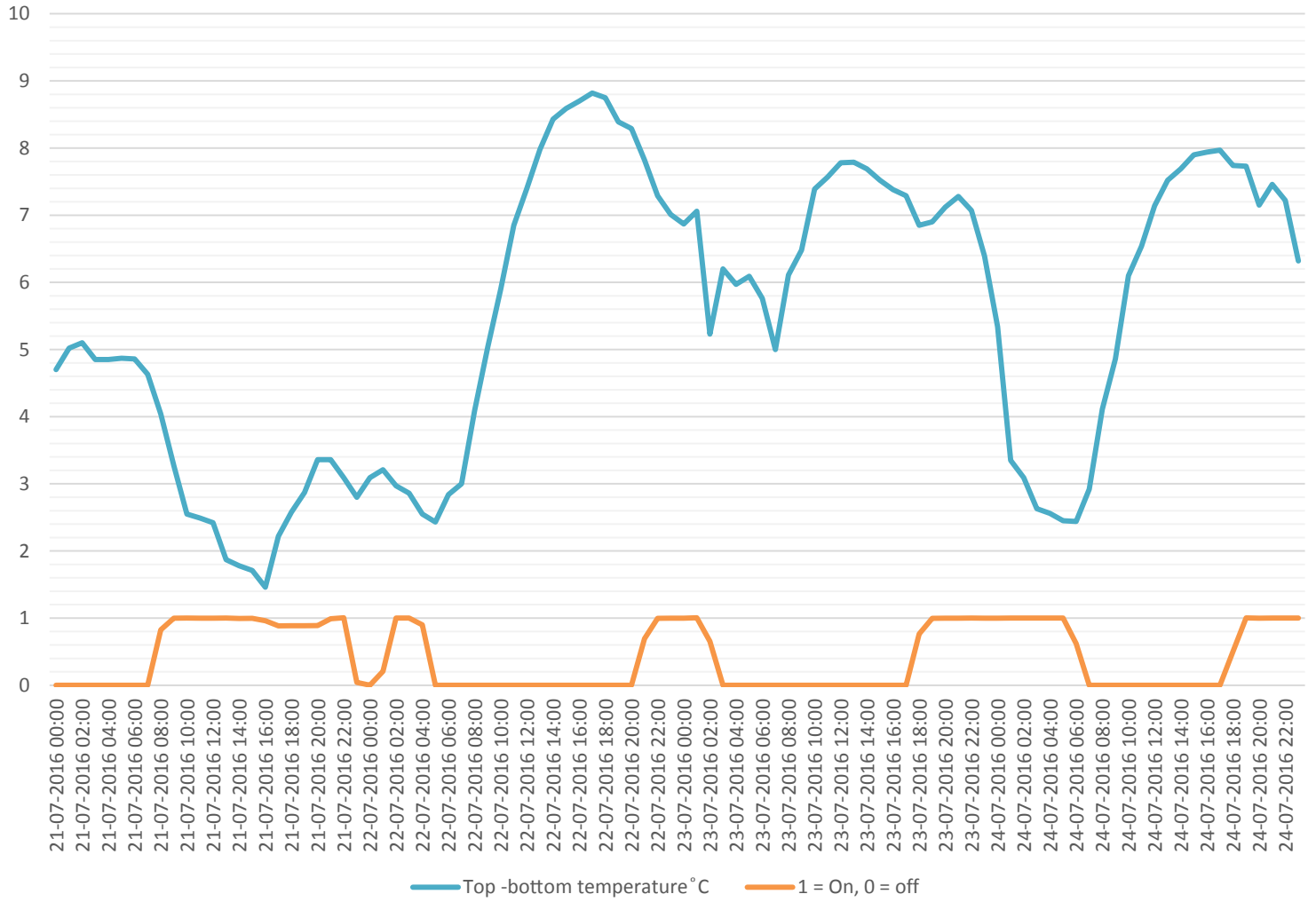
# Storage Tank Design Considerations

- A predefined weekly schedule manages the charging and discharging of the tank.
- Price for storage tank was comparable to the price of chiller capacity.
- Why horizontal orientation?

# Results

Blue graph: Difference in temperature between top of the warm section and bottom of the cold section of the tank during high load conditions.

Orange graph: Chiller is running = 1, Chiller not running = 0.



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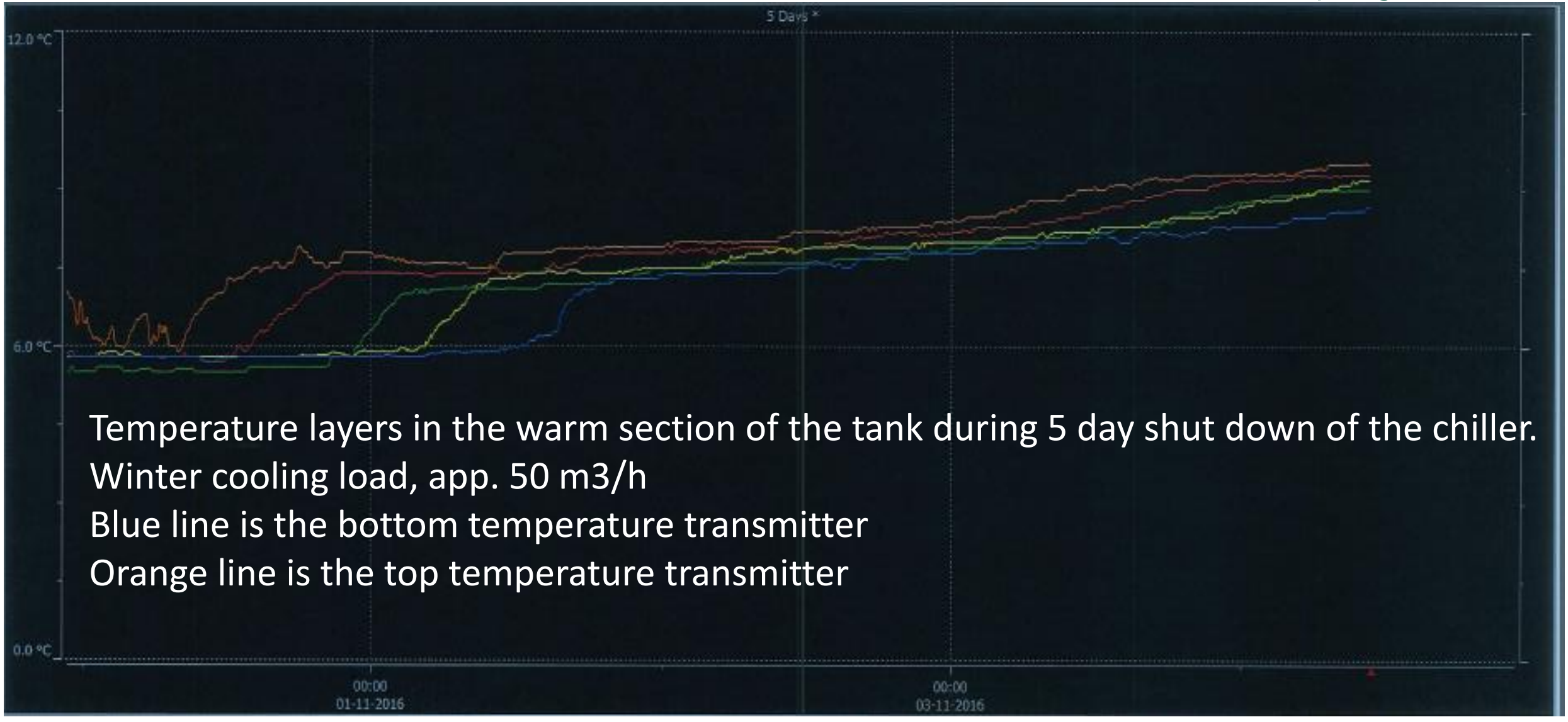


Temperature layers in the warm section of the tank during 5 day shut down of the chiller.
Winter cooling load, app. 50 m3/h
Blue line is the bottom temperature transmitter
Orange line is the top temperature transmitter

# Results

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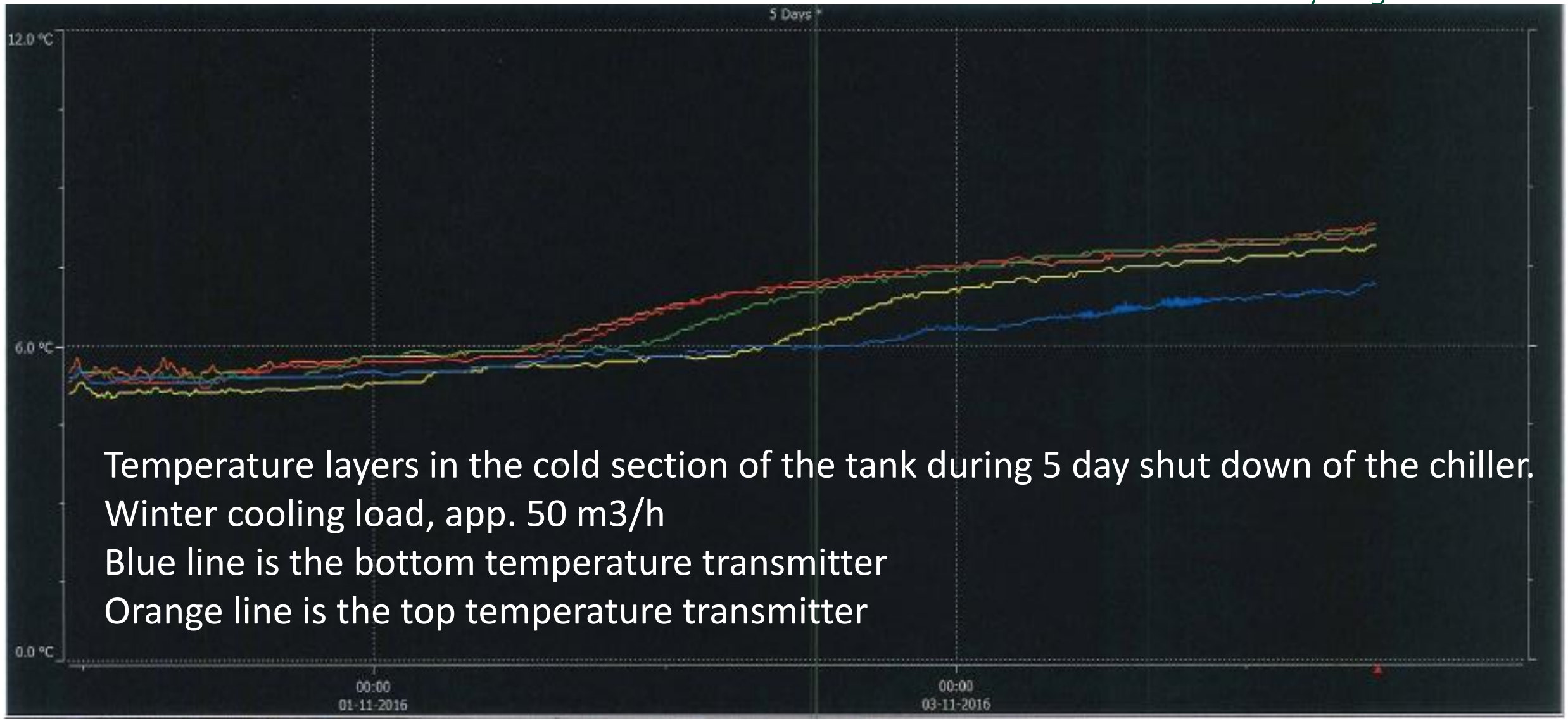


Temperature layers in the cold section of the tank during 5 day shut down of the chiller.
Winter cooling load, app. 50 m3/h
Blue line is the bottom temperature transmitter
Orange line is the top temperature transmitter

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Thank You for your attention