EXPLOSIONS FROM COMBUSTIBLE DUST.*

By PROFESSOR L. W. PECK.

I WISH to demonstrate to you this evening, by a few simple experiments, the fact that all combustible material when finely divided, forming a dust or powder, will, under proper conditions, burn with explosive rapidity.

If a large log of wood were united it might burn a week before being entirely consumed; split it up into cord wood and pile it up loosely, and it would burn in a couple of hours; again, split it into kindling wood, pile loosely as before, and perhaps it would burn in less than an hour; cut it up into shavings and allow a strong wind to throw them

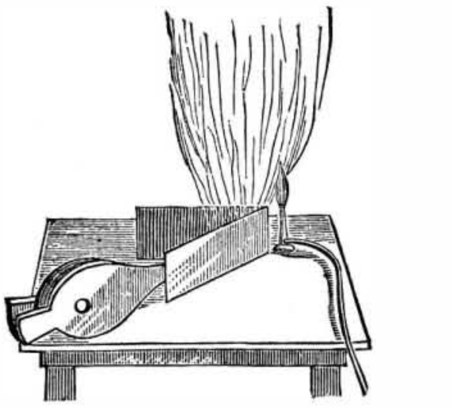


FIG. 1.

into the air, or in any way keep the chips comparatively well separated from each other, and it might be entirely consumed in two or three minutes; or finally, grind it up into a fine dust or powder, blow it in such a manner that every particle is surrounded by air, and it would burn in less than a second.

Perhaps you have noticed that shavings and fine kindlings will sometimes ignite so quickly in a stove that the covers will be slightly raised, the door forced open, or perhaps small flames will shoot out through the front damper. You have, in such a case, an explosion on a very small scale similar to that of the Washburn, Diamond, and Humboldt Mills of this city, on the night of May 2—upon which occasion the rapid burning of hundreds of tons of flour, bran, etc., completely demolished the solid-masonry walls, six feet thick, of the mills, and threw sheets of iron from the roof

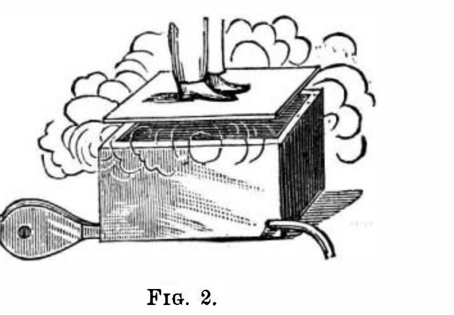


FIG. 2.

of the Washburn so high into the air that they were carried two miles by the wind before striking the ground.

Let us see now why such explosions occur. Wood has in in it a large amount of carbon, the material of which charcoal is composed, and the air is about one-fifth oxygen. Now, at the ordinary temperature, the carbon of the wood and the oxygen of the air do not combine; but, when they are heated, as by friction, concentration of the sun's rays, chemical action as from a match, or in any other way, they combine to form carbonic-acid gas. This chemical action produces a large additional amount of heat which keeps up the action as long as there is any carbon and oxygen left to unite, and also makes the temperature of the gas which is formed very high.

As the space occupied by the carbonic-acid gas and that occupied by the oxygen which entered into the combination

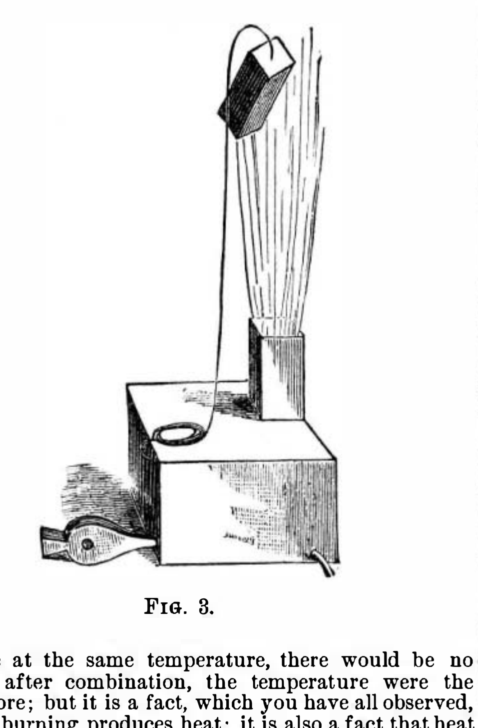


FIG. 3.

is the same at the same temperature, there would be no bursting if, after combination, the temperature were the same as before; but it is a fact, which you have all observed, that fuel in burning produces heat; it is also a fact that heat expands a gas, and it is this great amount of heat, taken up by the carbonic acid formed, that produces the immense pressure in all directions.

Let us return to our log of wood. There is exactly the same amount of heat and carbonic acid produced when complete combustion takes place in each of the cases of burning, the only difference being as to time. In the first case, the explosion or pushing aside of the surrounding air occupies a week, in the last only a second.

Snow-flakes fall gently upon your shoulders, and you are required to perform an insensible amount of work to resist the crushing effect of each flake; but suppose that all the snow that has fallen upon your head and shoulders for the last ten years was welded together in one solid mass of ice, weighing perhaps one hundred pounds, and that it should descend with the velocity of a snow-flake upon you, an immense effort would be required to prevent its crushing you, even if you were able to withstand the shock at all. The work of many days would be concentrated into an instant.

So it is with burning wood: four or five cords of wood, and a large stove, will give you a roaring fire all winter; the work done is manifested by the heat obtained, by the rushing of hot gases up the chimney, and of air from outside into the room through every crack. But, if the wood were ground into a powder and scattered through all the house, and burned instantly, the cracks, doors, windows, and flues, would not be sufficient to give vent to the hot gas, and the roof and sides of the house would be blown to pieces.

What is true of wood is also true of grains; also of vegetables, with their products when they contain carbon, with this exception: grain, either whole or ground, will not burn readily when in bulk. A fire could be built upon a binful of flour, and kept burning for half a day without igniting the flour; it would char upon the surface, but it lies in such a compact mass that the air does not get access to it readily, hence it does not burn.

I wish to show you now how combustible dust will burn when blown into the air by means of a pair of ordinary hand-bellows.

I have here two boards, about twelve by eighteen inches, nailed together, forming a V (see Fig. 1). Just outside of the V an ordinary Bunsen's gas-burner is placed, and within is a small handful of dust taken from a sash and blind factory. Upon blowing it smartly with the bellows a cloud is formed about fifteen feet high—extending, in fact, to the ceiling—which ignites from the lamp and produces a flash, very quick, and exceedingly *hot*, resembling very much a gunpowder flash. You will notice that a large amount of dust falls from all around the edge of the flame without burning; that is because it is not thick enough. Two things are necessary: first, that each grain of dust be surrounded with air, so that it can get the oxygen required *instantly;* and, secondly, that each grain shall be so near its neighbor that the flame will bridge over the space and pass the fire from particle to particle.

I think, after seeing the immense flame produced by such a small amount of fine saw and sand-paper dust, you will no longer wonder at the rapid spread of flames in furniture and similar factories. You know it is practically impossible to put out a fire after any headway is attained in these establishments; the draught produced will blow all the dust from

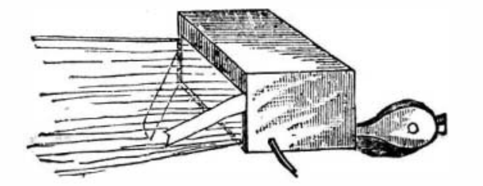


FIG. 4.

walls and rafters into the air, and the building in an instant is a mass of flame. Perhaps many of you remember the fire in the East-Side Saw Mills, a few years ago. Large masses of fine sawdust had probably collected upon the rafters, and the whole roof was perhaps filled with cobwebs loaded down with dust. A fire started from one of the torches used and shot through the mills with lightning-like rapidity, and, save for the fact that the ends and sides of the building were all open, there would have followed an explosion like that at the flour mills. As it was, the men had very great difficulty in escaping with their lives, notwithstanding that a short run in any direction would have taken them out of the mill.

It is very evident that too great care cannot be taken to keep all such factories and mills as free from dust as possible.

I will now blow some ordinary starch into the air in the same way, and you notice the flame is more vivid than in the last experiment, and, if you were in my position, you would notice that the heat produced is much greater. Notice now that this powdered sugar burns in the same way.

You will see from the experiments further on that three-quarters of an ounce of starch will throw a box, weighing six pounds, easily twenty feet into the air, and that half an ounce, burned in a box, will throw up the cover three inches with a heavy man standing upon it.

With these facts, which I have demonstrated before you, no one need regard as a mystery the Barclay street explosion in New York city, where a candy manufactory, in which large amounts of starch and sugar might in many ways be thrown into the air by minor disturbances, took fire and completely wrecked a building and destroyed many lives.

I will now burn in the same way some buckwheat, which, as you will observe, gives a very large blaze; now some corn-meal, which is too coarse to burn as well; now some rye flour, which burns much better than the corn; now some oatmeal, the finer part of which only burns; and so I might continue with all sorts of finely-ground vegetable material.

Let us take up now the products of the manufacture of flour from wheat. There were between three and four hundred tons of these materials, upon which I am now to experiment, in the Washburn Mill at the time of explosion, and there was a corresponding amount in the Diamond and Humboldt Mills, which, by their sudden burning, produced the second and third shocks heard directly following the explosion of the larger mill.

The wheat is first placed in a machine, where it is rattled violently and brushed. At the same time a strong draught of air passes through it, taking up all the fine dust, straw, etc., and conveying it through a spout to a room known as the wheat-dust room, or perhaps more commonly it is blown directly out of the mill.

You see some of this material here; it looks like the wood-dust of the first experiment, and, as you see, burns with a quick and sudden flash when subjected to the same conditions.

Here, then, we have the first source of danger in a flour-mill. A thick cloud of this dust, when conveyed through a spout by air, will burn in an instant if it takes fire; and, if there is any considerable amount of dust, as there would be if there were a dust-room, an explosion will follow which may become general if it stirs up a thick dust-cloud throughout the mill.

The wheat after it has been cleaned in this way goes to the crushers, which are plain or fluted iron or porcelain rollers, working like the rollers in a rolling mill. The object of these rollers is, I believe, to break off the bran in as large pieces as possible, and to crush out or flatten the germ so that it can be separated with the bran from the rest of the meal.

The crushed wheat goes now to the stones, where so much heat is produced (average 135° Fahr.) that a large amount of steam is formed from the moisture in the materials. This steam would condense in the meal and interfere with bolting, etc., if it were not removed. To effect this, another draught of air and another spout are employed, and, as might be expected, this current takes a large quantity of the very finest flour, called flour dust, with it. To save this, a room is provided near the end of the spout, called the flour-dust house. The spout conveying steam and dust enters this room on one side, and another spout opposite leaves it, passing to the open air. It is in this comparatively dead-air space that the dust settles, and can be collected from the floor. Here is some of this material, which, as you see, when blown into the air produces a vivid flash, extending from the table to the wall.

The evidence taken before the coroner's jury shows very clearly that it was this material that started the great explosion of May 2. Just how the mill took fire will probably never be known of course, but in all probability the stones either ran dry—that is, were without any meal between them—or some foreign substance, such as a nail, was in the feed, producing a train of sparks such as is produced by an emery wheel or a scissors-grinder's wheel. These sparks set fire to small wads of very hot dust, which, as soon as they were fanned into a blaze, communicated it to the spout and house full of dust. An eye-witness of the explosion first saw fire issuing from the corner of the mill where this flour-dust was situated, the end of the spout having probably been blown out. This fire was followed instantly by a quick flash, seen through all the windows of the floor upon which the flour-dust houses were situated, followed instantly by a flash in the second story, then the third, and, in rapid succession, fourth, fifth, and sixth stories; then followed the great report produced when the immense stone walls were thrown out in all four directions, and the roof and part of the interior of the mill shot into the air like a rocket.

It would seem that a blaze is necessary to ignite the mixture, for I have tried powerful electric sparks from a machine, and from a battery of Leyden jars; also incandescent platinum wire in a galvanic circuit, and glowing charcoal, without producing any fire, however thick the dust might be. Perhaps, however, under more favorable conditions, the dust would ignite directly from sparks, but it seems very improbable.

Let us continue now with the process through which the ground wheat is made to pass. From the stones it is conveyed to the bolting reels, where the very finest is sifted out first, and we obtain a grade of flour; after the finer material is sifted out it goes to a coarser bolt, where the "middlings," as it is called, passes through, leaving the bran which comes out at the end of the reel. The middlings, as it comes from the bolts, has fine bran and dust in it, and, to purify it, it is subjected to an operation similar to that of cleaning the wheat, that is, in the middlings purifiers it is subjected to a draught of air which takes away all the light bran and dust, leaving the heavier material (purified middlings), which goes again to the stones to be ground into flour.

Here is some of the dust from these "middlings machines;" you observe it burns as the other materials burned, quickly, and with intense heat.

Here is some of the purified middlings; each grain is comparatively large and heavy, making it difficult to blow it well into the air, but, as the blaze produced by each particle is quite large, a flash is produced which does not differ materially from the others.

Here is some of the general dust of the mill that is, dust swept up from the floors, walls, beams, etc. You will see it acts in all respects like the other substances.

And, finally, here is some of the flour taken this afternoon from the flour-sack at home; it burns, you observe, if possible, with even more energy than the other kinds of dust.

I have performed a few experiments, which I will now repeat, which will illustrate to you the immense power that these materials exert when burned in a confined space.

This box (Fig. 2) has a capacity of two cubic feet; the cover has a strip three inches deep nailed around it, so that it telescopes into the box; there is in this lower corner an opening for the nozzle of the bellows, in this an opening for the tube to the lamp. I place now a little flour in the corner, light the lamp, and my assistant places the cover upon the box and steps upon it. Take notice that upon blowing through the hole, and filling the box with a cloud of flour, the cover comes up suddenly man and all, until the hot gas gets a vent, and a stream of fire shoots out in all directions.

Here is a box (Fig. 3) of three cubic feet capacity, including this spout, nine inches square and fifteen inches long, coming from the top of it; at the ends doors are arranged closed like steam-boiler man-holes; openings for light and bellows are arranged as in the previous box.

Here is a box, weighing six pounds, that will just slip over the spout; it has a rope lest it should strike the wall after the explosion. Placing now the lamp in the box, some dust in the corner, and the box over the spout, we are ready for another explosion. You observe, after blowing vigorously for a second or two, the dust in the box takes fire; the box over the spout is shot off, and rises until the rope (about twelve feet long) jerks it back; it strikes the stage with great force, rebounds and clears the footlights, and would strike the floor below were it not for the rope.

I have thrown a box similar to this in the open air twenty feet high, while, as we shall see presently, less than an ounce of flour is being consumed.

I have fastened over the top of the spout five thicknesses of newspaper; upon igniting a boxful of dust as before, the paper is thrown violently into the air, accompanied by a loud report as it bursts.

For the last experiment I have a box of four cubic feet capacity (Fig. 4), five sides are one and a half inches thick, the remaining side one-quarter inch. Upon igniting the dust in this box, filled as in the other cases, the quarter-inch side bursts, and a stream of fire shoots out half way across the stage.

One pound of carbon and two and two-thirds pounds of oxygen, when they combine to produce carbonic acid, will evolve heat enough, if it were applied through a perfect heat

* Lecture delivered June 1, 1878, at Association Hall, Minneapolis, Minnesota, at the request of the millers of the city.—*American Miller.*

engine, to raise 562 tons ten feet high; if, therefore, forty per cent. of flour is carbon, it would require two and a half pounds to accomplish this result, if an engine from which there would be absolutely no radiation, conduction, or loss of heat, in any way, were a practical possibility. Let us see how much air would be required to supply oxygen enough. Under ordinary conditions every 100 cubic inches of air contains 7·13 grains of oxygen, from which we find that 151½ cubic feet of air would be required for the 2⅜ pounds of oxygen. Hence the 2½ pounds of flour must be equally distributed as a dust through 151½ cubic feet of air, in order to produce the most powerful result.

If forty-one ounces of flour requires 151 cubic feet of air for perfect combustion, one cubic foot of air will supply oxygen enough for 40-151 of an ounce of flour. Hence our box, which lifts the man so readily, burns half an ounce of flour or less; and the other, which throws the box into the air, three-quarters of an ounce, unless, as I think quite probable, an additional amount of air is drawn in through the cracks as soon as the vent is opened at the top of the box. In fact, these experiments work better if a few small holes are made near the bottom of the boxes.

It may be worthy of mention here, as a point of interest to insurance companies, that in all dust explosions, a fire precedes the explosion in every case. The dust must burn before the heat that produces the immense expansive force is generated.

Too great precaution cannot be taken in all kinds of manufactories, where combustible dust is produced, against fire, especially in those establishments where it is conveyed in thick clouds by air draughts through spouts and rooms.

IMPROVED CARDING MACHINE.

THE accompanying engravings represent an improved wool carding machine constructed by the Messrs. Pierrard-Parfaite, of Rheims, France. To this firm gold and silver medals were awarded at the Paris Exhibition for machinery for wool manufacture.

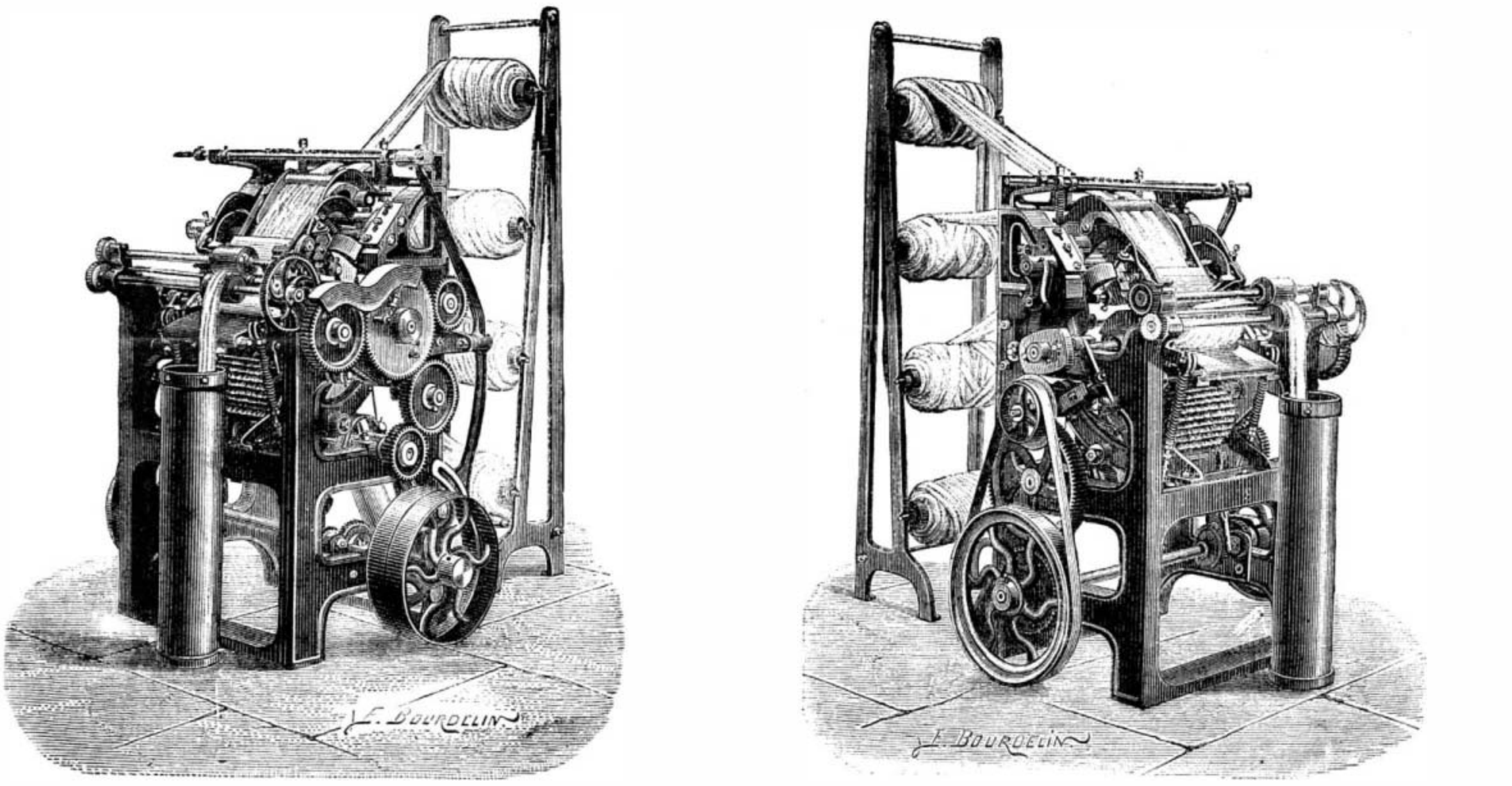
These machines are simple in construction, durable, easily regulated and cleaned. They differ from the ordinary machines principally by the arrangement of the cards. Of the latter there are two, as in the old machines, but, while in these one had an oscillating, the other a rotary motion, they are, in the Pierrard machine, both stationary and rotary.

These oscillations of the cards in ordinary machines were performed with little energy only; frequently the teeth did not penetrate the layer of wool; in that case the lower portion of the same would escape uncarded. The filaments, passing thus through the machine without being subjected to the action of the teeth, would form knots injuring the value of the wool. On the other side, the oscillations of the card caused the entire machine to shake continually, wearing it out soon, and producing at the same time goods of inferior value.

As above stated, this difficulty has been overcome by the peculiar arrangement of the cards in this machine. There are only four bobbins to feed the machine. The reduction of the number of bobbins has been found advisable for the sake of simplicity and to insure greater homogeneity of the carded wool.

When worn out, the cards may readily be removed and replaced by new ones.

These machines may of course be also used for cotton and other textile fibers.



PIERRARD-PARFAITE'S IMPROVED WOOL CARDING MACHINE.

[Continued from SUPPLEMENT No. 165.]

THE WONDERFUL RAILWAYS OF PERU.

Lima and Callao Railroad.—Landing at Callao, on your right, are the station and offices of the Lima and Callao Railroad. On the left, the wonderful "Oroya Railroad." The former, built twenty-nine years ago by Peruvians, was bought by an English company. From Lima to Chorillos—the Brighton or Long Branch of Peru—is another railway, costing, with the Lima and Callao road, $12,000,000. Both lines are under one control, and pay their English owners 12 or 13 per cent. on a capital of $4,000,000, which is now their assessed value. The rolling stock of these roads, until their twenty-fifth year exclusive right was finished, was very bad, and traveling uncertain. Trains started at fixed times or "thereabouts," which meant half an hour to four hours from schedule time.

The Callao, Lima, and Oroya Railroad, generally known as the Oroya Railroad, now the Transandine Railroad, is probably the most wonderful railroad in existence. It was contracted for by Henry Meiggs in 1869, at a cost of $21,804,000, or $27,000,000 in bonds. Work was begun in January, 1870. When commenced the English company had yet the right of way from Callao to Lima, and Mr. Meiggs could get no special rates for his material. The enormous cost of freighting everything for his road would make it ruinous to build. One day suddenly appeared hundreds of men evidently making a railway from Lima to Callao. The English company went to see about it, and then got out an injunction to stop the work. Mr. Meiggs calmly asked them whose land the workmen were on, and then they found he had quietly bought up all that land and was building a private road on his own grounds and for his own use. Leaving Callao the road to Lima is in the finest condition. Ballasted with cobble stones, no dust arises; trains every half hour; fare 40 cents; four separate depots accommodate different parts of the city. No one who makes a round trip on this road ever repents it, and seldom desires a second. The heights and distances are so great that few heads are not affected. From San Mateo to Anchi the road passes through the "Infernillos"—Little Hell. Nearly perpendicular walls from 2,000 ft. to 3,000 ft. hem in the river Rimac, having a width of from 200 ft. to 400 ft. At first it was proposed to make a cut in the side of these mountains, but, fearing the falling of loose rock, it was decided to tunnel. Miners were let down with ropes, one-quarter and one-half mile long, to certain indicated points on the rocky wall every 500 feet, more or less, and after they had entered a few feet began working to the right and left, using the entrance as a place from whence to throw the excavated material. About midway a bend in the river made it necessary either to make a dangerous curve or span the chasm. The latter was chosen, and now a bridge unites the tunnels about 400ft. above the river bed. Emerging from the second of these tunnels at Anchi, the Rimac is recrossed, and the road follows up the river Blanco a few miles, which it crosses, and then enters a mountain, where it turns around in a curved tunnel, and, emerging a few hundred feet above, recrosses the river and returns, passes Anchi, and continues up the river Rimac. At Chicla, a few miles further, the road passes the town, returns, crosses its own track and the Rimac, turns and passes again, and, reversing, returns and again doubles on itself, having passed Chicla five times. The view from the summit, 15,568 ft. at the entrance to the Galera tunnel, is not so imposing as at other points. A plateau of a few miles square with lakelets and patches of snow, and surrounded by peaks, many covered with snow, is all one sees. But the oppression of breathing, the quickened pulse, 130 to 140 per minute, the dull, dizzy head, the cold, frosty air, made an impression one never forgets. Just before reaching this plateau the road has made a wandering up the Chin Chau Valley, where the branch of the road to the silver mines of the Cerro de Pasco is being constructed. The former survey ran the branch from Oroya, but not being completed to that point, this nearer place of departure was chosen. It was hoped this road would extend to Tarma, then descend the Chanchamayo Valley—one of exceeding fertility—to Fort San Ramon, where direct communication could be had with Europe *via* the rivers Perene, Ucayali, and Amazon. The stations of the Callao, Lima, and Oroya Railroad are Callao to Lima 7½, Quiroz 11¾, Santa Clara 18½, Chonica 33½, Cocachacra 44¾, San Bartolome 46¾, Surco 55¾, Matucana 62¼, San Mateo 77½, Youli 119, Oroya 136. The rise from San Bartolome to the summit is almost all the way 4 ft. to every 100 ft. From the summit to Oroya is a descent of 3,390 ft., the steepest being from the tunnel to Youli. From Oroya the road is now being extended ninety miles northward to the famous silver region of Cerro de Pasco.

Lima and Pisco Railroad.—A contract was granted to the Ramos Brothers to build a railroad under this title southward along the coast from Lima, 145 miles in length, at a proposed cost of $9,400,000, incomplete.

Pisco and Ica Railroad.—This road, forty-eight miles long, cost $1,450,000. It passes through the vineyards of "Chincha alto" and "Chincha bajo" over rich fruit and agricultural lands to Ica. In front of Pisco are the Chincha or Bedbug guano islands. Pisco is famous for a clear, transparent brandy called Pisco, and another called Italia, made from the Italian grape. This road is rented for five years by the Government for $80,000 for the first two years and $105,000 for the last three years.

Mollendo and Arequipa Railroad.—Eighteen miles south of the port of Islay the river Tambo empties into the Pacific at Mejia Point. This was to be the landing place for the Mejia and Arequipa Railroad. Owing to it being often too dangerous to pass the surf, Mr. Meiggs conceived the idea of extending the line down the coast to Islay. Certain parties foreseeing this, bought up the land, and when he tried to purchase asked such exorbitant prices that he could not afford it, and, stopping nine miles south of Islay, made a landing in a crevice of the rock coast at a place called Mollendo. The road is now called the Mollendo and Arequipa Railroad. This and its continuation under the name of Arequipa and Puno Railroad and Juliaca and Cuzco Railroad is next in wonder to the Oroya, the stupendous work at the Infernillos only making the latter more remarkable. From Islay southward it runs to Mejia, then turning eastward, begins winding around the points of mountains and then up ravines; beginning five miles from Mejia to gain elevation, it also begins its windings.

At Cahuintala ravine the road becomes very remarkable. Three trains are often seen here one above the other. A cool head and steady nerve and close attention are needed by every engineer at this point. Reaching the Pampa of Cachendo, an extensive barren plain stretches as far as the eye can see, bounded in the distance by mountain peaks. The crescentic sand dunes hold their sway, and the heat from the polished pebbles causes many an inflamed eye. Till the railroad was built this was like the Arabian Deserts to cross. Many each year, lost and confused, laid down their lives on this plain. Even the civil engineers needed their utmost skill to find their way over the trackless desert.

Seventy miles from Mejia the road descends to the bank of the river Chile, which stream it follows to Arequipa, distant from Mollendo 107 miles, an elevation above the sea 7,560 ft. Begun May 27th, 1868, it was finished December 24th, 1870, with great festivities, and cost $12,000,000.

Arequipa, a city of 135,000, is the second city of the republic. At the foot of the volcano, "Misti," it has many times been in ruins. In 1868 it was nearly destroyed. From Arequipa the Arequipa and Puno Railroad takes its origin, 217 miles long, cost in bonds $32,000,000, in gold $25,280,000. Its windings and climbings, cuts and fills, are extensive, from 140 ft. in height and 500 ft. long to 50 ft. Want of water, it having to be carried on mules, made the first part difficult to build.

From the hot springs, "Aguas Calientas," the ascent is rapid to Chanaquos, and a corkscrew is straighter. Between Lumbay Bridge and the little lakes beyond the summit hail and snow, with terrific thunder and lightning, salute the traveler. The summit, 119 miles from Arequipa, 14,667 ft. elevation, is lower than the Oroya, but the climatic change from the coast appears to be greater. The average range of the thermometer is between 75° and freezing, and it is not uncommon to be burning up in the sun and freezing going on in the shade a few feet distant.

From "Lagunillas" to Puno, except its elevation, it presents nothing uncommon. At Juliaca its course is nearly south to Lake Titicaca and Puno. Lake Titicaca, the size of Ontario, is the largest body of water in the world at the elevation of 12,548 ft. On islands in its southern part exist the extensive ruins of Incal origin, and where history founds their "Plymouth Rock." Steamers run regularly from Puno to Chilillayo, where stages—Concord, American—connect with La Paz, the capital of Bolivia.

Juliaca and Cuzco Railroad.—From Puno to Cuzco, 140 miles north, an extensive plain, rich in minerals, metals, and pasturage, made a railroad less difficult of construction, yet it was estimated at $25,000,000. Difficulty of labor at elevations above 12,000 ft. increased the cost; 120 miles are finished. Since Juliaca was 28 miles in direct route to Cuzco, the road took that as its starting point, and is called the Juliaca and Cuzco Railroad. These three lines were contracted by Henry Meiggs, two being finished.

Ilo and Moquegua Railroad.—South of Mollendo, from the port of Ilo, a railroad is finished to Moquegua, 63 miles distant. Cost $5,025,000; H. Meiggs, contractor. The road is not paying expenses. Moquegua is the great grape country of Peru, and the Moquegua wine as celebrated as the Italia and Pisco brandies.

Arica and Tacnar Railroad.—Further south is Arica, the ill-fated. Ruined in 1868 by the tidal wave, it had but partially recovered when the 9th day of May, 1877, again submerged it. In 1852 Joseph Hegan signed a contract to build a railroad from Arica to Tacnar, 39 miles. It ran along the coast, turning east and north to Tacnar. In 1853 he sold his contract to an English company which had a capital of $2,000,000. Although Bolivia has a seaport, Cobija, Arica