U SIVA SANKAR
MD ABDUL KHADIR
and
K NAGESWARA RAO

Review of air cooling system at deep longwall project of an Indian coal mine

Longer panels and hot surface climates have combined with the traditional sources of mine heat to produce uncomfortable working environments on high production longwall faces. The heat load generated by increasing mining depths and mechanization in UG mines is becoming progressively more and more of a problem. Below a critical depth, which is a function of geothermal gradient, the rock thermal properties and level of mechanization, ventilation will continue to have a diminishing efficiency when combating this heat load. In such a case the solution is to invest in an artificial cooling system. This paper gives insight of the details of the project, heat generating sources, different air cooling systems, psychrometric studies and air cooling arrangement made in Adriyala longwall project, Singareni Collieries Company Limited.

Introduction

The current and the future underground coal mining in the Singareni Collieries Company Limited (SCCL) is making tremendous shift from the previous low capacity to high production mining. With near exhaustion of shallow deposits, underground coal mining has to be taken up at deeper horizons with challenging technological and operational conditions.

These operations involve heavy mechanization with 4MW to 8MW face machines operating at 400 to 600m depth at present, and mining depth will be 600 to 1200m in near future. Mines are served by large network of coal conveying systems with installed capacity ranging from 5MW to 10MW. Workings in underground extend to about 4.0-8.0km from surface. These high capacity machines, geo-mining conditions and faster extraction rates add substantial heat to working environment.

Adriyala project was planned to work in the depth range of 300m to 640m. The geothermic gradient is about 69m/ºC. To maintain comfort conditions at workplace, air quantity flow is to be substantially increased as primary effort which is considered as the low cost alternative. Apart from improving ventilation intensity, some organizational steps to eliminate sources of heat from intake air can improve workplace comfort.

Messrs. U Siva Sankar, Dy. Manager, Adriyala Longwall Project, SCCL, ulimella@gmail.com, Md. Abdul Khadir, Colliery Manager, Adriyala Longwall Project, SCCL, abdulkhadir1973@gmail.com, and K Nageswara Rao, Project Officer, Adriyala Longwall Project, SCCL, po_alp_rg3@scclmines.com

Majority of heat load to mine air in deep underground mines is attributed to increase of virgin rock temperature, heat from machinery and mine water. Coal mining regulations permit mining operations at maximum ambient temperature of 33.5ºC, for comfortable and productive mining operations, workplace temperature is to be maintained at about 28.0ºC. These conditions can be achieved by using various types of cooling systems to cool the mine air by basically using refrigerating machines.

Details of the Adriyala longwall project

To meet the increasing demand of coal, and as a part of the recent underground mechanization planning initiative, SCCL successfully commissioned a state of art high capacity automated longwall project at Adriyala longwall project (ALP) mine in 2014. The Adriyala longwall geological block area is more or less free from any major faults. The project is having 78.597Mt of extractable reserves within the depth range of 294 to 644m. The project life is about 35 years with a rated production of 2.817MTPA.

Entries made to this mine through highwall of the existing opencast mine (RG OC-II). These punch entries (PE) were meant for specific purpose such as coal, men and material transport besides downcast of the mine. Chairlift system is laid in PE-1 for men transport, main belt conveyor is laid in PE-2 for coal transport, and concrete road is laid in PE-3 for the movement of multi utility diesel vehicles (men and material transport), haulage track is laid in PE-5 for men transport using chair car system and haulage for material transport. Vertical shaft was sunk connecting all the seams to use as upcast of the mine. The layout of Adriyala longwall project is as shown in Fig.1.

To meet the ventilation requirements, a study was done by ISM, Dhanbad and according to the requirement mine drivages were developed. Adriyala Mine is accessed by four Punch entries and one shaft. Two main fans of 400kw and

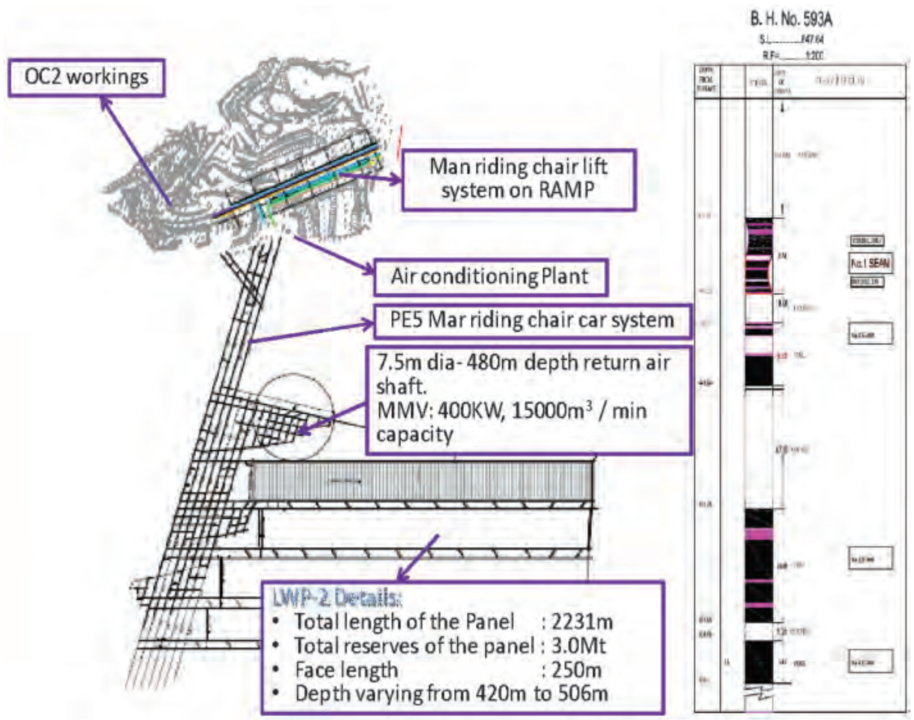

Fig.1 Layout of Adriyala longwall project

15,000 Cu.m/min and four booster fans of 55kw of 4,500 Cu.m/min capacities were procured from Zitron, Spain and installed.

The longwall equipment consists of EL3000 shearer with 2245kW installed capacity, armoured face conveyor (AFC) with installed capacity of 2565kW, beam stage loader (BSL) of 400kW, 146 shields of capacity 2×1150t and 1.75m width, 2×4.5MW of 11kV/3.3kV transwitches and 1600mm wide three kilometers long gate belt with 3×315 kW drives. The package includes SCADA (supervisory control and data acquisition system). The longwall equipment was provided by Caterpillar, Germany.

Heat sources in coal mines

The sources of heat in underground coal mines are well documented (Pickering and Tuck, 1996; Whittaker, 1979).

- Auto compression which increases the wet bulb temperature by approximately 0.4°C per 100m, depending on the surface wet bulb temperature;
- Rapid production and therefore release of heat from broken coal and rock at the working face and within the goaf immediately behind the face;

Oxygen depletion of 0.2 to 0.3% in return air quality measurements would add as much as 400kW of heat.

- High face air quantities and pressures with consequently larger volumes of air sweeping the goaf behind the face and returning onto the face at various locations along the face at near to the strata temperature;
- Increasing equipment power with accompanying heat dissipation;

Assuming 60% of total nameplate power, with as much as 70% of energy converted into heat.

- Two heading development using a single intake travelling road and homotropal belt roadway and single return for longwall operations;
- Down dip advance of workings with consequent auto compression and strata temperature increase.
- Longwall pump stations in panel intakes, and
- Other heat loads such as secondary fans, diesel equipment and ground water.

Cooling system practices

Cooling the mine ventilation can be achieved by direct cooling of the air by chilled water sprays, indirect by cooling coils or a combination of both. Deeper coal mines have employed both methods (Hamm E, 1979). The economics of underground versus surface cooling plants depends on a number of factors however the most significant are depth and the distribution of the workings.

Mine cooling systems are difficult to compare and contrast as there are not only many different cooling systems but each system varies widely by cooling capacity, operating cost, capital investment, efficiency, and more. How effective these systems are will also vary between different mine sites based on a variety of factors such as mine design, mining method, heat load, and more. Table.1 shows a comparison of different cooling systems with respect to cooling capacity, mobility, positional efficiency, and cost. Table.2 demonstrates the pros and cons of the current cooling strategies.

Over recent years the trend for the cooling of the mine climate at the larger depth mines is to install bulk air refrigeration plants on the surface. This provides an advantage for plant maintenance, larger installed capacities, heat dissipation and, if required, the circulation of chilled water. In consideration of coal mines and longwall faces, bulk air cooling plants for the mine intake air is inefficient with up to 30% of the mine ventilation being lost through leakage. Alternatively piping of chilled water underground to the working areas enables the air to be cooled for maximum effect near the longwall face. Insulation of these pipes is sometimes required to avoid water temperature rises although an exposed pipe does have some benefit in cooling the intake air stream.

The chilled water can be delivered anywhere in the mine

TABLE 1 COOLING SYSTEM ABILITY COMPARISON

Cooling system	Cooling capacity	Mobility	Positional efficiency	Cost
Surface bulk cooling	High	Stationary	Low	High
UG Bulk cooling	Medium-High	Stationary	Low	High
Ice Storage	Medium-High	Stationary	Low	Medium-Low
Spot	Low-Medium	Partially Mobile	Medium-high	Medium-Low
Micro Climate	Low	Fully Mobile	Maximum low	

TABLE 2 COOLING SYSTEM PROS AND CONS

Cooling system	Advantages	Dis advantages
Surface bulk cooling	Provides the greatest amount of cooling	Limited by the depth of the mine
UG bulk cooling	Generates the largest amount of cooling capable underground	Must reject heat to a return airway or through return waterlines to the surface
Ice storage	Utilizes natural cooling processes to reduce operating costs	Limited to cold climates
Spot	Mitigates heat in localizd areas	Must reject heat to a return airway or through return waterlines to the surface
Micro-Climate	Cools area directly around the mine worker	Workers are unable to always remain in air conditioned cabs. Current cooling garments aren't optimal for use in the min environment.

and can either directly or indirectly be applied to cool the intake ventilation. An indirect method of chilled water cooling using coils allows the water to be more easily managed and re-directed to other areas without entering onto the travelling road. However, cooling efficiency is compromised requiring higher water flows and the periodic cleaning of the coils of dust.

Direct air to water contact using spray chambers provides a more efficient cooling method. Applying a spray system closer to the longwall working area will require less water and power at the refrigeration plant. The advantage of a three heading longwall panel provides a second intake airway where a series of counter flow spray chambers can be installed with appropriate water sumps and pumping equipment.

Psychrometric studies and air cooling arrangement at ALP

To estimate the cooling requirement in longwall panel, psychrometric studies conducted in longwall panel-1, on 16.05.2015. Variation of wet bulb and dry bulb temperatures from surface to longwall panel tailgate return 30m was as shown below in Fig.2. It was also observed that that enthalpy raised from 85 kJ/kg to 125 kJ/kg from PE5D surface to LW TG indicating heat addition of about 2500kW.

Initially, when longwall panel-1 started wet bulb temperature was about 28^{o}C. But after working for 450m retreat, the face wet bulb temperature gradually increased to 32^{o}C due to heat generation from working machinery, large goaf area, hot strata water (35^{o}C) flowing along the bottom gate roadways and large volumes of coal cutting in the face. This resulted in frequent electrical breakdowns and machinery hydraulic problems after taking into consideration gate belt, energy centre, strata, goaf water; face machinery (Total: 2900kW), 1200TR capacity air chilling plant installation was advised by CSIRO and ISM, Dhanbad.

Air chilling plant was provided on the surface near the entrance of the PE5D on hired basis from Aggreko during November, 2015 for bulk air cooling of intake air. Initially air chilling plant 1200TR with air handling units (air cooled type) was installed to deliver 50 cu,m/sec of chilled air at 15^{o}C, which is circulated exclusively to the longwall face through a dedicated roadway PE5D, from surface. Due to use of this air cooling system, temperature at longwall face reduced from 33.0^{o}C to 28.5^{o}C resulting in improvement is workplace comfort, reduction of failure of electrical and electronic

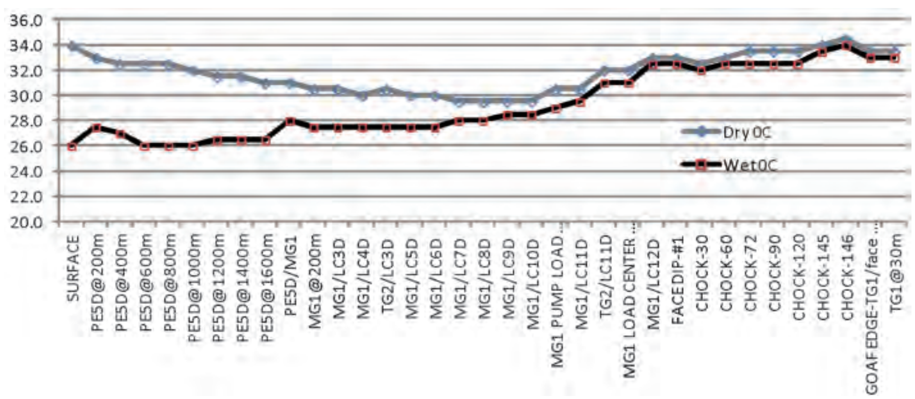

Fig.2 Variation of air temperatures from surface to LWP-1 tailage

Fig.3 (a) and (b) Cooling tower and bulk air handling unit (c) Chiller

equipment and improvement in productivity. In air cooled type chilling system water glycol was being used to bring down the temperature of the circulating water in AHUs to below 0ºC. It was insisted to discontinue use of water glycol because; it is very dangerous to the health of miners if it get mixed in the air through any leakage in the closed loop system at the AHU.

Later, for longwall panel-2 Air handling units were replaced with bulk air handlers (water cooled) to deliver the chilled air at 9.0ºC. with replacement of the air cooled type chilling system with water cooled type the efficiency of the cooling system was improved considerably.

The site equipments bulk air handling system of Aggreko, consists of four 406 TR water cooled chillers, two 10000kW cooling tower, three 2500kW bulk handling air units (BHAU) and one 15MVA*2Nos 11kV transformer, one 3.15MVA transwitch. The operating voltage of chillers is 415V. Energy consumption varies from 15 to 25MWH per day. The power consumption of water cooled chiller is lesser than air cooled chiller by 35 to 40%, occupies less space and consists less number of ducts. The overview of bulk air handling cooling system equipment is as shown in Fig.3(a), (b) and (c).

The variation of wet bulb and dry bulb temperatures of air from 50m of PE5D to longwall tailgate outby is as shown in Fig.4. At the entrance of PE5D, the chilled air nearly 3000 cu.m is delivered at 9ºC and it is mixed with surface ambient air and the mixed air temperature reaches to 18ºC at 50m below the PE5D. The gate belt and energy train are responsible for addition for temperature up to 2ºC each. The temperature at the main gate junction of the longwall face reaches to 28.5ºC, to enable comfort working conditions at longwall face.

Conclusions

After the introduction of air cooling system exclusively for longwall panel, production, and productivity was improved and electrical and electronic breakdowns were reduced to minimum. Cooling of mine intake air leads to minimum 15% the mine ventilation being lost through leakage and also more than 30% of air cooling lost due to travelling over long distance for about 5km in galleries. As a part of direct cooling, applying a spray system closer to the longwall working area will be a good option for getting maximum benefit of cooling and also water collected at the spray chamber is need to be pumped into the supply line to the face for dust suppression and motor cooling water. This provides additional cooling capacity at the face.

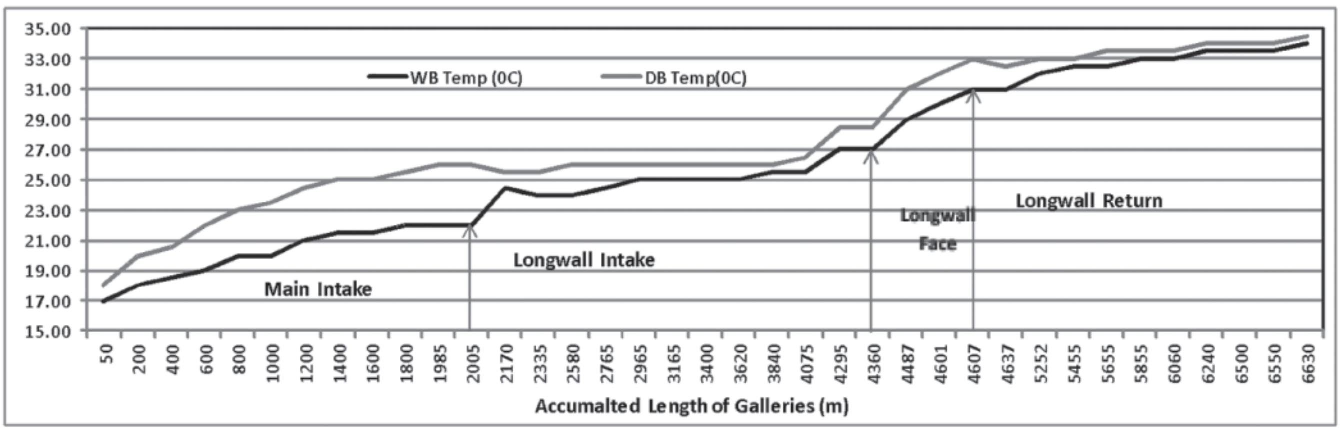

Fig.4 Temperature variation along accumulated length of longwall panel-2 from PE5D

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