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A study of water curtain parameters of underground oil storage caverns using time series monitoring and numerical simulation

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Introduction

■ **Underground oil storage has been widely used:**
High safety, less land use, less pollution, less investment in capital construction, low operation and maintenance cost

Project location	Stored item	Volume (10^4 m^3)	Rock type	Key parameters of water curtain system			
				Hole spacing (m)	Hole length (m)	Vertical distance (m)	Orientation
Pyongtaek, Korea	LPG	22.4	Gneiss	10	100-120	25	Horizontal and vertical
K-1, Korea	Gasoline	23	Granite	12	100-120	15	Horizontal
U-2, Korea	**Crude oil**	**429.3**	**Diorite**	**7, 14**	**110**	**20**	**Horizontal**
Ningbo, China	LPG	50	Tuff	10	100	10	Horizontal
Huangdao, China	**Crude oil**	**300**	**Gneiss**	**10**	**97-110**	**25**	**Horizontal**

Overview of project

■ **Engineering geological condition:**

The main lithology in the study area is granitic gneiss. There are two faults in the project location, which crosscut caverns along the East-West direction approximately.

Fig. 1. Location of surface faults: (a) west side of ventilation tunnel entrance. Tunnel face of main caverns: (b) mileage 0+430 of the No. 1 main cavern, (c) mileage 0+137 of the No. 3 main cavern.

Underground water-sealed oil storage technology

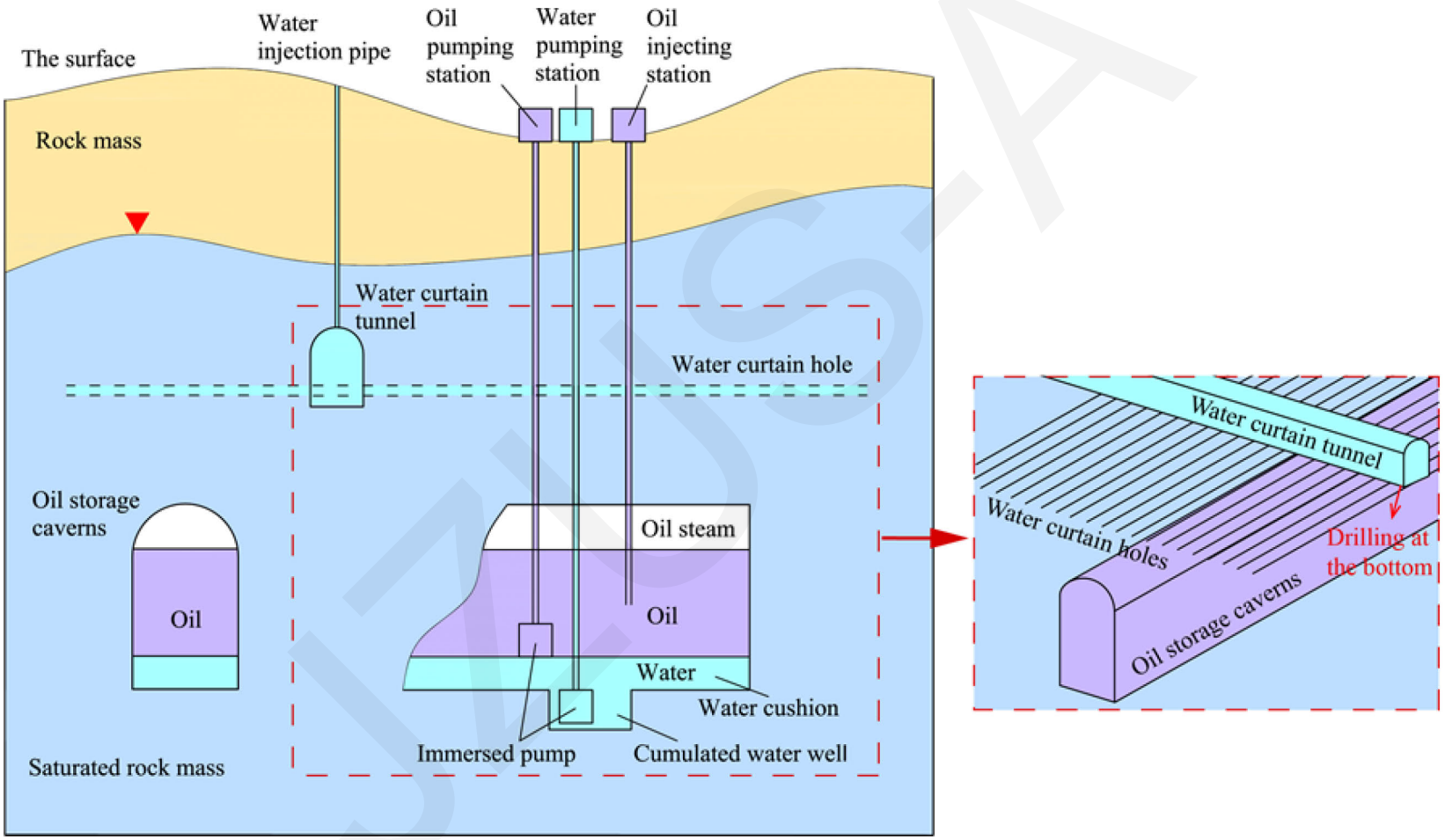

Fig. 2. Operation of a typical UOSC

Pore pressure monitoring of water curtain tunnel

■To understand the operation of water curtain system and water curtain pressure, a certain number of osmometers are buried in the water curtain tunnels to observe the pore pressure of water curtain.

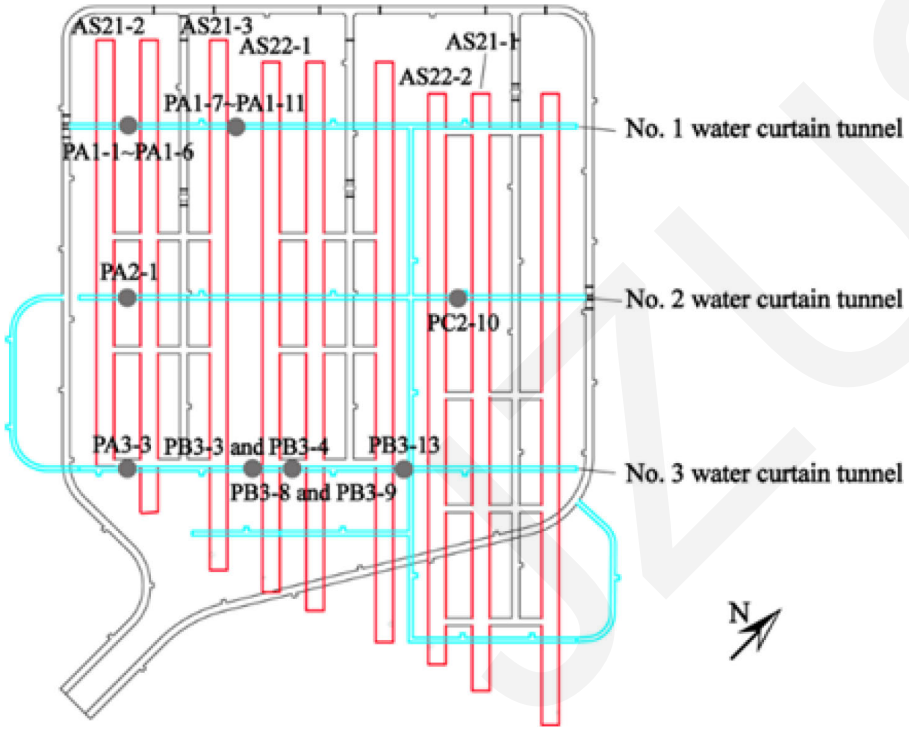

Fig. 3. Study monitoring points location.

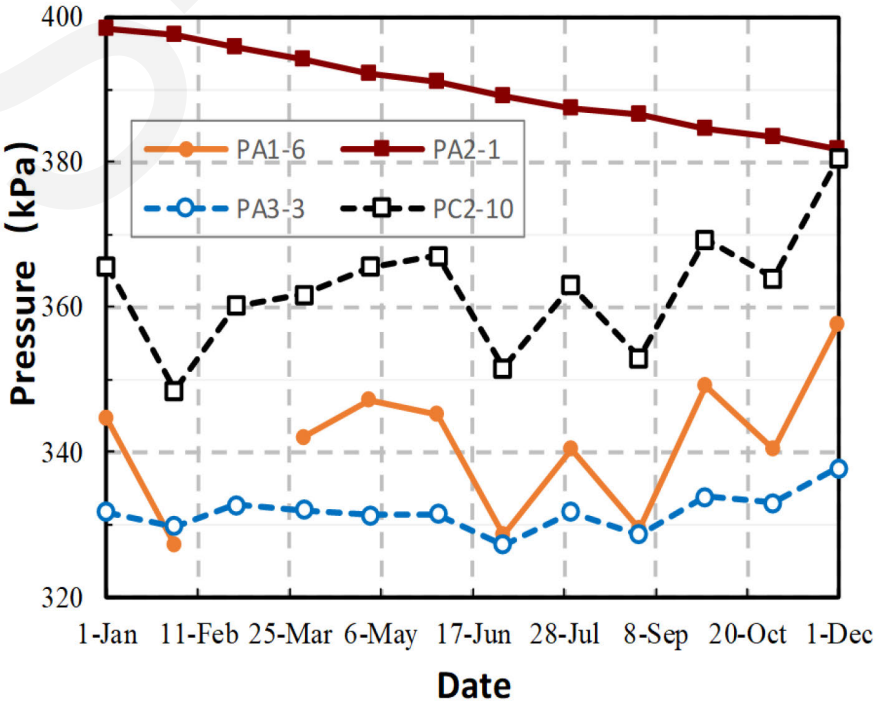

Fig. 4. Seepage pressure of monitoring points

Study on optimal design of water curtain system

■ The boundary conditions: the left and right sides are zero-flow boundaries; the upper and lower boundaries are pressure boundaries, allowing groundwater to freely cross the boundary surface.

■The arrows show the velocity vector distribution of the fluid, indicating the water-sealing effect around the cavern under each hole spacing.

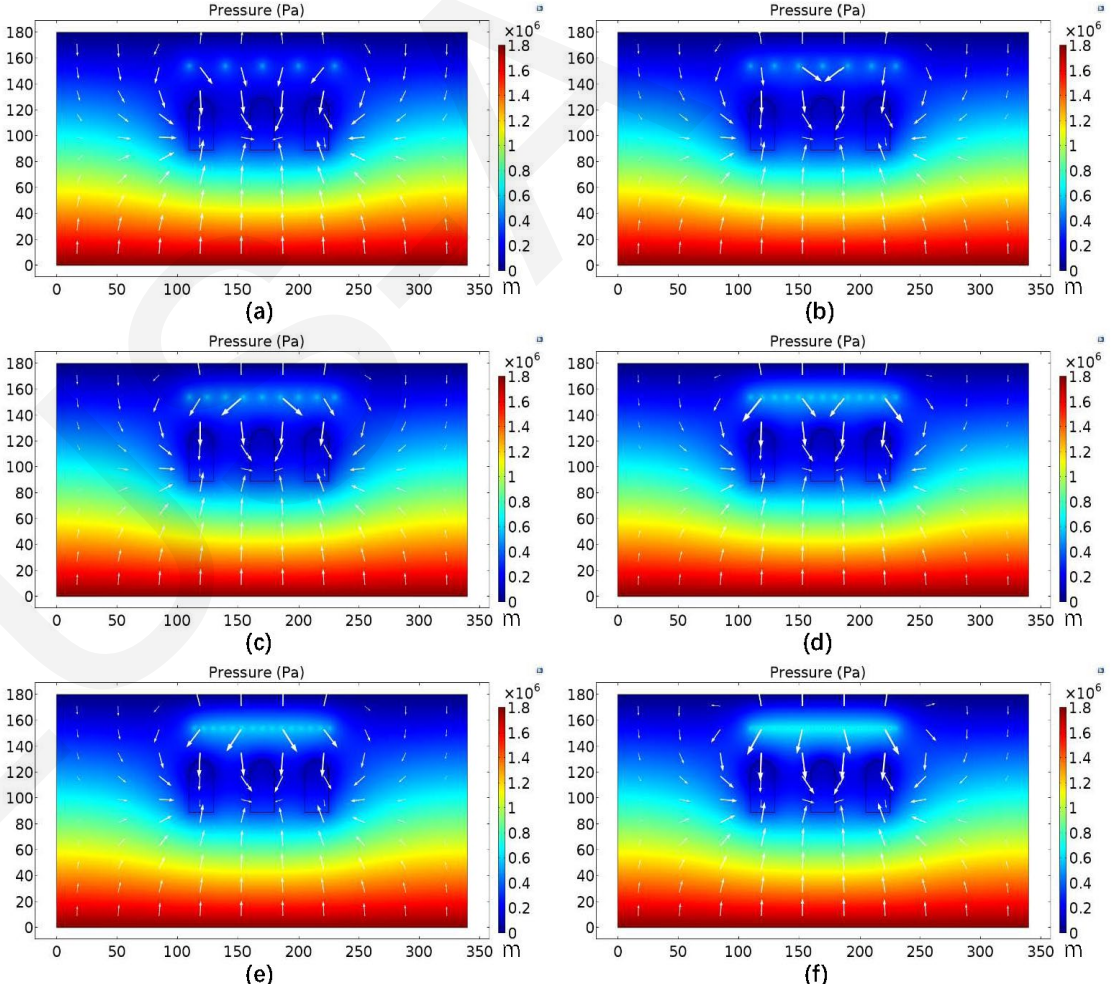

Fig. 5. Pore pressure distribution and Darcy velocity field. WCH spacing is: (a) 30 m, (b) 20 m, (c) 15 m, (d) 10 m, (e) 8 m, (f) 5 m.

Study on optimal design of water curtain system

- When the water curtain hole spacing is 15~30 m, the pore pressure is less than the gravity stress.
- The water-sealing property cannot be guaranteed.

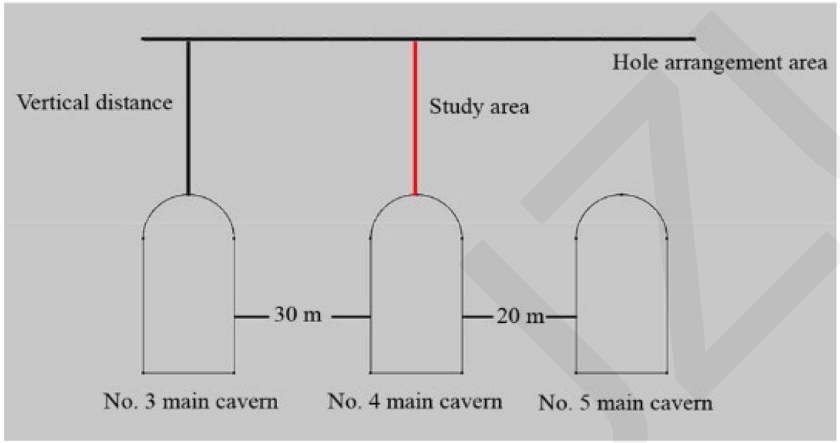

Fig. 6. Study area for Fig. 7

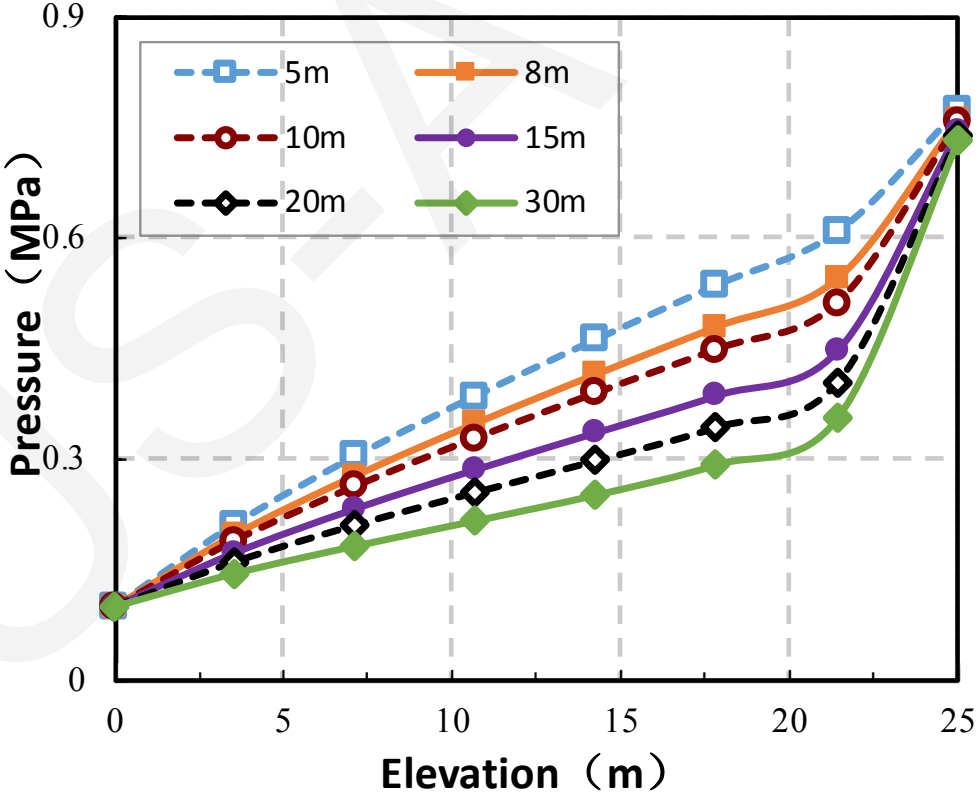

Fig. 7. Pressure at the elevation of 0~25 m at different WCH spacings (The horizontal plane at the top of the caverns is taken as the zero datum)

Conclusions

- The optimal water curtain hole spacing of this underground water-sealed oil storage caverns is 10 m, the reasonable distance between the water curtain hole and the cavern is 25 m, and the optimal water curtain pressure is 70 kPa.
- There is a critical value (10m) in the design of the water curtain hole spacing. When the hole spacing is larger than this value, water seal fails, and if it is smaller than this value, the effect improvement is not obvious and the cost increases much.
- When the water curtain hole spacing is 10 m and the water curtain pressure is 80 kPa, the water curtain system with horizontal holes has a vertical action range of about 25 m.