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Ventilation at the Portovelo mines

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VENTILATION AT THE PORTOVELO MINES

by

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Ventilation at the Portovelo Mines

Table of Contents

List of Illustrations

Ventilation at the Portovelo Mines, Ecuador*

This paper was written with two objects in view: (1) To describe in detail what has been done toward the ventilation of the main unit of the Portovelo mines and the results; (2) to give information that may be useful to anyone who may have to make a preliminary mine ventilation survey, with recommendations for the improvement of the existing system and finally the maintenance of the improved system.

General Description

The mining operations of the South American Development Co. at Portovelo, Province of El Oro, Ecuador, are described here only briefly, as a full discussion does not fall within the scope of this paper.

The orebodies are of the steeply dipping, gold quartz vein type, averaging about 2.0 meters wide. As shown in Fig. 1, the ore chutes are relatively far apart, making considerable development work necessary before connecting raises can be driven between the levels. Faulting[1] on a large scale and a parallel vein system have made long dead-end drifts and many crosscuts necessary in the exploration of veins. The ventilation of these dead ends is described under Auxiliary Ventilation. The method of mining[2] is the filled rill stope method,

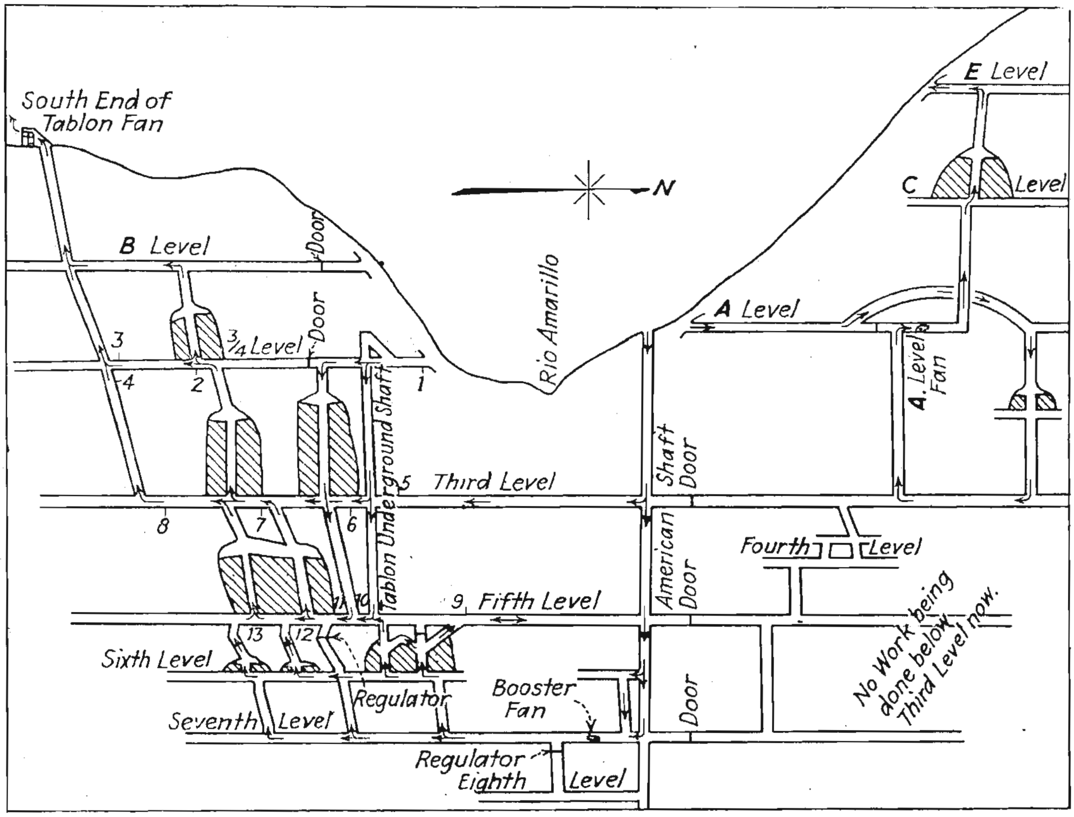

FIG. 1.—PROFILE OF PORTOVELO MINE WORKINGS CONSIDERED IN VENTILATION PROBLEM.

TABLE 1.—*Monthly Average Maximum and Minimum Temperature as Recorded at Portovelo, Ecuador*

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1927	Max...	75.8	76.4	78.0	78.9	80.4	80.9	82.5	81.5	80.1	81.5	81.9	82.6
	Min...	68.8	69.5	69.8	69.5	69.3	67.6	65.3	66.5	67.6	68.3	68.9	68.9
1928	Max...	77.0	77.0	78.5	79.0	78.5	78.5	81.1	80.6	82.5	83.5	82.6	81.4
	Min...	67.9	68.1	67.6	68.0	68.5	66.7	64.2	65.6	67.1	67.9	67.7	68.3
1929	Max...	79.5	77.2	78.6	79.6	78.8	78.6	81.5	81.2	82.9	82.3	81.6	80.2
	Min...	67.2	67.9	68.0	67.5	67.7	66.3	64.1	65.7	67.1	67.2	67.5	68.0
1930	Max...	79.5	77.4	79.0	79.2								
	Min...	67.8	67.4	68.0	67.8								

similar to the method that is largely employed at the Butte mines.

The main shaft of the mine is in the Amarillo Valley, on either side of which mountains rise abruptly to a height of several hundred feet above the collar of the shaft. Entrance is made to the mine: (1) Through the American shaft, which extends vertically from the surface to a depth of 1100 ft., of which only the first 700 ft. are in active use at the present time; (2) levels are driven from the American shaft at intervals of 30 m. (100 ft.), of which only the third, fifth and seventh levels need be considered in the ventilation problem; (3) adits at intervals of 30 m. (100 ft.), with a few exceptions, above the collar of the American shaft. The main adits on the south side are 3/4 level adit, A level adit, E level adit, E1/4 level adit and F level adit.

Surface Temperature

A record of the maximum and minimum daily temperature readings has been kept for a period of 30 years. This record shows that the average maximum temperature for the last four years has been 80.8° F. and the average minimum 68.2° F. It also shows that the difference between maximum and minimum monthly average for the last four years has ranged between 6° and 20° F. Table 1 shows the maximum and minimum average monthly temperature for the years 1927, 1928, 1929 and 1930 to date. The temperature readings were taken in the shade and indicate only the air temperature, which is not high enough to require refrigeration for mine ventilation purposes, nor low enough to materially change the mine temperature.

Humidity

At the latitude of the mine there are two distinct seasons of the year; the wet season, December 15 to June 15, and the dry season, June 15 to December 15. During the wet season rains occur daily, averaging about 60 in. of rainfall per year. In the dry season there is very little precipatation. (See Table 2.)

The humidity of the air on the surface is higher than might be expected, especially during the dry season. A record of the relative humidity at the collar of the American shaft shows that the average for the period July 15 to August 15 was 48 per cent.; that from May 8 to June 8, 64 per cent.

The humidity of the mine air, however, is independent of the surface humidity and the air attains a high relative humidity soon after entering the mine. The high humidity is due to:

1. Mine water. Enough water seeps from the rocks to keep the back of many of the drifts and stopes permanently wet, and in some places there is such an ex-

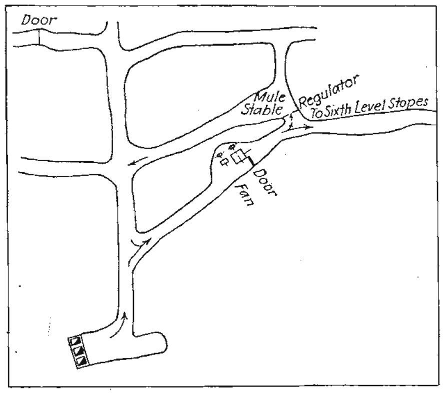

FIG. 2.—PLAN OF SEVENTH LEVEL STATION AND FAN SITE.

TABLE 2.—*Portovelo Rainfall Record, in Inches*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1927	17.45	12.35	10.95	3.25	1.50	0.35	0.0	0.05	2.05	2.10	1.30	2.10	53.45
1928	10.85	9.65	23.10	22.75	8.10	2.10	1.10	0.0	0.10	0.20	1.50	4.45	83.90
1929	7.65	14.55	11.00	8.70	4.98	1.35	0.0	0.0	0.85	1.35	2.70	3.25	56.38
1930	6.25	13.45	17.05	13.40									50.15

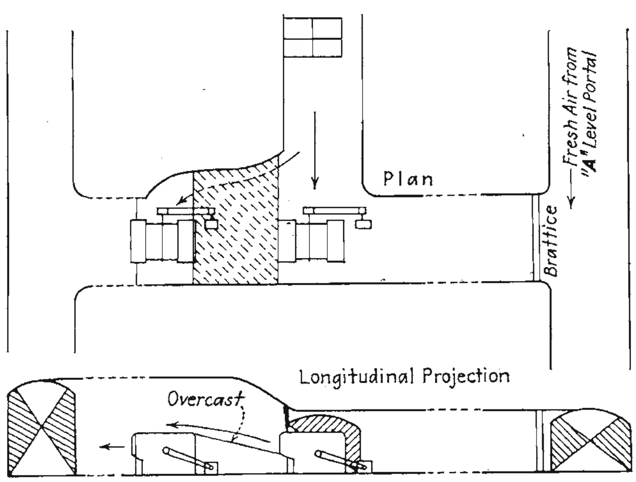

FIG. 3.—PARALLEL SET-UP OF TWO EXHAUST FANS ON A LEVEL.

cess as to form drippers.

2. Underground streams. In several places underground streams have been tapped, which have tended to saturate the air.

3. Water from drills. To reduce the possibility of the miners contracting silicosis, dry drilling is prohibited. Although there is less water from wet drilling than from the sources mentioned above, it tends to keep the relative humidity at the working places very near 100 per cent.

4. Perspiration from men and animals underground. This source of moisture, although small, locally tends to saturate air of low velocity that might otherwise be fairly dry.

Ventilation in the Past

The system of ventilation in operation before the changes described in this paper were made was as follows:

A Sturtevant, Silentvane No. 95, design 2, double-width double-inlet fan, located at 3/4 level portal, forced fresh air along the drift (Fig. 1). Some air passed up through the 3/4 level stopes and out to the surface; the remainder passed down to third level through two operating stopes. From third level the air was forced to fifth level through two operating stopes, and then to seventh level through a manway. The air on third level and fifth level was kept from returning to the American shaft by doors in the drift south of the shaft. On seventh level the air went north, past the American shaft, where it was diluted with fresh air.

A booster fan of local make was placed on seventh level, north of the American shaft, and a Sturtevant fan similar in design and capacity to the one at 3/4 level portal was located at F level portal, in the north end of the mine (Fig. 7). These two fans working in series exhausted the air from the mine. The American shaft was kept downcast, to preserve the shaft lining, which at that time was wood.

Under this system the maximum amount of air circulating in the mine was 33,000 cu. ft. per minute, as all of the fans operated in series.

Air splits are considered essential in good ventilation practice, and in some parts of the United States they are required. As stated later, the new system of ventilation was based on this principle, while the old system worked on a series plan, using the same vitiated air over and over again.

Preliminary Conclusions

After a preliminary study of the problem of ventilating this mine the following conclusions were reached:

1. That the pressure system employed in the south part of the mine should be changed to an exhaust

system. This change was decided upon because: (a) It was desired that air splits be employed as frequently as practicable, in order that partly vitiated air might be diluted before passing to the next working place. The use of air splits, while possible with a pressure system, can be handled more easily with an exhaust system. As was noted under Ventilation in the Past, the same air was used over and over, so that it was thoroughly vitiated on reaching the exhaust passage. (b) With the two fans in series, as in the original set-up, approximately 33,000 cu. ft. of air per minute was circulated through the mine, while with the same two fans exhausting independently twice as much air was circulated.

2. That a line of raises should be driven in the south part of the mine, to be used primarily for ventilation purposes.

3. That the fan which had been forcing air into the south part of the mine should be moved to the Tablon shaft, where the air raise from B level to the surface had broken through.

4. That the booster fan formerly mounted north of the American shaft on seventh level should be moved south of the shaft, to force air south to sixth level stopes, as well as deliver some air north through the mule stable (Fig. 2).

5. That a system of air splits should be adopted as far as possible.

6. That solid platforms in raises to be used for airways should be replaced by lattice platforms.

7. That it would not be practicable to reduce the humidity of the mine air.

8. That, due to the high humidity and prevailing rock temperatures, large quantities of air at high velocity would be necessary at all working places.

9. That it would not be advisable to precool the air to be used for ventilation.

Fan Installations

An untimbered inclined raise was driven from B level to the surface, about 700 m. (2300 ft.) south of B level portal. A Sirocco fan designed to exhaust 60,000 cu. ft. of air per minute with 31/2-in. water gage has been installed in the fan house at the collar of this raise, replacing the 33,000 cu. ft. per minute fan that was placed there as a temporary installation. The fan house was constructed of crosslapped boards, gunnited on the outside to make the walls fire-resisting as well as airtight. The roof was made airtight by inserting a layer of tar paper between the crosslapped boards.

Two Sturtevant fans, each designed to deliver 33,000 cu. ft. of air per minute against 31/2-in. water gage, are to be installed in the north part of the mine.

Fig. 3 shows that these fans can be operated either in series, in parallel, or singly, depending upon conditions in the mine as they change from time to time. Changing conditions will determine the mode of running fans. Tests were made, and at the present time the fans will operate best in parallel. Later, as resistance in the ventilation circuit increases, it may be necessary to run the fans in series. In general, if the mine has high resistance, two fans will deliver more air when operating in series; with low resistance, two fans will deliver more air when operating in parallel.[3]

At present no mining is being done in the Cantabria stopes, so that these raises and stopes are kept open for the exhaust air from the A level fans. Later, however, after the Soroche and Tamayo stopes are exhausted, the Cantabria stopes will again be worked. When men are working in the Cantabria stopes, they can be furnished with fresh air from the same fan set-up, merely by replacing the brattice shown in Figs. 3 and 7 by a regulator. The air then will enter the portal at A level, pass through the fan, up through Cantabria and out. The amount of air left circulating through Soroche and Tamayo stopes will be controlled by the regulator.

Evasé Chimney

When a fan is working as an exhauster, the air leaves the fan at high velocity, causing a high percentage

TABLE 3.—*Velocity Pressure in Relation to Length of Chimney*

Length of Chimney, Ft.	Velocity Pressure Recovered, Lb. per Sq. Ft.	Length of Chimney, Ft.	Velocity Pressure Recovered, Lb. per Sq. Ft.
0	0.000	8	1.382
1	0.323	9	1.449
2	0.580	10	1.506
3	0.787	11	1.555
4	0.955	12	1.597
5	1.092	13	1.633
6	1.206	14	1.664
7	1.302	15	1.691

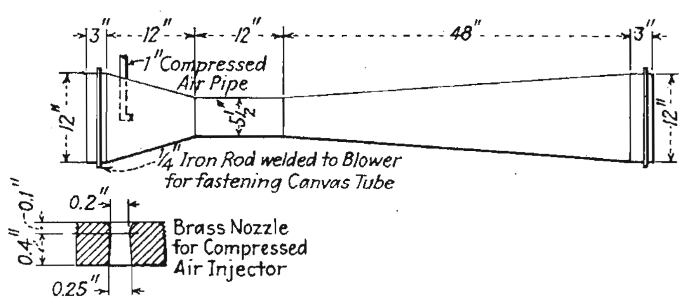

FIG. 4.—MODDER BLOWER.

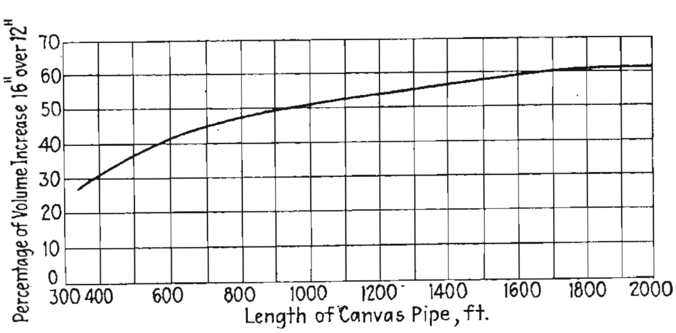

FIG. 5.—CURVE SHOWING ADVANTAGE OF USING THE LARGER SIZE OF CANVAS PIPE.

loss of kinetic energy. If the air leaving the fan can be slowed down (made to rise to atmospheric pressure gradually) some of the velocity pressure is converted to static pressure.

The Evasé chimney is an old device for recovering static pressure on exhaust fans, but I believe a description of how we designed the chimney for our fan may well be given here. The chimney should expand gradually, otherwise eddy currents are set up and the recovery is poor. Let the area at the fan discharge be A_1 and the area at the top of the chimney A_2. Let Q be the quantity flowing in cubic feet per second. Then the velocity at the throat is Q/A_1 and the velocity at the top is Q/A_2. The velocity pressures at these two points are $WQ^2/2GA_1$ and $WQ^2/2GA_2$, where W is the weight of 1 cu. ft. of air. If conversion is perfect, the velocity pressure recovered is $\frac{WQ^2}{2G}\left(\frac{1}{A_1^2}-\frac{1}{A_2^2}\right)$. As the conversion is never perfect, a factor representing the efficiency of conversion must be used. A chimney with a 10 per cent. slope was decided upon. W. H. Carrier[4] gives 70 per cent. for the efficiency of a conical diverging nozzle with a 10 per cent. slope.

The tabulation in Table 3 was made from the above formula. These data were plotted on rectangular coordinates, from which it was apparent that an appreciable saving is made by using a chimney 10 ft. long, while beyond that point the velocity pressure recovered is not appreciable per unit length of chimney. Therefore a chimney 10 ft. long was decided upon as economical.

Auxiliary Ventilation

Here, as at other mines, the problem of furnishing fresh cool air to dead-end workings can best be solved by using small electrically driven fans, delivering air to the face through canvas tubes. At present there are two Coppus TM-6 fans and two Sirocco 21/2 Troy fans, which are used where relatively long lengths of canvas tube are needed.

Where conditions make the installation of an electric blower impracticable, an injector blower of the Modder deep type (Fig. 4) has been found convenient and effective, when the distance for delivering the air is not over 300 ft. As these blowers, made in the machine shop at a low cost, have no moving parts, there is no maintenance cost, and since they require only a common air hose connection they can be installed quickly and easily. Where the face to be supplied with fresh air by an electric blower is too far for efficient operation, an injector blower has been found effective, installed directly in the line about one-third of the distance from the fan to the face.

The outlet of the canvas tube should be as close to the workers as convenient, never farther away than 25 ft. Hence, two short sections of tube (25 ft. and 50 ft. long) are furnished to the men in each dead end. When a face has been advanced 25 ft. beyond the last 100-ft. section of tube, a 25-ft. section is put on. After another 25-ft. advance, the 25-ft. section is replaced by the 50-ft. section, and finally the 25-ft. section is added, making a total of 75 ft. Thus the end of the tube is kept within 25 ft. of the face at all times.

When canvas tubing was first used for ventilating dead ends in this mine, the miners did not understand the necessity for keeping the tube hung properly, in good repair and free from holes, and for keeping it close to the face. The tube was placed near the working place, in spite of the workers, and now they seem to realize the improved working conditions and maintain the tube themselves.

Some time ago a considerable quantity of 12-in. Ventube was stocked. When the next order is made, it will probably be for 16 in. tube, because of its increased efficiency (Fig. 5). For furnishing air to men working in raises while no drilling is being done, a compressed-air hose is used, with a special nozzle. The nozzle (Fig. 6) was made in the mine machine shop. The body is packed with waste to prevent free escape of air. As expanding air absorbs considerable heat, a given quantity of compressed air will have a greater cooling and drying effect than a

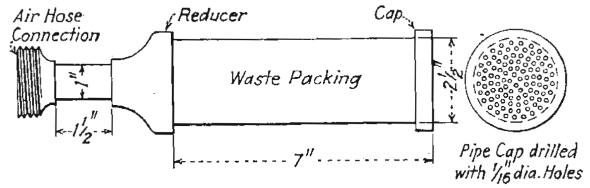

FIG. 6.—NOZZLE FOR DIFFUSING COMPRESSED AIR IN RAISES.

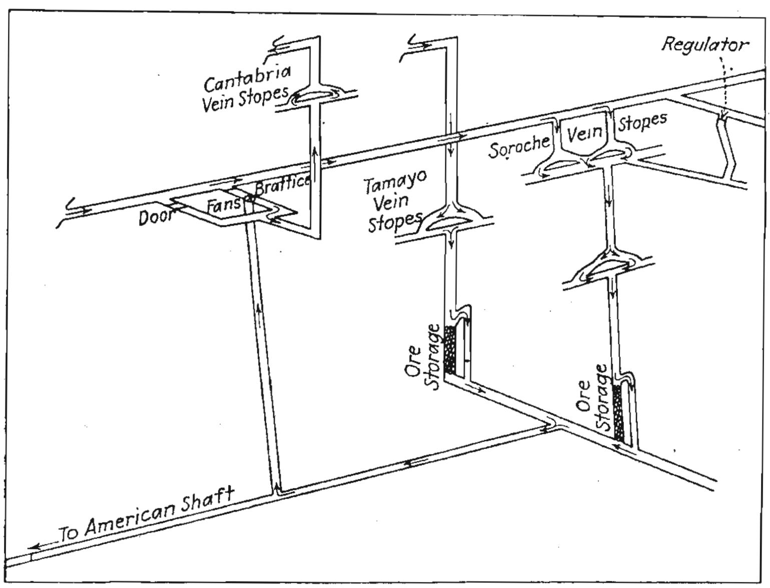

FIG. 7.—VENTILATION SYSTEM IN NORTH PART OF MINE.

like quantity of air forced to the back through canvas tubing.

Ore Transfer Raise Used as Airway

On several occasions it has been necessary to use a one-compartment long raise for an ore transfer as well as for an airway. An existing raise can be made to serve both purposes at a cost much lower than that of driving a completely new raise. This is done by driving a new small raise 15 ft. from the old one, the height depending upon the size of the old raise and the desired capacity of the ore chute. The two are then connected by a raise inclined up from the old raise, so that muck dropped through the transfer cannot fall into and block the ventilation raise. This plan, tried twice, works well so long as the chute is kept drawn down below the connection (Fig. 7).

Because of the large quantity of water in all parts of the mine, there is no dust underground, therefore there is little objection to a high velocity in the mine airways. When the velocity is sufficient to make a candle flame flicker badly, electric lights are used.

Air Splits

Every advantageous opening for admitting air to the mine workings is utilized. This, of course, must not be understood to mean all openings, for some entries have to be blocked by doors or brattices to force the air to traverse the lowest working level and not short-circuit. This is done for several reasons; besides putting different parts of the mine on independent air sources, the velocity in any one entry for the same total volume of air is greatly reduced, with consequent reduction in the resistance offered to the flow of air in the mine. The reduced resistance in turn allows more air to flow.

Air enters the south part of the mine through A level and 3/4 level portals, splits and goes to the lower levels through the Tablon underground shaft and an abandoned stope (Fig. 1). The former split delivers air to the third and fifth levels, while the latter delivers fresh air to the fifth level only.

The mine north of the American shaft receives fresh air through A level portal and an abandoned stope that opens into C level and D level portals (Figs. 1 and 7).

Cooling Air for Ventilation Purposes

Inasmuch as the rock temperature at the present depth of mining is not over 91°F., there is no special need for refrigeration, even locally. Sufficient fresh circulating air will cool the working places to a comfortable working temperature.

Water sprays have been tried for cooling, but were found unsatisfactory, because the temperature of the air was so nearly the same as that of the cooling water that very little cooling resulted from letting the air pass through a number of sprays.

Mine Fires

It is believed that there is little danger of serious fire in this mine, for the following reasons: (1) Little timber is needed, as the cut and fill method of stoping is used; (2) the water in the rock cavities and the high relative humidity of the mine air keep a great part of the timber damp, (3) green timber is used; (4) all timber is of hard wood; (5) there is very little timber in the hoisting shafts. The American shaft is concrete cribbed and the guides in the Tablon underground shaft are carried on stulls.

The fire hazards might be listed as follows: (1) Underground store houses; (2) electrical equipment in the mine; (3) accumulated inflammable refuse left on the levels.

The fan houses are designed so that the direction of air in the mine can be reversed if necessary. A list of contingencies that would necessitate the reversal of the fans is too long and varied to be of interest here. The decision as to whether the fan should be reversed or not should be left to some one thoroughly familiar with the air currents in the mine and the effects that the reversal would have upon the existing currents.

In making any decision as to changing the direction of air flow by manipulating the fan, the questions to be considered are: Will the new condition create a passage that will be free from smoke and gas, through which men may leave the mine? Will the passage so created differ materially from that generally used by the men as they leave the mine? This consideration is important, for the men are liable to be excited in case of fire and to choose their usual exits, regardless of signs or warnings that may be posted to the contrary.

Method of Taking and Recording Observations Underground

It has been the writer's object, in computing quantities underground to get relative volumes rather than exact volumes of air. This was done because: (1) The purpose is not to furnish a specified quantity of air to each working place, governed by the number of men working there, but to furnish sufficient excess to cool the place to a comfortable working temperature; (2) it was desirable to make observations quickly and thus complete a ventilation survey in the shortest possible time.

Readings are taken at the same place in each measured cross-section, for periods of one minute, until two readings check reasonably well. Whenever the observer takes a reading at one of these stations he assumes a standard position; namely, facing at right angles to the direction of air flow, with the anemometer held at arm's length in the center of the drift and about one-seventh of the height below the back. Although this does not give a true value for the quantity of air passing the particular point, it

Working or Location	Mark.	Vel. Ft/Min	Area	Temperature. W.B.	D.B.	Air Condition	Personal Reaction.	Remarks.
¾ Portal ¾ L				74½	77	A	Too cool for comfort.	Intake Air.
	1	742 735	Same			A	ditto	Water in ditch. Walls from half way up side are dry.
4-23-30	5.	450 452.	Same	74½	77.	A.	ditto.	Very dry here. No water at all.
	2.	680. 675.	Same.	73	73	A	ditto.	Water on floor and in ditch. Walls damp.
	6.	155 162	See over	79½	80	B	Warm but not uncomfortable	Floor wet. Water in ditch. Walls Fairly dry. Timbered.
	7.	900 925	See over					

a

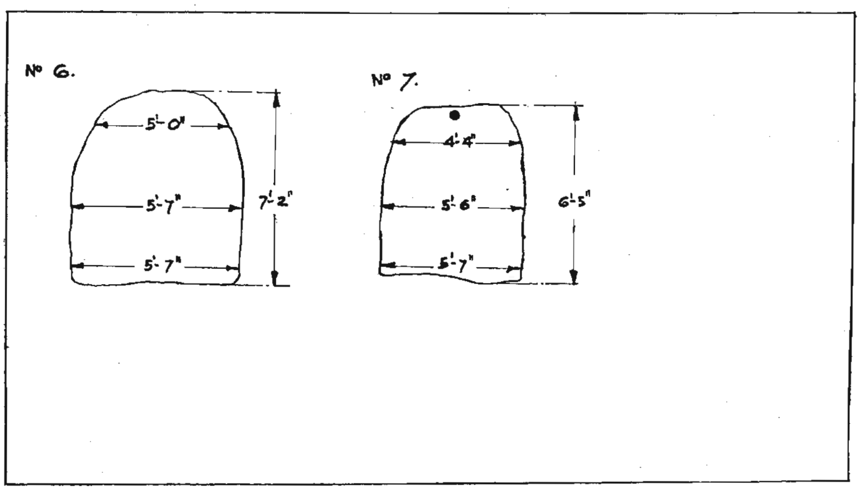

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FIG. 8.—MINE RECORD SHEET.
a. Front. *b.* Back.

gives a relative value which will show an increase or decrease in volume, as the case may be.

Width and height are measured at desirable cross-sections in the drifts. These measurements are plotted and their area found by a planimeter. The positions are numbered, their numbers being marked on the wall of the drift or side of the raise, and are called ventilation stations; each is marked on a profile of the mine workings, the directions of the air currents being also indicated. This profile is kept up to date, showing all raises, stopes and drifts in the mine that are important with respect to ventilation.

Fig. 8 is a copy of a mine record sheet. Separate sheets are used for each set of readings.

When computing the exhausting power of the main fan more careful observations are taken. The anemometer is operated from a rod 3 ft. 6 in. long, the clutch of the instrument being manipulated by the observer by means of wires reaching from the instrument to the handle of the rod.[5]

Conclusions

After observing the ventilation in this mine, the writer feels qualified to make the following suggestions:

1. To spend a large sum of money to make a few main drifts cool will not give efficient ventilation and certainly will not justify the cost.

2. To ventilate stopes two openings must be maintained, one on the high-pressure and one on the low-pressure side, so that the air will circulate. This may seem obvious, but its importance often is not appreciated.

3. To be effective the canvas tube that delivers air from a small fan or blower to the face must be kept free from kinks, free from leaks and its end within 25 ft. from the workers that it is meant to serve.

It is regretted that no temperatures were taken in the mine before the 33,000-cu. ft. fan was moved from 3/4 level portal to the present fan site on Tablon. Records were not taken because the old system was obviously so wrong that there was no doubt in the management's mind that the change would be for the better. A record was made, however, of the temperatures in the mine (April, 1929) soon after the fan was moved. Temperatures were again taken at similar positions in the mine after the 33,000-cu. ft. fan had been replaced by a 60,000-cu. ft. fan.

These comparative temperatures are given in Table 4. The location of the various ventilation stations is shown in Fig. 1. The most apparent drops in temperature are at No. 5, a main haulageway, where the drop was from

TABLE 4.—*Temperatures Recorded in the Portovelo Mines*
See Fig. 1 for Positions of Stations

Stations	April, 1929	May, 1930		Difference
	Dry-bulb Temp., Deg. F.	Wet-bulb Temp., Deg. F.	Dry-bulb Temp., Deg. F.	
1	75	74½	80½	
2	83	80½	80½	2½
3	84	82	82	2
4		82½	82½	
5	87	74½	74½	12½
6	80	75½	75½	4½
7	86	79	79	7
8	88	83	83	5
9	87	86	86	1
10	87	75	75	12
11	86	77	77	9
12	87	77	77	10
13	88	83½	83½	4½

a dry-bulb temperature of 87° to 74.5° F.; at No. 8, the main return air course from the lower levels, where the drop was from 88° to 83° F.; at No. 10, a main split of fresh air to working stopes, where the drop was from 87° to 75° F. These comparisons serve to show the change in air temperature in the mine and emphasize the necessity of air splits.

The writer does not wish to convey the idea that these temperature drops are entirely due to changing the mine from a pressure to an exhaust system. He does, however, contend that in the circumstances an exhaust system, in conjunction with more openings in the mine and more air splits, is responsible for the improvement that is so apparent over conditions of a year ago.

Acknowledgments

The writer is indebted to W. B. Phelps, General Superintendent of the South American Development Co. at Portovelo, Ecuador, for his kind assistance and helpful criticism; to Luther Yantis, Chief Engineer of the South American Development Co. at Portovelo, Ecuador, for helpful criticisms and the use of the company's maps and drawings in the preparation of this report, and to the South American Development Co. for providing the opportunity to study the ventilation problems at the mine.

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