The Edwards Furnace.

Concentrating Machinery.
New Ore Treatment Plant at the Mining School.

Kenneth A. Mickle.

The idea of having a treatment plant in connection with the Mining School was put forward by the late Mr. A. L. Mills, who worked very energetically and successfully in securing concessions and donations from various mining machinery firms for this purpose. Unfortunately, Mr. Mills did not live to see the work completed. Once started, however, the idea took on well, and the building as originally designed had to be enlarged to make room for the additional material that was obtained.

It was somewhat difficult, owing to the non-homogeneous nature of the various units of machinery, to arrange them into a composite ore dressing mill, and it fell to the lot of Mr. Donald Clark, late Lecturer in Metallurgy, to arrange the various details to the best advantage. As it now stands, the plant should be of great service to men doing their mining course, by enabling them to get some practical experience in ore dressing and treatment before leaving the University. As a B.M.E. of this University now managing a mine at Broken Hill, put it to the writer, "The fellows doing mining will at least recognise a 'jig' when they see one."

The plant consists primarily of a crushing platform, elevating, sizing and classifying machinery, concentrating tables, a roasting furnace and small cyanide and chlorine plants, together with concrete sand pits for storage of products.

The crushing platform is fairly well equipped, consisting, as it does, of a small stamp battery, a set of rolls, a jaw rock-breaker, and a combined rock-breaker and rolls.

A small 3-head Austral Otis battery, with stamps of about 300lbs. will serve for material that has to be fairly finely crushed. It is provided with copper plates for amalgamation. After passing over the plates, the crushed ore can be classified in a spitz shaped hydraulic classifier. The overflow from this classifier flows over canvas strakes into three settling spitzkasten. The heavier product from the hydraulic classifier flow into a launder on to a small Wilfey table. This table is about half the size of the ordinary No. 5 Wilfey, but will probably be able to treat all the material the small battery is capable of crushing.

The lighter material and slimes settling in the three compartments of the spitzkasten can be drawn off through spigots into a launder running on to a moving belt vanner of the Luhrig type.
On the crushing platform there is also a May Bros. combined crushe and rolls. These rolls will crush ore from pieces of 5in. diameter, down to \( \frac{3}{4} \)in. They discharge on to an impact screen, which is run at about 190 bumphs per minute, the fines passing through, and the coarse passing over the screen into the boot of an Austral Otis bucket belt elevator. This elevates the coarser material to a set of 10in. x 7in. Roger Rolls, which discharge into a launder conveying the crushed material on to the impact screen again.

The crushed ore, passing through the screen, runs by way of a launder to the head of a May jig. This is a 4-hutch jig, with fixed screens on which the bed lies, and with four adjustable plungers, a fifth compartment collecting the tailings. With the present arrangement the slimy water overflowing from the jig runs over a full sized Card concentrating table. Cone pulleys are being installed to enable the speed of the different units to be altered without altering the speed of the engine.

There is also a small Jaques jaw rock breaker, which should prove useful for crushing coarse and lumpy ore to a size suitable for feeding to the Roger Rolls.

All the tailings and slimy water from the concentrating tables and jig flow through launders to a concrete settling pit divided into six compartments, arranged as regards flow, so as to give the greatest available settling capacity. A small centrifugal pump will elevate the practically clean water from the last compartment to two 400 gallon tanks for use again in the various machines as desired. As the level of the ground on which the plant is built was less than 2ft. above the drain running to Grattan-st., the concrete floor was laid sloping from each end of the building to two falls about 6in. to facilitate the running off of spilt water.

For roasting pyritic ore or concentrates a small Edwards furnace has been installed. This is really only a model, being but 13ft. x 4ft. 8in. over all. It is provided with four water cooled rabbles and a large dust chamber between the furnace and the stack. This small furnace may serve its purpose with simple pyritic ores, but it is doubtful if good results can be obtained from those that are at all refractory, e.g., Cassilis sulphide ore, as the hearth length is insufficient.

A small chlorination plant, consisting of solution vats for bleaching, powder and sulphuric acid and lead lined ore and solution vats can be used for chlorinating roasted concentrates, etc. The ore vat, which has a capacity of about 2½ tons, is provided with a lid, which can be water sealed and used for the gas chlorine process, as well as the solution method if desired.

There is also a small cyanide plant, consisting of a solution and ore vat, with a five compartment zinc precipitation box.
and concrete sump. A double acting hand pump lifts the solution from the sump back to the solution vat.

The motive power is derived from a 20 h.p. Crossley gas engine, running at 250 R.P.M. The engine can be run on the town gas supply or from a gas producer using charcoal as fuel.

The whole plant is enclosed in a substantial jarrah building of 90ft. x 30ft., with an engine house and shed for the producer plant. A "lean-to" extension for the storage of ore is also provided.

It is intended that the plant, to a limited extent, will be available for public crushing, etc. It has already had an extended run on a parcel of ore from the Cobar Copper Mines.

The principal requirements to make the plant fairly complete, are:

1. A secondary grinding machine, such as a small Ball mill or grinding pan. At present there is no arrangement for fine grinding.

2. A small Berdan pan.

3. A small flotation plant of the Minerals Separation type for preference; one capable of treating a few cwt. per day would be sufficient. The latter is most important, as this is certainly the coming method for concentrating sulphide ores.

The above additions would make the plant complete, and an invaluable adjunct to the laboratory work.
The Ventilation of Deep Mines.

Trevor W. Ross, B.M.E.

THE OBJECTIVE OF VENTILATION.

Good ventilation is needed for two reasons—humanity and efficiency; the effects of various air-impurities on men may be conveniently summarised:

Deficiency of Oxygen: The effects of deficiency of oxygen in the air are the same whether the percentage of oxygen, or its pressure is diminished; therefore as a general rule the increased pressure due to depth in mines more or less compensates for diminished percentage of oxygen.

A diminution from 20.93% to 15% has no effect on men, though a candle would be instantly extinguished in such air.

As the diminution proceeds, the first symptoms are that any great muscular exertion is less easy, and causes dizziness and shortness of breath. Consciousness is lost when the percentage falls below 7%.

The Victorian legal minimum for 8 hour shifts is 20%. The British Royal Commission on Mines (1910) recommend 19% as a minimum.

Excess of CO₂: Candles are extinguished when the CO₂ rises above 2.22%, and all lights (e.g., acetylene) are quenched before 3% is reached. Above this, breathing becomes very noticeably deeper and more frequent, until at 5% to 6%, there is marked panting and a higher pulse-rate. Above 10% there is violent panting, throbbing and flushing of the face, with headache on returning to fresh air; the CO₂ assumes a narcotic effect, and at 25% death may occur after several hours. The lungs endeavour to keep the pressure of the CO₂ in the air in the lung cells at 5½ to 6% of one atmosphere, so that if the percentage of CO₂ in the atmosphere rises, the breathing becomes just sufficiently stronger to compensate for this; this method of regulation is extraordinarily delicate.

The British Royal Commission on Mines (1910) are of the opinion the CO₂ from inorganic or ground sources may rise to 1½% without harm, e.g., in coal mines. However, CO₂ from respiration, lights, or blasting is liable to be accompanied by other vitiation of a serious kind, and so in Victoria 0.25% CO₂ is the maximum permitted for eight-hour shifts. In Western Australia, 0.25% is the maximum permitted, and in the Transvaal, 0.20%.
Carbonic Oxide: This gas is the cause of nearly all the deaths in colliery explosions and in underground fires. Unsuitable or badly handled explosives also give rise to much trouble; thus nitro-glycerine detonated gives off 0.00%; burnt, 35.9%; blasting powder, 33.75%; gunpowder, 7.52%.

The oxygen absorbed by the lungs is taken up by the blood as an unstable combination with the hemoglobin, and so carried to the tissues, where it is liberated. Hemoglobin forms a more stable compound with CO, and when saturated with CO, cannot take up any O, so that as the blood takes up CO, so it loses its power of carrying oxygen, until death from want of oxygen ensues. Of course, this is an example of mass action, the one gas tending to drive the other out of the hemoglobin, the final result being the balance struck between the two conflicting processes. If a person, poisoned with CO, is removed to fresh air before death occurs, then in the course of several hours, the CO may be turned out of the hemoglobin.

With 0.04% CO, the blood finally becomes a third saturated with CO, with 0.08%, half saturated, with 0.16%, two-thirds saturated, etc. The process of absorbing is slow, and man may go a long way into a poisonous atmosphere, and be unable to return. Thus if the air contains 0.2% CO, it will be at least 30 minutes before his blood becomes even half saturated. Herein lies one of the great dangers of CO poisoning.

Sulphuretted Hydrogen: Dogs and cats will be killed in 90 seconds by 0.2% H₂S, and 0.05% produces alarming symptoms on men, in a few minutes. In most cases, pyrites is the source of this gas, but, fortunately, it can generally be easily detected by its odour, unless in large quantities, when men are struck down with great suddenness.

Nitrous Fumes: When nitro-explosives fume off, instead of exploding, they give off CO and NO in place of CO₂ and N. The NO combines with O to form NO₂, which is very irritating, and extremely dangerous when in appreciable proportions, as it produces an acute bronchitis. Thus mice exposed for 30 minutes to 0.05% NO (0.77% NO₂) died within 24 hours, of bronchitis, although the animals seemed to be only slightly inconvenienced at the time. Fortunately, nitrous fumes can be easily detected by their smell.

Moisture: In still air, during rest, the maximum WET BULB temperature which can be borne for several hours without marked pathological symptoms is 88°-90°F. Neither the dry bulb temperature, degree of humidity, nor percentage of moisture matters by itself.

In a good air current, the critical wet-bulb temperature is 91.4°-93.2°F, while for hard work, in still air, the critical point is 78.8°-80.6°F. At 81°F, wet bulb the work a man is capable of doing falls off rapidly, and what undoubtedly suffers very heavily is the pocket of the mine-owner.
In Victoria, the maximum wet bulb temperature for eight-hour shifts is 83°F.

In Western Australia, the maximum is 80°F. wet bulb, 87°F. dry bulb.

Dust: This is the most serious impurity to be contended with, and is too large a subject to include in this paper.

Out of the 142 men, who had ever worked machine drills, who died during 1900-2 in the Redruth district, Cornwall, England, 133 died of lung diseases, at an average age of 37.2 years, and an average of 7 years working machine drills.

In Victoria every effort is made to suppress all dust with water, the regulations on the subject being very strict.

I have taken the liberty of using Dr. J. S. Haldane's data very freely in the above summary, as he is the greatest authority on the subject.

SOURCES OF HEAT.

The Rock: There is a zone a small depth below the surface which is always at the mean annual temperature of the district, which for Bendigo is 58.7°F., at a depth of about 150 feet. Below this zone, the rock temperature increases regularly, at the rate of 1°F. per 73 to 75 feet for Bendigo, 1°F. per 200 to 207 feet for Johannesburg, and 1°F. per 60 feet for Cornwall.

Thus, at the 3280 feet level of the Clarence, the rock temperature was 101.0°F. by measurement, and by calculation should be 101.0°F. At the bottom of the Victoria Quartz shaft, 4614 feet below the surface the rock was 118.2°F.

Therefore, the deeper a mine is, and the more ground broken per day, the greater the circulation of air necessary to keep down the temperature.

Men, lights, and explosives all give off a certain amount of heat, which in a confined space like a rise, will send the temperature up considerably. In the Ironbark, the temperature in the top of a rise 100 feet above the 330 feet level, with 4 men, one shift per day, hand drilling, the temperature was 72.7°F., wet bulb, 73.6°F. dry bulb, although the rock temperature at this depth is only 59.7°F.

Decomposition of Mineral and Organic Matter: When pyrites decomposes, large quantities of heat are liberated, even enough to set the mine on fire in some instances.

Organic matter, such as the timbering, may give off a little heat, while in alluvial mines, it sometimes happens that the black wash gets exceedingly hot, owing to decomposition of the organic matter it contains.

Water: Water that finds its way into the workings of a mine after traversing through hot rock, is naturally hot itself, and thus heat, sometimes in considerable quantities, is brought into the mine. Thus in the New Chum Railway, at the 4284 feet level, the water was 114°F.
Although the Great Extended Hustlers is a downcast shaft, the air reached the 3055 feet plat at 81°F. It was found that the mine water was leaving this plat at 91°F., and discharging from the pump-column at the surface at 68.5°F., thus giving up 5,160 B.T.U. per minute, out of a total of 14,010 acquired by the air on its journey down. If this heat transfer could be stopped, the air would reach the 3055 feet plat 10°F. cooler, so experiments are still being carried on to this end.

Exhaust from Machine Drills, etc.: As the air used expands to atmospheric pressure adiabatically, some heat is absorbed to bring this exhaust air to the average temperature.

Upcast Air: This air removes heat from the mine, owing to its higher temperature, and higher percentage of water vapour. The specific heat of air is 0.24, and the latent heat of aqueous vapour is 1112 Farenheit units. A circulation of 10,000 cubic feet of air per minute entering the mine at 60°F., humidity 75%, and leaving at 75°F., humidity 100%, would therefore remove 11,000 B.T.U. per minute.

Compression: As the air descends the shaft, the pressure rises, and adiabatic compression takes place.

The work done = \( -\frac{P_1 V_1 \gamma}{\gamma - 1} + \frac{P_2 V_2 \gamma}{\gamma - 1} \), \( \gamma \) being the ratio of the specific heat at constant pressure to that at constant volume = \( \frac{0.2374}{0.1663} = 1.408 \)

Let the air start at temperature \( T_1 \), pressure \( P_1 \), volume \( V_1 \), moisture (grains per cubic foot) \( m_1 \), then, let \( T_2, P_2, V_2 \), be the final quantities, \( T_1, V_1 \) being unknown.

Then \( P_1 \frac{V_1 \gamma}{460 + T_1} = P_2 \frac{V_2 \gamma}{460 + T_2} \) \( \gamma = \text{constant} \quad \ldots \ldots \ldots \quad (1) \)

Also \( \frac{P_1 V_1}{460 + T_1} = \frac{P_2 V_2}{460 + T_2} \) \( \quad \ldots \ldots \ldots \quad (2) \)

Eliminating \( V_1, V_2 : \quad \frac{P_2}{P_1} \frac{\gamma - 1}{\gamma} = \frac{P_2}{P_1} \frac{\gamma - 1}{460 + T_1} \)

Whence \( T_2 = (460 + T_1) \left( \frac{P_2}{P_1} \right) \frac{\gamma - 1}{\gamma} - 460 \quad \ldots \ldots \ldots \quad (3) \)

Whence B.T.U. absorbed =

\( \frac{V_x}{460 + T_1} \times 39.85 \times \frac{P_1}{\pi} \times 0.2374 \)

Where \( \pi = 30^\circ \) barometer.
Now let the air become saturated with moisture, according to

\[ M = .003828 (T-K)^2 + 3.04. \]

<table>
<thead>
<tr>
<th>Temperature</th>
<th>50°</th>
<th>60°</th>
<th>70°</th>
<th>80°</th>
<th>90°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of K</td>
<td>33.11</td>
<td>33.29</td>
<td>33.95</td>
<td>34.4</td>
<td>34.45</td>
</tr>
</tbody>
</table>

Let \( T, M, P_2, V \) be the final conditions reached, then moisture taken up

\[ = M-M_1 \text{ grains per cubic foot.} \]

Now let the latent heat of aqueous vapour

\[ L = 1116.5 - .71 T, \]

hence B.T.U. absorbed

\[ \frac{(M - M_1)}{7000} \times V \times (1116.5 - .71 T) \text{ by moisture (4)} \]

Also B.T.U. given up by air

\[ \frac{(T_2 - T)}{460 + T_1} \times 39.85 \times \frac{P_1}{\pi} \times .2374 \text{ (5)} \]

These quantities are equal; \( V, M, \) are known in terms of \( T, \) which is the only unknown.

Example 1: Let \( V_1 = \) unity, \( P_1 = \pi = 30', \)

\[ T_1 = 60^{\circ}F., M_1 = 4.33 \text{ grains per cubic foot} \]

(75\% saturation), \( P_2 = 33'. \)

Then from (3),

\[ T_2 = 74.5^{\circ}F. \]

In (4), as a first approximation, let \( V = V_1 = \) unity, and let the term \( .71 T = .71 \times 60 = 4.26, \) when the expression becomes

\[ \frac{(M - M_1)}{7000} \times 1112.2 = .00011 (T - 33.3)^2 - .206 \]

Also (5) becomes

\[ \frac{(T_2 - T)}{460 + T_1} \times \frac{39.85}{520} \times .2324 = 1.355 - .0181 T \]

Equating (4) to (5) and simplifying:

\[ .00061 T^2 - .0224 T - .883 = 0 \]

whence \( T = 61.0^{\circ}F. \)

Example 2: Let \( M_1 = 5.77 \) grains per cubic foot (100\% saturation),

\[ z \]

Then (4) becomes

\[ .00061 (T - 33.3)^2 - .436 \]

While (5) is as before; equating and simplifying:

\[ .00061 T^2 - .0224 T - 1.113 = 0 \]

whence \( T = 65^{\circ}F. \).
SOURCES OF CO₂.

Men: An average miner gives off 1.5 cubic feet of CO₂ per hour.

Lights: A candle gives off 0.5 cubic feet of CO₂ per hour. An acetylene lamp, with a burner consuming 5 cubic feet of gas per hour, gives off 10 cubic feet of CO₂ per hour.

Explosives: When a nitro-explosive detonates properly, the only gases produced are CO₂ and N.

In the Ironbark Mine, at the 480ft. level, three men working hand labour 618ft. east of the shaft, with no definite circulation of air, caused the atmosphere to contain 0.95% CO₂. Pipe ventilation was installed, circulating 292 cubic feet per minute, and so reducing the CO₂ to 0.105%.

In Lansells 180 No. 2 Mine, with over 30 men per shift, the CO₂ averaged 0.82%, no very definite circulation being established. When temporary measures caused 1,650 cubic feet of air to circulate per minute, the CO₂ averaged 0.20%, and when a permanent circulation of 6,420 cubic feet per minute was made by sinking a ventilation shaft, the CO₂ fell to 0.095% on the average.

Timber, etc.: Large quantities of CO₂ are given off in hot wet upcast shafts.

Thus the upcast air of the New Chum Railway, after work being stopped 12 months, contained 0.12% CO₂, and the upcast air of Lansell’s 180 (the Victoria Quartz is the downcast) contained 0.10% CO₂ after a six months’ stoppage of work. Again, the upcast air of the Great Extended Hustlers Pups. shaft contained 0.195% CO₂ after 8 days’ stoppage of work, while the upcast air of the Cornish United contained only 0.05% CO₂ after the same stoppage, the shaft being cooler and drier than the others.

The country: In alluvial mines, enormous volumes of CO₂ are generated in the country by the decomposition of the organic contents, and when the barometer drops, this CO₂ invades the workings of the mines. In quartz mining, this difficulty does not occur, but small quantities are generated by the decomposition of pyrites and calcite thus:

\[
4 \text{FeS}_2 + 15\text{O}_2 + 8 \text{H}_2\text{O} = 2 \text{Fe}_2\text{O}_3 + 8 \text{H}_2\text{SO}_4
\]

\[
8 \text{H}_2\text{SO}_4 + 8 \text{Ca CO}_3 = 8 \text{CO}_2 + 8 \text{Ca SO}_4 + 8 \text{H}_2\text{O}.
\]

The “black damp” thus formed contains 12.4% CO₂, and 87.6% N. The CO₂ may be carried down the mine by percolating water; thus at the Fortuna Hustlers, the water was allowed to accumulate 60ft. below the bottom plat, no bailing being necessary, owing to the adjoining mine draining away enough water. The CO₂ at the plat was 0.24%, and the shaft was encrusted with gypsum. The water was then regularly bailed once a week, when the CO₂ fell to 0.065%.
Compressed air: When a compressor runs too hot, inferior oil is used, or the receiver is not cleaned sufficiently, CO$_2$ may be generated by the decomposition of the oil. In one case the compressed air contained 0.48% CO$_2$.

**THE CIRCULATION OF AIR.**

In all the mines on the Bendigo field, the motive power which circulates the air is natural, that is, it is due to the difference in weight between the upcast column and the downcast column of air, owing to the difference of their mean temperatures. The effect of the difference in the heights of the sills of the shafts in deep mining is slight, and may generally be neglected. The Great Extended Hustlers has a fan to aid the natural motive power, but at present, it is not used.

*Fig. 1*

In figure 1, let AB, and CD be two shafts, connected by a level BC. Let their depths be $H_1$ and $H_2$, and $\pi$ be the barometric pressure per square foot at the level of D.
Let \( T_1, T_2 \) be the mean temperatures of the air in the columns A, B, CD.

Now \((460 + T)\) cubic feet of air at \( T^\circ F\), weigh 39.85 lbs. Hence the weight of the column A, B, 1 foot square is

\[
\frac{39.85}{460 + T_1}
\]

and of CD is

\[
\frac{39.85}{460 + T_2}
\]

Therefore the barometric pressure per square foot at B is

\[
\left\{ \pi + 39.85 \frac{H_2}{460 + T_1} \right\}
\]

and at C is

\[
\left\{ \pi + 39.85 \frac{H_2}{460 + T_2} \right\}
\]

assuming the air is blocked.

The difference in pressure is thus

\[
\left\{ \pi + 39.85 \frac{H_2}{460 + T_1} \right\} - \left\{ \pi + 39.85 \frac{H_2}{460 + T_2} \right\}
\]

or

\[
39.85 \frac{H_2}{460 + T_1} \left( \frac{T_2 - T_1}{(460 + T_1)(460 + T_2)} \right) \text{ lbs. per square foot.}
\]

In circulating the air, nearly all this pressure is expended in friction, the kinetic energy being very slight.

As the friction in the levels, stopes, winzes, etc., is much greater per unit of length than that in the shafts, it follows that with the same connecting workings, the deeper mines will have a greater circulation than the shallower ones, as the motive pressure varies directly as \( H_2 \), the depth. Further, it also varies practically as \((T_2 - T_1)\), and as this difference is greater, the greater the depth, the deeper mines get a much greater circulation than the shallower mines, other things being equal, a very important and fortunate circumstance.

Example 1: A shallow mine, 400ft. deep. Let the temperature at A, be 60°F., at B 62°F.; mean, \( T_1 \), equals 61°F.

Let the temperature at C be 72°F., and at D 68°F.; mean, \( T_2 \) equals 70°F.

\[
39.85 \frac{H_2}{460 + T_1} \left( \frac{T_2 + T_1}{(460 + T_1)(460 + T_2)} \right) = 0.517 \text{ lbs. per square foot.}
\]

Let \( K \) be the equivalent length of the connection BC, expressed as having the same friction per foot as the shafting.

Then pressure per square foot used in overcoming the friction of one foot of shafting

\[
= \frac{0.517}{800 + K}
\]
On a hot day the temperature at A may be sufficiently high to stop or even reverse the current, making the air "hang," a very unsatisfactory state of affairs, especially when it reverses every morning and evening, with stagnant periods at each reversal.

Example 2: A deep mine, 4000 ft. deep. Let the temperature at A be 60°F, at B 80°F; mean $T_1$ equals 70°F.

Let the temperature at C be 86°F, at D be 76°F; mean $T_2$ equals 81°F.

$$39.85 \cdot H_2 \left\{ \frac{T_2 - T_1}{(460 + T_1)(465 + T_2)} \right\} = 6.14 \text{ lbs per square foot}$$

As before, the pressure per square foot used in overcoming the friction of one foot of shafting

$$= \frac{6.14}{800 + K} = \frac{0.614}{800 + \frac{K}{10}}$$

Which is a much higher figure than the previous result,

$$= \frac{0.517}{800 + K}$$

The weather has practically no effect, as the surface air soon cools down to the temperature of the shaft, which is jacketed with cool rock.

<table>
<thead>
<tr>
<th>Name of Mine</th>
<th>Approximate Depth of Shaft</th>
<th>Approximate Volume circulating, cubic feet per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bird's Reef</td>
<td>400'</td>
<td>2,000</td>
</tr>
<tr>
<td>Central Red White and Blue</td>
<td>400'</td>
<td>2,800</td>
</tr>
<tr>
<td>Lansell's 180 No. 2</td>
<td>700'</td>
<td>4,600</td>
</tr>
<tr>
<td>North Red White and Blue</td>
<td>1960'</td>
<td>15,000</td>
</tr>
<tr>
<td>Virginia</td>
<td>2300'</td>
<td>20,000</td>
</tr>
<tr>
<td>Koch's Pioneer</td>
<td>2650'</td>
<td>10,000</td>
</tr>
<tr>
<td>Garden Gully</td>
<td>2650'</td>
<td>16,600</td>
</tr>
</tbody>
</table>

The air leaves the surface more or less dry, and soon becomes saturated, and as its temperature rises, continues to be saturated with moisture. Owing to the high latent heat of evaporation of water, the downcast air keeps much cooler than it would if it did not pick up any moisture.

As the air returns to the surface, and passes through cooler zones of rock, it loses a great deal of heat by condensation of
its moisture, its temperature dropping only slightly. Thus, the moisture in the air keeps the downcast cooler, and the upcast hotter than would be the case with dry air.

Air leaks: If hotter air leaks into a downcast shaft, or cooler air leaks into an upcast shaft, it lowers the motive pressure by lowering \((T_2 - T_1)\), it increases the volume moving, and so the friction, without increasing the net circulation, and it does not go the way it is needed. Leaks are therefore unmitigated evils. Sometimes it may occur that the leakage is so serious, that the air moves in a vertical circle without discharging.

Figure 2 shows how this may occur, the little arrows indicating air leaks past the doors. These doors, which have only to resist a very slight pressure, must still be built very solidly, preferably in brick frames, to withstand the severe concussions during blasting.

Frictional Resistance to the Air Current: This is a matter requiring a lot of attention, as an apparently slight irregularity in the air passage may mean a serious diminution of the volume of air circulating. At Lansell’s 180 No. 2 mine, the upcast for 200 feet was the ladder compartment; when the opening at surface was 300 square inches, 856 cubic feet per minute discharged, and when the opening was increased to 543 square inches, by knocking off a plank, the discharge was
1170 cubic feet per minute. When the ladder sollar was replaced by gratings, this increased to 1650 cubic feet per minute. This shows how slight an obstruction may cause a serious blockage.

To obviate the blockage of the cages and the ladders in the other three compartments, all deep shafts in Victoria must have a clear airway, at least 10 square feet in area, known as the fourth compartment. This airway is also invaluable for sinking and crosscutting in deep ground.

Circulation in cross-cut or level:

Figure 3A shows how the cold air displaces the warm air and establishes a circulation. Figure 3B shows what happens when the level rises very rapidly, the area c d e f being stagnant.

Figure 3C shows the effect of a block in the roof, the area c d e f being stagnant, and Figure 3D the effect of a block, as a heap of "dirt" on the floor, the area c d e f being stagnant; as a case in point, at the north end of the Central Red, White and Blue Co's. 318ft. level, at the point g, the air was 65.8°F. wet, and 68.1°F. dry bulb, CO₂ 0.145%, while at the point f, the air was 67.8°F., 69.2°F., wet and dry, CO₂ 0.232%, a rise of 2.0°F. wet, and 1.1°F. dry bulb, CO₂ 0.087% in a few feet.

A perusal of Figure 3A will show that the higher the level the more distinct the currents become, and the better the circulation.

Sometimes it is necessary to install a line of pipes, say 12in. diameter, with a fan or jet (acting as an injector) of compressed air or water, to force air into the end, or draw it out, as convenient. By blowing the air in, it arrives, drier and uncontaminated, yet exhausting the air seems to clear the smoke quicker. Referring to Figure 3A again, it will be understood that to exhaust the air and discharge it at a, pipe line
should be in the roof, so as not to confound and contaminate the natural circulation; similarly to blow the air in, the pipe line should be as low as practicable, taking its supply at $b$; at the Great Southern Garden Gully, the pipe line, although in
the roof, blew the air in, so that it returned the contaminated air making its way out naturally; the result was the men did not use the pipe line, since they found that the smoke cleared quicker without it; the remedy was easy, namely, to reverse the jet and draw the smoke out.

Circulation in Shafts and Winzes:

Figure 4A shows how the air circulates in a general way, while 4B, a two-compartment winze, shows the currents divided and made distinct; accidental causes determine which side will be downcast, and which upcast. However, the circulation is generally ample. When a winze is sunk from a level, a stopping is sometimes built, as in Figure 4C, to produce a good positive circulation. When a shaft is to be sunk in deep ground, the fourth compartment can be utilised, as in Figure 4D, to carry the air up into a sollar, which discharges through the door in the cross-cut, to the upcast side of the mine. In the Victoria Quartz mine, the bottom plat was 4254ft. below the surface, and the bottom of the shaft 4614ft., yet, owing to the circulation being established as in Figure 4D, the temperature at the bottom was only 80°F. wet, 80.5°F. dry bulb, the rock being 118.2°F. This is the deepest gold mine in the world.

Circulation in Rises: Rises are the most troublesome of all workings to ventilate, as natural circulation is nil; diffusion is the only aid to artificial means. It is difficult to instal auxiliary ventilation, too, because when firing is done, the rock is hurled down the rise, and would smash up any obstruction in the way.

Figure 5A shows an ordinary rise, the men working on a staging on stalls. In the Bird’s Reef mine, in such a rise less than 20ft. above a current of 2032 cubic feet of air per minute
at 68.2°F. dry, 67.2°F. wet bulb, CO₂ 0.085%, the air was 74.0°F. dry, 73.0°F. wet bulb, CO₂ 0.922%. This was remedied by putting in a brattice to shoot the air up the rise. Figure 5B shows a box rise, the central portion being built up with logs and mullock. Often a compressed air jet is played up one side, thus keeping the air moving; the compressed air pipe is not so vulnerable as ventilation piping. The dotted lines on Figure 5B show how a circulation can be established if a current is available, and Figure 5C shows how this can be done with pipe ventilation, the trap door being opened when firing.

Ideal Ventilation at Great Depths: The necessities are a fourth compartment, all winzes with two compartments, no rises, and sollars to handle the current, the cross-cuts being very high.
Assuming that the bottom cross-cut is connected with the workings above, and there is a good circulation established, and that it is desirable to sink another "lift," the shaft will be sunk, the plat cut, and the cages brought down to it as shown in Figure 4D. The cross-cut will now have to be put out, and the winze sunk to meet it from the level above as shown in Figure 6.

After this development work is finished, and a reef is being worked, the air circulation must be still kept up to the working faces by means of sollars, and if necessary, auxiliary appliances.

All the mines mentioned in this paper are on the Bendigo field.