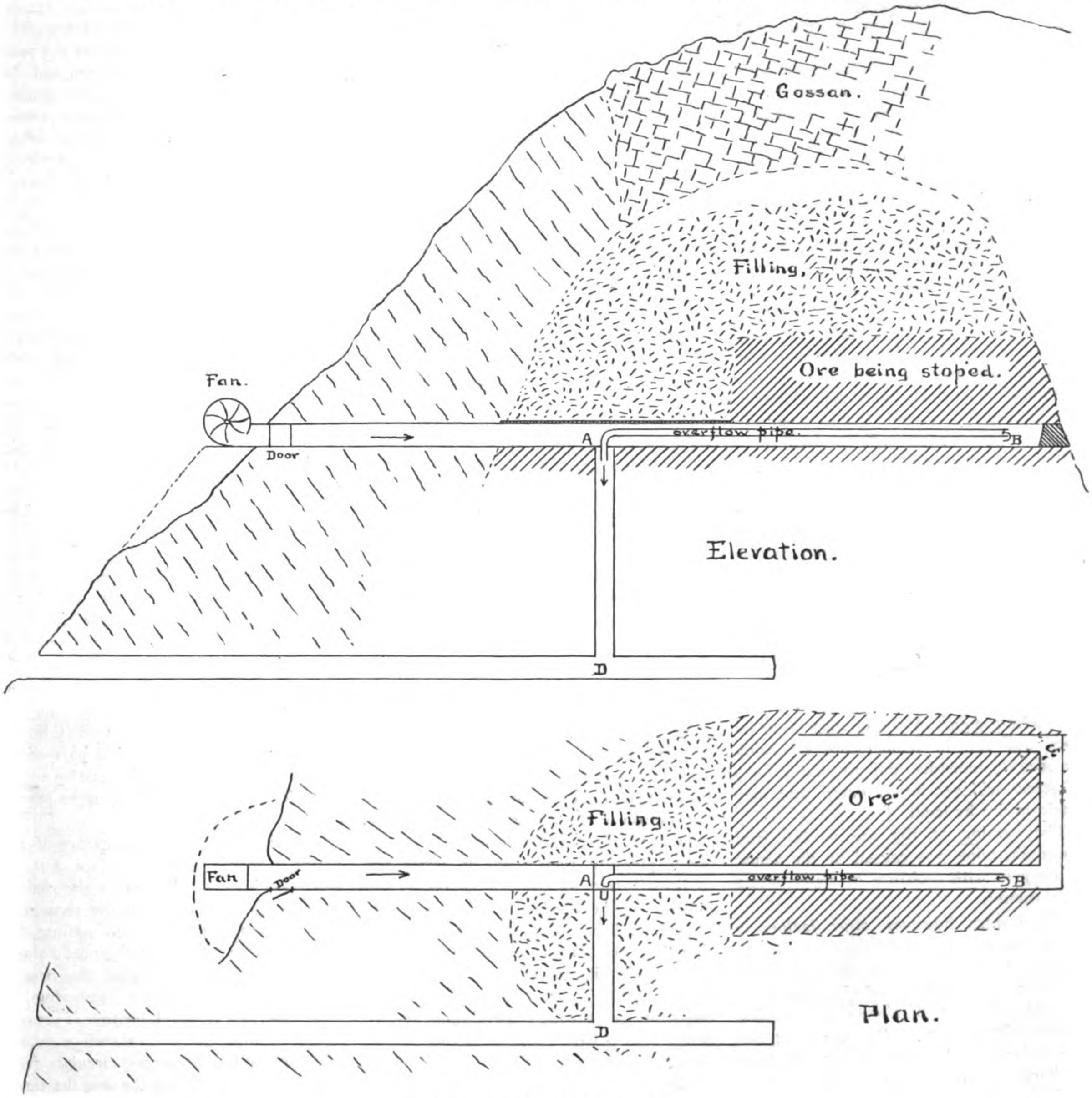
Controlling and Extinguishing Fires in Pyritous Mines.

BY LEWIS T. WRIGHT.

The Iron Mountain mine in Shasta Co., California is a large mass of cupriferous iron pyrite. In mining this the immense cavities formed by the galleries, stopes, and workings are filled with rock. In course of time it was found that the mine temperature had increased and was increasing. The ventilation system was that almost invariably used in metalliferous mines, viz: natural ventilation. The pyrite in places became hot. One morning a faint odor of sulphurous acid was observed, and by midday it had increased to such an extent that a large part of the mine had to be abandoned. The mine was on fire and the gases from the fire made it necessary to leave the workings. The fire proceeded rapidly through parts of the filling and the workings, burning out the timber. The fire was extinguished by heroic means and the use of water. The problem then was, however, to find a means of cooling the working places so that work could be carried on in them, and also to prevent gases from fires that might originate in filled ground from spreading to the workings, to extinguish fire that might originate in covered ground, without interfering with the mining operations, and to prevent small traces of gases from such fires from entering the workings where their presence would drive out the miners. I was able to solve this problem by a process of reasoning based partly on knowledge derived in theoretical study, and partly by the observation of the facts of the case.

The question was "What was the cause of the heating of the ground that was the precursor and cause of the fire?" Some thought it was the pressure of the backs on the filling. No doubt in the settling and packing of this by immense weight above there might be some heat generated. So many million tons falling so many feet in such a time would produce a calculable amount of heat. Some thought it was the kaolinization of the rock filling and adjacent country. I reasoned as follows: A mass of pyrite dry and at normal temperature, like a specimen in a museum, does not become hot, does not oxidize and may for all we



PLAN AND ELEVATION OF WORKINGS.

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know last a million years without change, if so preserved; but a heap of pyrite exposed to moisture and oxygen does oxidize, and that reaction produces heat. The majority of chemical actions proceed at a greater rate as the tempature rises. There is an initial temperature at which the action commences and proceeds slowly; then if the temperature rises, the action proceeds much faster and finally becomes very rapid and even violent.

I once performed the following experiment on a coal that was known to be fiery: I powdered it into a fine condition, moistened it, and left it in a heap. When it commenced to warm up, I placed some of it in a tube and allowed at first fresh air to pass through it, but very gently. It became warmer. I then increased the flow of air and it became hot, and then by greatly increasing the flow of air it was brought into a state of vivid combustion. The essence ot this experiment is, that where there is chemical action producing evolution of heat, care must be taken to lose heat by radiation and convection at a less rate than that at which it is produced. The temperature then will rise and the action will proceed at a faster rate; the gain in temperature becomes increasingly rapid and combustion finally ensues.

Heaps of cupriferous pyrite in Spain are washed judiciously with water for the extraction of copper, and their temperature rises, thus promoting the desired sulphatizing action, but the temperature is not allowed to rise to the point of combustion. I have seen heaps of iron filings, by careful watering and protection from loss of heat, brought in their interior to the melting point. A single wisp of straw does not rise in temperature by being exposed to moisture and air, but a heap of straw will get hot if damp, and may catch on fire by itself.

The heating of the ore in the Iron Mountain mine was caused by the action of oxygen, with moisture or water acting as a carrier.

There were, however, other factors in the problem. The workings had to be ventilated, but it was thought that the addition of air to fire would be dangerous. But take the case of a coke fire burning actively in a grate. By spreading out the embers on the ground they will cease to burn and cool off. An excess of air will in this way put out the fire. With the natural system of ventilation then in use at Iron Mountain I had frequently occasion to observe that air coming from certain crevices would put out the light of a candle and there was other evidence that the ground as a whole was porous.

There was still another factor in the problem, viz., an extinctive atmosphere, one in which certain classes of combustion cannot proceed for reason of either a total want of oxygen or its dilution by other inert cooling gases. Carbonaceous flames are extinguished when the surrounding atmosphere contains less than a certain amount of oxygen, say about 15 per cent.

The roasting of metallic sulphides proceeds less slowly when the surrounding gases are deficient in oxygen and will cease entirely when the oxygen falls below a certain amount. If the heat production is less than the heat loss by radiation or air cooling, then the temperature of a burning body will fall, and falling below the temperature of ignition will cease to burn.

Some of the factors in the problem were the porous ground; the material that was combustible and could heat itself and take fire; and the fact that it could be cooled if hot and if on fire could be extinguished either by a great excess of air, or by deficiency of it. I reasoned that by forcing through the drifts a sufficient quantity of air it would be possible to cool off the external faces of heated blocks of ore, or if an extinctive atmosphere could be maintained in the interior of the blocks of ore and filling, accumulation of this interior heating could be prevented. By maintaining in the open workings an atmospheric pressure slightly above that in the ground (which is practically that of the atmosphere), the gases from the interior could be kept from penetrating into the workings and driving us out of them. By keeping this pressure at a proper point the gases could be held in the interior where they would act as an extinctive atmosphere.

I caused, therefore, powerful fans to be fitted up at certain entrances, which were closed by doors and provided with ducts for the air from the fans. The air was driven by the fans through the workings, maintaining a pressure slightly above that of the outside atmosphere. If the friction of the air drifts was not sufficient to produce this excess over atmospheric pressure, then doors or baffles had to be adjusted to hold the gases in the interior of the blocks of ore and filling, the object being to push back the gases slowly to the surface, through the mass of ore and filling, using just enough pressure to make a movement of air from the workings through the filling, and to assure that it would not be in the reverse direction.

The system was started and within twenty-four hours the workings operated on were freed of smoke and bad air, and in a few days the heated faces of ore cooled off and became dry. If the fans were stopped a few minutes, traces of foul gases and sulphurous acid were perceived; on restarting the fans these disappeared. This was the condition desired. The foul air was being held back in the interior where it would extinguish the fire and delay or prevent combustion.

The men in charge soon became expert in the use of the system. If evidences of fire are noticed in the interior of a section of ground, by balancing the air pressure around it by means of the fans and doors, etc., the fire can be held in an extinctive atmosphere, when it quickly dies out. Use is also made of this system in attacking blocks of heated ore, the ore faces being quickly cooled off by air currents. The system installed fulfilled a triple purpose. It supplied the fresh air required by those working in the mine, cooled off the heated faces of ore and, due to the permeable nature of the ground, enabled us to keep an extinctive atmosphere in the interior of the blocks of ore and filling, and prevented the pernicious gases of smoldering fire from entering th workings.

In practice it is found that a pressure of air from 1½ to 3 in. of water gauge has to be maintained in the workings to provide the fresh air to hold back foul gases. In working up to a face of ore at the end of a drift or stope that is approached from any entry through which there is a free current of air, there may not be enough circulation of air resulting from the movement of air through the broken ore face, and an overflow pipe can be used to take some air out of the end of the chamber to a point where the pressure may be less. In a case in point, the air pressure in a chamber was 2½ in., but the movement of air through the ore was not sufficient to give a good cool circulation, and an overflow pipe was put in and this reduced the pressure in the chamber to 1½ in., but gave the required circulation.

In other cases the loss of air in its passage through the workings may be excessive because of the extremely broken character of the rock in that part of the drift. In that case it is the custom to line the sides and top with planking to prevent too great a loss of air.

The ore often has a temperature of 430° F. on a freshly broken surface, but this will cool very rapidly (in a day or so) on its exposed surface by the passage of cool air along its face. This cooling does not penetrate very deep, since holes a few inches in depth reveal the original temperature, so that the timbering has to be carefully watched, because if pressing tightly against the ore in such a manner that the cooling air cannot circulate freely between the timber and the ore, the timber will become heated and even ignited. Water lines are carried into all the stopes and there is a man on duty who extinguishes such fires.

Of the air delivered into the mine, at times as much as two-thirds is lost in the workings, only one-third reaching the exit tunnels.

The accompanying sketches show a block of ore being stopped. The overflow pipe and lining over the filling are always necessary.