Effects of ventilation and gob characteristics on spontaneous heating in longwall gob areas

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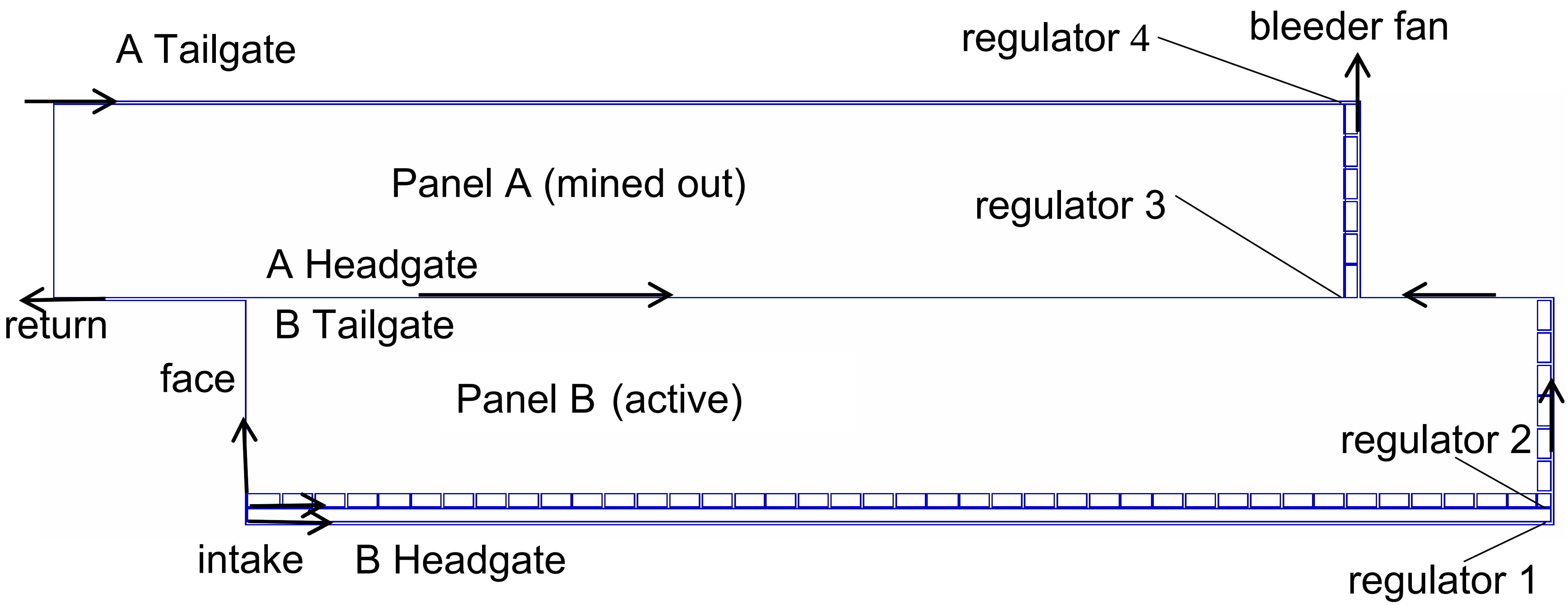
Introduction

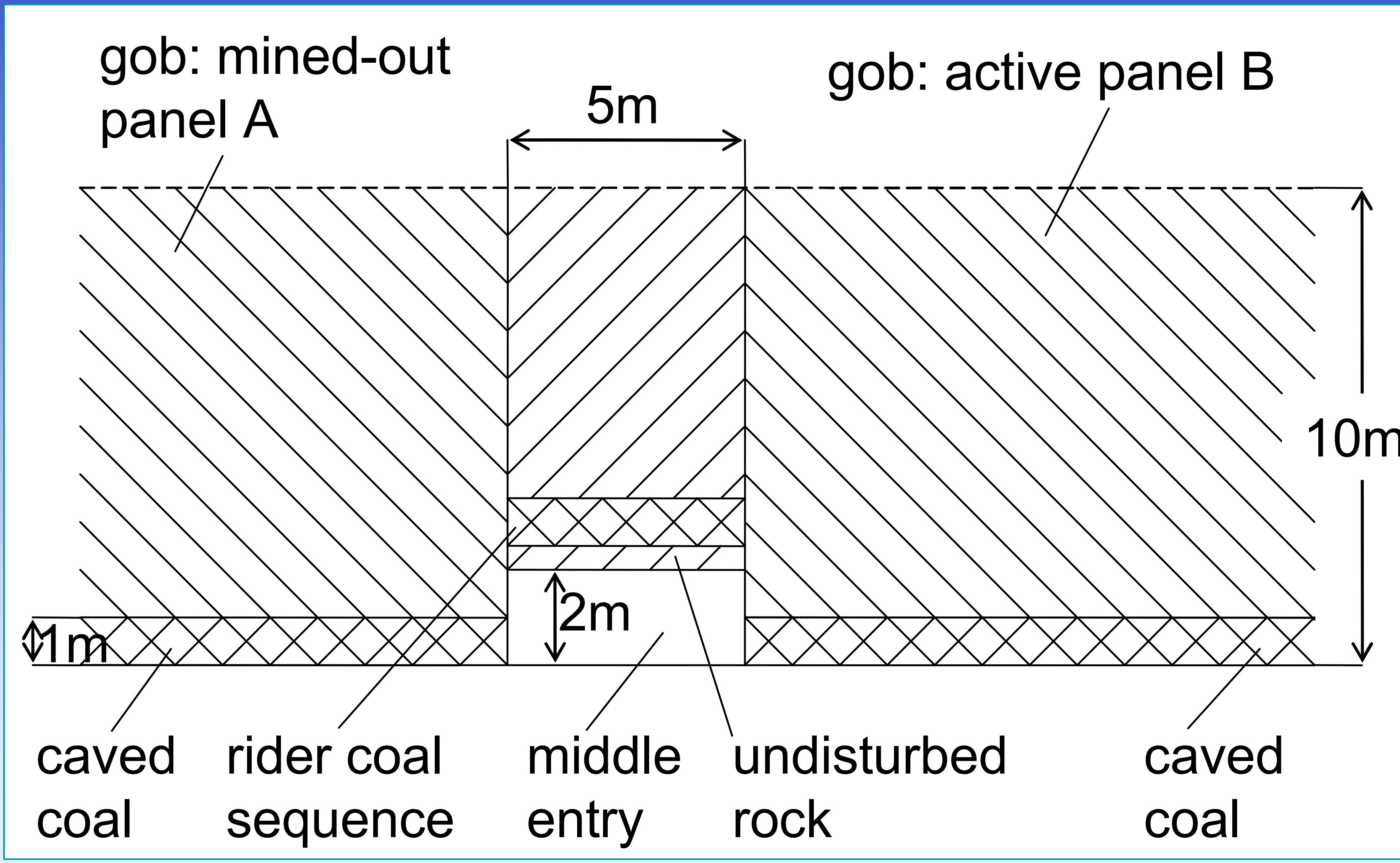
- Spon comb fires in the U.S.: 25 reported underground fires from 1990-2006
- Most spon comb fires occurred in gob areas
- Self-heating tendency of coals: laboratory evaluation
- CFD modeling of spontaneous heating: 3-dimensional, realistic mine ventilation, methane emissions, coal chemistry

Gob layout



- Two panels, each 2000 m x 300 m x 10 m
- Airways: 2 m high, 5 m wide

Caving coal layer



Modeling coal oxidation

- Low temperature coal oxidation:
  Coal + $O_2 \rightarrow CO_2$ + 0.1CO + heat
- The dependence of reaction rate on temperature and oxygen concentration:
  $$Rate = A[O_2]^n \exp(-E/RT)$$
- Heat was dissipated by convection and conduction, gas was transported by convection and diffusion
- Reaction surface area: surface-to-volume ratio

Estimation of gob permeability

- Based on geotechnical modeling of longwall mining using FLAC
- A simple equation was used to estimate the changes in permeability in the caved rock:

$$k = f\left(\frac{n^3}{(1-n)^2}\right)$$

Numerical modeling

- CFD software: FLUENT
- Basic flow field without coal oxidation: steady-state simulation
- Coal oxidation: unsteady state simulation
- Methane emissions: released uniformly along the border between the gob and the overlying reservoir, 281 cfm for panel B, 50 cfm for panel A; Face emission: 29 cfm

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Boundary conditions
(base case)

Three-entry bleeder system:

- -3.0 in w.g. at intake inlet,
- -3.5 in w.g. at the return outlet,
- -11 in w.g. at the bottom of the bleeder shaft,
- total intake airflow 87,000 cfm,
- 60,000 cfm to the face
- 50,000 cfm at the return

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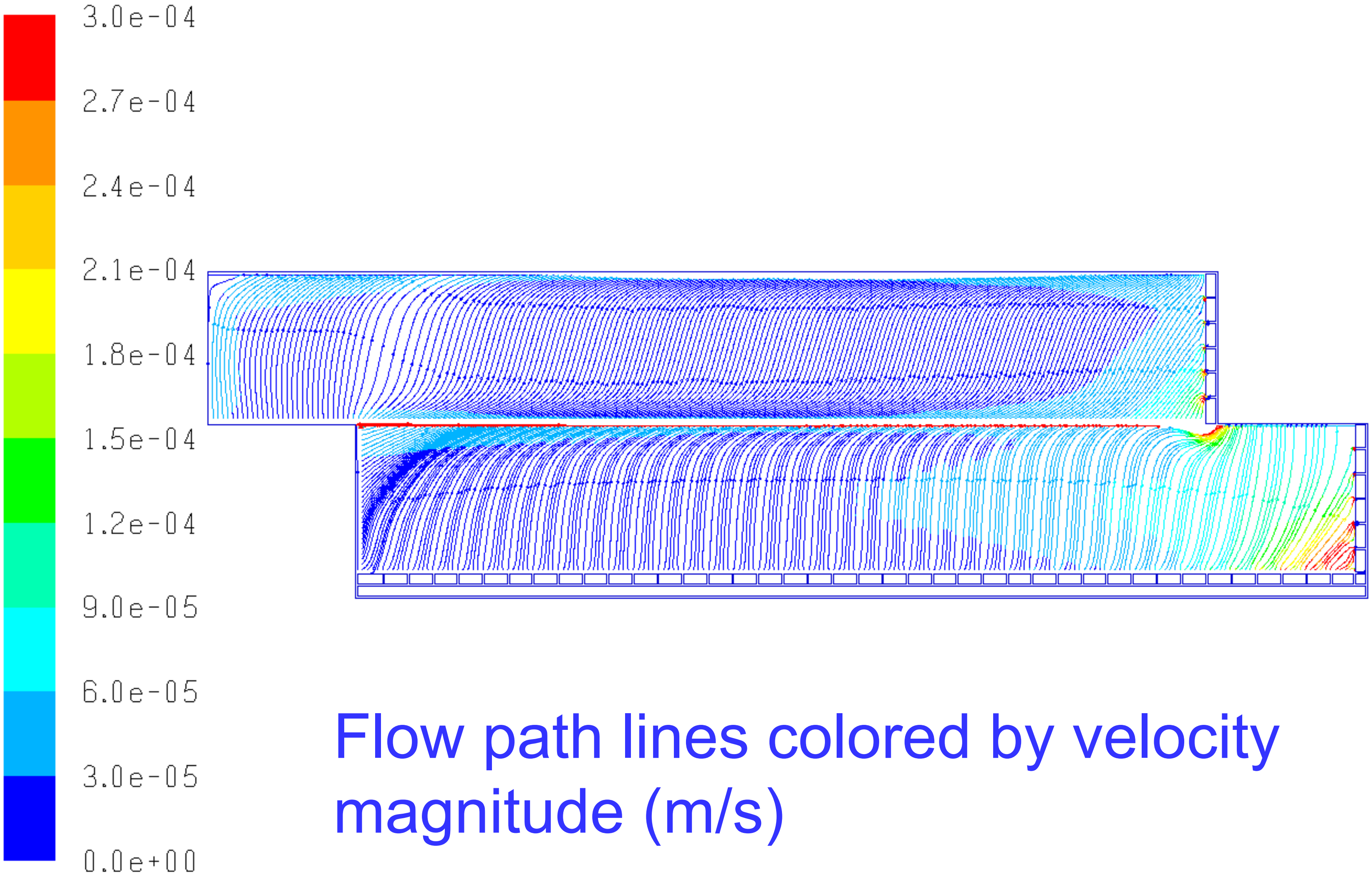
Flow field inside the gob

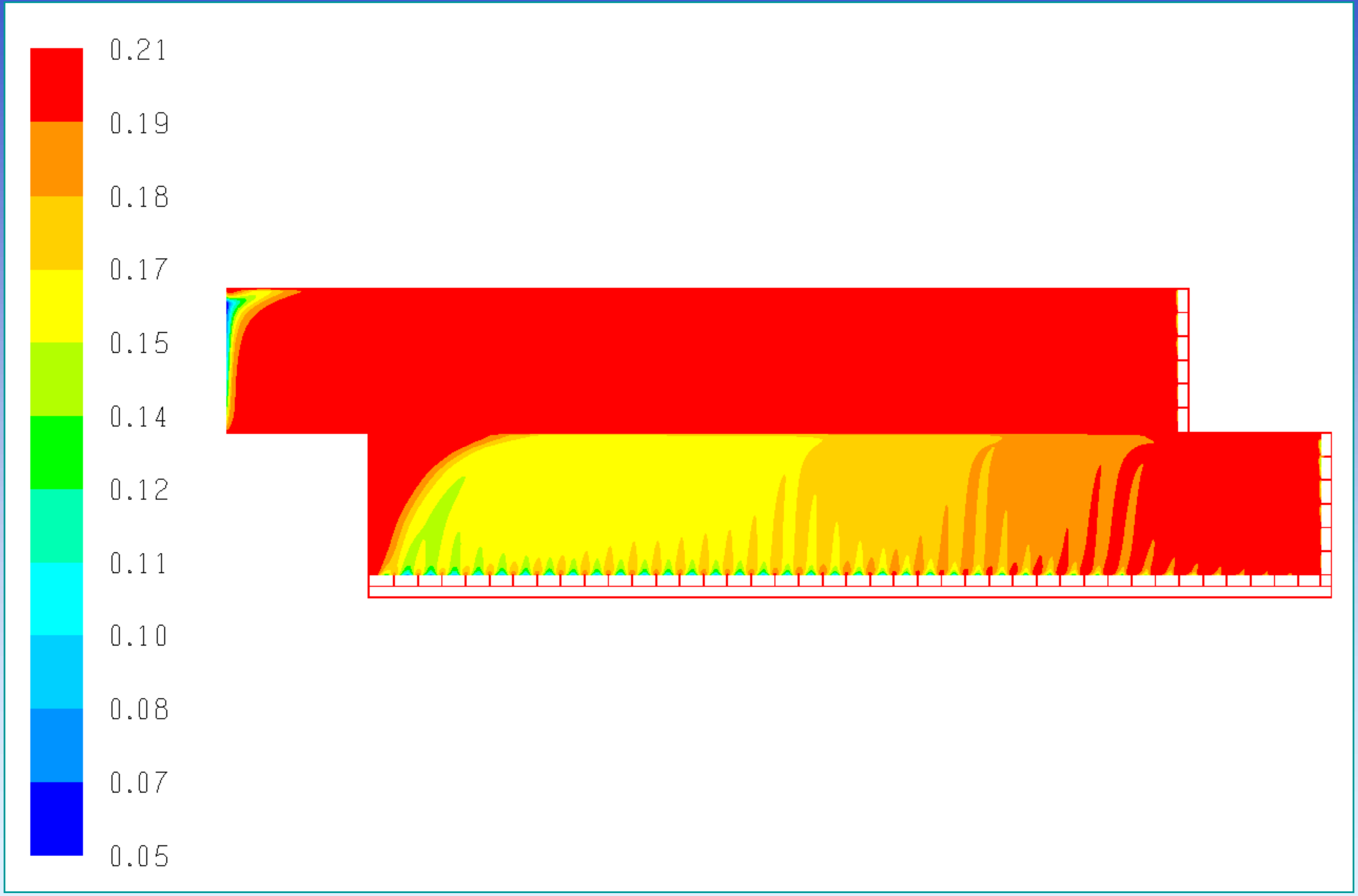
- Steady-state simulation without coal oxidation, used as the initial conditions for unsteady-state simulations
- Flow in the gob: 3-dimensional, flow in the vertical direction weaker than in the other two directions
- Results presented at a virtual horizontal surface 1 m from the bottom of the coal seam floor

Flow patterns inside the gob



Flow path lines colored by velocity magnitude (m/s)

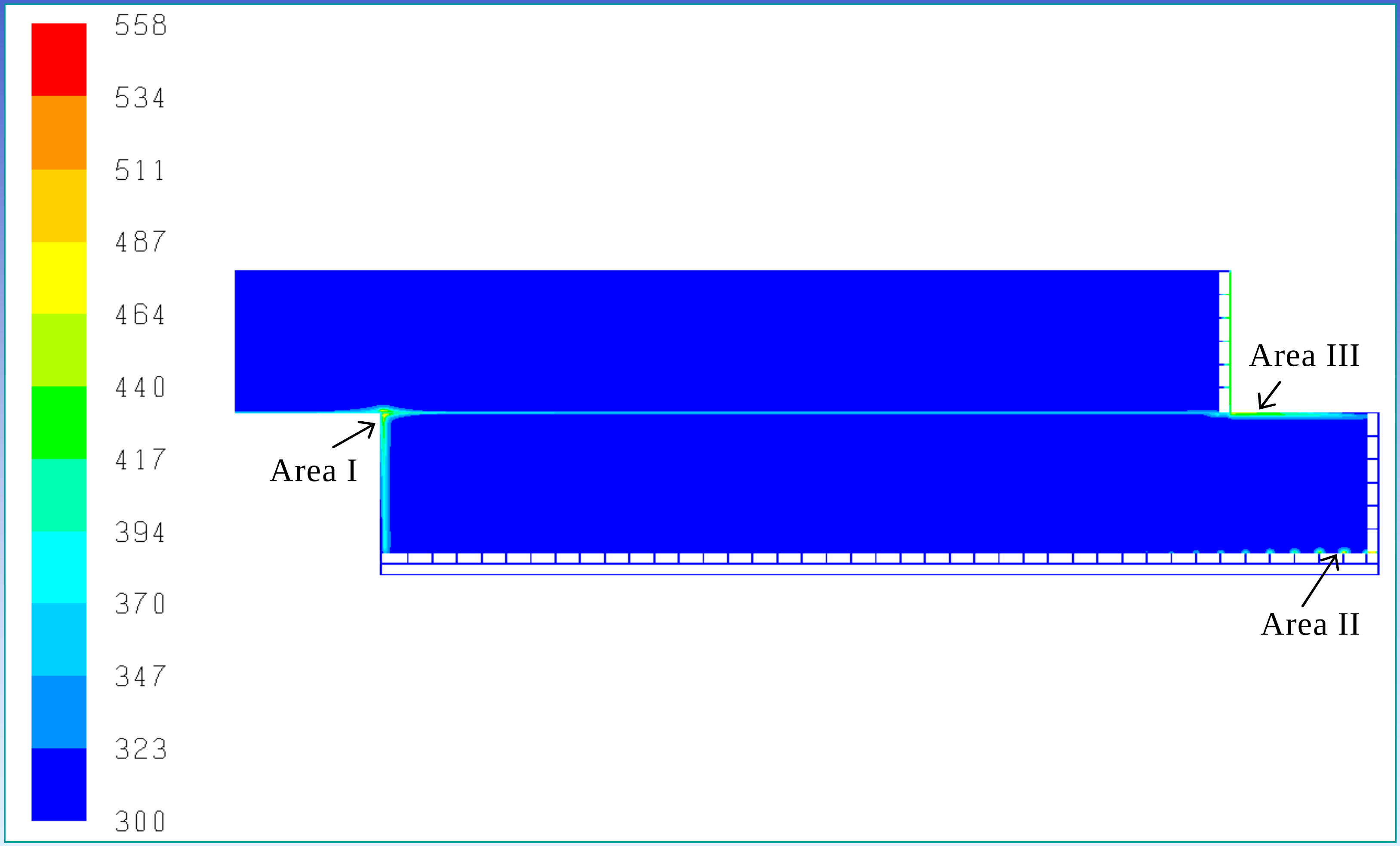
Oxygen distribution



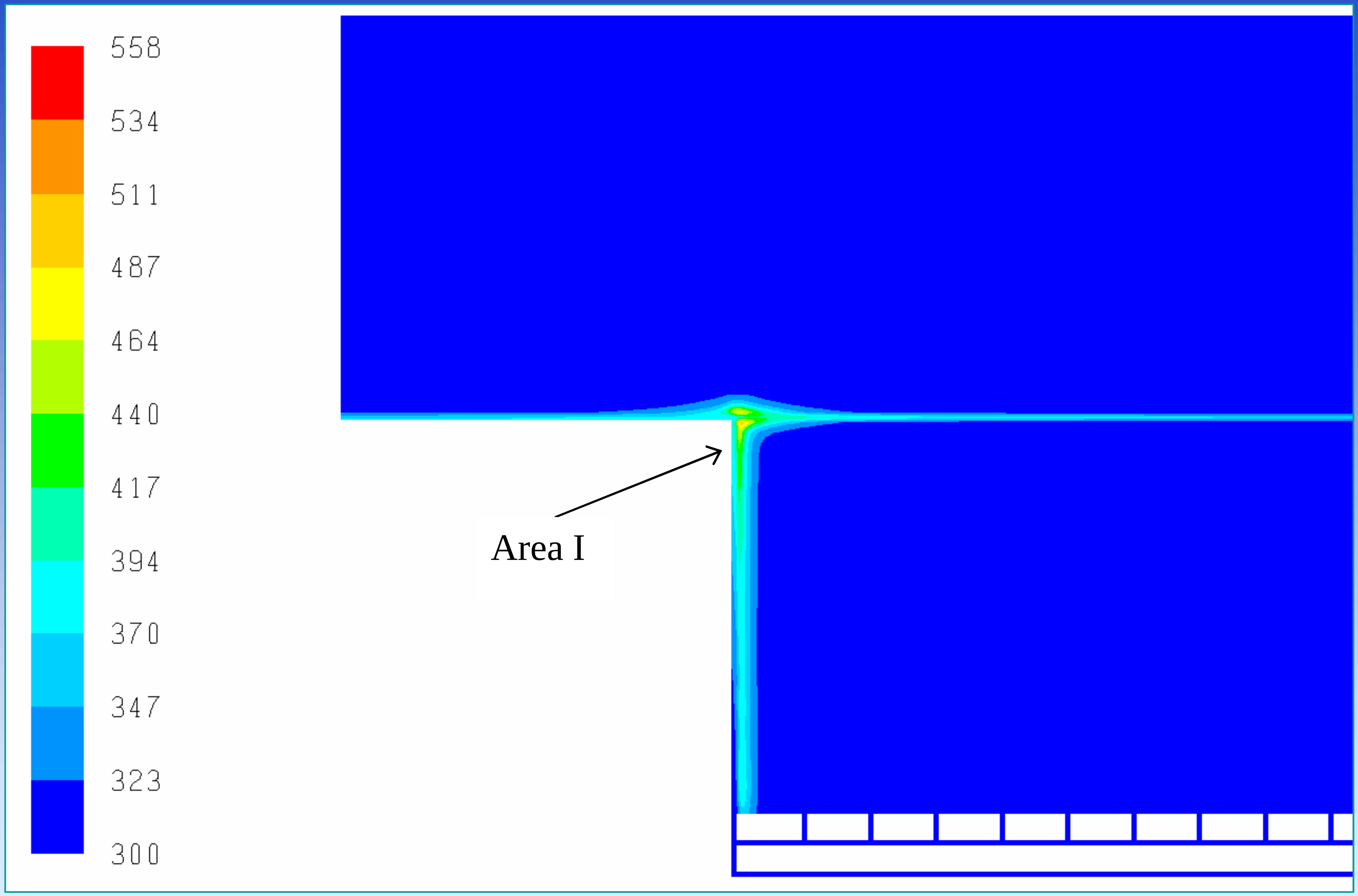
Oxygen concentration (1=100%)

Base case results

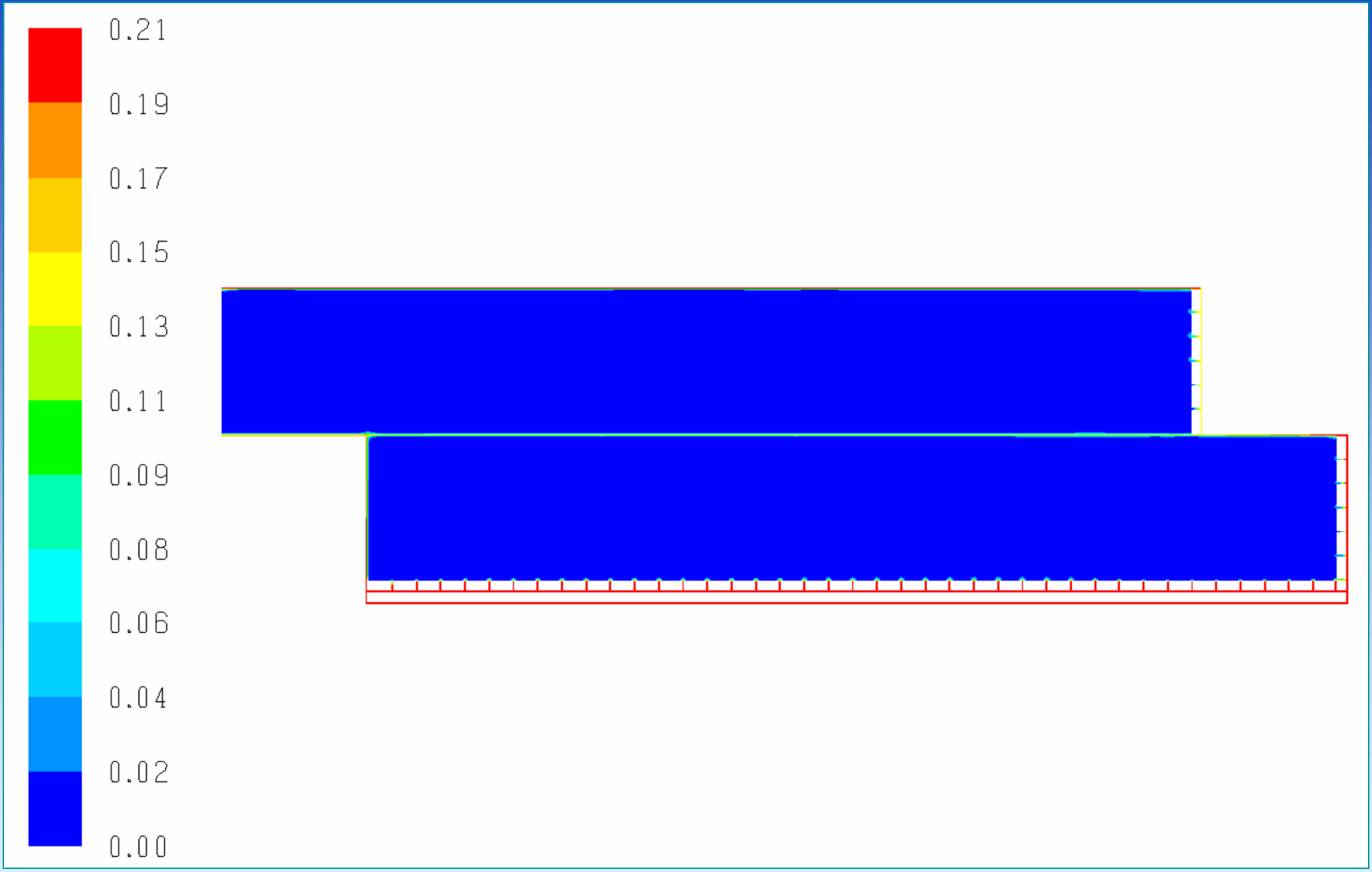
(high volatile C bituminous coal)



Temperature distribution (K) for the base case after 9 days.



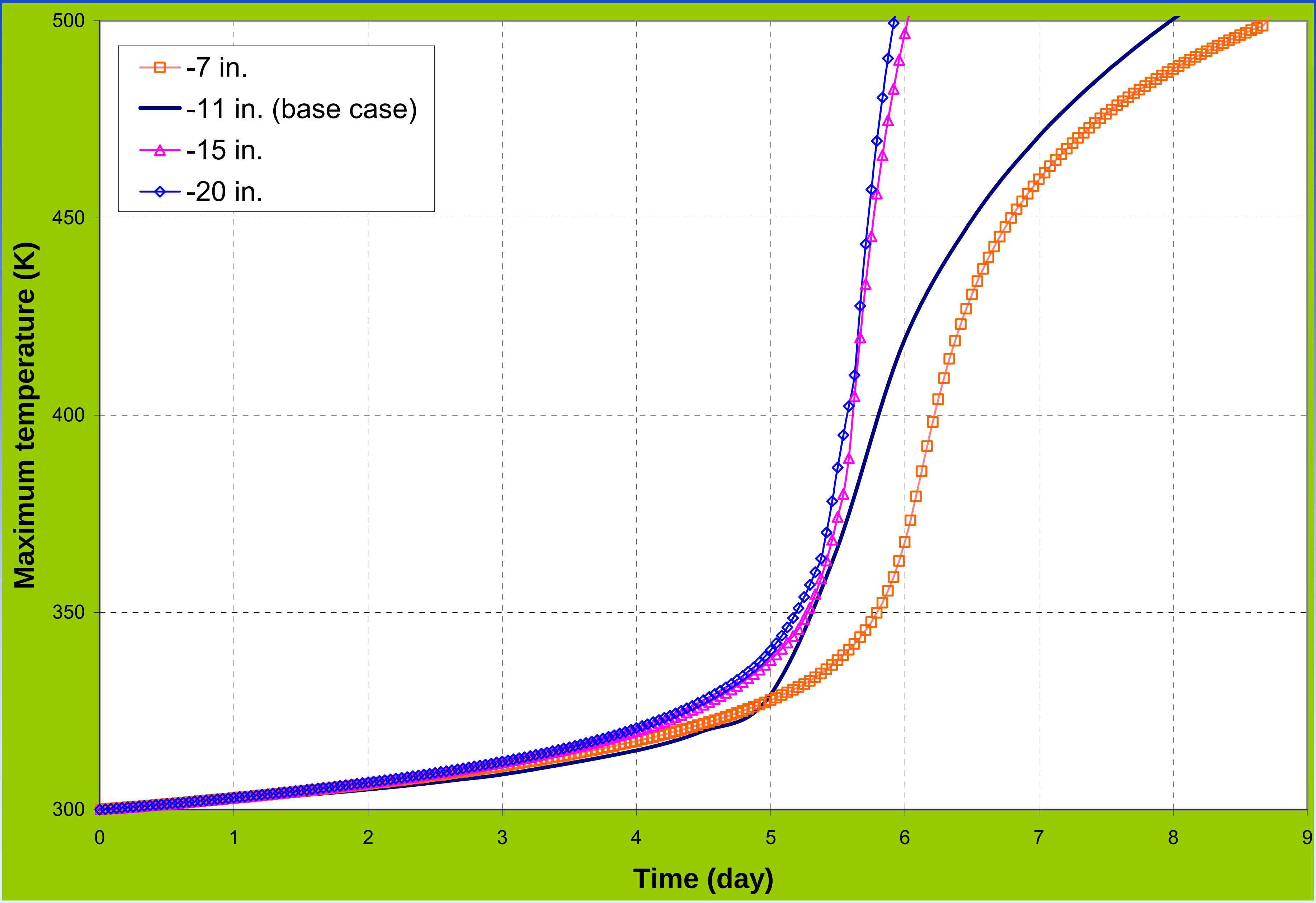
Temperature distribution (K) in area I for the base case after 9 days.



Oxygen concentration (1=100%) distribution
for the base case after 9 days

Effect of pressure at the bottom of bleeder shaft

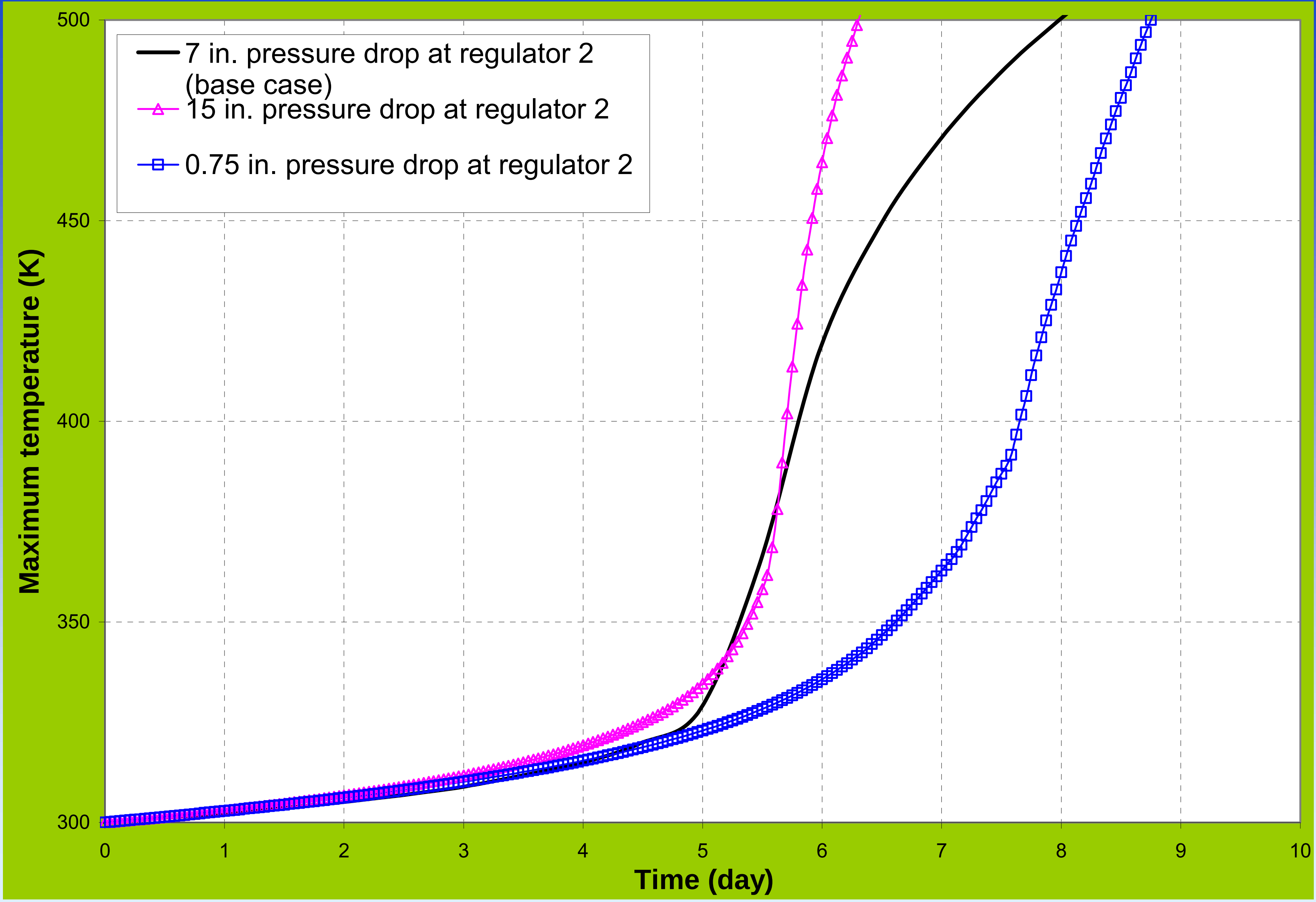
- -7 in.
- -11 in. (base case)
- -15 in.
- -20 in.



maximum temperature-time histories

Effect of resistance in the second entry inby the longwall face

- 0.75 in.
- 7 in. (base case)
- 15 in.



maximum temperature-time histories

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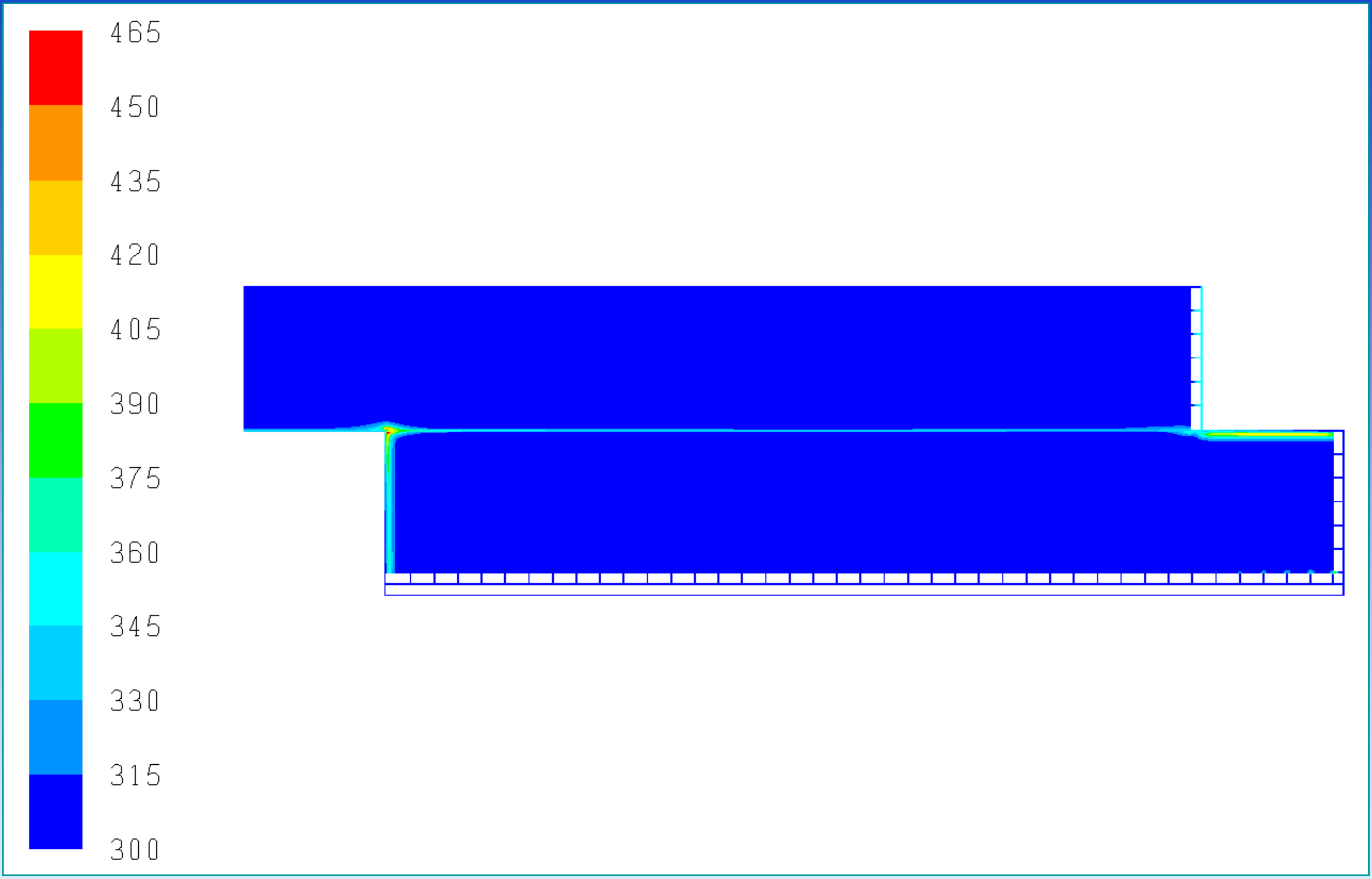
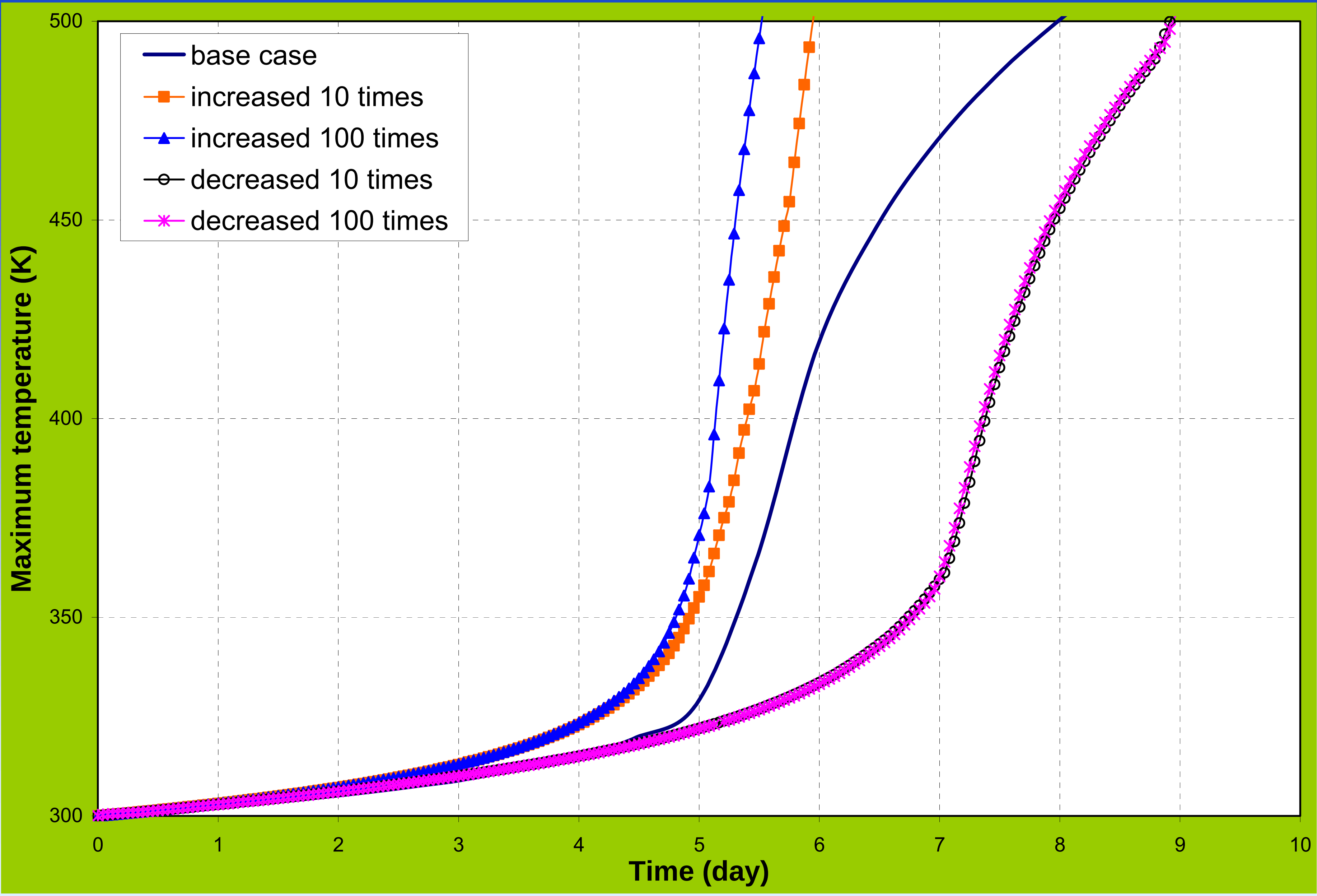


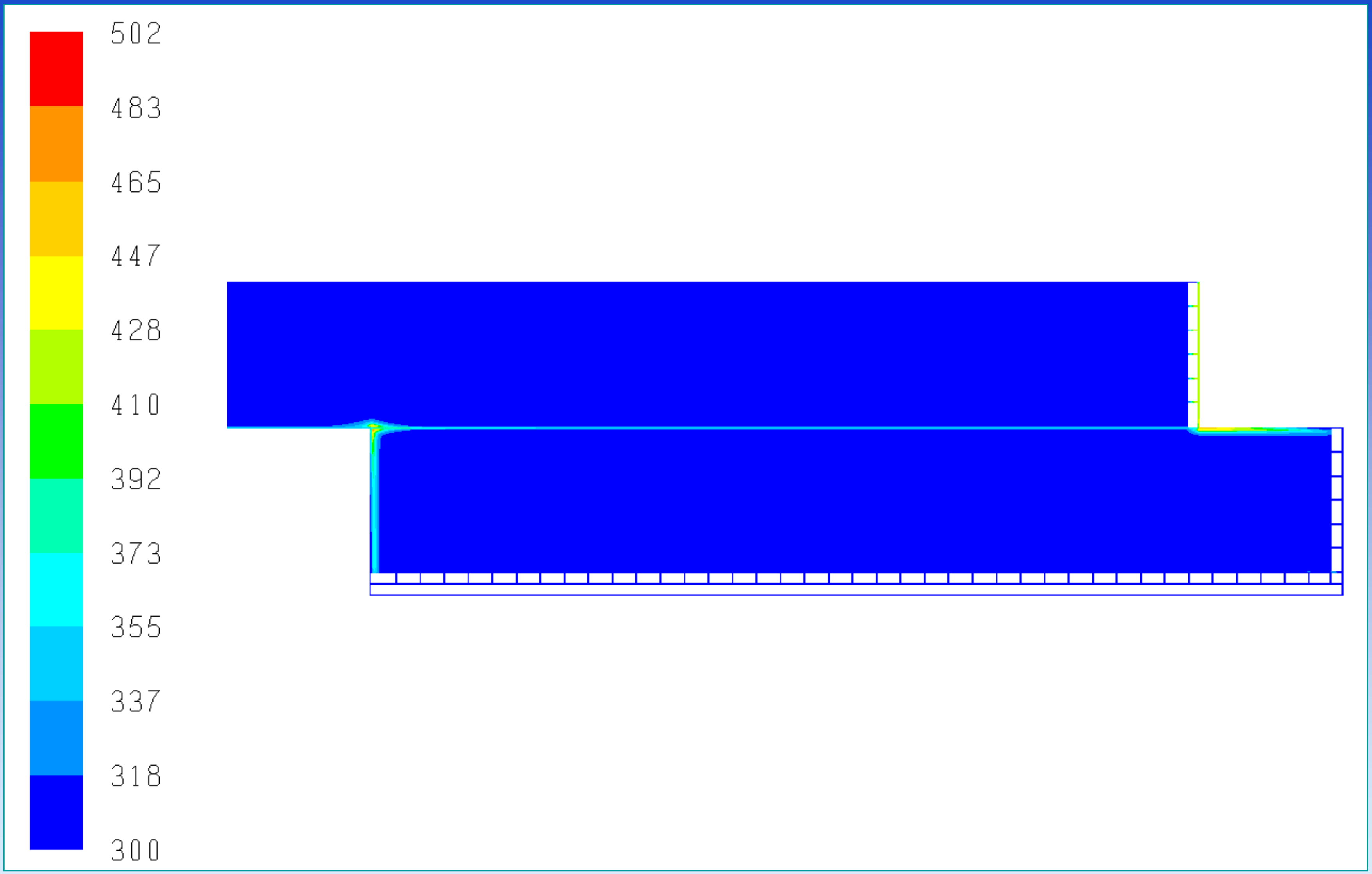
Temperature distributions (K) after about 9 days with 0.75 in. pressure drop at regulator 2

Effect of gob permeability

- Base case
- Increased 10 times
- Increased 100 times
- Decreased 10 times
- Decreased 100 times



maximum temperature-time histories



Temperature distributions (K) after about 9 days with permeability decreased 10 times

Conclusions

- Parametric study on effects of ventilation parameters and gob permeability on the spontaneous heating in longwall gob areas was conducted .
- Under the modeling conditions, increasing the pressure differential across the gob area increased the rate of maximum temperature rise.
- The increase had no effect on the induction time

Conclusions – cont.

- Decreasing the pressure differential across the gob increased the induction time while the rate of maximum temperature rise did not change significantly.
- With the increase of permeability, the induction time was decreased, while decrease of permeability increased the induction time.

Questions?