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Members are therefore urged to save their TECHNICAL PUBLICATIONS.
Protective Measures against Gas Hazards at United Verde Mine

BY OSCAR A. GLAESER,* JEROME, ARIZ.

(New York Meeting, February, 1930)

The United Verde Copper Company's mine is at Jerome, Ariz. The orebodies are of the schist replacement type, the main sulfide mass being a large lens-shaped body approximately 7 acres in cross-sectional area. In general, the mineralization is found along the iron schist contact, with the orebodies extending about 1000 ft. along this contact and varying from a few feet to 250 ft. in width. Three types of ore are mined; schist porphyry and the so-called "heavy" or "massive sulfide" ore. Approximately 50 per cent. of the total tonnage mined at present is of the latter class. A representative analysis of this ore indicates 42 to 46 per cent. sulfur.

Because of the high sulfur content, blasting in this ore is an extremely hazardous operation. Not only does it endanger the lives of men who may be in the mine at blasting time but it also becomes a potential fire menace when timber is in close proximity to shots being fired in these massive sulfides. The origin of the fires of 38 years ago, embers of which are glowing to this day, may perhaps be attributed to dust explosions due to blasting in the massive sulfides of those early square-set stopes.

DUST EXPLOSIONS

Dust explosions in coal mines are a common source of mine disasters. That such explosions may be of common occurrence in metal mines is not generally known, but it is known that metal-mine dust will explode and such explosions have been investigated by the U. S. Bureau of Mines at the Pittsburgh Experiment Station. Samples of "heavy sulfide" ore from the United Verde mine were used in the tests. After studying the results of the tests it was concluded¹ that:

1. Dust explosions were initiated in sulfide ore dust in the gallery with a charge of as low as 75 g. of 60 per cent. gelatin dynamite.
2. The exploding dust generated considerable pressure.

* Safety & Ventilation Engineer, United Verde Copper Co.
3. Ignitions were obtained with each of the explosives used.
   a. 60 per cent. ammonia gelatin dynamite,
   b. Permissible gelatin dynamite,
   c. FFF black blasting powder,
   d. 60 per cent. gelatin dynamite,
   e. An ammonia nitrate permissible.
4. There was no "zone of doubt" as to whether ignition did or did not occur. The dust ignited strongly or not at all.
5. The atmosphere contained as much as 2.46 per cent. SO₂ gas after an explosion of sulfide dust in the gallery. The amount of magnetic particles in the dust deposited on the gallery surfaces showed that over 90 per cent. of the particles that had been raised into the exploding cloud had entered into the burning reaction.
6. It took a larger charge of the permissible gelatin than of the 60 per cent. gelatin to ignite the dust.

Conditions Causing Explosions

Exactly what transpires at the face when an explosion occurs is not known, of course. The sulfide ores are extremely hard and tough, and require a relatively heavy charge of explosive. The ore breaks with sharp edges and is heavy, both attributes having a tendency to create dust to a greater degree than with common ores. Furthermore, because of its greater weight the dust settles quickly, thus accumulating in close proximity to the working face. The first few shots to "go off" charge the atmosphere with their own dust and stir up the dust that has accumulated during the shift. Finally some shot with considerable flame ignites this suspended dust and an explosion occurs.

The explosions are always local. They do not propagate and are not of sufficient violence to cause destruction. The gas seems to hang together and to move in a body. It is not easily scattered and dispelled into the air current. It has the appearance of a dense white cloud, and usually fills the entire mine opening.

Dangerous Gas

That the gas is generated in dangerous concentrations is a fact. On several occasions fatalities have occurred when men have tried to fight their way through it. Samples of gases were taken in a heavy sulfide drift 15 min. after blasting and were analyzed by the U. S. Bureau of Mines.² The analyses indicated 0.09 per cent. SO₂ and 0.07 per cent. H₂S. A concentration of 0.05 per cent. of SO₂ is dangerous to persons exposed longer than 30 min., while a concentration of 0.06 per cent.

H₂S will cause unconsciousness within 2 min. and death within 15 minutes.

In order to protect life and property against this ever-present menace, efforts were made to eliminate the cause. Experiments along this line were not entirely successful. Permissible explosives were tried without success, as is also indicated by the Bureau of Mines experiments. Thoroughly wetting down the walls and muck pile before loading and a conscientious effort at tamping have reduced the number of dust explosions to some extent, but not entirely; however, it is believed that the fire hazard is considerably reduced by these precautions. So far it has been customary to use dry tamping previously loaded into paper tamping bags. Wet tamping will be tried soon, and it is believed that the wet clay will prove superior in every respect to the screened dry clay, which is now used.

While these efforts have had a tendency to reduce the hazard, they have not eliminated it. Other means for greater safety had to be found. It was decided to do all blasting under greater regulation and to so control the ventilating air currents that with reasonable care men would find a clear passage to the shaft.

**Regulating the Blasting**

All heavy blasting is confined to the end of the shift and heavy blasting in the “massive sulfides” is confined to the end of the afternoon shift. Only block hole blasting is permitted during the lunch hour. These regulations assure a clear atmosphere throughout the day, and since the shifts change on the surface, sufficient time elapses between the blasting at the end of the day shift and the beginning of the afternoon shift for the air currents to sweep the mine free of all powder smoke. The graveyard shift is small, consisting chiefly of timber “rustlers,” who can easily avoid any local gas condition. Gases are seldom found in the mine when these men go to work; only occasionally is even a trace detected.

**Table 1.—Blasting Schedule**

<table>
<thead>
<tr>
<th>Spitting Time</th>
<th>Levels'</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day Shift</strong></td>
<td></td>
</tr>
<tr>
<td>3:15 p. m.</td>
<td>300 to 2100 Incl.</td>
</tr>
<tr>
<td>On signals</td>
<td></td>
</tr>
<tr>
<td>3:20-3:30 p. m.</td>
<td>2250</td>
</tr>
<tr>
<td>3:35-3:45 p. m.</td>
<td>2400</td>
</tr>
<tr>
<td>3:50-4:00 p. m.</td>
<td>2550</td>
</tr>
<tr>
<td>3:50</td>
<td>2700-3000</td>
</tr>
<tr>
<td><strong>Afternoon Shift</strong></td>
<td></td>
</tr>
<tr>
<td>11:40 p. m.</td>
<td></td>
</tr>
<tr>
<td>11:45-11:55 p. m.</td>
<td></td>
</tr>
<tr>
<td>12:00-12:10 a. m.</td>
<td></td>
</tr>
<tr>
<td>12:15-12:25 a. m.</td>
<td></td>
</tr>
<tr>
<td>12:20</td>
<td></td>
</tr>
</tbody>
</table>
A blasting schedule for different sections of the mine and for individual levels has been established. To increase the safety factor, a system of electric blasting signals is in operation from the 2100-ft. level downwards (Fig. 1).

The blasting above the 2100-ft. level is all done at one time. This is possible because of the class of ore mined, the location of the stopes with respect to other workings above and the direction of the flow of air. Below the 2100-ft. level the workings are somewhat more concentrated, more mining is done in the massive sulfides and the flow of any split air is through several working places.

![Electric Blasting Signal](image)

Fig. 1.—Electric Blasting Signal, showing pull switch, lights and horn.

Beginning with the 2100-ft. level and going downward, the levels are connected by electric signal lines with pull switches and lights on each level. At blasting time the shift boss on the 2100-ft. level sends an order to blast. He stations himself at the blasting signal and checks his men out as they pass him on their way to the station. When they have been checked out past this point he flashes the clearance signal to the 2250-ft. level. The shift boss there receives and returns the signal. This clears the boss on the 2100-ft. level and he goes to the station.
TABLE 2.—Fresh Air Distribution

<table>
<thead>
<tr>
<th>Level</th>
<th>Volume, Cubic Feet</th>
<th>Level</th>
<th>Volume, Cubic Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>24,000</td>
<td>2,100</td>
<td>16,500</td>
</tr>
<tr>
<td>1,200</td>
<td>11,000</td>
<td>2,250</td>
<td>31,500</td>
</tr>
<tr>
<td>1,350</td>
<td>9,500</td>
<td>2,400</td>
<td>40,000</td>
</tr>
<tr>
<td>1,500</td>
<td>8,500</td>
<td>2,550</td>
<td>18,000</td>
</tr>
<tr>
<td>1,650</td>
<td>16,500</td>
<td>2,700</td>
<td>10,000</td>
</tr>
<tr>
<td>1,800</td>
<td>23,000</td>
<td>2,850</td>
<td>7,500</td>
</tr>
<tr>
<td>1,950</td>
<td>15,500</td>
<td>3,000</td>
<td>8,500</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>240,000</td>
</tr>
</tbody>
</table>

The boss on the 2250-ft. level then sends out his order to blast. The checking out process and signalling to the next lower level is then carried out again, as described. Blasting signals at present are used down to the 2550-ft. level and soon will be extended to the 2700-ft. level. Table 1 gives some idea of the time required to carry out a blasting operation.

The actual loss of time at the working face is not great, as approximately the same time interval is required to transport the men to their particular level when going on shift.

VENTILATION

The safety of this system of blasting by electric signals is absolutely dependent on an ascending air current. It can readily be seen what
would happen if one or more raises were downcast; the fumes from
the blasting on the level above would come down into the stops where
men were spitting their shots and probably would trap them there.
The air current must be so distributed and controlled that its move-
ment will be upward.

Air splits, which were described in an earlier paper, have aided
materially in maintaining an ascending air column. It should be under-
stood that all levels are supplied with fresh air (see Table 2) but that
certain split levels or gathering levels for return air are so arranged that

the gathering of the return air and its passage into the main return is
separated from the fresh air, which might have to be admitted to the level
by means of bulkheads, overcasts or doors, as the case may demand.

A sketch plan of the 2100-ft. level is presented in Fig. 2. This is the
lowest gathering level in the mine for vitiated or return air. Practically

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all the air that is admitted on the levels below the 2100-ft. (see Table 2) is removed to the main return of this level. At the same time fresh air in considerable volume is admitted for special use in an outlying district. Fig. 3 is a detailed sketch of the fresh air by-pass and over-cast. The tool room, which happens to be on the return-air side, is kept dry by fresh air that is taken into the magazine through a 16-in. metal pipe.

In order to force the return air to leave the workings on this level, it was necessary to effect a seal somewhere between the 2100 and the 1950-ft. levels. A 30-ft. floor pillar was left in place on the 1950-ft.

level. All raises that were carried through to the 1950-ft. level have been covered by iron doors placed in reenforced concrete collars (Figs. 4 and 5). The floor pillars act as supporting pillars, and with the iron doors in place form a horizontal fire break as well as serving as an air stopping. The cover doors of the raise are kept closed at all times, which assures positive control of the ascending air column on the 2100-ft. level. It further assures a constant supply of fresh air to the levels above, uncontaminated by smoke, gases or vitiated air from the levels below.

SAFETY CHAMBERS

Some years ago gas chambers were necessary for the safety of mine employees, but recently their importance has not been so pronounced.
The present method of blasting and the greater control now exercised over the air currents give reasonable assurance of safe exit. As an additional safety precaution, one or more safety chambers are still maintained on each level, into which men may retreat in any emergency and feel safe as long as the compressed-air lines are intact.

The safety chambers are in dead ends of drifts. A standard-type mine door is installed as far from the face as space outside of the chamber will permit. The chamber is supplied with electric light, water and compressed-air lines. A sign on the door instructs men to close the door and turn on the compressed air. Valves controlling both air and water are inside the chamber. The escaping compressed air builds up sufficient pressure within the chamber to keep out all gases under normal conditions. As an additional precaution, a 1-in. perforated air line is fastened on the outside of the door frame along the sides and top (Fig. 6). The pipe is placed so that the perforations will direct the air diagonally across the door opening. It is assumed that this flow of air will not only aid in keeping gases from the door but will tend to dilute any approaching gas. This pipe is connected to the compressed-air line inside the safety chamber. The flow of compressed air through it is controlled by a separate valve.

Signs at various points on the level indicate the direction to the nearest safety chamber, and a green light is placed at the drift intersections leading to the chambers so that men can readily locate them.

Safety chambers should also be useful if men are trapped by a fire. They have never been needed for this purpose in the United Verde mine.
but they should be as effective as a barricade. When used for such an emergency, however, not too much dependence should be placed in the compressed-air supply. If the air line passes through the fire zone, it will soon be burned out or broken, and the air supply would stop, of course. In mines where safety chambers are maintained for this purpose, the piping should be so arranged that the compressed-air will flow to the safety chamber from at least two different sections of the mine, to assure, as far as possible, a continuous supply.

**Fire Watchmen**

The United Verde mine is patrolled by fire watchmen who have no other duties. They are given a definite beat to cover. Stations have been established where they leave a card on which is written the date, time, condition of that particular district, and their initials. These cards are picked up several times a week and filed away. The watchmen are required to report to the Safety Department daily.

**Results of Safety Measures**

Blasting signals were installed in August, 1926, and a definite system of ventilation has been established since that time. Rigid adherence to blasting regulations and constant attention to ventilation are the contributing factors largely responsible for the fact that there has been no recurrence of gas accidents since August of 1926.