

# Bidirectional Automatic Control Waterproof Gate in Daizhuang Coal Mine

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**Abstract.** The coal mine in the area of 1160 and 2160 mining area of Daizhuang coal mine is threatened by thirteen limestone water and ordovician limestone water, coal in the 2160 mining area need to be sent to the -580 belt conveyor system via the belt conveyor of 1160. In order to isolate the two different direction water disaster area, we decided to establish a bidirectional waterproof gate chamber. In order to close the waterproof gate quickly and effectively, decided to design the automatic control system of waterproof gate with programmable control technology, accomplish automatic control and remote control of the waterproof gate. After the completion, perform quick closing test, verify its in the 50s, quickly closed waterproof gate.

## 1. Introduction

The hydro geological conditions are complicated and the water inrush is very dangerous in Daizhuang coal mine, to ensure the safe and sustainable development of enterprises, maximize the exploitation of coal resources of Daizhuang coal mine. It is necessary to build a bidirectional waterproof gate chamber in the belt lane where 1160 mining area and 2160 mining area both use. Through the automatic control system of the waterproof gate, the waterproof gate of the water inrush disaster area is quickly shut down, to make the mining area quarantined, limit the scope of disaster impact to the minimum.

## 2. Geology introduction

The under-group coal seams in Daizhuang coal mine mainly produces 16 and 17 coal seams, the direct filling water source of 16 and 17 coal is ten lower limestone water, the water yield property of ten low limestone aquifers is good, and local ten low limestone aquifers and thirteen limestone aquifers, Ordovician limestone aquifers have vertical hydraulic connection. Thirteen limestone aquifers, Ordovician limestone aquifers are rich in water, high water pressure, and high water inrush risk.

## 3. Water gate chamber design

### 3.1. Water gate chamber location selection

The water gate chamber shall be located in a hard, stable, complete and dense rock formation, avoid karst fault, joint and fracture zone. The chamber should be located in small section and straight line, not be located in the coal seam and should not be affected by mining, setting protective coal and rock pillars around it.

The gate chamber is arranged in the crossheading of the district sublevel in -580 horizontal north wing concentrated orbit rise, the distance of the crossheading in main haulage way of the 2160 mining area is 20.6~38.7m, It is located at the base of 8 limestone rock. The elevation of the chamber floor is



-468.6m. The rock body is relatively complete, have good construction conditions.

### 3.2. Choice of chamber structure

The roadway of the chamber is a semicircular arch, net width is 4.2m, net height is 1.5m, net cut area is 13.23m<sup>2</sup>, use bolting and shotcreting. To facilitate the installation of the water gate, the front and back of the chamber where build by laying bricks or stones the self-closed need to widen the expanding, after enlarged, the net width of the roadway is 4.8m, net height is 2.1m, net cut area is 19.13m<sup>2</sup>.

The chamber is in the belt roadway; keep the MLZ/2000 x 2320 single rectangular steel shell waterproof door in the direction of 1160 mining area, as a manual gate chamber. Set two waterproof gates in the direction of 2160 mining area, one choose ZM-PD /1700 x 2600 automatic double-fan waterproof gate, installed in the belt roadway gate chamber; Another one choose the ZM-PD /900 x 2600 automatic waterproof gate, installed in the pedestrian gate chamber for pedestrians. The belt roadway gate chamber and pedestrian gate chamber connect to the manual gate chamber, forming a bidirectional waterproof gate chamber.

### 3.3. Determine chamber design parameters

#### (1) Design hydrostatic pressure

The pressure level of the waterproof gate is determined according to the design of hydrostatic pressure; the calculation formula is as follows:

$$P = \rho gh = 4.95 \text{ Mpa} \approx 5 \text{ Mpa} \quad (1)$$

In the formula:  $P$ —Hydrostatic pressure value, Mpa;  $\rho$ —Density of water, 1000kg/m<sup>3</sup>;  $h$ —Maximum head height.

The static water level of the ordovician limestone water is 36.54m,  $h = 36.54 - (-468.6) = 505.1$ .

By the calculation, the maximum hydrostatic pressure to resist is 5Mpa, consider the surplus coefficient, and choose the nominal pressure 5.5Mpa waterproof gate.

#### (2) Design value of concrete strength of chamber

According to the concrete strength design value specified in *specification for structural design of concrete (GBJ10-89)*, choose concrete with a strength grade of C30, cement label P.O32.5, ratio: water: cement: sand: stone = 0.38: 1: 0.958: 2.462 (Weight ratio). Its axial compressive strength  $[\sigma] = 15 \times 0.9 = 13.5 \text{ MPa}$ , allowable shear strength  $[\tau] = 2.09 \text{ MPa}$ .

### 3.4. Determine the main body size of the chamber

According to the water gate chamber, gate valve, pipeline, door fan installation and transportation, ventilation, pedestrian and other requirements, determine the characteristics of the front and rear chamber. And then it's based on the characteristics of the front and rear chamber, shear strength of C30 concrete and ompressive strength of rock body, according to the relevant regulations in *Mining engineering design manual*, select the “calculation formula of inverted truncated cone shaped wall” to determine the main length and main width of the chamber. The calculation formula is as follows:

#### (1) Determine the stress attenuation segment length of the gate wall

$$L_i = [\ln(\gamma_o \gamma_f \gamma_d P) - \ln(f_t)] / 0.3986 = 4.375 \text{ m} \approx 4.4 \text{ m} \quad (2)$$

In the formula:  $L_i$ —the stress attenuation segment length of the gate wall;  $\gamma_o$ —Coefficient of structural importance, take 1.1;  $\gamma_f$ —partial safety factor for action, take 1.3;  $\gamma_d$ —Structure coefficient, take 1.2;  $f_t$ —Design value of concrete axial tensile strength of C30 concrete, take 1.5N/mm<sup>2</sup>;  $P$ —Waterproof gate chamber is designed to withstand water pressure, take 5N/mm<sup>2</sup>.

#### (2) Determine the length of gate wall

According to the layout of the water gate in this chamber:

$$L = 2L_i + L_o = 8.8 \text{ m} \quad (3)$$

In the formula:  $L$ —the length of gate wall;  $L_o$ —the length of the stress recovery section of the gate wall, considering the layout of bidirectional waterproof gate chamber, take 1.2;

(3) Determine the maximum excavated section of the chamber

$$S_2 = (\gamma_o \gamma_f \gamma_d \gamma_{sd} P + f_{cc}) S / f_{cc} = 42.17 \text{ m}^2 \quad (4)$$

In the formula:  $S_2$ —The maximum excavated section of the chamber;  $\gamma_{sd}$ —The Coefficient of action instability, the value range is 1.2~2.0, the compressive strength of surrounding rock is low and water pressure big is going to be a big value, take 2.0;  $f_{cc}$ —Design value of compressive strength of C30 concrete, values for the design value of compressive strength of C30 concrete multiplied by the 0.95, take  $15.0 \times 0.95 = 14.25 \text{ N/mm}^2$ ;  $S$ —The net sectional area of the roadway before and after the gate wall, take  $19.13 \text{ m}^2$ .

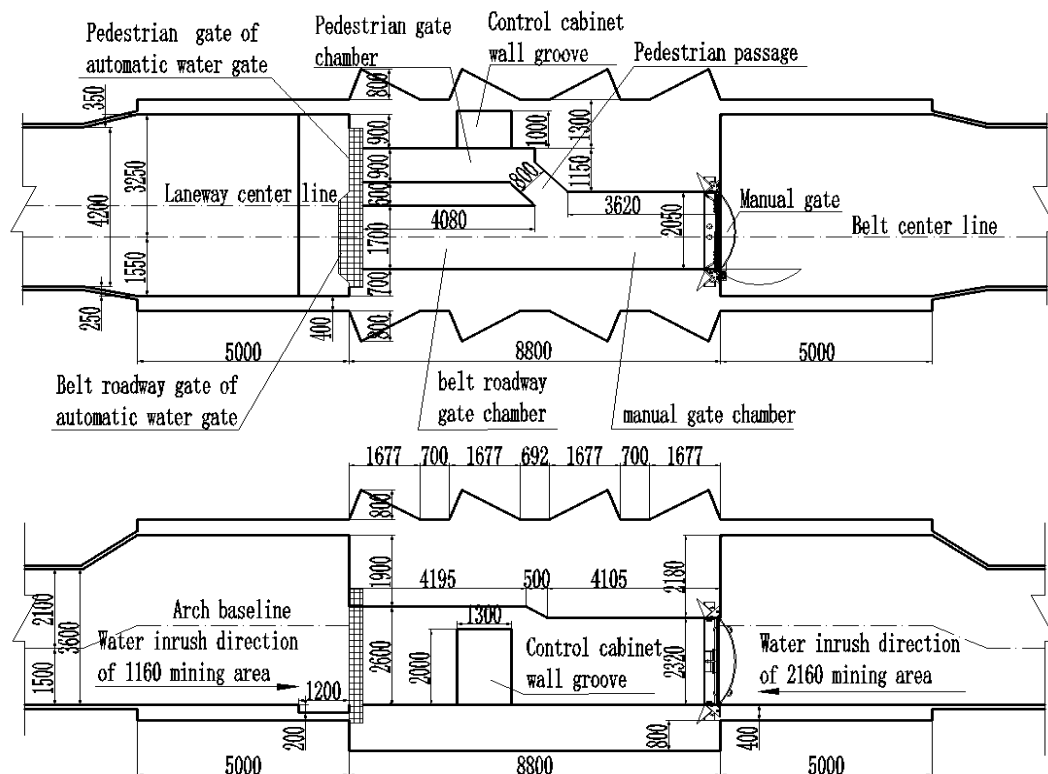
(4) Determine the embedding depth of chamber wall

$$E = \frac{-(\pi B + 2B + 4h_3)^2 + \sqrt{(\pi B + 2B + 4h_3)^2 - 4(4 + \pi)(2Bh_3 + 0.25\pi B^2 - 2S_2)}}{2(4 + \pi)} = 1.12 \text{ m} \approx 1.2 \text{ m} \quad (5)$$

In the formula:  $E$ —The embedding depth of chamber wall;  $B$ —The net width of the roadway before and after the gate wall, take 4.8m;  $h_3$ —The net height of the roadway before and after the gate wall, take 2.1m.

To sum up, the length of the chamber wall is 8.8m; the embedding depth of chamber wall is (including the laying bricks or stones of the wall) 1.2m.

The two sides of the chamber are concrete masonry with a length of 5m and a thickness of 400mm, both the chamber and the concrete masonry are use high - label cement for repeated grouting reinforcement, the final grouting pressure of the main body of the chamber reaches 1.5 times of the design value of water pressure, namely 7.5MPa. As shown in Figure 1. The plane and profile of the bidirectional waterproof gate chamber.



**Figure 1.** The plane and profile of the bidirectional waterproof gate chamber

#### 4. The automatic control system of the waterproof gate

To improve the mine automation and information management level, reduce labor intensity, in order to achieve automatic control on site or remote control can quickly close the gates within 50s, design and

establishment of automatic control system for waterproof gate.

#### *4.1. The on-site control system*

The on-site control system on the one hand linked to field devices, to collect information, complete the gate of the automatic control field, on the other hand linked to station control level, transmit real-time information, accept the orders.

*4.1.1. Field devices in the on-site control system.* The on-site control system completes the switch action of the gate by controlling the field devices, the field devices is all installed in the gate control cabinet, Includes the gate position sensor box, the liquid control device explosion-proof electromagnetic valve group, the electronic control device PLC programmable explosion control box and the energy accumulator.

*4.1.2. The on-site control system node.* The on-site control system node has the functions of collecting field information, completing information exchange and accepting orders from superior. The specific function of each node is: The water level and pressure sensor respectively collect the water level and the water pressure; The angle sensor and the switch gate position sensor can detect the water gate position and determine the state of the gate; The surveillance camera collects the state of the gate, and it is uploaded to the ground dispatching centre through the network transmission device; The voice and light alarm apparatus have alarm function to remind underground workers and operators; The gate controller controls the opening and closing of the waterproof gate.

#### *4.2. The remote control system*

The remote control system uses network switch as the core to form a network, includes the centralized control layer and the central control layer, used for receiving real-time information on site, after the staff analysis, give control orders to the waterproof gate.

*4.2.1. Remote control system control layer setting.* The centralized control layer is located in the gate management unit duty room of the alleys. The installation has 1 LCU cabinet and 1 optical end machine, used to receive signals such as gate position, limit and water level, and continue to upload to the central control layer, has the authority to control the shutoff of the waterproof gate. The central control layer is located in the machine room of ground management unit control center, there is an industrial-level monitoring machine installed, also equipped with data server, network optical transmitter, uninterrupted power supply and other equipment, there are functions such as data calculation and processing, monitoring and control of gate operation condition, send control instructions and so on. Both control layers are equipped with surveillance cameras to record real-time information on the site, upload monitoring computers to store and establish real-time databases.

*4.2.2. Remote control system intelligent communication system.* The intelligent communication system is used to connect three control layers to complete interlayer information transmission. It takes the communication substation as the centre, on the one hand, information collected by each intelligent sensor in the on-site control layer is uploaded to the communication substation via the M-BUS bus, then transferred to the ground monitoring host through the data conversion bus; On the other hand, the ground monitoring host sends control command or alarm information and their corresponding addresses through the data conversion bus to the communication substations, again by the communication substation through the M-BUS bus distributed to the corresponding intelligent sensor. Set up the communication interface to make the smart units more convenient access to the M-BUS bus, the interface circuit is designed based on TSS721A, realize the functions of M-BUS /TTL signal conversion and bus power supply to reduce the power consumption of smart units.

#### *4.3. Automatic control system action flow*

The waterproof gate is fully open under normal conditions. When a water inrush disaster occurs, water level sensor and pressure sensor collect water level and water pressure information, upload to the gate

control cabinet, the PLC programmable controller in the control cabinet responds to the information quickly, produces shutoff gate signal. At the same time, the real-time information collected by intelligent sensors and surveillance cameras in the on-site control layer to be uploaded to the monitoring room through the intelligent communication system, the staff judged the situation on the disaster occurred spot, remote order to close the gate, remote issued an command to close the door, the shutdown command is sent through the intelligent communication system to the PLC programmable controller in the field control cabinet. PLC programmable controller according to self-generated command signals or received command signals to execute the application, control the electrical control device for hydraulic hoist to start the oil pump unit, turn on the corresponding solenoid valve to push the oil cylinder out, and then drive the gate to close. In this process, the position information of the gate is collected from the angle sensor and the switch gate position sensor, determine the closing state of the gate, make sure the gates are airtight, after airtight the gate closed indicator lights. The voice and light alarm apparatus in the field are responding to the danger signal, send the alarm signal, inform the field personnel to evacuate immediately.

The control authority of remote control is higher than that of on-site automatic control; the staff in the control room can modify the on-site automatic control results, prevention of systematic misjudgment. And they're independent of each other, the other one still works when one fails, make sure to close the waterproof gate quickly when the water burst.

### 5. Test of application effect of waterproof gate

After the waterproofing gate chamber and its automatic control system are completed, closing test is required, to verify the reliability of the automatic control system.

The closing test is divided into two parts: on-site automatic control shutdown test and remote control shutdown test, the on-site automatic control shutdown test was completed by field simulation of water inrush to make waterproofing gate automatic control system shut down waterproof gate, the remote control shutdown test was completed by close the waterproof gate through a remote control system in the ground control room, record the time required for two tests to close the gate, after closing the door, check whether the system is abnormal and make a detailed record.

Through test and observation, whether it is on-site automatic control or remote control, the closing time is about 50 seconds, and there were no abnormalities in the whole process, meet the design requirements.

### 6. Conclusion

The Daizhuang coal mine has design and established a bidirectional waterproof gate chamber and its automatic control system. When the water inrush occurs in the actual underground work, the gate is quickly and accurately closed, the water inrush mining area is isolated, and the design aim of adjacent mining area protection is realized. Provides experience for coal mine with similar situation.

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