Mine Water Used to Heat Ventilation Air at Henderson Molybdenum Mine

Eivind B. Jensen

Energy costs are escalating dramatically and energy availability in the required forms and quantities is increasingly uncertain. Thus, the methods chosen to heat large quantities of ventilation air can have a significant economic impact on a mining operation. At the Henderson molybdenum mine near Empire, CO, however, most ventilation air is heated by a source that is essentially free −29.4°C (85°F) warm mine water. This article describes this economical approach to heating ventilation air and provides a brief overview of the Henderson mine ventilation system.

Introduction

Though temporarily shutdown due to the depressed economy, the Henderson mine is a large underground molybdenite producer, using a continuous panel-caving mining system. The location of the ore body requires access from the surface through three shafts, the collars of which are located about 3.15 km (10,350 ft) above sea level. At this altitude, normal temperatures are such that heat must be added to intake-ventilation air for about half of each year. This prevents ice from building up in the intake shafts, waterlines from freezing underground, employee discomfort, and equipment-related problems such as pneumatic rock drill icing and cold starting of diesel engines.

Because of topographic and environmental constraints, the Henderson mill and concentrator are located 24 km (15 miles) from the mine, on the west side of the Continental Divide. All ore from the mine is transported to the mill by an electrified rail haulage system, with 15.4 km (9.6 miles) of the trip being underground through a double-track tunnel. A shaft at the midpoint of the tunnel exhausts air drawn from the mine and from the portal that is at an elevation of 2.7 km (8,950 ft). Intake air at the portal must be heated for part of the year to prevent ice buildup.

Mine Ventilation System

The mine ventilation system uses three sources of fresh air and two exhausts. The primary fresh-air intake is No. 3 shaft. It is concrete lined to a diameter of 7 m (23 ft) for a total depth of 698 m (2,291 ft). An airflow of 755 m^3/s (1.6 million cfm) is supplied to this shaft by two vane-axial 932-kW (1,250-hp) fans on the surface. The air is distributed within the mine by means of fresh-air distribution levels connected to production and development levels by raises.

A secondary source of fresh air to the mine is provided by No. 2 shaft, the primary man and material access. This shaft is concrete lined to a diameter of 8.5 m (28 ft) for a total depth of 946 m (3,105 ft). Downcast airflow is induced by a pressure differential produced by the fans in the system such that net intake and exhaust volumes are equal. The No. 2 shaft flow of 165 m^3/s (350,000 cfm) enters the mine network from the production and haulage levels.

Exhaust air is moved from the various working levels through connecting raises to exhaust collection levels that return it to No. 1 shaft. No. 1 shaft is the primary mine exhaust. It is concrete lined to a diameter of 7 m (23 ft) for a total depth of 788 m (2,584 ft). Three vane-axial 932-kW (1,250-hp) exhaust fans are located at the collar of No. 1 shaft, producing a flow of 850 m^3/s (1.8 million cfm).

In addition, an airflow of 71 m^3/s (150,000 cfm) from the intake distribution level is exhausted via the haulage tunnel, by means of No. 4 shaft located midway in the tunnel. The main features of the mine ventilation network are summarized in Fig. 1.

Ventilation Air-Heat Plants

No. 3 Shaft

In the early design phase of No. 3 shaft, it was recognized that air heating would be required to maintain underground temperatures above 0°C (32°F) during cold winters in the Colorado mountains. When the air reaches the mining

Elvind B. Jensen is the industrial engineer at Amax Inc.'s Henderson mine, Box 68, Empire, CO, 80438

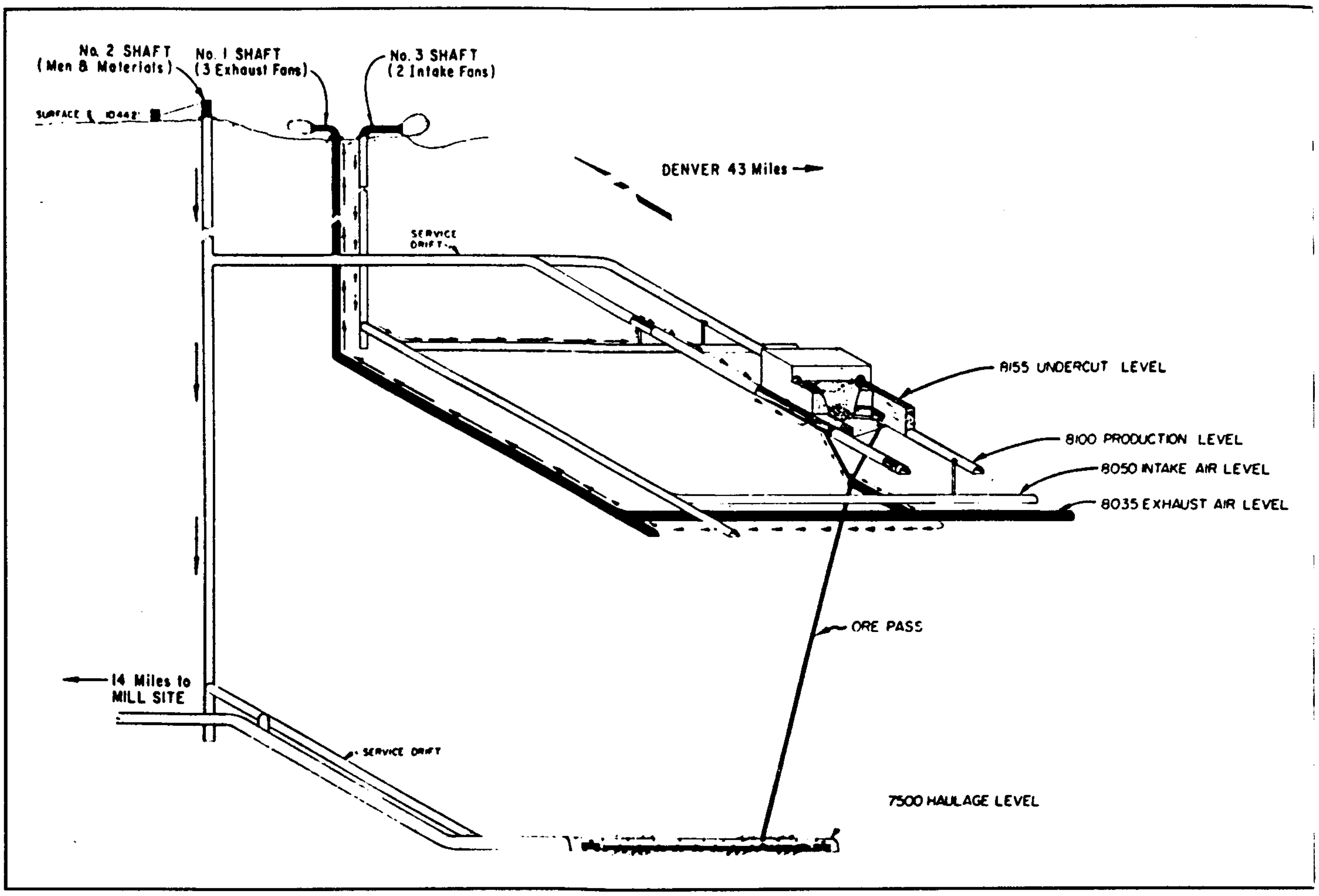


Fig. 1—Present mine ventilation system.

levels it already has experienced a natural rise in temperature of 11°C (20°F). This is due to adiabatic compression in the shaft that contributes 6.9°C (12.5°F) and due to heat transfer from the ground and fan motors. Therefore, additional heating is only required below −11°C (12°F).

The No. 3 shaft heat plant was started up last year. It represents an economic alternative to plants using conventional energy sources, because the heat source is essentially free. The primary heat source is the 29.4°C (85°F) water that is pumped from the mine at a rate of 63-79 L/s (1,000-1,250 gpm) at No. 2 shaft. The geothermal gradient at Henderson is such that at the lowest mine level virgin rock temperatures approach 32.2°C (90°F). Mine water must be cooled in any case because of stringent stream discharge temperature requirements. When mine air heating is not required, the water is cooled at a pond equipped with aeration sprays.

Warm mine water is pumped from No. 2 shaft to an insulated 416.3 kL (110,000-gal) surge tank from which it flows by gravity to the No. 3 shaft heat plant. The water is strained and passed through a series of heat exchangers and then discharged. The heat is transferred to a 50% ethelene glycol solution that is pumped to 10 fin-tube glycol-to-air heat exchangers located in wall openings of two structures enclosing the two intake fan inlets. To compensate for the additional air resistance of the heat exchangers, each is equipped with a 30-kW (40-hp) fan. By design, the mine water enters the plant at 26.7°C (80°F) and is discharged at 4.4°C (40°F). At a water flow of 63 L/s (1,000 gpm), energy is transferred to the glycol solution at the rate of 5.9 MW (20 million Btu per hr). This heat will raise the air temperature—at a flow of 755 m^3/s (1.6 million cfm)—by about 9.4°C (17°F). Actual temperature gains will vary from the design value depending on the outside temperature, humidity, and air density.

Thus, heat from mine water alone is sufficient to prevent freezing temperatures underground if the outside temperature is greater than −20.6°C (−5°F). However, conditions colder than this do occur for about 60 hours in an average season and up to 200 hours in an unusually cold season. Some form of supplemental heat is required, therefore, and is provided by a hot-water boiler with a rated output of 7 MW (24 million Btu per hr).

The boiler is fired with waste oil collected throughout the year and stored in a 178-kL (47,000-gal) capacity tank adjacent to the heat plant. The oil, with a heat value of 41.8 MJ/L (150,000 Btu per gal) is generated in a quantity of about 151 kL/a (40,000 gal per year) and, thus represents a significant energy source. In the past, this used motor and lubricating oil was sold to a commercial recycling company. But the oil is now more valuable as a fuel, with filtration being the only treatment required.

The waste-oil boiler is connected to the system so that the gylcol solution, already heated by the mine water, may have additional heat added before reaching the shaft air heat exchangers. The operating procedure is to fire the boiler when the outside temperature falls to about −17.8°C (0°F) and shut it off when the temperature rises back to this level. The additional heat from the boiler will prevent any potential freezing conditions underground except for a few hours each year when overnight temperatures fall briefly as low as −34.4°C (−30°F). A simplified schematic of the No. 3 shaft heating plant is shown in

Fig. 2. Table 1 summarizes the operating ranges.

On the average, the No. 3 shaft heat plant can be expected to supply 26.4 TJ/a (25 billion Btus per year). Compared to conventional sources, that represents a substantial operating cost saving. In addition, the geothermally heated water and waste oil are energy supplies that are not subject to interruption, curtailment, or other restrictions.

No. 2 Shaft

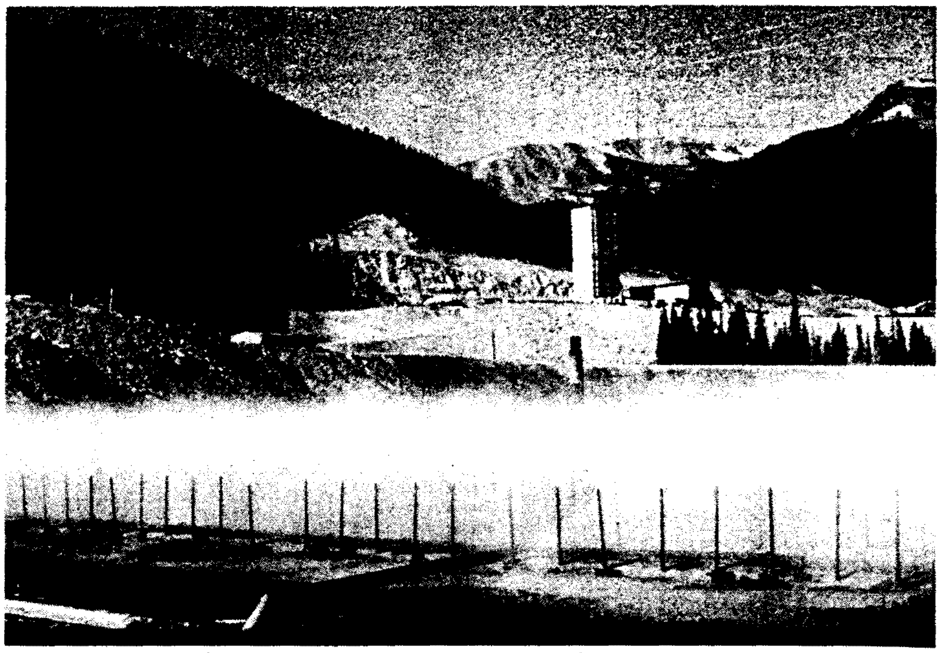
The primary heat source for the 165 m^3/s (350,000 cfm) of ventilating air pulled down No. 2 shaft is the waste heat generated by cooling the surface air compressor plant. This plant consists of four four-stage centrifugal compressors with a capacity of 14.2 m^3/s (30,000 cfm) at a pressure of 758 kPa (110 psi) and a total connected load of 4.85 MW (6,500 hp). At full capacity, roughly 4.1 MW (14 million Btu per hr) must be dissipated to properly cool the compressors.

In winter, the compressor heat is transferred to a 50% ethelene glycol solution that is pumped to nine fin-tube glycol-to-air heat exchangers, connected in parallel and located in openings in the concrete walls of the headframe. The quantity of heat contributed to the mine air in this manner varies with the loading of the compressors in response to variations in the need for compressed air underground. The waste-heat recovery can range from 0.79 MW (2.7 million Btu per hr) with one compressor running to the maximum 4.1 MW (14 million Btu per hr) with all four compressors fully loaded. On the coldest days, when compressor waste heat is insufficient for air heating needs, supplemental heat can be added to the glycol by a natural gas-fired boiler. Since the Henderson mine is an interruptable gas customer, backup fuel is provided in the form of propane. The main features of the No. 2 shaft heat plant are summarized in Fig. 3.

Haulage Tunnel

Heat is supplied to the 118 m^3/s (250,000 cfm) of intake air at the haulage tunnel portal by four electric resistance heaters with a total output of 2 MW (6.8 million Btu per hr). These heaters are thermostatically controlled so that from one to four heaters may be operating in response to ambient temperatures. The remote location of the tunnel portal precluded more cost-effective alternative forms of energy such as are used for mine air heating. However, control of this heat plant now forms an integral part of the electrical power management program at Henderson. It represents a significant load (3-4% of the total system load) that can be shed to avoid costly demand peaks.

This is implemented by providing the crusher operator at the mill site, about 8 km (5 miles) away, a kW meter to monitor the load of the substation supplying the haulage system. If the haulage system load reaches a predetermined level the crusher operator will remotely shut off the portal heaters for a brief period until the local peak has passed. In the past, haulage system demand peaks have frequently coincided with total system peaks. So this procedure provides a simple yet effective means of saving part of the demand charges on the monthly utility bill.



Mine water is cooled at an aeration spray pond before stream discharge.

Future Requirements

In the future, No. 5 shaft will be

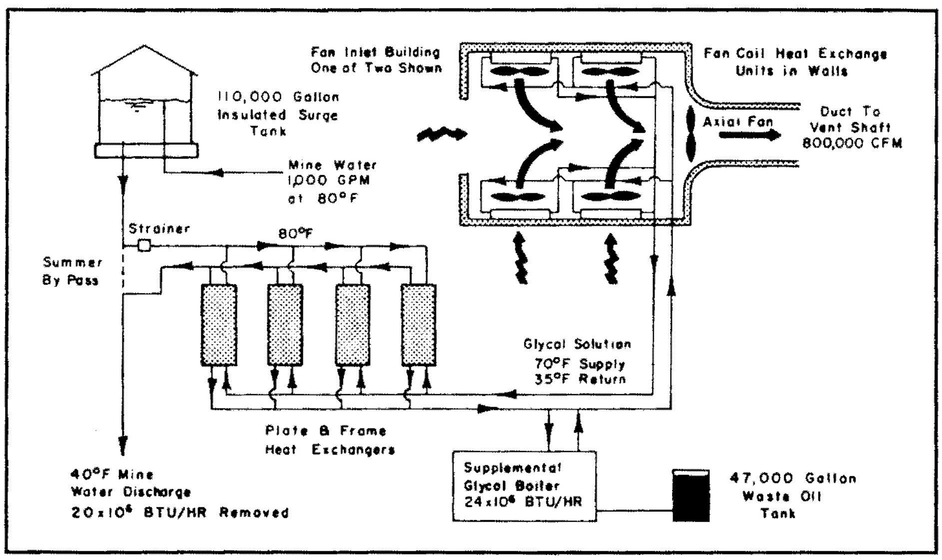


Fig. 2—No. 3 shaft heat plant schematic.

Table 1—No. 3 Shaft Heat Plant Operating Ranges

Outside Temperature	Mine Water Heat	Waste Oil Boiler	Air Temperatures Underground
>12°F	No	No	>32°F
12° to 0°F	Yes	No	49° to 37°F
0° to −25°F	Yes	Yes	47° to 32°F

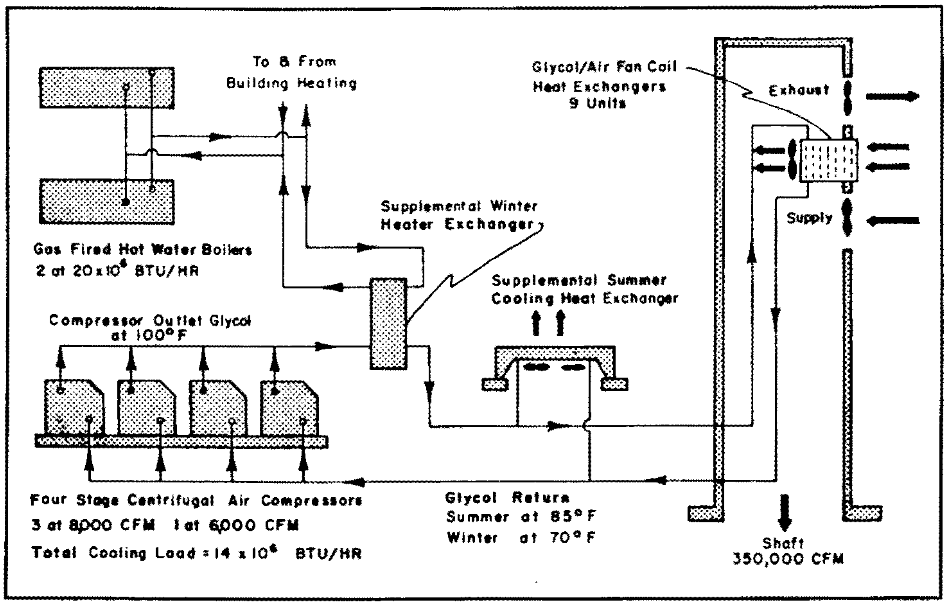


Fig. 3—No. 2 shaft heat plant schematic.

completed at the mine site as part of a plan to double the mine ventilation capacity. It will be concrete lined to a diameter of 9.75 m (32 ft) for total depth of 792 m (2,600 ft). No. 5 shaft will ultimately support an exhaust air flow of 1650 m^3/s (3.5 million cfm) with four 1.3 MW (1,750 hp) in-flight-adjustable vane-axial fans.

No. 1 shaft will have its air flow reversed, supplying 755 m^3/s (1.6 million cfm) of additional fresh air to the mine to provide the required increase in intake capacity. Air heating requirements for No. 1 shaft then should be the same as the No. 3 shaft because they have equivalent air flows. The future mine ventilation system schematic is shown in Fig. 4.

Alternative energy sources and heating plant designs for No. 1 shaft are being evaluated with respect to three main criteria: capital cost, operating cost, and long-term energy availability. In addition to more conventional sources such as natural gas and electricity, the feasibility of extracting heat, both sensible and latent, from the exhaust air stream at No. 5 shaft and transferring it to intake air at No. 1 shaft is being evaluated.

Conclusion

The mining industry today is confronted with economic challenges that demand diligent attention to cost control. With a recent history of volatile energy costs and long-term uncertainty about energy availability, a clear commitment to sound energy management is becoming increasingly important in the overall effort to control costs and ensure continuity of operation. Heating of large volumes of ventilation air consumes large amounts of energy. So it is an area that has received significant attention at Henderson, resulting in several energy efficient and cost effective systems.□

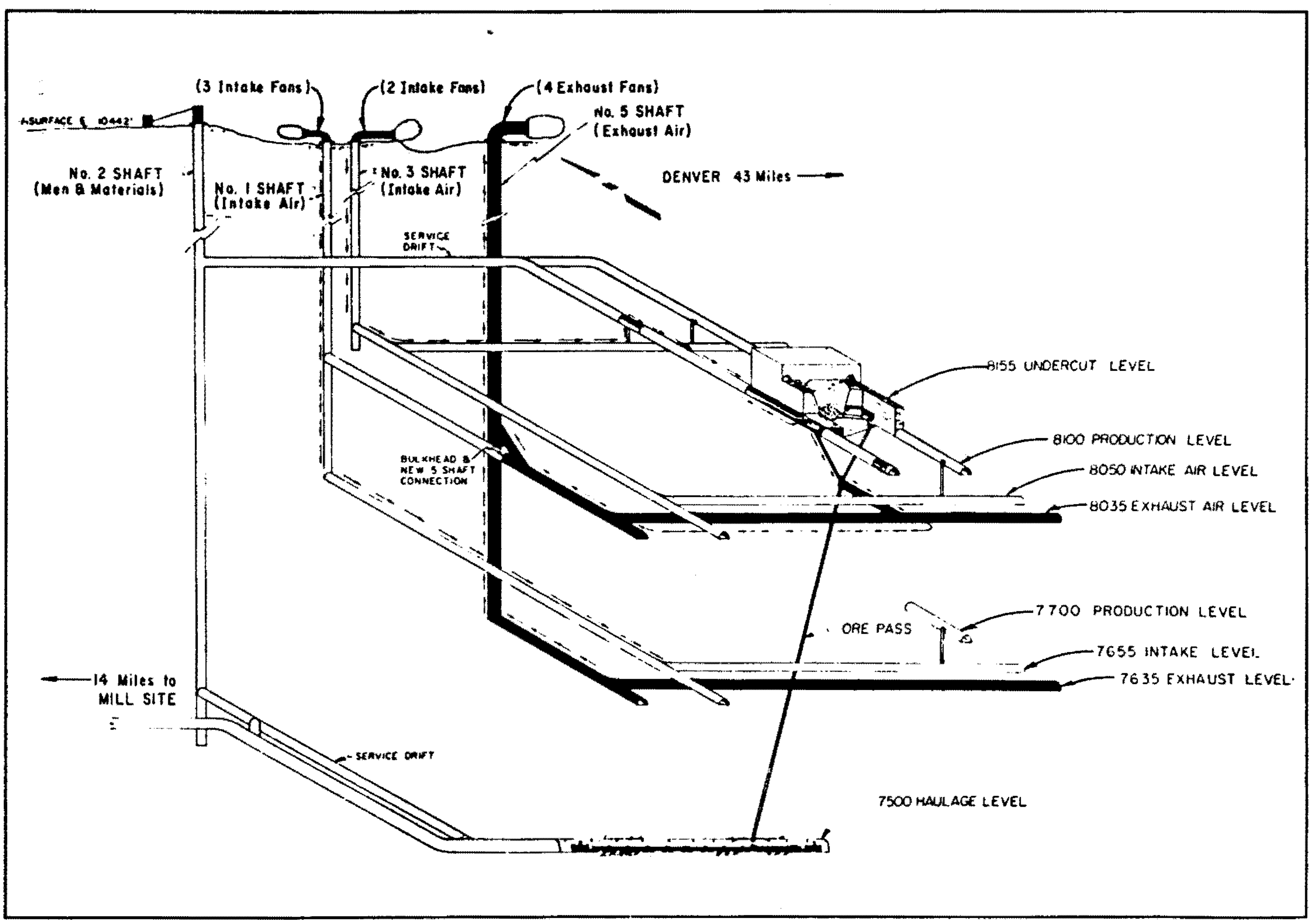


Fig. 4—Future mine ventilation system.