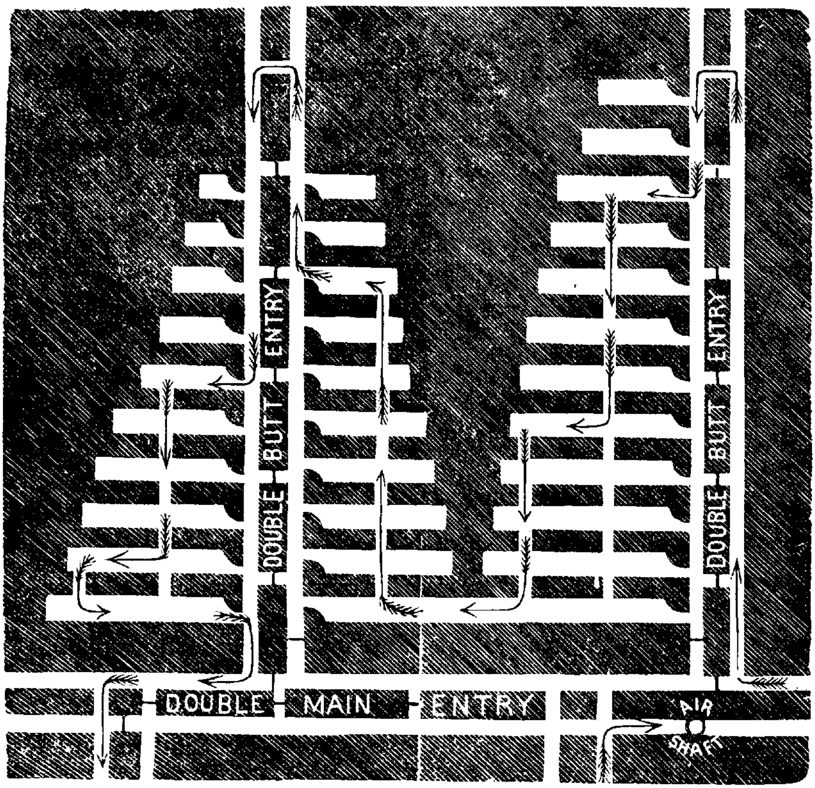

THE VENTILATION IN COAL MINES.

BY ANDREW ROY.

In laying out the workings of mines two general systems are adopted with the view as well to provide the means for circulating currents of air through the workings, as for mining away the coal bed, namely: the long wall system and the pillar and room system. By the former method all the coal is excavated as the workings advance progressively forward, the overlying strata being allowed to fall down and close in behind the miners, who maintain traveling-ways by cutting up the floor or blasting down the roof. In the latter method columns of coal are left in the mine as the workings advance for the support of the superincumbent strata, these columns being attacked afterwards; sometimes in a series of rooms as the workings advance, but more generally after all the rooms have been finished up to the boundary line of the mining plant. Long wall mining, although it can be applied to more advantage in many seams of coal than pillar and room practice, has not yet obtained a foothold in Ohio mines, all our coal being won by the pillar and room system.

Pillar and room working, as its name indicates, consists in forming pillars and rooms, alternately, the proportion of coal mined away to that left standing being governed by surrounding circumstances and conditions. Rooms are made wide and pillars narrow when the roof is hard and firm, and the thickness of the overlying strata is not great; when the roof is tender, and the superincumbent strata heavy, narrow rooms and strong pillars are required.

In opening a mine on the pillar and room system, gangways, entries, headings or galleries, as they are variously called, are first run forward on the face and end slips of the coal bed. These entries, which in all well regulated mines are made double, constitute the main avenues of the mine; they are usually driven much narrower than the rooms or chambers so as to make them extra safe, as well as to add strength to the pillars. The rooms are invariably started from off the butt entries of the mine. In both entries and rooms breakthroughs require to be made from one working place to another at stated intervals for the passage of the ventilating currents of air.



In all mines in this State in which improved mining systems are understood, no working place is driven forward more than forty yards ahead of the circulating current until a breakthrough is cut in the pillar, from one working place to another. All breakthroughs, except those last made near the working faces of the mine, are built up and rendered air-tight by battice trap doors, or otherwise, in order to force the air currents forward when the people are employed, for the tendency of the current is to follow the easiest route to the upcast.

In mines in which no fire-damp is given off, fully 100 cubic feet of air per miner per minute should be circulated in the mine; in mines which make fire-damp a much greater quantity is required, particularly if the fire-damp is emitted copiously. But this current must be made to sweep through the interior of the mine, where the men are employed, or it will do little or no good. There may be ten times the amount of air required for the sanitary condition of a mine entering by the intake and being discharged by the upcast, and yet the working places in the interior be in a very defective condition. Under every system of ventilation there is a loss of air by leakage.

When two separate openings of different depths are made into a mine a current of air is set in motion by the natural pressure of the atmosphere. In winter the lower opening will be the downcast, and in summer it will be the upcast, because during winter the atmosphere outside is denser and consequently heavier than the air of the mine, while in summer the reverse is the case. During those seasons of the year in which the mine atmosphere and the air outside approximate each other in density there will be no motion, or it will be so slight as to be of little service.

As underground excavations become more extensive the natural forces, even during seasons most favorable to their operation, become wholly inadequate as a ventilating power, owing to the resistance which the top, bottom and sides of the airways offer to the moving current of air, and artificial ventilation has to be applied to produce a circulation required, to sweep away the gases and render them harmless. Furnaces and fans are the favorite powers applied to produce artificial ventilation. Frequently exhaust steam from the steam pump at the bottom of the upcast or pumping shaft is applied; but while this is a valuable auxiliary, it is too weak a ventilating force in a large and extensive mine to be used alone.

The furnace has long been the favorite method of producing ventilation among practical men, but of late years exhaust fans of the Guibal, Waddle, Schiele and other patterns have been introduced, and have worked so successfully as to supplant the furnace nearly altogether over large and important mining districts in England and the continental States of Europe. The furnace in its first cost is cheaper than the fan, and in deep mines is capable of doing equally effective work, while for shallow shaft mines the fan is both cheaper and more effective as a ventilating power. The furnace is likely, however, to continue as a ventilator as long as coal mining is followed.

The proper construction of a ventilating furnace is a debatable question among mining engineers. A thin, wide fire and low arch more effectually heat the passing current of air and so add to the ventilating power of the furnace than a furnace having a high arch. The arch, in my judgment, should never be higher than 3½ feet above the bars, and the wider the furnace is the better, and the whole width should be kept constantly and uniformly heated. As furnaces are ordinarily built they do not admit the whole amount of air which they are capable of moving, hence it is found to add to their ventilating power to provide side chambers. The object of these chambers is to admit the passage of columns of cool air between the furnace and pillars of coal for the purpose of preventing the pillars taking fire, but the chambers are found in practice to add to the amount of current. This fact produced quite a discussion among some of the members of the Ohio Institute of Mining Engineers at the Nelsonville meeting in May, 1882. The Orbiston Mine, which is opened on the thick coal of the Hocking Valley, was visited by several of the members of this society. The air courses are 8 feet wide and 8 feet high, making a sectional arch of 64 feet. The furnace is 6 feet wide, 3½ feet high above the bars, and has two side chambers for the passage of cool air. Mr. Palmer, the mining boss, stated that when these chambers were opened the amount of current was increased fully 2,000 feet per minute, the column of air moved being about 30,000 cubic feet per minute. Mr. Hazeltine contended that there must have been a mistake committed in taking the measurements, as the cool air which passed through the side chambers would, by mixing with the hot air which passed through the furnace, decrease the temperature in the upcast shaft and so reduce rather than increase the amount of air in circulation. I have taken measurements frequently in mines where the current was increased in quantity where side chambers were opened. Mr. Hazeltine was undoubtedly correct in theory, but his idea did not embrace the whole theory. The greater the heat communicated to the air of the upcast, the greater must of course be the ventilating pressure. The power was lost in the passage of air through the furnace, for the sectional area of the furnace was only 11 or 12 feet, being fully five times smaller than the airway of the mine, while the column of air itself became expanded to more than double its volume in passing over the fire. The resistance which the air encountered at the furnace checked the column, which found vent when the side chambers were opened; hence the increase in the quantity of air. The cool air which escaped through the side chambers would, on uniting with the hot column which passed over the fire, decrease the temperature to some extent and so lessen the ventilating pressure, as Mr. Hazeltine suggested; but this counterpoising influence was overcome to the extent of an increase of 2,000 cubic feet. Some years ago the furnace attendant in a mine in the Mahoning Valley in digging coal for the furnace near the bottom of the upcast shaft accidentally cut into the shaft. As soon as the coal was removed the flow of air increased 60 per cent. The mine boss was astonished and delighted, and when I visited the mine afterwards he told me that he had made an important discovery in mining ventilation, and proposed applying for a patent on it. I told him his furnace was too small for the requirements of the mine, that the air had not room to pass through the furnace, and his plan was, not to apply for a patent, but to pull down his furnace and treble its sectional area and he would behold still more surprising results in the increase of current.

Where the airways of a mine are of, say 30 feet of a sectional area, a furnace 7 feet wide and 3½ feet high above the bars, will, I think, approach systematic perfection. The furnace has a limit to its power, and when it is reached we pile on coals in vain. In building a furnace it adds to its efficiency to slant it upward inside of the bars, say one foot in six until the upcast shaft is reached.

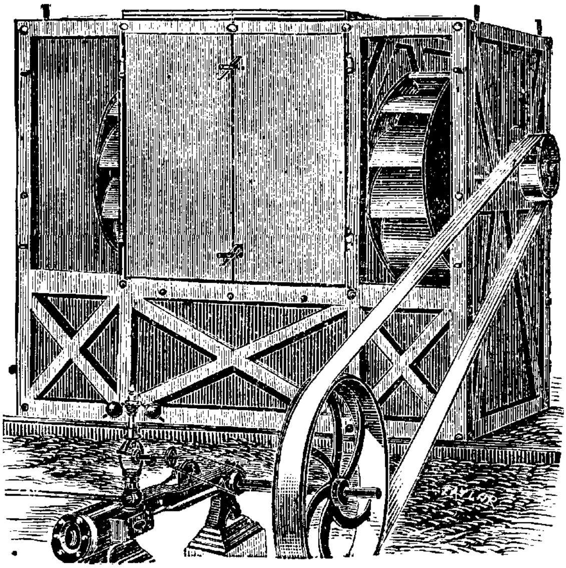
In the mines of this State, the quantity of air moved by a properly constructed furnace ranges from 2,000 to 6,000 cubic feet per minute for every foot of breadth of fire. The depth of the ventilating shaft, its freedom from water, the size of the air-courses of the mine, the temperature of the outside atmosphere, all combine in determining the quantity of air which can be moved through a mine by furnace ventilation. In winter, as stated in the opening paragraph of this paper, the natural forces aid the ventilation, while in summer the natural forces oppose the furnace, like a steamboat going up stream. In deep mines, like those in England, the natural current is in the direction of the upcast all the year round, because the mine air of deep mines is always rarer than the atmosphere on the surface; but while in summer there is no opposing force to overcome, there is little assistance given, the temperature of mine and surface air being so nearly equal in weight. In winter the natural forces and the furnace in proportion to the difference of temperature of the mine and surface air. The practical power of the furnace is in proportion to the depth of the shaft, the power being as the ratio of the depth; hence, a shaft 400 feet deep will, with the same furnace, all other things being equal, move double the quantity of air as a shaft 100 feet deep. This practical fact is not as well understood as it should be, the common impression being that shallow mines move more air than deep ones with the same ventilative power. Until within a few years ago, it was a rare thing to see a roomy, well constructed furnace in a coal mine in this State, owing to this mistaken view of the influence of heated air in shafts.

Fan ventilation, on the other hand, is more effective in shallow than deep mines, but fan ventilation has only recently been applied in this State, and is not making as rapid headway as could be wished, mainly from the fact that the first cost of the fan is considerably greater than that of the furnace, and in drift mines it is as costly at all times, because at drift mines the fan and engine require the attendance of an engineer, as the furnace requires an attendant. In a shaft mine the hoisting engineer can attend both engines, which is a saving of one man at the mine, besides the saving in the coal required to maintain a ventilating furnace. Whenever furnace ventilation is applied the supply of air is liable to great irregularity by neglect of the furnace man; and the danger of fire, of which we have so many fatal examples, is ever present. Moreover, in mines where the furnace is placed at the bottom of the hoisting shaft the guides, the ropes and the timber of the shaft are subject to injury from the gases given off by the furnace. All these evils are obviated by the fan, in addition to the daily saving in fuel and attendance.

The best ventilating fans are constructed on centrifugallar principle, and those of the Waddle, Schiele and Guibal patterns, as already stated, have attained high fame in England and the Continental States of Europe. Guibal's is preferred to the others and is probably the best ventilating fan for the use of coal mines ever applied in any country. This fan has a large diameter, some of those used at the deep and extensive mines in England ranging from 40 to 50 feet. The blades of the fan, eight in number and 10 feet wide, are inclined backward and the air is discharged through an adjustable shutter into an expanding chimney about 20 feet in height; this fan, although more extensively applied in the coal mining districts of England and Continental Europe than all other fans combined is yet mainly confined in this country to the anthracite region of Pennsylvania, because such costly and elaborate arrangements as attend its construction are not required to produce the limited currents of air which suffice for our shallower and smaller mines. From 250,000 to 300,000 cubic feet of air per minute are frequently produced by means of the larger Guibal fans in the mines of England.

The Champion fan, which was introduced in the mining regions of Ohio and other western States a few years ago, gives very satisfactory results. Wherever this fan has been introduced mining engineers and mining bosses declare that they could not be hired to go back to the furnace as a ventilating power.

This fan consists of two revolving wheels set in one shaft, a few feet apart; the blades are so constructed that they do not oppose any flat resistance to the air, being curved backward and run into the circumference. There are several sizes made, which range from 4 to 10 feet in diameter; the speed of the fan is from 200 to 600 revolutions per minute and from 10,000 to 60,000 cubic feet of air per minute is put in motion throughout the mine, according to the size of the fan, the speed at which it is run and the frictional resistance which the air encounters in traversing the galleries of the mine. The air is received between the wheels of the fan and is expelled direct to open day, and the machine is constructed that it can be used either as an exhaust or blowing fan without changing the gearing or stopping the engine. This advantage will be duly appreciated by mining bosses who are plagued with wet shafts which freeze in winter.



All of the fans mentioned in this paper are operated on the exhaust principle, which is found in practice to be much more effective than blowing air through the mine. Blowing fans are, however, occasionally used, and there are two of this kind in the Mahoning Valley, one at the Church Hill Shaft in Trumbull county, and the other at the Leadville Shaft in Mahoning county. The diameter of these fans is about 7 feet, the width of the blade being 3 feet. They move each from 14,000 to 16,000 cubic feet of air per minute and serve every purpose for which they were intended.

GASES IN COAL MINES.

The more common gases which are generated in coal mines are known among miners as fire-damp, after-damp or choke-damp, black-damp and white-damp. Fire-damp is the light carbureted hydrogen gas of chemistry, and consists of one volume of the vapors of carbon and two volumes of hydrogen, condensed by affinity into one volume. One thousand cubic feet of atmospheric air at the temperature of 32 degrees, and a pressure of 14.7 pounds, weighs 80.728 pounds, and one thousand cubic feet of fire-damp, under the same conditions, weighs 45.368 pounds; the weight of the fire-damp is, therefore, .562 as compared with common air. Being thus lighter than the atmosphere by nearly one-half, it occupies the roof and higher places in mines. In its pure and undiluted state fire-damp will neither support light nor life, but when mixed with twice its bulk of air, it may be breathed, although with suffering. Fire-damp requires a mixture of five times its volume of air to constitute an explosive compound; with this proportion the explosion is very feeble. When a little more than nine times the volume of air is added to one volume of fire-damp, it forms the most powerful explosive mixture. In this condition, the instant a naked light is brought into contact with the gas, it explodes with the rapidity and violence of gunpowder, and produces the most dreadful results. When more than fourteen times the volume of air is mixed with fire-damp it again ceases to be explosive. Fire-damp is chemically composed of—

	By atoms.	By weight.	By volume.
Hydrogen	2	24.6	2
Carbon	1	75.4	1
	1	100.	1 Cond.

After-damp is the product of an explosion of fire-damp, and contains, when the gas is exploded, 71 parts of pure nitrogen, 9.5 parts of carbonic acid gas, and 19 parts of steam. Immediately after explosion the steam condenses, leaving 7.5 parts of nitrogen and 1 part of carbonic acid out of 8.5 parts, which is a most deadly gas. On the occasion of a disastrous explosion of fire-damp, more lives are generally lost from breathing the after-damp than from the rolling violence of the burning gas. The insiduous after-damp spreads through the mine, and the miners are soon overpowered by the surcharged atmosphere. A painless stupor gradually overcomes them, and they fall asleep in death.

Black-damp is the carbonic acid gas of chemistry; it is frequently called "stythe" by English miners. Its effect upon animal life are akin to those of the after-damp of an explosion. In its pure state it is a deadly poison, neither light nor life being capable of existing amongst it, and the miner's lamp, when placed in a solid stratum of it, becomes instantly extinguished as though it were plunged in water. When only 10 per cent. of black-damp is diffused through the air of mines, a light cannot be maintained; after a light ceases to burn it is never safe for a miner to trust himself for any length of time in such an atmosphere. Black-damp contains two atoms of oxygen and one atom of carbon; its specific gravity is 1.524, common air being one, the oxygen, by weight, forming 72.73 per cent., and the carbon 27.27 per cent. of the gas. Being thus considerably heavier than air, it occupies the floors of mines when in a pure state, but, like other gases, it readily diffuses itself with atmospheric air.

The white-damp of mines is the equivalent of carbonic oxide. This gas is much more deleterous to animal life than black-damp; for air containing only 1 per cent. of white-damp is unfit for human respiration, and, if breathed for a few minutes, will surely cause death. Unlike black-damp, which ordinarily extinguishes the miner's lamp before prostrating his energies, white-damp will support combustion amidst a deadly atmosphere. Miners have frequently been found dead in air charged with white-damp, while their lamps continued to burn with great clearness. The effects of this gas upon animal life are similar to those of black-damp and to the after-damp of explosion—the miner falls asleep, and after insensibility overcomes him, if not speedily removed, he dies. White-damp is composed of one atom of oxygen and one atom of carbon. By weight this gas contains 56.69 per cent. of oxygen and 43.31 per cent of carbon; its specific gravity is 975.195, being little less than atmospheric air. Sulphureted hydrogen gas is also frequently found in coal mines. It is called white-damp by miners, like carbonic oxide; it is, however, readily distinguished from carbonic oxide by its peculiar smell, which resembles that of rotten eggs. Sulphureted hydrogen consists of 1 atom of sulphur and 1 atom of hydrogen; by weight it contains 94.15 per cent. of sulphur and 5.85 per cent. of hydrogen. This gas is met in abandoned workings in which iron pyrites are undergoing decomposition. It is also generated by contact of hydrogen with sulphur in a comminuted form. Like carbonic oxide, the miner's lamp will burn with clearness in a deadly mixture of this gas. When 3 per cent. of sulphureted hydrogen is found in the air of mines, human life cannot exist except with suffering. It produces fainting fits, giddiness and asphyxia.

These gases are generated in mines from a variety of causes. Fire-damp escapes from the fissures and minute pores of the coal and its associate strata. It is seldom met with in very alarming quantities in drift or level free mines, or in shafts of moderate depth. The most fiery mines are those between 600 and 1,200 feet in depth; below this zone fiery beds of coal are met, but it is the exception rather than the rule. Fire-damp exists in mines in a highly compressed state, being pent up in the interstices and fissures of the coal by the counterpoising pressure of the atmosphere. When the barometer falls, indicating a lightening of atmospheric pressure, the pent-up gas escapes in greatest volumes. Many fatal mining explosions are due to this cause. This gas also frequently escapes in the form of blowers, which produce a hissing voice, and which, when ignited, burn like a long blow-pipe. The fire-damp of coal mines is one of the most fatal and dangerous elements ever encountered in human enterprise.

Black-damp, like fire-damp, is liberated from the coal and its associate rocks; it is also generated by the burning of lights in the mine, by the exhalations of men and animals, by decaying woodwork and decomposing strata; the gases formed by blasting also aid in the formation of black-damp. This gas is perhaps a more deadly as it is a more subtle enemy of the miner than even fire-damp; the effects of fire-damp are instantaneous, while those of black damp are slow in operation, gradually but surely undermining the constitution and killing its victims by inches.

White-damp is formed largely from the products of exploded gunpowder; it is also generated freely in waste and abandoned parts of mines, particularly where breeding fires are liable to break out. Both sulphureted hydrogen and carbonic oxide are formed by breeding fires.

The presence of these gases in mines makes ventilation a paramount consideration in working coal or other minerals. Above ground vitiated air immediately flies upward into space, but the air of mines has to circulate from one working place to another, frequently traveling from ten to twelve miles and supplying 300 men and horses before it reaches the upcast shaft and is delivered today. As it moves along the labyrinthean passages of the mine it becomes more and more vitiated and unfit for breathing from the loss of oxygen, which is replaced by the noxious and poisonous gases collected on the way. When we consider the numerous complaints which reach the public ear, arising over the condition of badly ventilated public buildings and workshops, and remember the numerous treatics which have been written on the best methods of improving the ventilation of such buildings, we are forcibly reminded of those dark subterranean workshops, amidst which the causes which tend to vitiate the atmosphere are multiplied a hundred fold, and where not even a ray of God's sunlight can ever come.

THURSDAY'S PROCEEDINGS.

An excursion was planned to visit the Church Hill and Garfield shafts in Liberty township and the Shady Side shaft in Vienna township, Trumbull county. The programme included visiting and inspecting the Church Hill Mine in the forenoon, dinner at Vienna, inspecting the Shady Side and Garfield Mines in the afternoon, and our executive session in the Excelsior Hall, Youngstown, at half-past seven P. M.

The Church Hill Mine, first inspected, was sunk in 1880 and is an extension of the Church Hill Slope situate one mile north, and which was opened in 1867. This coal basin is one of the largest and most profitable in the Mahoning Valley. The proprietors of the mine pay a royalty of 40 and 50 cents per ton for all screened, merchantable coal. The vein is 2 to 4½ feet in thickness, and of superior quality in that superior coal field of Ohio. The deposit exists in the form of a number of basins which lie along side of each other without break in the continuity of the bed. The coal, however, grows gradually thinner as it ascends the sides of the troughs; but it seldom becomes so reduced in thickness as to fall below a minable vein. The manner of working is by following the swamps with main gangways wherever these swamps lead, and opening up entries on the butt or end slips of the coal. The rooms are opened on the butt entries; they are made ten yards wide, stumps or ribs of coal 8 to 10 feet feet in thickness being left between rooms for the support of the roof and incumbent strata. The shaft is ventilated by a fan of the same pattern as that in use in the Leadville Mine. The air is blown through the mine, the return or upcast current being discharged through the hoisting shaft. By this arrangement no ice is ever formed on the pit.

Owing to the number of visiting engineers more time was consumed in inspecting this mine than was laid down on the programme, and it was noon before the visiting party started for Vienna.

After dinner the Shady Side Mine was visited. The shaft was sunk last year and is supposed to tap the last minable basin of coal in Vienna township. The mine looks well; the coal is of excellent quality, and the deposit promises to be a remunerative one for the operators. The coal of Vienna township, in which this mine is opened, is the most northerly deposit of the lower No. 1 coal of the Mahoning Valley. The coal was discovered in 1870, after the State Geologists had pronounced against the existence of any deposit so far north. The prospectors had no knowledge of Geology, and commenced explorations without knowing whether they were inside our outside the coal belt. When they struck coal, which they did in the first hole they bored, they found some difficulty in inducing capitalists to encourage their mining venture. Much unfriendly criticism was indulged in at the expense of the schoolmen who had previously pronounced the township barren of coal.

Theoretically the Geologists were right in assuming that coal would not be met so far north, because the geological guide—the Cuyahoga shale which underlies the coal bed, is exposed along the highlands of the Mahoning River and its tributaries fully 100 feet above the horizon of the coal seam. Owing to the fact, however, that the coal is met resting in basins or troughs which have been cut deep into the Cuyahoga shale before the coal vegetation was deposited, the blunder of the Geologists was a pardonable one.

The visiting engineers did not reach the Garfield shaft until five o'clock P. M.; but the attractions were so inviting that all descended in a body and advanced underground to the farthest end of the mine. This mine is remarkable for the number of "horsebacks" encountered in working away the coal, and illustrates the uncertainty of mining enterprises in this coal field. The borings indicated a rich deposit, and several of the holes went down on coal four feet in thickness, while a few yards distant not an inch was met. The company in opening the mine spared no pains to provide the best and safest machinery and the most approved appliances for working and ventilating the mine.

The visiting engineers passed the day in the mines and found much of interest and instruction. They expressed themselves, one and all, delighted with the excursion and with the treatment they had received from the resident engineers and citizens of the Mahoning Valley. The Executive Committee, who had charge of the Institute, are entitled to great credit for the happy manner in which everything was arranged for the comfort and information of the members of the Institute. Owing to the lateness of the hour in returning to Youngstown, (8 P. M.) the meeting arranged to take place at the Excelsior Hall at 7:30 was adjourned to the parlor of the Tod House. At 9 P. M. the Institute met in executive session, President Roy in the chair.

THE PRESIDENT.—The Institute will now come to order. The first business to be transacted will be the reading of a paper by Mr. Howell, on The Manufacture of Tin in the United States.
