operate eight motor cars of thirty horse-power each, and to light four horse-stables, three car-barns, and the generating station, — about five hundred lights of sixteen-candle power each.

The road as at present equipped is two and eighty-five one-hundredths miles long, and has three grades, each about sixteen hundred feet long with a three per cent rise. On the day of trial a motor car with a trailing car attached, loaded very heavily, made the distance in twelve minutes, and while on the grades the speed obtained was as high with the car added as that of the motor car by itself, showing conclusively that the Thomson-Houston motors are of sufficient capacity to do in the most satisfactory manner the work cut out for them. There is no unpleasant jerk or jar in starting the car, such as is found in many systems, and no scientific or mechanical knowledge is necessary to handle the car, which is controlled with ease.

The road when finished will be nearly six miles in length, making a round trip of twelve miles; and this, if proven successful, will be but a start in the rapid-transit line by the Consolidated Street Railroad Company. They have under way the plans for a one thousand horse-power plant for the hills, and the present plant will be enlarged to accommodate at least two more down-town lines. They also contemplate the equipment of from fifty to seventy-five cars, and expect to have the whole completed and in running order by the first of next year.

The recognition by this company of the merits of the Thomson-Houston electric railroad system is a very strong point in favor of that company; and as they gave practical demonstrations of their ability to fulfil their promises, they undoubtedly merit the honor thus paid them.

## THE PŒTSCH FREEZING PROCESS IN MINING OPERATIONS.

A BRIEF description of the freezing process devised by Herman Pœtsch for sinking shafts in quicksands and other difficult ground was given in these columns in April last. The process has been successfully applied in sinking a shaft for the Chapin Mining Company at the Iron Mountain mines in Michigan. In this case, so thoroughly and effectively was the freezing done that, although the shaft was finished some two months ago, the earth surrounding it is still frozen solid in places.

The following description of the difficulties overcome and the methods employed in sinking the shaft mentioned is furnished us by the Pœtsch-Sooysmith Freezing Company of this city, who control the patents covering the process in this country.

A shaft fifteen and a half by sixteen and a half feet was to be excavated through quicksand to a ledge about a hundred feet below the surface. The mining company put the freezing pipes into the ground three feet apart, in a circle twenty-nine feet in diameter, and, with the exception of two of the pipes, down to the ledge. This proved to be a difficult task on account of the many bowlders encountered. A ten-inch casing pipe with flush joints was first drilled down by various means, a drill being worked within the pipe when necessary and the material removed by jetting or by a sand pump. The casing pipe being once down to the ledge, a freezing pipe was placed inside, and the outer casing pipe drawn up and used for the next pipe. The freezing pipes left in the ground were eight inches in diameter, the lower ends being closed. Inside of these eight-inch pipes were placed pipes one and a half inches in diameter, open at the bottom. These inner pipes, as well as the outer pipes, were connected together at the top of the ground, as shown in the pipes at the left of the illustration, forming a complete circuit, through which a cold brine was circulated.

The brine used was a solution containing about twenty-five per cent of calcium chloride, which has a very low freezing point. The brine was cooled with an ice machine, having a refrigerating capacity of fifty tons of ice per day. The ammonia was compressed to about 135 pounds per square inch, and cooled by passing through coils immersed in water kept cold by pumping from a brook. Then the ammonia was allowed to expand through coils immersed in the brine and finally returned to the compressor.

The temperature of the expanded ammonia was such as to cool the brine to a few degrees below zero, Fahrenheit. This brine, being circulated through the ground pipes, was raised in temperature about 2° F. After forty days' freezing, an ice wall ten feet thick was formed around the shaft. The excavation, commenced soon after starting the ice machine, had in the meantime reached a depth of forty feet. Thirty days more sufficed to reach the ledge. The shaft was, for convenience, curbed as the excavation proceeded. This was, however, not necessary, as the walls would have stood vertically throughout the whole depth very well. The temperature of the air within the shaft was generally below the freezing point, and there was no indication of the exposed material thawing. The curbing was made of horizontal sets of timbers, sixteen inches square, placed two feet apart, with four-inch vertical plank behind the timbers. The cross walls were put in place afterwards.

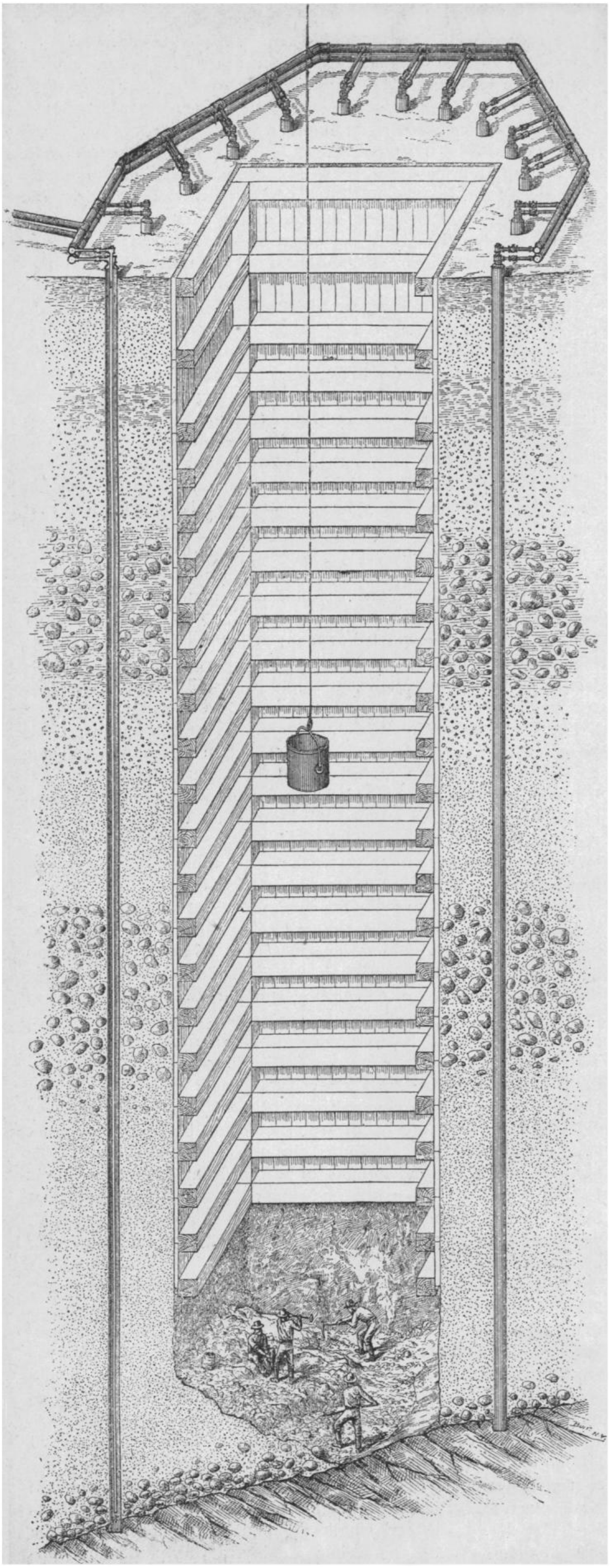
The timbering was supported from one set to another by bolts placed near the corners of the shaft, the whole system being suspended from cross timbers at the surface of the ground. The unfrozen area within the shaft grew less as the actual running time of the freezing machine increased. By the time a stratum of bowlders was encountered, the frozen area reached nearly across the shaft; but when quicksand containing a large percentage of water was passed through, the unfrozen area was greater. The reason of this is readily understood when it is remembered that the specific heat of water is about five times as great as that of any of the other materials, and therefore the strata containing most water would require more cold and would be longer in freezing.

The hardness and appearance of the fractures of the frozen quicksand approached those of sandstone. Granite bowlders embedded in it showed a decided tendency to fracture across rather than break loose. The tensile strength of the frozen ground, as determined by a cement-testing machine, was equal to that of the best neat Portland cement, and varied from 350 to 450 pounds per square inch, and its strength against crushing, as determined from inch square cubes, was 850 pounds per square inch. This furnishes data from which the strength of the surrounding frozen wall may be computed as an arch. An ice wall ten feet thick will be found sufficiently strong for any case likely to occur. Near the bottom the freezing extended within the circle solidly ten feet from the pipes. It is not known how far it extended outside, as no borings could be made through it. A test pit was sunk outside the shaft as far as the water would permit (some fifteen feet), and from this it appeared that the freezing extended outwardly from the pipes about three-fourths as far as within the circle.

The material was mostly loosened by picks and chisel bars. Powder was used for blasting for a considerable time, but this was discontinued for fear the concussion might injure the pipes or fracture the wall. The material was hoisted out by an iron bucket, which also took out the water that stood in the unfrozen centre. There was no appreciable inflow of water until the excavation had reached nearly to the ledge, when a small amount was noticed.

On reaching the ledge, it was discovered that it was so fissured and disintegrated as to allow water to come in under the frozen wall at a corner in the vicinity of one of the pipes that did not extend to the ledge. The shaft was allowed to flood, water being pumped into it at the same time to prevent as much as possible the flow of water through the opening. An eight-inch freezing pipe was put in place in the shaft, the foot being directly at the opening, and earth was piled around it, the purpose being to freeze the leak off. Then cold brine was circulated through the whole system of freezing pipes for ten days uninterruptedly, when the water was pumped out, and the seam was found to be quite closed; but there was still a small amount of percolation through the ledge, requiring occasional pumping to clear the shaft; ice had collected several inches thick on the side shaft, and several feet in the corner, where the extra freezing pipe was placed.

The work of removing the earth which had been thrown in and the clearing up of the bottom continued for two weeks, when the water from the ledge increased at such a rate that it was decided to lay short auxiliary freezing pipes against the leaks and freeze the ledge itself. This was done, the shaft was flooded again, and the brine circulated thirty days. When the water was pumped out, the leakage was found to be small, and excavation was proceeded with. The soft, shaly rock was removed till a hard bear-



PŒTSCH FREEZING PROCESS IN SHAFT SINKING, AS APPLIED AT THE CHAPIN MINE.

ing was obtained for the timbers, and the timbering was completed from the surface of the ground to the excavated depth.

The obvious remedy for inflow from the rock will be in the future to put the pipes far enough into the ledge to freeze off the surface seams. Pipes are now being put down for a coal mining shaft at Wyoming, Pa., and they will be put several feet into the rock, which will no doubt intercept all troublesome percolation.

This operation of this process was the first application on any considerable scale in the United States. Water is the engineer's most troublesome enemy, and its conversion into a barrier of defence is a triumph of engineering as effective as it is novel. This process can be applied to excavations for bridge piers, to tunnels, and to other general work of a difficult and expensive character as well as to shafts. But in shaft work alone it should be invaluable, as by it numerous valuable deposits of coal and other minerals, now inaccessible on account of overlying strata of water-bearing materials, can be reached, as in the case of the Chapin mines, and in those Belgian coal mines which first led Mr. Poetsch to devise his process.

## THE PRODUCTION OF SUGAR.

YESTERDAY the formation of sugar by plants, says Ward Coldridge, in *Knowledge*, was one of the mysteries of nature. Chemists and botanists, while they knew that ordinary chemical attractions must be the cause, were yet completely in the dark as to how these forces worked. They realized that plants started with carbonic acid and water, and from these waste products of animal existence built up in some unknown way the complex compound, sugar. From the deadly choke-damp to the luxury sugar was a great transformation. The plants could thus build, but men of science could not comprehend the process.

To-day, as the result of some brilliant researches, the explanation has been found. A simple compound, the formation of which by the plant can be readily accounted for, has been transformed into a sugar. To understand the process, it must be realized that abundant evidence proves that plants promote processes which are the opposites of combustion or oxidation. Plants liberate oxygen from its compounds, and absorb that with which it was previously combined. They can liberate oxygen from so stable a compound as carbonic acid, and in water find a source for the hydrogen which is essential to their development. The products which could thus be formed are, respectively, from carbonic acid, the lower oxide of carbon and oxygen; from water, the gases hydrogen and oxygen. Experiments have shown that under the influence of the silent electric discharge, and even without it, carbon monoxide and hydrogen combine to form a simple compound, formic aldehyde, which is immediately connected with the formic acid of the ant and of the stinging-nettle. So the changes which occur in the plant under the combined influence of sunlight and chlorophyl may be represented in symbols as follows: —

$$\underset{\text{Carbonic acid.}}{CO_2} = \underset{\text{Carbonic oxide.}}{CO} + \underset{\text{Oxygen}}{O} \quad ; \quad \underset{\text{Water}}{H_2O} = \underset{\text{Hydrogen}}{H_2} + \underset{\text{Oxygen.}}{O}$$

$$CO + H_2 = \underset{\text{Formic aldehyde.}}{CH_2O}$$

This formic aldehyde was the substance experimented on. When it was suitably treated in the presence of the hydrate of lime, Ca $(HO)_2$, it was induced to combine with itself and to form another compound. The latter is composed of the same ultimate indivisible particles (atoms) and in the same proportions; but they are now differently arranged side by side, and with a larger number in the unit aggregation which chemists call molecules. This compound has now been finally proved to contain not one, but at least two or three members of the family of substances, carbohydrates, to which sugar belongs. Thus in our laboratories can now be imitated the process of which plants previously held the secret.

While, however, the fact is marvellous that a sugar has been obtained artificially, it must be remembered that the process is absolutely uneconomical, for the yield is very small. This remark, too, applies to another process of artificial production. The sweet viscid liquid, glycerin, and its stinking, irritating offspring, acrolein, which gives the nasty smell of burning fat, have both been transformed into sugar; but the quantity obtained is very small in pro-