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Chamber method of ventilation – a proven technology for reducing leakage of air into the goaf

Improvement in climatic conditions at workings in mine having surface cracks by increasing fan capacity is a risky proposition. It may lead to spontaneous heating in the mine due to leakage of air from surface caused by increase in cumulative pressure drop measured from the surface. The above problem cannot be addressed by conventional ventilation system.

A new method of ventilation named "Chamber method of ventilation" have been evolved to ventilate the workings under the situation mentioned above, The method is superimposed on the existing ventilation system of the mine without much modifications or any adverse effect on ventilation of remaining districts. The method was successfully implemented at 1 & 2 incline mines, Jhanjra project, Eastern Coalfields Limited (ECL) to reduce surface air leakage for control of fire in a working longwall panel and for improvement in climatic condition.

Introduction

Comfortable workplace environment is one of the main contributing factors in achieving targeted production in mines. Several researchers all over the world are engaged since many decades in designing suitable and efficient ventilation system for underground mines. Exhaust system of ventilation is one of them, which is commonly adopted in most of the Indian coal mines. The system though effective in providing adequate ventilation but with increase in extent of the mine the system demands periodic upgradation and at times replacement of main mine fan by higher capacity fan to meet the ventilation requirement.

Underground mines in our country are quite old and extensive. Some of them are embedded with complex geo mining conditions viz. multi-seam working having interconnected goaves, shallow cover and thick seams with geological disturbances like faults and dykes. The situation becomes worse in case of surface connection through cracks. Under the circumstances, improvement in climatic condition at the workings by increasing mine ventilation pressure to circulate more quantity of air beyond a critical value often increases risk of spontaneous heating/fire. Multi-zonal ventilation system, evolved by CMRI [1, 2], have proved to be useful which provides fresh air through boreholes close to workings. The system does not call for much increase in main fan pressure or replacement of main fan by higher capacity fan.

Ventilation of longwall working faces particularly being worked at shallow cover needs special attention to avoid leakage of air from the surface through cracks as well as direct air leakage from bottom gate into the goaf.

To address the problem authors have developed a new concept of ventilation named Chamber method of ventilation. Principle and practices of the Chamber method of ventilation and methodology adopted to implement the technique in one of the major coal producing mines in ECL has been discussed in this paper.

Chamber method of ventilation

It is a ventilation arrangement which is superimposed on the main ventilation system to reduce the cumulative pressure drop in a desired area without affecting the main fan pressure and ventilation in other part of the mine. A simplified layout of the system is shown in Fig. 1.

The basic requirements of the system for its implementation in a mine include:

- Ventilation survey data of the mine for computer simulation studies and to workout design parameters of the system.
- Conversion of affected area into a chamber by closing cross connections.
- Axial-flow fan of suitable capacity compatible to main fan
- Two regulators of variable aperture, R1 and R2. R1 regulator is meant for creating pressure difference across the panel to achieve optimum flow of air at the face with

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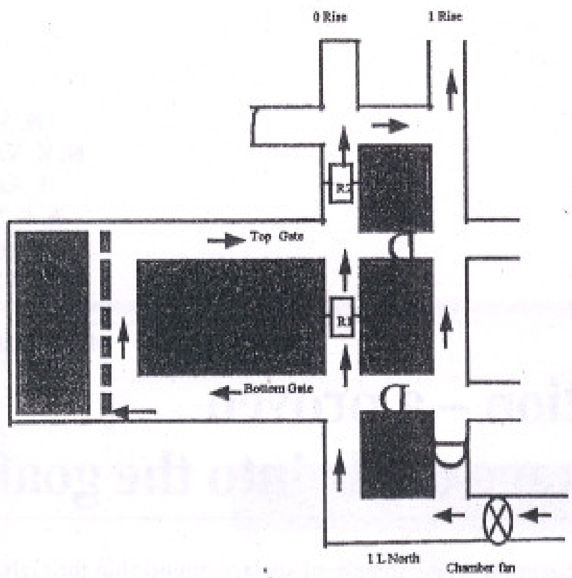

Fig.1 Layout of chamber ventilation system

minimum leakage of air into goaf and R2 is to raise the pressure of the chamber to a desired level so that goaf pressure remains slightly positive than the atmospheric pressure.

Advantages of the system

- It reduces the pressure differential across the parting between the seams as well as surface.
- The optimum air flow rate can be maintained with minimum leakage of air into the goaf.
- Leakage of air/influx of noxious gases in the area from other part of the mine is stopped.
- Surge of air into the goaf after stoppage of main fan is reduced considerably and thereby the environmental condition of goaf remains almost stable.
- Monitoring of the environmental condition of goaf becomes easier, which may help in early detection of spontaneous heating.
- It reduces the requirement of nitrogen/foam in order to keep the goaf in inert condition.

Case study

The problem

Fire in AW1 working longwall face in RVII A seam at No. 1 & 2 Incline mines of Jhanjra project of ECL was reported on 28.8.99 after progress of the face by 115 m from the installation chamber. All conventional methods failed in controlling the fire and the panel had to be sealed three times within a period of six months due to recurrence of fire after reopening.

Jhanjra project has the reputation of successful completion of 10 (ten) longwall panels at shallow depth (about 40 m). The success at Jhanjra brightened the prospect of longwall technology at shallow depth in Indian coal mines. However, fire in AW1 longwall panel, RVIIA seam not only crippled the Jhanjra mine by bringing all production activities to a halt but also had a much greater suppressive impact in the entire mining industry of the country as the story of longwall technology in the country seemed to be leading to a sad end besides locking of coal worth about Rs.1000 crores.

Particulars of the mine

The mine, 1&2 Incline of Jhanjra Area of Raniganj Coalfields is situated about 200 km from Kolkata, India. Jhanjra Area extends to about 12 sq. km which is encircled by faults with throws varying from 10 to 30 m. Jhanjra block has nine viable seams with total extractable reserves of 212 million tonnes of coal. It is being extracted by two mines viz. 1&2 Inclined mine and main industrial complex. Depth of the seams varies from 38 to 380 m. Details of thickness and depth of the five top seams are given in Table 1.

Table 1

	Seam number	Thickness, m	Depth, m
1.	RVII	1.27 - 4.23	76
2.	RVIIA	0.45 - 4.11	109
3.	RVI	2.15 - 5.60	201
4.	RV	2.90 - 6.64	231
5.	RIV	3.75 - 11.27	257

The seams are degree II gassy. In Incline 1 & 2 mine workings are spread in two seams viz. RVII and RVIIA. In RVII seam a manual section is in operation and ten longwall panels have already been successfully completed, whereas in RVIIA seam developments by road header machine in east and west sides of the property are in progress and one longwall panel (AW1) in west side of the mine has just started. Layout of panels and developments in RVII and RVIIA seams are shown in Fig.2. Entries into the mine are through Incline 1 & 2 and 'D' shaft sunk up to RVII seam. No 1 & 2 Incline mine was producing about 3500 tonnes of coal per day deploying 1200 personnel before the onset of fire in AW1 panel.

Ventilation circuit

The mine is being ventilated by an axial-flow fan in exhaust mode (make Voltas, Model VF 2500) installed at Incline No.1. The fresh air reaches the mine through Incline No.2 and shaft 'D' situated at extreme boundary of the property. The mine is developed between No.2 Incline and 'D'shaft along RVII and RVII A seams. No.1 dip having conveyor belt installations all along its length is connected with Incline No.1 serving the purpose of main return airways and transportation of coal of the total mine. The air flowing down through Incline No.2 is mostly utilised for ventilation of workings of RVII seam and developments of RVIIA seam whereas air entering through 'D' shaft is used for ventilation of isolation stoppings of sealed longwall panel of RVII seam and longwall panel AW1 of RVIIA seam. Air enters through 'D' shaft into RVIIA seam flows along shaft level, 1 L north sump, 0 dip and reaches to bottom gate of AW1 longwall panel. Return air of AW1 flows along top gate 0 rise and joins the main return flowing along 1st rise and No.1 incline. Ventilation layout of the mine is shown in Fig. 2.

Some details of AW1 panel

AW1 longwall panel with single entries, retreat and U-system of ventilation is the first panel in RVIIA seam. This panel is located below the caved and sealed longwall panels W1 and W2 in RVII seam. Details of the panel are given in Table 2.

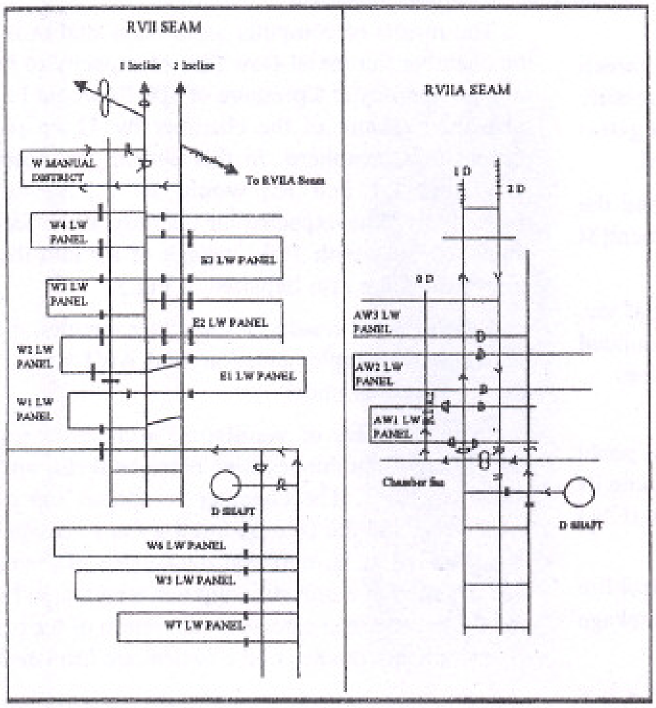

Fig.2 Schematic ventilation layout of 1&2 incline mine, Jhanjra area, Eastern Coalfield Limited

TABLE 2

Name of the panel	AW1
Name of seam	RVIIA
Seam thickness	3.2 m
Length of panel	850 m
Depth from surface	97 m
Parting between RVII & RVIIA seams	40 m
Length of face	120 m
No. of chocks	82
Chock resistance	(4×550) tonnes
Distance of installations chamber between AW1 & W1 panels	40 m
Date of starting of the panel	08.06.1999

Investigation carried out

VENTILATION INVESTIGATION

The investigation in respect of pressure and air quantity survey was carried out in the mine. The results of investigation were utilized in computer simulation studies to work out design parameters of the chamber method of ventilation for implementation in the mine.

PRESSURE SURVEY

Pressure survey was carried out in RVII and RVIIA seam of the mine by "hose and trailing method" using recently calibrated instruments viz. incline manometer, pitot tubes etc. Infact about 3 km distance was covered in RVII and RVIIA seam along intake and return airways. Pressure results are graphically represented in Fig.3.

AIR QUANTITY SURVEY

Air quantity survey was carried out in the mine using recently calibrated anemometer at more than 20 strategic

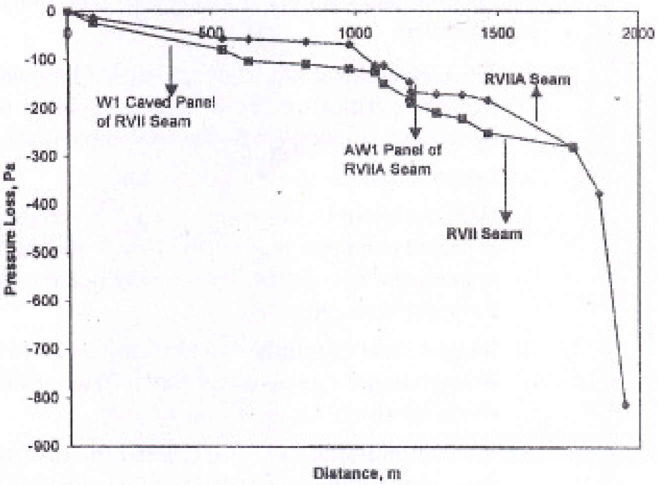

Fig.3 Pressure gradient along RVII & RVIIA seam of 1&2 incline mine

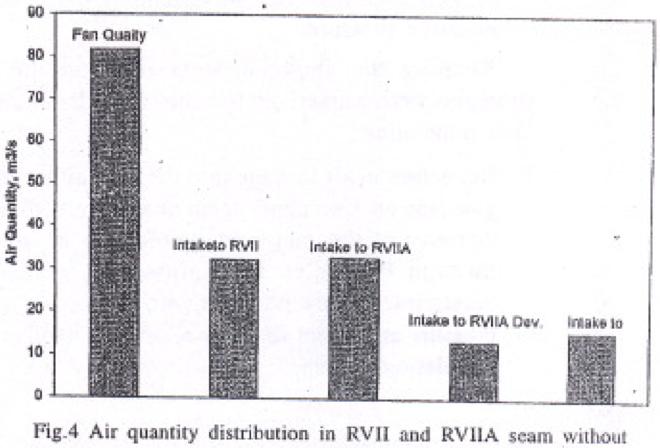

Fig.4 Air quantity distribution in RVII and RVIIA seam without chamber

locations to ascertain the air quantity distribution in the mine. Results are graphically represented in Fig. 4.

Discussion of results

The results of I pressure survey revealed that the cumulative pressure drop measured from the surface to the W1 caved panel, RVII seam and AW1 longwall panel, RVIIA seam were (–)112 Pa and (–)146 Pa respectively which might have been responsible for leakage of air from surface and goaves of upper seam. Similarly, the pressure differential across the panel was about 54 Pa, which might have been responsible for more leakage of air into goaf through bottom gate.

The result of air quantity survey revealed that air quantity in bottom gate was 16.6 m^3/s and air quantity flowing through face was 8.8 m^3/s. Hence the air leakage into the goaf through bottom gate was about 7.8 m^3/s i.e about 47% of the air quantity available at the bottom gate.

Hence to reduce cumulative pressure drop between surface and the panel AW1 as well as to reduce pressure differential across the panel (between top and bottom gates) adoption of chamber ventilation system was proposed.

In addition to the above, further investigations and the information and data provided by the mine management[3] revealed that:

1. The conventional model of packing of longwall goaf viz. free zone, critical zone and compact zone as propounded by various authors[4] are not applicable in this mine.
2. Location of seat of fire was not known.
3. Heat could not be dissipated even after keeping the panel in sealed condition more than 90 days and maintaining its temperature below 10°C by pumping liquid nitrogen (LN_2) through different boreholes.
4. Requirement of nitrogen gas was too much to control fire in operating longwall panel due to uncontrolled leakage of air into/from the goaf.
5. Rate of emission of CO increased rapidly within a few days after getting an indication of its presence in the face. There was no method available to monitor the status of fire vis-a-vis its early detection when the panel was in opened condition. All the boreholes were showing high negative pressure.

Keeping the above aspects in mind the following strategies were worked out to control the fire under operating face in the mine.

1. Reduction in air leakage into the goaf either from bottom gate side or from upper seam or surface with adequate air quantity at the face and monitoring of status of fire through boreholes by maintaining pressure of the boreholes slightly positive with respect to atmospheric pressure and upper seam by adopting chamber method of ventilation system.
2. Further, to reduce oxygen (O_2) percentage in the goaf, plugging of air path from top and bottom gate sides particularly along the barrier to create nitrogen (N_2) bank in the floor of the goaf was ensured. For this purpose high pressure high stability nitrogen foam technology[5] was proposed.

Implementation of the techniques

COMPUTER SIMULATION STUDIES

Before implementation of the technique in the mine, the ventilation network of the mine incorporating chamber, chamber fan and regulators as shown in Fig.2 was simulated into computer using VENT program, of CMRI. The design parameters of chamber ventilation viz. fan capacity, aperture of regulators to be installed in the chamber around AW1 longwall panel were worked out.

The results of computer simulation studies revealed that the chamber fan (axial-flow fan) of capacity to deal with 41 m^3/s air quantity at a pressure of 300 Pa would be required to raise the pressure of the chamber by 42 Pa positive with respect to atmosphere. In this system the aperture of the regulators R1 and R2 would be 2.25m^2 and 0.62m^2 respectively. The expected air quantity at the face would be about 8.0 m^3/s with 10% leakage of air into the goof. The other results are also depicted in Fig.5.

Based on the results of computer simulation studies the technique was implemented around AW1 panel. The details are discussed as under:

In this system of ventilation a chamber was made by closing cross-cut connections between 0 rise and 1st rise as shown in Fig.2. The chamber comprises top gate, bottom gate, 0 rise and the face. A forcing fan of designed capacity was installed at 1L north on intake side of the chamber. R1 was installed in companion dip between top and bottom gate and R2 between top gate and main return of the panel. Results of performance studies of the system are furnished in Table 3.

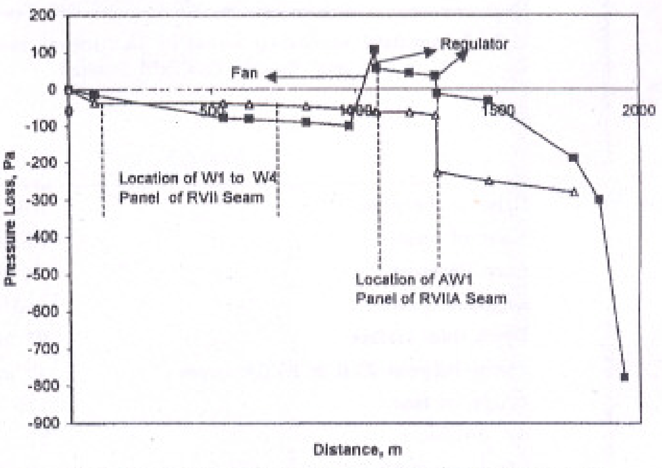

Fig.5 Pressure gradient along RVII and RVIIA seams after implementation of chamber and fan.

TABLE 3

Fan make	Voltas
Fan type	PV-160
Fan pressure	314.0 Pa
Air quantity handled by fan	41 m^3/s
Pressure of chamber measured at top gate	(+) 98.0 Pa
Air quantity at face	8.0 Pa
Airquantityat face	6.70 m^3/s
Air quantity at R_1	20.0 m^3/s
Pressure of borehole No.5	(+) 20.0 Pa
Air quantity at bottom gate	7.43 m^3/s
Leakage of air into goaf	0.76 m^3/s
Pressure developed by main fan	785 Pa
Air quantity handled by main fan	90 m^3/s

The results of the performance studies revealed that the cumulative pressure drop between surface and AW1 was raised from (–) 146 Pa to (+) 20.0 Pa . It is worth mentioning that the pressure of AW1 was higher from rest part of the mine and chances of leakage of air from any place to AW1 is redundant. The positive pressure of the AW1 facilitated the process of environmental monitoring of AW1 panel through boreholes provided at different locations in the goaf to locate the seat of fire and injection of LN_2 and helped in identification of location of fire.

The results also revealed that the reduction in leakage of air was from 7.8 m^3/s to 0.76 m^3/s whereas reduction in air quantity at the face was from 8.8 m^3/s to 6.7 m^3/s. The reduction in pressure drop across panel was from 54 Pa to 8 Pa. Finally, after optimization of fire control measures air quantity at the face was increased to 12 m^3/s at pressure drop across the panel 21 Pa.

Further, to dilute O_2 percentage in the goaf plugging of air path from top and bottom gate sides particularly along the barrier and create N_2 bank in the floor of the goaf was ensured. For this purpose high pressure high stability nitrogen foam technology comprising foam generating machines and foaming agent from Technovent Pty Ltd, Czech Republic was used. Another foaming solution from Control System, Kolkata, India was also used when the foaming agent from Czech was exhausted. The efficacy of the foam technology depends on location of injection of foam; amount of foam injected and frequency was optimized by injecting through different borehole and monitoring the goaf environment through remaining boreholes. Details of foam technology has been discussed elsewhere[6].

DISCHARGING CO INTO ATMOSPHERE THROUGH BOREHOLE

When CO at face increased from permissible limit, pressure of the chamber was increased by closing regulator R_2 underground and boreholes 5, 2 and 3 were opened to allow discharge of goaf air to atmosphere[6]. However, care was taken to see that fresh air from longwall face did not leak into goaf. For this purpose LN_2 injection through borehole Nos. 12 & 13 at the same rate of air discharge was maintained. This measure proved effective.

Finally, after progress of the face by 240 m the seat of fire was fallen into dead zone and the fire was controlled. Extraction of the panel was completed successfully without any fear of fire. The extraction of coal from this panel was 0.7 million tonnes worth Rs.70 crores. Further, with these techniques it is expected to extract about 1.0 million tonnes of coal worth Rs.100 crores from the same seam.

Conclusions and recommendations

Conclusions that emerged during dealing with fire in AW1 panel are as under:

1. Reduction in air leakage into goaf either from bottom gate side or from upper seam or surface even when adequate air quantity flows through the face by application of chamber method of ventilation around AW1 panel was very effective in control of fire.
2. Monitoring of status of fire through boreholes by maintaining pressure of the boreholes slightly positive and analysing the air samples by multi-gas analyser provided an accurate status of the fire affected area and helped in locating the actual seat of fire.
3. Plugging of air path from top and bottom gate side particularly along the barrier and creation of N_2 bank in the floor of the goaf by injection of high pressure high stability N_2 foam was found effective in eliminating/ reducing leakage of air to seat of fire.
4. Method to check flow of CO from seat of fire to face by discharging of CO in the atmosphere through boreholes when concentration of CO at the face is exceeding the permissible limit was found quite effective. However, it must be worked out and executed carefully and the amount of goaf air discharged must be replaced by infusion of same amount of N_2 into goaf through borehole.

The technique is general enough to implement in the other mines under similar situations.

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The opinions expressed in this paper are those of the authors and not necessarily of CMRI.

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