

Research on the Gas Tunnel Ventilation

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ABSTRACT Along with the development of high speed railway, the ratio of high gas tunnel in construction process becomes more and more. Meanwhile, ventilation is an important measure to make sure security of gas tunnel construction, it is a key problem that whether the ventilation system is perfect or not. Through the research of actual gas tunnel, not only to meet the demands of construction, but also to save cost, therefore, it is key point of modern gas tunnel construction.

KEYWORDS

High gas
Tunnel
Ventilation

1. Ventilation Design

According to high gas geological condition of the Laozhou tunnel, general ventilation scheme is gallery ventilation, in order to make sure the ventilation effect, take the cross channel spacing no more than 300m into consideration, specific phases ventilation scheme as follows:

The first stage: before the first cross connecting press-in type is adopted. One 2×110kw axial flow fan with φ1800mm air hose is set in main tunnel, and one 2×55kw counter-rotating axial fan is set in parallel adit.

The second stage: after the first cross connecting type of roadway all negative pressure ventilation system is adopted. Two fan are set in main hole, keep ventilation separated. On one hand, one 2×110kw counter-rotating axial fan with φ1800mm air hose blowing ventilation, on the other hand, keep parallel adit ventilating through cross, one 2×55kw counter-rotating axial fan with φ1500mm air hose is set to ventilate by press-in type. Take the narrow cave entrance into consideration, the first cross through tunnel is in and out transportation channel, dig specific airway on the left of flat guide in entrance, One 2×110kw coal mine explosion-proof draw-out ground of axial flow ventilator is set with another standby application, and air door is set in proper place of access adit. 2 drought fans in main hole move forward with digging, the distance between fan in main hole and excavation face is no less than 330m, and the distance

between parallel press-in fan and excavation face is no less than 350m, besides, it should on the basis of no recirculating air. Anti-static and flame retardant flexible duct is adopted in φ1800mm and φ1500mm air hoses. According to ventilation test condition, for the gas accumulated easily space, plus SLFJ100-2T explosion-proof jet fan in the main hole and proper space of parallel adit, cross channel joint. Partial ventilation is carried out to eliminate accumulation gas.

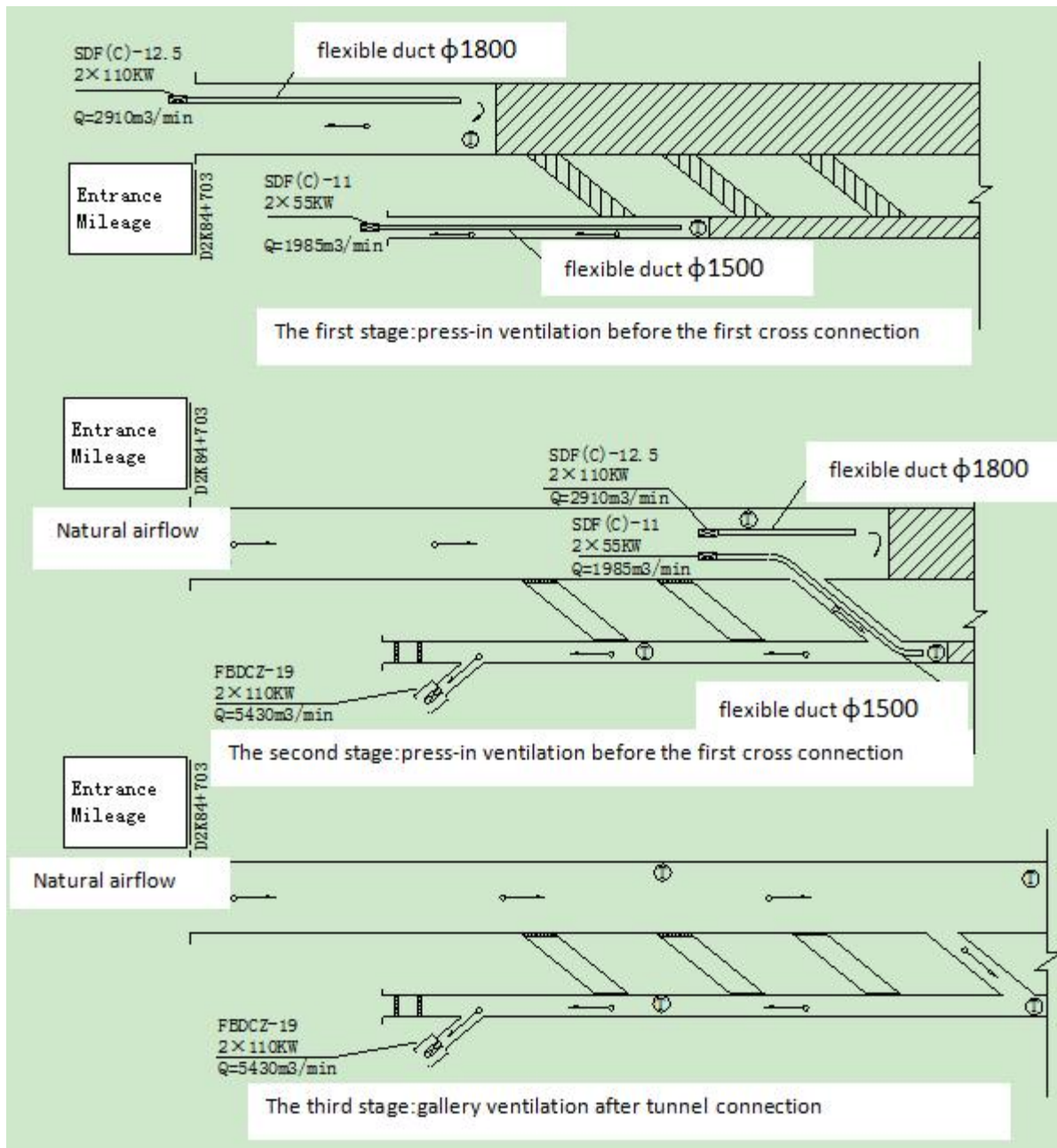
The useless crosses are closed except crosses near the digging face.

The third stage: gallery ventilation is adopted after tunnel connection. Ventilation system should be adjusted in time after the whole tunnel connection. one 2×110kw coal mine explosion-proof draw-out ground for screw axial flow ventilator is opened separately in both in and out entrance of parallel adit to form gallery ventilation in order to avoid gas over-ranging.

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doi: [10.18686/wcj.v5i1.6](https://doi.org/10.18686/wcj.v5i1.6)

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The third stage: gallery ventilation after tunnel connection

2. Ventilation construction test

Due to different main hole's flat guild sections of Laozhou Rock tunnel, respectively checking measure is adopted. According to ventilation scheme, checking is impossible in the first stage, only trackless transport of main hole and parallel adit need to be checked. Ventilation is the key method for removing dust and smoke and diluting gas.

(1) Ventilation standard

- ① wind speed of dispersing gas is over 1m/s
- ② oxygen content : no less than 20% by volume

- ③ gas density : less than 0.5%
- ④ the highest permission density of CO is below 0.0024%
- ⑤ CO₂ density : less than 1.5% by volume
- ⑥ nitric oxide : convert into NO₂: below 0.00025%
- ⑦ the biggest permission density of dust: above 10% oxides and free dust 2mg each m³
- ⑧ temperature in the hole should be below 28°

(2) Ventilation requirements checking

Take full use of flat guide tunnel ventilation theory to make sure ventilation unblocked.

Laozhou Rock Tunnel construction ventilation checking as follows:

According to The Gas Tunnel and Technical Specification and related ventilation booklets, calculate the tunnel ventilation, pressure into the type of roadway ventilation related parameters, so that selecting the fan type.

(3) Air volume required in trackless transport

① According to the minimum allowed inside wind speed to calculate : $Q1=60VS$

Among this : V—The minimum wind speed ensure the stable wind flow in the hole , gas tunnel 0.3m/s ;

S—The excavation area , main hole grade III wall rocks $S=121.79m^2$.

$Q1=60VS=60 \times 121.79 \times 0.3=2192m^3/min$.

②According to the largest people number in the hole in the same time to calculate : $Q2=4KN$

Among this : 4—each person air feed standard per minute , m^3/min

K—tunnel ventilation coefficient , including tunnel air leaking and mal-distribution etc. , take $K=1.25$;

N—the largest people number in the hole in the same time who work in the hole , use 100 to calculate.

$Q2=4KN=4 \times 1.25 \times 100=500m^3/min$.

③ According to the absolute gas emission quantity to calculate : $Q3= KQ \text{ absolute}/(Bg \text{ allow- } Bg \text{ send})$

Among this :Q absolute—The absolute gas emission quantity measured values , Take the fort mountain tunnel reference value $3.03 m^3/min$,

Adjust according to the real condition in construction. Bg allow - face allows the gas concentration, 0.5%; Bg send- gas concentration into the wind, take 0. Spare coefficient K - air volume, namely considering unbalanced from the tunnel air leakage, gas emission coefficient, Take $K = 1.6$

$Q3=KQ \text{ absolute}/(Bg \text{ allow- } Bg \text{ send})=1.6 \times 3.03/(0.5\%-0)=970m^3/min$.

④ According to the dilution and the required air volume of blast fume to calculate:

$Q4=\{7.8(A \times (S \times L)^2)\}^{1/3}/t$

In this expression : A—Blasting the maximum charge , main hole III class surrounding rock blasting explosive load $A=300Kg$, according to the real condition to adjust in construction,

S—The excavation area , main hole III class surrounding rock $S=121.79m^2$;

L—distance between ventilator and face $L=500m$;

t—ventilating time , 20 ~ 30min in general, take 30min

$Q4=\{7.8(A \times (S \times L)^2)\}^{1/3}/t=\{7.8 \times (300 \times (121.79 \times 500)^2)\}^{1/3} / 30 = 2694m^3/min$.

⑤ calculate according to explosion in the same time $Q5=5Ab/t$

In this expression : A—Blasting the maximum charge , main hole III class surrounding rock blasting explosive load $A=300Kg$, according to the real condition to adjust in construction,

b—Explosive amount of harmful gas generated per kilogram , take $b=40m^3/ Kg$;

t—ventilating time , 20 ~ 30min in general, take 30min

$Q5=5Ab/t=5 \times 300 \times 40/30=2000m^3/min$

⑥According to the hole to use internal combustion machinery air volume requirements to calculate.

$Q=Q0 \times \Sigma P$

In this expression,

Q0—Tunnels using diesel equipment unit power needed for air volume index, the rules and regulations of railway tunnel construction , 1kW unit ventilation should be no less than $3m^3/min$, take $3m^3/min/kW$ as index.

ΣP —At the same time operating within the hole of all kinds of diesel engine power sum, shown in the following table ;

No.	Equipment	power (kW)	number	note
1	loader	160	1	
2	excavator	160	1	
3	Motor car	118	4	
4	Other equipment	100	1	
	In total	892	7	

Therefore :

$$Q = Q_0 \times \Sigma P \\ = 3 \times 892 \\ = 2676 \text{ m}^3/\text{min}$$

In the three calculating ventilation air volume above, design ventilation air volume in trackless transport according to $Q=2676 \text{ m}^3/\text{min}$.

To calculate according to the results above, take the maximum value

$2676 \text{ m}^3/\text{min}$ as air requirement in tunnel main hole.

1.2.2 Positive hole pressure into the fan selection and check computation.

In accordance with the maximum air requirements of main hole digging face $2676 \text{ m}^3/\text{min}$ to select ventilator, choose specific explosion-proof pressure into the type axial flow ventilator SDF(C)-12.5 type $2 \times 110 \text{ kW}$ ventilator made by Shanxi Ma xin feng kang ventilator Co.,ltd. Along with ventilation pushed forward of main hole face, diameter of air hose is 1800 mm , the function is high speed air volume $1548 \text{ m}^3 \sim 2910 \text{ m}^3/\text{min}$ and air pressure $1378 \sim 5355 \text{ Pa}$.

Wind speed checking: taking maximum air volume $2910 \text{ m}^3/\text{min}$, calculate with III class fracture surface $S=121.79 \text{ m}^2$, the maximum wind speed is $2910 \div 121.79 \div 60 = 0.40 \text{ m/s}$. Due to $0.40 \text{ m/s} < 1 \text{ m/s}$, gas flow may formed on the top of tunnel main hole, and take in the fresh wind which make auxiliary partial fan, axial laminar flow inside lane set in ram, ram corresponding length hole on the roof, dilute blow gas in laminar flow.

(4) Air requirement of flat guild trackless transport

① According to the minimum allowed inside wind speed to calculate : $Q_1=60VS$

In this expression : V —The minimum wind speed ensure the stable wind flow in the hole , gas tunnel 1.0 m/s ;

S —The excavation area , main hole grade III wall rocks $S=21.31 \text{ m}^2$.

$$Q_1=60VS=60 \times 21.31 \times 1=1279 \text{ m}^3/\text{min}$$

② According to the largest people number in the hole in the same time to calculate : $Q_2=4KN$

Among this : 4 —each person air feed standard per minute , m^3/min

K —tunnel ventilation coefficient , including tunnel air leaking and mal-distribution etc. , take $K=1.25$;

N —the largest people number in the hole in the same time who work in the hole , use 50 to calculate.

$$Q_2=4KN=4 \times 1.25 \times 50=250 \text{ m}^3/\text{min}$$

③ According to the absolute gas emission quantity to calculate : $Q_3= KQ \text{ absolute}/(Bg \text{ allow- } Bg \text{ send})$

Among this : Q absolute—The absolute gas emission quantity measured values , Take the fort mountain tunnel reference value $3.03 \text{ m}^3/\text{min}$,

Adjust according to the real condition in construction. Bg allow - face allows the gas concentration, 0.5% ; Bg send- gas concentration into the wind, take 0 . Spare coefficient K - air volume, namely considering unbalanced from the tunnel air leakage, gas emission coefficient,

Take $K = 1.6$

$$Q_3=KQ \text{ absolute}/(Bg \text{ allow- } Bg \text{ send})=1.6 \times 3.03/(0.5\%-0)=970 \text{ m}^3/\text{min}.$$

④ According to the dilution and the required air volume of blast fume to calculate:

$$Q_4=7.8(A \times (S \times L)^2)^{1/3}/t$$

In this expression : A —Blasting the maximum charge , main hole III class surrounding rock blasting explosive load $A=60 \text{ Kg}$, according to the real condition to adjust in construction,

S —The excavation area , main hole III class surrounding rock $S=21.31 \text{ m}^2$;

L —distance between ventilator and face $L=500 \text{ m}$;

t —ventilating time , $20 \sim 30 \text{ min}$ in general, take 30 min

$$Q_4=7.8(A \times (S \times L)^2)^{1/3}/t=7.8 \times (60 \times (21.31 \times 500)^2)^{1/3} / 30=493 \text{ m}^3/\text{min}$$

⑤ calculate according to explosion in the same time $Q_5=5Ab/t$

In this expression : A —Blasting the maximum charge , main hole III class surrounding rock blasting explosive load $A=60 \text{ Kg}$, according to the real condition to adjust in construction,

b —Explosive amount of harmful gas generated per kilogram , take $b=40 \text{ m}^3/\text{Kg}$;

t —ventilating time , $20 \sim 30 \text{ min}$ in general, take 30 min

$$Q_5=5Ab/t=5 \times 60 \times 40/30=400 \text{ m}^3/\text{min}$$

⑥ According to the hole to use internal combustion machinery air volume requirements to calculate.

$$Q=Q_0 \times \Sigma P$$

In this expression,

Q_0 —Tunnels using diesel equipment unit power needed for air volume index, the rules and regulations of railway tunnel construction , 1 kW unit ventilation should be no less than $3 \text{ m}^3/\text{min}$, take $3 \text{ m}^3/\text{min}/\text{kW}$ as index.

ΣP —At the same time operating within the hole of all kinds of diesel engine power sum, shown in the following table ;

No.	Equipment name	power (kW)	number	note
3	Motor car	118	4	
4	Other auxiliary equipment	100	1	
	total	572	5	

So :

$$Q = Q_0 \times \Sigma P$$

$$= 3 \times 572$$

$$= 1716 \text{ m}^3/\text{min}$$

Taking the maximum ventilatory volume calculated from the above three, the ventilation rate of the trackless transport scheme is designed as $Q = 2676 \text{ m}^3/\text{min}$.

According to the above results, the maximum air volume required by the main tunnel is $2676 \text{ m}^3/\text{min}$.

The determination of the required air volume: according to the above calculation results, take $1716 \text{ m}^3/\text{min}$ as the maximum for flat guide required airflow.

(5) Selection and check of flat guide press type fan

The fan is determined by the maximum air volume $1716 \text{ m}^3/\text{min}$ required by the flat guide tunnel face, which is explosion proof type axial flow fan, SDF (C) - 11 type 2 x 55 kw fan, and placed into the main tunnel with duct diameter of 1200 mm, constraining to the flat guide tunnel face through horizontal channel excavation and pushed forward the ventilation, with performance of: the high-speed airflow $1015 \text{ m}^3 \sim 1985 \text{ m}^3/\text{min}$, wind pressure $pa \ 624 \sim 4150$.

Wind speed calculation: according to the draw out ability with maximum air volume of $1985 \text{ m}^3/\text{min}$ and flat guide section $S = 21.31 \text{ m}^2$ to take wind speed checking calculation, the maximum wind speed is: $1985 \div 21.31 \div 60 = 1.54 \text{ m/s}$.

(6) The selection and calculation of the drawing type wind turbine in the tunnel (flat guide)

According to the principle that tunnel ventilation type fan capacity must be greater than the press in type fan capacity, the required maximum air volume of main tunnel is $2676 \text{ m}^3/\text{min}$ and required maximum air volume of flat guide tunnel face is $1279 \text{ m}^3/\text{min}$, determine to install 1 set FBDCZ - 19 type 2 x 110 kw coal mine explosion-proof draw-out type axial flow ventilator in the flat guide mouth to implement negative pressure ventilation, with stand-alone high-speed airflow of $2550 \text{ m}^3 \sim 5430 \text{ m}^3/\text{min}$, wind pressure of $116 \sim 3417 \text{ Pa}$; Maximum draw out air

volume of $5430 \text{ m}^3/\text{min} >$ maximum press-in air volume of $(2910 + 1985)$ after = $4895 \text{ m}^3/\text{min}$, which can meet the requirements of tunnel ventilation.

Maximum wind speed calculation: according to the maximum draw out air volume of $5430 \text{ m}^3/\text{min}$, flat guide section $S = 21.31 \text{ m}^2$ to make wind speed checking calculation, the maximum wind speed is: $5430 \div 21.31 \div 60 = 4.25 \text{ m/s}$.

Wind speed calculation: according to the minimum draw out air volume of $2550 \text{ m}^3/\text{min}$, flat guide section $S = 21.31 \text{ m}^2$ to make wind speed checking calculation, minimum wind speed is: $2550 \div 21.31 \div 60 = 1.99 \text{ m/s} > 1 \text{ m/s}$, conforms to the requirements of the minimum wind speed to disperse gas accumulation.

III Construction ventilation monitoring

Ventilation detection system must be established during the tunnel construction, to measure the parameters of meteorological parameters, wind speed, air volume and so on.

Monitoring of the duct: use 5 rings 10 spot method with 1.3m Pitot's tube, U type pressure gauge to test pipeline total pressure and static pressure, use 1.3m Pitot's tube, DGM-9 compensated micro manometer to test ventilation tube wind dynamic pressure.

Ventilation monitoring: on the same section of the pipeline ventilation measuring point with the electronic wind speed meter to test wind speed, air volume in 9 point method.

Test of meteorological conditions: use digital thermometer testing pipe to test the inside and outside temperature of the pipe, with the aneroid barometer, psychrometer to test the humidity value of air pressure at different points in the roadway. Blasting fume and poisonous gas diffusion rule in tunnel test: using P-5 type digital dust meter automatically record soot concentration dynamics changes per minute of each measuring point, far infrared CO tester recorded carbon monoxide concentration dynamic changes of the blasting fume of each test point. Monitoring of construction ventilation in different construction stages, make improvements according to the results of the test system. Ventilation detection equipment see table 5.3.1.

Table5.3.1 Ventilation detection equipment

No.	Name	Model	Unit	Quantity		remark
				Main tunnel	Flat guide	
1	Pibtot's tub	1.3m	piece	3	3	
2	pressure gage	U type	piece	3	3	
3	compensate-type micropressure	DGM-9	piece	2	2	
4	wind velocity indicator		set	2	2	
5	thermometer	digital	piece	2	2	
6	barometer	aneroid	piece	2	2	
7	psychrometer		piece	2	2	
8	dust gauge	P-5type	set	3	3	
9	CO tester	far infrared	set	3	3	

3. Construction ventilation management

Laozhouyan tunnel is gas tunnel. So construction ventilation is an important link in tunnel construction, the focus of construction management, and the guarantee to the rapid construction of the tunnel and the key to normal operation. Combined with the previous gas tunnel ventilation experience and mature technology, method, conduct scientific management on Yunding tunnel construction ventilation, formulate a scientific, reasonable ventilation scheme and practical security measures.

(1) . Mounting stable ventilator bracket, avoid shaking vibration during operation. Setup rigid duct connection in the fan export, and add flange gasket between the fan and duct outlet. Rigid duct joins the light air tube binding three times, to reduce the local air leakage and resistance.

(2) . Ventilation machine can put into use after acceptance, and must adopt special person management system, according to the procedures required to operate the fan, truthfully fill out the records. It is forbidden to stop at random, and implements listing management.

(3) . Fan should be in accordance with the provisions, implement the "three", namely, special transformer, dedicated line and special switch. Fan should be set up two power supplies, when all the way to stop the power supply, the other should be within 15 min in all the way through, ensure the normal order of the fan.

(4) . During construction, the continuous ventilation should be implemented. Due to maintenance, power outages and other reasons to stop the wind, must withdraw the staff, cut off the power supply, and set up fences, warning signs in the entrance. Before ventilation recovery, gas concentration must be checked. When gas concentration does not exceed 1% in the stop wind zone, and the gas concentration is not more than 0.5% within 10m of the fan and its switch's airflow, ventilators can be manually operated. When gas concentration in the stop wind zone is more than 1%, safety measures must be made to eliminate the gas, and return air system must also cut off power and withdraw people. Only confirmed by check that the gas concentration in stop wind area is less than 1% can be manually restore ventilation machine for main tunnel of all electrical equipment.

(5) . Wind pipe must adopt antistatic, flame retardant duct, with a factory certificate. When the distance between wind nozzle to the excavation surface is less than 5m, blasting operation is prohibited when removal tunnel face wind tube.

(6) . Wind pipe hanging and maintenance of each team should be specifically responsible. Each team must be on all the wind pipe inspection, dealing damage in a timely manner, damaged ducts must be promptly replaced. Wind pipe 100 meters of air leakage rate should not exceed 2%.

(7) . Hanging wind pipe should be flat and smooth, straight. In operation, according to the inside pipeline layout design wind pipe midline, drilling and installing high-strength bolts in every 5 m, arranging $\phi 6$ mm steel wire and pulling up the wire. Wind pipe hanging in the cable. In order to avoid fracture of $\phi 6$ mm reinforced bar by shock wave vibration or moist air corrosion inside the cave, adding 10mm nylon rope hanging ring. Design a bend or slow turn in the turning, do not turn dead corner.

(8) . Ventilation duty personnel must review the gas shift, master the situation of gas change, when finding any problem, treat in no time and report to the dispatch room department.

4. Ventilation management of tunnel through time

Ventilation must comply with the following provisions when the tunnel is at the entrance section of the tunnel and the exit section of the tunnel through:

(1) . In distance more than 50m before through, you must stop one tunnel work surface, according to the ventilation of the third stage, do a good job in the preparations for the ventilation system.

(2) . When joining up, it must be unified command by someone on the spot, stop tunnel face excavation , keep normal ventilation, set fence and warning label, check the wind conditions and the gas concentration of tunnel face and return current, when the gas concentration out of gauge, should be dealt with immediately. Before each blasting of tunnel face excavation, gas concentration of the tunnel face and its return current must be checked by chosen person and the gas inspection worker together, whenever the gas concentration overrun, must first stop digging work in the tunnel face and then process gas, only if the gas concentrations of two tunnel face and its return current is below 1.0%, tunnel face in excavation can start blasting. Before each blasting, two constraints entrance must be alert.

(3) . After tunnel breakthrough, separately open 1-2 x 110 kw coal mine explosion-proof draw-out ground for axial flow ventilator in the flat guide import and export ,forming roadway ventilation to prevent gas overrun, after wind ventilation system stabled, can return to work.

5. Safety technical measures for ventilation construction

(1) . After the second horizontal channel is well versed in the main channel, as the air return way of

the main channel must immediately set two air doors at the first cross channel for eliminating short circuit wind; After the third horizontal channel is well versed in the main channel, must immediately set up two air doors at the second cross channel to close (the first horizontal channels demolish the air door, build up permanently closed ventilation facilities at each side of the 4ms of the construction.); And so on. In order to avoid the ventilation system in disorder, partial ventilator sucked wind circulation, ensure that the ventilation system is stable and reliable.

(2) . Cross channel within the damper must install locking device to prevent opening two dampers at the same time causing airflow short circuit. Air door construction must do edging along the mouth.

(3) . Airtight of the horizontal channel must be regularly checked and maintained. Airtight construction must meet the quality requirements, keep tight and smooth. Airtight and main channel and flat guide wall must be in the same plane, and there must be no blind alley. If there is a blind alley due to limitation, must set up the fence, reveal the warning label, to prevent staff from entering.

(4) . Strengthen the daily maintenance, inspection and management of jet fans to ensure their continuous normal operation.

6. Concluding remarks

Through the design and practical application, the ventilation scheme can fully meet the needs of the construction site, ensure the tunnel air is clear. Through flat guide ventilation can rule out all dirty air within the construction area, meanwhile, the gas concentration can be reduced to a safe range within a specified time after the blasting of the construction, and the scheme can be applied in other highly gassy tunnel.

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