FLOWNEX®

SIMULATION ENVIRONMENT

CASE STUDY

EMERGENCY VENT FLARE ICE BUILD-UP ESTIMATION

This case study demonstrates the use of Flownex to estimate the thickness of expected ice layer build-up on the outside surface of a low temperature emergency vent flare stack.

Use this link to access the Flownex network:

Download the Flownex network

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CHALLENGE:

A low-temperature emergency flare stack needed to be assessed for potential ice build-up on its outer surface during emergency venting of sub-zero gas. The goal was to estimate the worst-case ice thickness along the stack so that structural loads could be evaluated. The challenge was to account for the combined effect of extremely cold internal flow and external radiation from the flare flame.

BENEFITS:

Flownex was selected because it enables engineers to combine fluid flow and heat transfer in one model, making it possible to represent:

- Internal convection from very cold gas,
- Radiation from the flare flame, and
- Heat conduction through the metal and ice layers.

Its built-in Composite Heat Transfer (CHT) components and Designer tool allowed quick setup of a layered conduction model and automated solving for ice thickness.

SOLUTION:

A simplified Flownex model of the flare stack was created using eight pipe sections, each representing a 3-m segment of the 24-m stack. Radiation heat flux values from a FlareSim study were applied to each section. An ice layer was included as a second solid layer in the CHT components, and the Designer was used to solve for the thickness required to reach an external ice surface temperature of 0 °C.

The simulation produced ice-thickness profiles for two wind conditions, giving engineers a practical estimate of worst-case build-up along the stack.

INTRODUCTION

Emergency vent flares discharge cold gas when process equipment cannot operate normally. In cases where the gas temperature is extremely low, ice can form on the outside of the flare stack due to heat transfer from the ambient and the flame. This added mass may influence structural loading.

A Flownex model was used to estimate the potential ice layer thickness during such events, providing a practical approach for design engineers.

SYSTEM DESCRIPTION

The flare system consists of a 24 m vertical stack venting a methane-rich gas at −82 °C. During emergency flaring, the internal gas rapidly cools the metal wall, while the external flame provides radiation heating. Wind affects flame orientation and radiation levels but has limited direct convective influence on the outer surface under low-wind conditions.

Radiation flux values along the stack were obtained from a FlareSim model under two wind speeds: 11 m/s and 1 m/s. The stack was divided into eight calculation segments.

FLOWNEX MODEL

The flare stack was represented in Flownex as a vertical pipe divided into eight sections, each 3 m tall, matching the radiation data obtained from FlareSim.

A boundary condition was applied at the flare tip to specify the gas mass flow rate and temperature (−82 °C), while the outlet was left to exhaust to ambient conditions.

Each 3 m pipe section was linked to a **Composite Heat Transfer (CHT)** component. The CHT elements were used to represent:

1. **Convection from the gas to the pipe wall,**
2. **Conduction through the pipe wall,**
3. **Conduction through the forming ice layer**, and
4. **Wall heat flux from flame radiation** applied to the outer surface.

Radiation flux values were assigned individually to each CHT component based on the corresponding FlareSim results. The internal surface of each CHT component exchanged heat with the cold methane gas flowing inside the stack via convection.

To determine the **ice layer thickness**, the CHT component was configured with two solid layers:

- Layer 1: Pipe wall

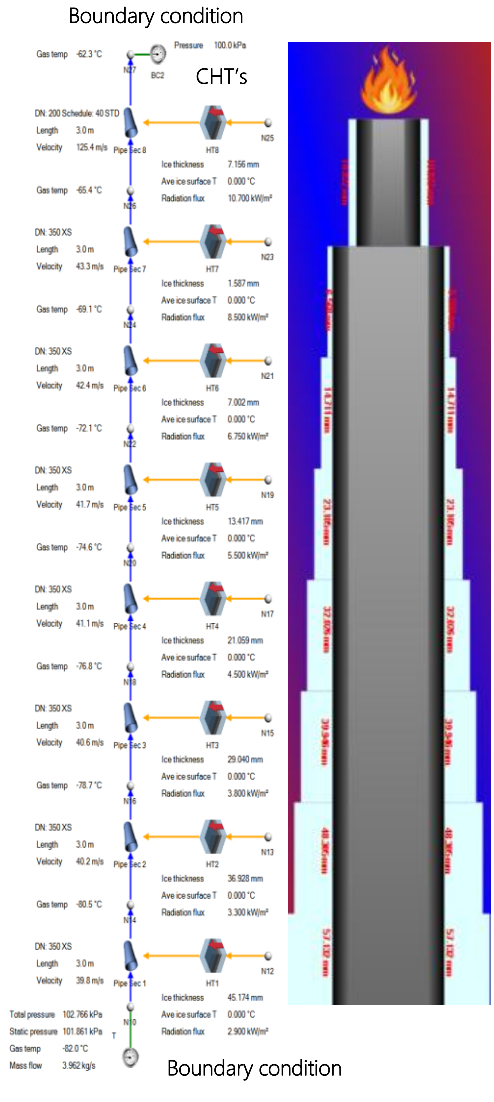

Figure 1: Flownex model

- Layer 2: Ice (thickness initially unknown)

Flownex's Designer tool was then used to iteratively adjust the ice thickness until the CHT element's *external surface temperature* reached 0 °C. This temperature represents the point where ice formation would stop growing outward.

The same procedure was repeated for each of the eight stack sections, producing an ice thickness profile along the full height.

RESULTS

Estimated ice thicknesses were determined for each 3-m section of the stack. Results showed:

Table 1: Flare Vent Ice Layer Thickness

Elevation [m]	Ice Layer Thickness [mm]	
	11 m/s Wind	1 m/s Wind
22.5	7.2	10.0
19.5	1.6	6.6
16.5	7.0	14.7
13.5	13.4	23.1
10.5	21.1	32.0
7.5	29.0	39.9
4.5	36.9	48.3
1.5	45.2	57.1

Key observations:

- Ice thickness increases toward the base of the stack where radiation flux is lowest.
- Higher wind speed increased flare flame length reducing ice thickness due to increased radiation.
- The topmost section behaves differently due to higher gas velocities inside the smaller-diameter tip.

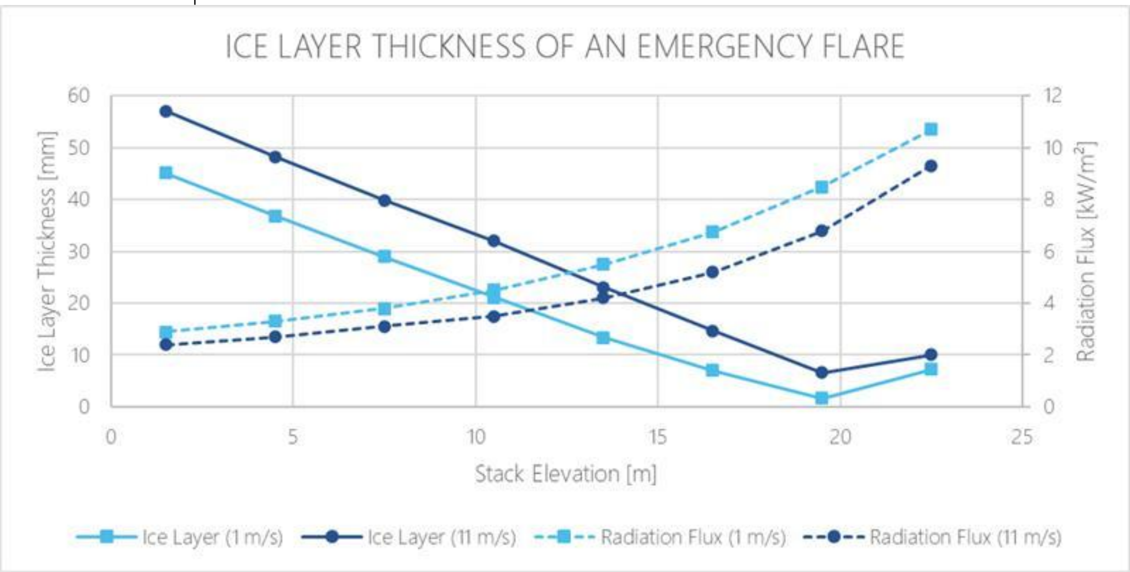

Figure 2: Emergency Flare Stack Ice Layer Thickness

These results provided engineers with a practical, section-by-section estimate to support structural calculations.

CONCLUSION

Flownex was used to build a simple, targeted model to estimate ice build-up on a low-temperature flare stack. The approach allowed rapid evaluation of ice-layer growth under varying radiation conditions, producing thickness profiles that can be directly applied in structural assessments.