MINE VENTILATION SYSTEM
AT
BHP COPPER
SAN MANUEL DIVISION
UNDERGROUND SULFIDE OPERATION

March 1997

Preface:

This document has been prepared as a general information circular for persons interested in the ventilation system at BHP Copper's San Manuel Mine. It also satisfies MSHA regulation 57.8520, which requires a written plan of the mine ventilation system. Maps kept in the Ventilation Department's office of the latest Temperature-Airflow Survey, and Mine Fire Doors and Bulkheads are used in conjunction to help satisfy the MSHA regulation. Abbreviated ventilation maps are included in this report in **Appendix V**.

The document is, in part, a compilation of assorted information available in other information packets concerning the property.

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1.0 Mining System

A brief description of the San Manuel mining system is necessary to understand how the ventilation system works.

The block caving mining system at San Manuel is now categorized into the upper levels in which haulage trains and armored cribbed transfer raises are utilized. The second category is the new 3570 level in which conveyor belts are used to convey ore from the panels to the shafts. A second notable change for the new level is that the transfer raises are now bored and lined. The rest of the mine layout is essentially the same except for the development sequencing.

The San Manuel mine operates with a full gravity block caving system. The orebody is divided into panels 140-ft. to 150-ft. wide. These panels are further divided into blocks of varying sizes. The initial block undercut in any panel is at least 210-ft. by 140-ft. to 150 ft. to ensure sufficient size to induce proper caving action. Subsequent blocks vary in size according to production requirements. Undercuts are generally taken in sequence from the initial undercut toward the outer edges of the orebody.

Where the orebody is high and essentially vertical, the lift or slice being mined is normally 600-ft. high. However, in areas where the orebody has considerable dip or rake, sublevels 300-ft. apart are used to maximize extraction. Mining is accomplished through a pair of levels. The upper level is the mining or grizzly level and the lower level is the haulage level (figures 1 and 2). Level placement and design are based on a preselected undercut elevation dependent on orebody geometry. For the levels 2950 and above the sill of the grizzly level is currently placed 22-ft. below the undercut elevation and the haulage level is 82-ft. below the undercut. For the new Lower Kalamazoo levels of 3440 and 3570 the sill of the grizzly level is currently placed 22-ft. below the undercut elevation and the haulage level is 152-ft. below the undercut.

The levels are parallel and are sloped to provide a downhill haul for loaded trains at a 0.4% grade to the shafts. Haulage trains are used on the 2950 levels and above. Conveyors are used on the 3570 level.

2.0 Development

2.1 Primary Development

Primary development starts with shaft sinking or deepening to a depth sufficient to allow loading facilities, spill handling facilities and sumps. Haulage and grizzly levels require peripheral drifts surrounding the orebody. These are called fringe drifts on the grizzly level and haulage drifts on the haulage level. While these are being driven, support facilities are developed around the shafts. When the haulage level development reaches an appropriate stage, panel drifts are started. For the haulage levels 2950 and above, these cross the orebody on 70-ft. centers and are centered below each half of each panel. For the 3570 level these cross the orebody on 150-ft. Centers and are centered below each panel.

Some of these are pull-through panels and some are back-in panels that are dead ended. Panel drifts are connected with vent crossovers at various places to facilitate ventilation and emergency access. Concurrently with haulage panel development, panel drifts are driven on the grizzly level. These are driven across the orebody on 290-ft. to 300-ft. centers to serve pairs of panels. All drifts throughout he orebody are concrete lined for maximum support. Most peripheral drifts have timber support for the levels 2950 and above and steel circular sets on the 3440 and 3570 levels. Ground support is varied to meet special conditions.

2.2 Secondary Development

Secondary development, or block preparation, begins as soon as a sufficient amount of primary development is accomplished to allow access to the mining area. Following is a brief description of the secondary development sequence for the 2950 levels and above. Included are comments on how the new hybrid block caving system impacts the conventional design. Afterward you will find abbreviated sequencing descriptions for both the conventional and hybrid secondary development methods. The main changes occur in the development sequencing of transfer raises and grizzly lines.

2.2.1 Raise Stations and Chutes

On the haulage level, secondary development starts with the excavation of raise stations and installation of the pony sets. Typically, these are spaced every 35-ft. to 50-ft along the drift, in conjunction with the grizzly drift spacing above. When the raise stations are completed, preparation is made for the drawing of ore by the installation of chutes and trolley power for the 20 ton haulage locomotives for the haulage levels 2950 and above, and for the installation of conveyors on the 3570 level.

2.2.2 Transfer Raises

Transfer raises are then driven and lined with armored cribbing. They are normally four foot square above the junction and four and one half feet square below, and are driven blind with a bell at the top.

2.2.3 Grizzly Lines

When the raises are in, secondary development can begin on the grizzly level. Grizzly drifts are typically driven on 35-ft. Centers, for the 2950 levels and above and 50-ft. centers for the 3440 level, and are at right angles to the panel drifts over the tops of the raises. Most of the broken rock falls down the raise so very little mucking is required. Raise tops and grizzlies are installed as the drift proceeds. The drift is temporarily supported with wire mesh and rock bolts.

Next, the raise tops are formed and concreted. Permanent ground support of the drift is accomplished by placing plywood forms in the drift starting from the far end and retracting outward to the panel drift. Windows are boxed in for a draw raise on each side of the grizzly. Grizzlies are spaced on 17.5-ft. centers for the 2950 level and above and either 25-ft or 37½-ft for the 3570 level. Concrete is placed behind the forms pneumatically and the forms are removed for reuse. The completed grizzly drift is equipped with air, water and guide rods for muck control boards. Sprays are installed under each grizzly for dust control.

When several grizzly lines are driven an access drift is driven parallel to the panel drift at the far end of the block. Rubber tired muckers are used to remove excavated rock. The access is formed and poured grizzly drift size. The drift provides ventilation connections and emergency access.

2.2.4 Undercut Development

The next step is to drive the draw or finger raises. These are driven blind up to the undercut elevation, the muck dropping through the grizzly rails into the transfer raise. Two draw raises are equipped with ladders to provide access to the undercut. When undercutting above a draw point has been completed production can begin.

2.2.5 Summarized Conventional Secondary Development Sequence

The secondary development sequence can easily be reduced to the following steps.

- Excavate and install raise stations on the haulage level.
- Install pony sets and chutes

- Excavate Transfer raises with armored cribbing, 4'x4' above junction, 4½'x4½' below the junction.
- Excavate and grizzly lines without diesel equipment such as LHDs.
- Excavate undercut level.

2.2.6 Summarized Sequence for 3440 and 3570 Secondary Development

The secondary development cycle for the new hybrid block caving system is.

- Excavate grizzly lines with the use of LHDs.
- Excavate and install raise stations and pony sets on the haulage level.
- Drill pilot hole from grizzly line to pony set.
- Back ream a 5-ft diameter hole to 10-ft, stop and install chute, and then complete reaming of borehole to the grizzly level.
- Ream backovers.
- Excavate undercut Level.(Note undercutting is done in same manner as done for the upper levels.

This system provides for the removal of ore to shafts via conveyors instead of by haulage trains.

3.0 Ore Production

Muck is pulled from grizzly level draw points by means of several tools; bars, hooks, and double jacks. The flow of rock is regulated by the control board, which is raised and lowered in front of the draw point. Boulders too large to fit between the grizzly rails (90 lb. salvaged rail spaced at 16-in.) must be sized with the double jack hammer before they will fall into the transfer raise. When boulders in draw points hang up and stop the flow of muck, secondary blasting is required. Scheduled quitting time blasts are also used to fragment boulders on the grizzly that are too large to be broken with a double jack.

Once the ore is in the transfer raise, it can be loaded into ore trains by car loaders on the haulage level for the 2950 level and above and onto conveyor belts for the 3570 level. Car or conveyor loaders, standing in pony sets above the panel drifts, load a train or conveyor belt as it passes below. Chute doors are air-operated guillotine type with undercut gates and are used on the 2950 level and above. An additional center loading chute is used on the 3570 level in conjunction with the guillotine door. Signal lights operated by pull bottles located in all pony sets provide a means of communication between car loaders and the motorman where haulage trains are used. Ore is conveyed to the to the #3 shaft area via train or conveyor. Where trains are utilized the it is dumped by either an ASEA or a rotary dump. Four production shafts hoist the ore to the surface. It is then run through a primary crusher and stored in bins, ready for transportation to the mill for processing.

4.0 Ventilation

4.1 Overview of the Ventilation Scheme

The ventilation at San Manuel is very simple. Air is downcast through #1, #4, and #5 shafts to each production level; motivation is provided by a main intake fan on the main crosscuts of each production level. The air passes through this fan to the fringe drifts, and into the working panels through panel drifts. Airflow inside the panel splits east and west through grizzly lines and into the access drift. From the access drift air is drawn through low pressure booster fans exhausting to the haulage level. The air then courses north and south through panel haulage drifts to the main haulages which carry it to the four production shafts. These production shafts, #3A, #3B, #3C, and #3D, exhaust the air to the surface.

#1 and #4 Shaft provide the majority of the air used in the San Manuel orebody. #5 Shaft supplies a portion of the intake air on the 2615 level and is the sole intake for the Kalamazoo orebody. Numerous shops and pump stations also intake air directly of #5 Shaft exhausting directly into the production shaft area. The current ventilation system uses roughly 8,150 Hp to intake and distribute 1,300,000 cfm throughout the mine (Figure 3).

4.2 Production Ventilation

In the usual pattern, there are two panels developed between two parallel panel drifts. These production panels are separated by an access drift, the same size as a grizzly line, which does not connect to the fringe drifts. Air from the panel drift is coursed through the grizzly lines to the access drift, and down a vent raise (Figure 4). A typical vent raise installation, for the 2950 levels and above, consists of a bottom mounted 20Hp, 1760RPM fan which keeps 25,000cfm of air moving in the right direction. For the 3440 and 3530 levels the fans will be mounted at the top of the raise. Vent raises are spaced about one per three or four grizzly lines. Compressed air movers provide additional motivation for air movement in the grizzly lines.

4.3 Development Ventilation

4.3.1 Conventional Primary Drifts

The "conventional" primary drift refers to a drift driven with compressed air jumbos or jacklegs, compressed air mucking machine, and track mounted battery motor and cars. Headings are driven using a blowing ventilation system which picks up air from a nearby turnout or crossover drift. The vent line is typically 24 in. diameter fiberglass or galvanized pipe. A 20Hp, 25¼ fan is used to provide 7,500 cfm for a 500 ft. drive. For longer drives, fans are placed in series on 500 ft increments. If working conditions dictate, 50-ton, 7,000 cfm refrigeration units provide cooling in the headings. For the most part, use of compressed equipment to drive primary drifts has been phased out.

4.3.2 LHD Primary Drifts

The "LHD" primary drift refers to a heading driven with diesel equipment; 2 to 4-yd loaders and a diesel/hydraulic drill. LHD headings also utilize a blowing system with 30 to 42 in. fiberglass or vent bag vent line. A 36 in., two stage, 1760 rpm, 60Hp, fan will provide 17,000 cfm for a 900 ft. drive. Refrigeration units/cooling coils are used for cooling in LHD headings where needed.

4.3.3 Conventional Secondary Development

Conventional Secondary development, which is to say transfer raise, grizzly line, draw raise, and undercut, is done by compressed air movers. Different types of compressed air movers are unique to each job.

4.3.4 LHD Undercuts/Grizzly Drifts

LHD undercuts were used in the past and are currently being re-tested for lower Kalamazoo purposes. Past LHD undercuts have utilized .5 to 2-yd^3 loaders with a forced air distribution system using 24 in vent bag. The most recent test involved use of a single electric 40 hp(Jetair 25.25-17.5-1750) fan to provide air up in the undercut. Small 16 in. compressed air fans, vent bag, and air movers are then used to distribute air for the ½-yd^3 loader.

LHD grizzly lines are ventilated with either a 20 or 40 hp fan. The ventilation system can be set up as either a blowing or exhausting system. The location of vent raise fans or transfer raises determines which type of system will be installed.

4.4 Operational Problems in Ventilation

One of the greatest problems of ventilating the San Manuel Mine is inherent in the development sequence. Because production blocks are always developed from the center of the panel towards the fringe drifts, production lines are downstream of the those under development. Therefore, air coming in from the fringe drifts tends to short circuit down to the haulage level through open transfer raises in the developing portion of the panel (figure 5).

In active production areas, a portion of the air entering the grizzly line will also tend to short circuit down open raises before reaching the chute tapper on the far end of the line. The opposite is also true; air can upcast through empty raises located near the access drift and vent raise fans. This tends to reduce the overall intake capacity of vent raise fans.

The closure of areas due to ground movement is always inherent with the block caving system. Panel drifts usually take weight during the undercut sequence and squeeze in. Grizzly drifts will often cave and become dead ended, limiting the airflow capability. Access drifts often squeeze and a vent raise will occasionally succumb to ground weight before an area has been depleted.

Heat emanating from depleted, but non-bulkheaded grizzly lines is a continuing problem. Air coursing down grizzly lines that are active, but not being pulled at the particular time is a problem that is partially compensated for by the use of air movers. Curtain system to control these portions of the air loss have been investigated fully but have not been accepted by the workers, nor heavily enforced by supervision.

The running of muck through the grizzlies from the draw raises can tend to generate large amounts of dust. Dust control sprays are used to help control this dust; chute tappers are also trained to stay on the upwind side of the grizzly, although this is not always possible. Dust generated on the haulage by loading extremely dry muck often can become a problem. Again, dust control sprays are part of the carloading system. A certain amount of dust is also exhausted via vent raise fans to the haulage levels. To compliment standard draw and haulage level dust control sprays, installation of additional sprays on the haulage level have become standard in the past few years.

4.5 Organization of the Ventilation Department

The Ventilation Department reports to a Staff Engineer of the Mine Planning group, who works for the Mining Division's Planning Director. The Ventilation Department's primary responsibility is planning and maintaining all aspects of the underground ventilation system. Ventilation assistance is also provided to other Divisions within Magma Copper's Corporate structure as requested. The department normally consists of two to three persons, one of whom is the Senior Ventilation Engineer and in charge; the other two are usually graduate engineers in a one to two year training period. Sometimes a student is used during the summertime. There are also two construction miners assigned to the department to provide basic ventilation construction work.

4.6 Routine Surveys

A good portion of ventilation personnel time is taken up inspecting work areas, making and processing routine measurements, and ordering ventilation supplies as needed underground. Routine temperature and air flow measurements are used to monitor working conditions and to make sure ventilation quantities in diesel use areas are adequate. Main fans, booster fans, air doors, and other ventilation equipment is checked to ensure proper operation. Three main types of surveys are run:

4.6.1 Bi-Annual Shaft Intake and Exhaust Report

This report measures the main intakes and exhausts throughout the mine and sums them by intake level, exhaust level and shafts. This is used to determine the overall condition of the main fans and shaft airflows and shows where major changes occur in the ventilation system. Unexplained discrepancies from previous surveys are investigated. Report distribution is minimal.

4.6.2 Bi-Annual Temperature-Airflow Survey

This report is run once in the summer and once in the winter and helps meet government regulations. It is a detailed study of temperature and airflow distributions throughout the entire mine. It is done in conjunction with a bi-monthly report as intakes and exhausts are a portion of the study. The information is not compiled into a report form, but the quantities and temperatures are logged onto level maps which are kept in the Ventilation office. Historical surveys are kept on file in the Mine Administration vault. This survey also provides data used for the Ventilation Network File, information used in a ventilation simulation program.

4.6.3 Area Surveys

Besides these surveys, localized surveys of air distribution are run as necessary to pinpoint problems.

4.7 Ventilation Planning

The long term planning of ventilation requirements is currently done by a mine ventilation simulation program called VNETPC. This program has the capacity for network balancing and/or fire simulation. The input data for this file is the Ventilation Network File as mentioned above, and is based on actual data and resistances unique to the mine. Input and output from various network simulation runs are kept in printout form in the Ventilation Department files. Floppy disk copies of network simulations are also kept. Day to day planning, such as the determination of exact locations of small fans, is done largely from experience and practical considerations in cooperation with Mine Operating and Electrical departments.

4.8 Liaison with Operations

As mentioned, the Ventilation Department has assigned to it, a two man construction crew. These men are used to perform routine tasks such as bulkheading, cleaning and installing production fans, etc. Haulage construction crews assist with vent raise fan installation and salvage as needed. Mine Operating construction crews provide development fan and vent pipe installation work. Mine Mechanical crews provide main fan installation and maintenance and air door upkeep. Electricians furnish fan circuits as required.

Ventilation Engineers attend various production and development meetings held during the week to stay abreast of current activities and address related concerns that are noted during these meetings.

4.9 Carbon Monoxide Sensor Network

In 1991 a Carbon Monoxide (CO) monitoring system was installed in the mine to detect fires should they develop. CO sensors are located on the North and South haulages in the #3 Shaft area of all haulage levels. Additional CO sensors are located in the conveyor drifts which are located on the 3440 and 3530 levels. The monitors are connected to strip recorders in the surface Control Center.

The Control Center also monitors the on/off status of all main fan intakes. Each individual main fan is also monitored for vibration and bearing temperatures.

5.0 Ventilation Plan as per MSHA Regulation 57.8520

A plan of the mine ventilation system shall be set out by the operator in written from. Revisions of the system shall be noted and updated at least annually. The ventilation plan or revisions thereto shall be submitted to the District Manager for review and comments upon his written request. The plan shall, where applicable, contain the following:

(a) The mine name

. (b) The current mine map or schematic or series of mine maps or schematics of an appropriate scale, not greater than five hundred feet to the inch.

5.1 Mine Ventilation Maps

The mine maps can be found in **Appendix V**. The maps are an abbreviated form of the mine ventilation maps that can be found in the Ventilation Department. The maps include the following and conform to the requirements set forth by MSHA regulation 57.8520. The maps shall show:

1. Direction and quantity of principle air flows;

2. Locations of seals to be used to isolate abandoned workings;

3. Locations of areas withdrawn from the ventilation system;

4. Locations of all main, booster and auxiliary fans not shown in subsection (d) of this standard; *Since it is not feasible to show all the mine fans on these ventilation maps an inventory sheet showing the location of all mine fans is included in **Appendix III**.*

5. Locations of air regulators and stoppings and ventilation doors not shown in subsection of the standard;

6. Location of overcasts, undercasts and other airway crossover devices not shown in subsection of the standard;

7. Locations of known oil and gas wells;

8. Locations of known underground mine openings adjacent to the mine.

9. Locations of permanent underground shops, diesel fuel storage depots, oil fuel storage depots, hoist rooms, compressors, battery charging stations and explosive storage facilities. Permanent facilities are those intended to exist for one year or more;

10. Significant changes in the ventilation system projected for one year;

5.2 Mine Fan Data

Descriptions of all mine main and booster fans can be found in **Appendix IA** and **IB**. This information is intended to satisfy subsection C of MSHA regulation 57.8520.

The information in **Appendix IB** describes the types of booster fans used at this mine.

5.3 Subsection D of 57.8520, Ventilation Sketches

Diagrams and descriptions of sketches showing how ventilation is accomplished in each typical type of working place including the approximate quantity of air provided, and typical size and type of auxiliary fans used can be found in **Appendix II**.

Sections 4.2 and 4.3 of this report describe how ventilation is accomplished for typical working places. Section 4.2 and figure 5 describe and depict production ventilation.

5.4 Subsection E of 57.8520, Diesel Equipment

A description of the number and type of internal combustion engine units at this mine can be found in **Appendix IV**

Appendix IA

Main Fan Information

Appendix IB

Booster Fan Information

Appendix II

Diagrams depicting typical production and ventilation setups.

Appendix III

Locations of mine fan installations including total name plate horsepower.

Appendix IV

Diesel Unit Information

Appendix V

Mine Maps