their bulk and the cost of transit. Within the past few years we have seen great iron and steel works moved from the Midlands and transported to the coast. The railways, in spite of all the advantages they offered, strangled them with their charges, and it was only under the cheaper conditions of ocean transit that they could live. When the prices of cotton goods fell, Manchester found the cost of 36 miles of railway carriage to and from Liverpool so intolerable that it spent millions on a ship canal. From the same city the historical works of Sharp, Stewart & Co. were removed to Glasgow in search of better economic conditions, among which reduction of carriage expenses was a most important item. Hence we see that not only formerly, but also to-day, people who have to earn their living must live—not where they would choose—but where they can thrive the most. Hence we understand how it was that towns grew so slowly until the railway arose to alter our social conditions.

Modern cities are absolutely dependent on the locomotive for their existence from week to week, and it really seems as if some of them were so large that they could not be fed by any other means. Formerly cattle were driven to London, to be there slaughtered, but one shrinks from picturing the state of our roads if that practice still prevailed. Of course our highways have long since ceased to grow. As the town stretches outward into the country, streets multiply, but main avenues remain much as they were at the beginning of the century. The railways carry the increased traffic, and if they were abolished, the first thing to be done would be to build roads to replace them. But even were all done that is possible to replace the railroad and the locomotive, the removal from other industries of the large amount of labor required for transportation, and the immense rise in price of all heavy or bulky materials, would, as we have pointed out, so transform our social conditions that we should have to give up the greater part of what we regard as the pleasant side of life. One does not need to be very old to notice the great change that has come over the habits of the middle and the lower middle classes. What fifty years ago were luxuries are now necessities, while the necessities of those days are re-

century is the rapid increase of knowledge and its immediate dissemination. The increase in labor-saving devices has set at liberty great numbers of men who are able to devote themselves to intellectual pursuits, and to place on record the results of their researches. Their writings, instead of passing slowly and fitfully through a small circle of readers, flash over the world and are accessible to all. We remember once reviewing a book in which the author ascribed the theory of evolution to the express train, because, he argued, without our modern system of railways it would have been impossible to gather together the immense mass of facts necessary to justify the hypothesis. Possibly he was correct; certainly the man of science is as deeply indebted to the railway as is the engine driver, who, but for the locomotive, would have had to gain his living by carrying heavy burdens on his shoulders, instead of merely watching a steam motor do his work for him.

In concluding, it is sad to have to confess that while the railway has given to the bulk of us easier lives and more time for intellectual enjoyment, we have not been able to overtop the mental stature of those that went before us. We suppose that there are now in this country a hundred poets and dramatists for every one in the time of Elizabeth, but how much more worth are the writings of the few than of the many! Our artists, again, have the run of all the galleries of Europe, and can compare the styles of all ages, but still the old masters, who often lived and died within the bounds of a petty Italian state, are beyond their rivalry. Our architecture, alas! is worse than our art. In all these things we must confess our inferiority. Even in science, which is our strong point, Newton, Kepler, and Copernicus stand head and shoulders above us. Great men cannot be made by machinery, and, indeed, it seems as if our modern system were antagonistic to their growth. The average man gains immensely by having a vast amount of information placed at his command, and by being able to enter any field of research that attracts him, but the genius seems to suffer. His relative mental stature is, of course, depreciated by the presence of a crowd of fairly big men among whom he is placed, while his

crucible of refractory earth, No. 12, capable of containing 1 kilo. The crucible, covered with its lid, is heated for one and a half hours in a Perrot furnace. After cooling, the oxide is a dense powder of a violet gray, corresponding to the formula MoO_3 . One heating yields from 760 to 770 grammes of oxide. This oxide was mixed with sugar charcoal, in powder, in the following proportions:

Oxide.....	300 grammes.
Charcoal	30 grammes.

In this mixture the oxide is in decided excess compared with the charcoal. The powder is heaped up in a crucible of coke and submitted to the action of an arc produced by a current of 800 amperes and 60 volts for six minutes. We must avoid the complete fusion of the metal, so as to leave a solid layer in contact with the crucible which would be strongly attacked by the liquid molybdenum. Under these conditions we obtain a metal perfectly pure and free from carbon; it is easy in one hour to prepare more than 1 kilo.

If this preparation lasts more than six minutes, the molybdenum obtained is liquefied, corrodes the crucible, becomes carburized, and we obtain a gray cast metal, very hard and brittle.

CAST MOLYBDENUM.

This cast metal has a specific gravity of 8.6 to 8.9, according to its proportion of carbon. When saturated with carbon it is much more fusible than molybdenum. When rich in carbon it is gray and brittle; at 12.5 percent. of carbon it becomes white, and can be broken up upon the anvil only with difficulty. It presents all the characteristics of the molybdenum studied by Debray. It rapidly dissolves carbon, and abandons it on cooling in the state of graphite, precisely as does cast iron. Nevertheless, when saturated with carbon it yields a carbide, crystallized in fine needles. Gray cast molybdenum is very hard; it scratches steel and quartz. When melted, it becomes a very mobile liquid, which can be poured while giving bright sparks and abundant fumes of molybdic acid. We have been able to melt and cast ingots of from 8 to 10 kilos. These castings had the following compositions:

	White.	Gray.
Molybdenum	95.83	92.46
Combined carbon.	3.04, 3.19, 2.54	4.90, 5.50
Graphite.....	0.00	0.00, 1.71
Slags.....	0.74, 0.53, 0.62	—

MOLYBDENUM CARBIDE.

This compound is prepared by heating in the electric furnace molybdenum binoxide with an excess of charcoal. The best proportions are: Binoxide, 250 grammes; charcoal, 50 grammes. The duration of the heating is from eight to ten minutes with a current of 800 amperes and 50 volts. If we use an excess of charcoal, it is found in the mass in the state of graphite.

The regulus obtained is of brilliant white and has a crystalline fracture; it splits readily. It is readily crushed on the anvil, and we may separate from it small elongated prisms of a distinct crystallization. Its specific gravity is 8.9, and its composition is Mo_2C .

ANALYSIS.

In the various specimens described in this memoir, the molybdenum, after treatment with nitric acid, has been precipitated as mercurous molybdate, and finally determined as binoxide. When the carbide contains no graphite, the carbon was separated by pure dry chlorine, and then determined by combustion in oxygen, according to the weight of carbonic acid collected. According to this method, the portions of carbon are always rather low.

We have obtained the following figures:

				Theory for Mo_2C .
Molybdenum.	93.82	—	—	94.12
Combined carbon.	5.62	5.53	5.48	5.88
Graphite.....	—	—	—	—
Slags.....	0.17	—	—	—
	99.61			

If the carbide contains graphite, it is attacked in a flat bottomed flask traversed by a current of oxygen. The gases evolved pass into a tube filled with copper oxide, the watery vapor is retained in a tube filled with sulphated pumice, and the carbonic acid is fixed in potassa. The increase of the weight of the potassa tube shows the carbonic acid, and consequently the carbon. The acid liquid of the flask, after filtration and washing, shows the graphite, and the molybdenum is next determined by mercurous nitrate. This novel method gave as results:

	9.	10.
Molybdenum.....	92.60	91.90
Combined carbon....	5.15	5.43
Graphite.....	1.61	1.98

On taking account of the graphite and calculating the proportion of molybdenum to the carbon we find:

	9.	10.	Theory Mo_2C .
Molybdenum.....	94.45	94.10	94.12
Combined carbon....	5.55	5.90	5.88

PURE FUSED MOLYBDENUM.

Pure molybdenum has a specific gravity of 9.01. It is a metal as malleable as iron. It can be easily filed and polished, and forged hot. It does not scratch either quartz or glass. When free from carbon and silicon, it scarcely oxidizes in the air below a dull redness. It may be kept for several days unchanged in water, whether ordinary or charged with carbonic acid. In presence of air below dull redness it is covered with an iridescent film, as is steel. About 600° it begins to be oxidized, and yields molybdic acid, which is slowly volatilized.

A fragment of molybdenum heated for some hours in a sloping porcelain tube over an analytical furnace yields, in the upper part of the tube, a felted mass of crystals of molybdic acid. The metal is not covered with any other oxide, and finally disappears, leaving a fine crystallization of molybdic acid. If heated before the gas blowpipe, a fragment of molybdenum emits vapors in considerable quantity. If heated before the

ROCK IN THE FORM OF A TIGER, SITUATED IN THE WOODS OF PAIOLIVE.

garded as only endurable under the stress of the direst poverty. If we search the very meager accounts the historians provide of the manners of the middle ages, we encounter a picture of dirt and discomfort which is absolutely revolting to us. The alteration from the former state of things to the present is almost entirely due to the locomotive and the railway, particularly in northern climes. In southern Europe and in sub-tropical regions life is easier. Clothing and shelter are only required in a very moderate degree, while the soil gives its harvest without much labor on the part of the husbandman. It was under these favorable conditions that the ancient civilizations were reared, aided almost always by successful conquest, and the enforced labor of captive races.

The steam railway is, as we have said, the greatest labor-saving machine that the world has ever seen. If it were only that, it would still excite our admiration, and its inventors and builders would deserve our gratitude. But its effects in the moral and intellectual world probably exceed those in material affairs. Just as people bred in a city differ from their consins of the country, so do the inhabitants of a developed land stand out in comparison with one that still depends on the wagon and the stage coach for its transport. To find on one's breakfast table the replies to letters addressed only twenty-four hours previously to correspondents 400 miles away; to be able to enjoy the exhilaration of tearing through the country at the rate of 40 or 50 miles an hour; to be able to travel from London to Vienna in less than two days; all these are mental stimuli that infallibly show their effect on a population, and cause it to live at a higher rate—to take more out of time—than is possible when one must either remain in one spot or spend a good part of life in getting from place to place. Time is money to most of us, and it is only a small part that we can spend as we please. The major portion is mortgaged beforehand for food and clothing. What we can get out of the remainder in the way of knowledge, experience, and widened views of the world and man depends very much on the facilities we have for locomotion. Not only have we the benefit of what we gather ourselves in this way, but we also share in the gleanings of others. The most characteristic feature of the nineteenth

actual size does not come up to that of the giants of the past.

In all professions we find it admitted that the places of the great men of the early part of the century are not filled again. The average knowledge and ability of the members is immensely raised, and capable men can be counted in dozens where once they were to be enumerated in twos and threes. But it is seldom that we find any that stand apart from their class, on a distinct plane, as was once the case. Our modern improved methods, according to which knowledge is treated as a raw material by mechanical methods, and is then administered like physic, is enormously successful up to a certain point. But beyond that point, the influences which are typically represented by the locomotive tend to repression. The role of machinery is to duplicate existing objects; creation is beyond its scope.—Engineering.

ROCK SIMULATING A TIGER.

THE photograph reproduced herewith was taken in the woods of Paiolive (Ardèche.) It represents a rock in the form of a tiger lying upon its belly with the forelegs extended. It is in the midst of a locality in which rocks abound, which contains many curious things, and which is but little visited.—La Nature.

PREPARATION AND PROPERTIES OF PURE MELTED MOLYBDENUM.

By HENRI MOISSAN.

IN a former paper we have shown that it is easy to produce cast molybdenum, by heating in the electric furnace a mixture of charcoal and of the oxides of this metal. We shall now give the continuation of our researches on this question.

We must first mention that molybdenum, which is obtained in a pulverulent state by the reduction of the binoxide in hydrogen, was fused by Debray before the blowpipe only in the form of small globules containing 4 to 5 per cent. of carbon.

To prepare molybdenum we set out from pure ammonium molybdate, reduced to powder and placed in a

oxyhydrogen blowpipe, it burns without melting, giving off abundant fumes of molybdic acid and leaving a blue oxide, sparingly fusible. If heated in a current of pure oxygen, it takes fire between 500° and 600°; and if the current is rapid, the combustion may continue without the intervention of any extraneous source of heat.

This combustion ensues with intense incandescence, and may serve as a fine lecture experiment.

Melting potassium chlorate attacks molybdenum with violence. The chlorate is melted, and a fragment of molybdenum thrown upon its surface, when it becomes incandescent and revolves upon the surface of the liquid.

The temperature of the reaction rises rapidly, the molybdenum burns with flame, and there escape abundant white fumes of molybdic acid, which remain suspended in the air in the form of white floating filaments. Sometimes the fragment of molybdenum is raised to a temperature high enough to perforate the side of the capsule, which is melted in contact with the metal.

Melting potassium nitrate under similar conditions yields a reaction similar, though less violent, with formation of an alkaline molybdate.

A mixture of molybdenum and lead peroxide heated in a test tube produces a great liberation of heat and light.

Sulphur has no action at 440°, but hydrogen sulphide at 1,200° transforms molybdenum into a bluish gray sulphide, amorphous, having the properties of molybdenite, and leaving, on friction, a black mark upon paper.

Fluorine does not attack molybdenum in fragments, but if the metal is coarsely powdered, there is formed, without incandescence, a volatile fluoride.

Chlorine attacks molybdenum at dull redness, but without incandescence. With bromine the action takes place at a cherry red heat, but without great intensity.

Iodine has no action at the temperature of softening glass.

Silver, zinc and lead fluorides are decomposed, but without the formation of volatile fluorides.

Phosphorus perchloride, if slightly heated, readily attacks molybdenum, forming a volatile chloride, which is easily modified in presence of atmospheric moisture, taking a fine blue coloration.

This reaction is produced with most of the compounds of metallic molybdenum—the oxides, the sulphide, molybdic acid, and the molybdates. It may serve for the rapid detection of metallic molybdenum or its compounds. It is effected in the following manner:

Into a small test tube we put a fragment of the substance in question, adding a little phosphorus perchloride, and heating gently. There are formed reddish fumes of molybdenum chloride and oxychloride, which condense in a brown ring more or less intense. If the quantity of molybdenum is very slight, the ring may be scarcely visible. It will then be sufficient to expose it to moisture to see it take an intense blue tint, due to the formation of hydrated chloride.

The action of hydracids upon pure molybdenum is almost similar to that which they exert upon cast molybdenum. These experiments, however, have been described by different observers, Bucholz, Berzelius and Debray. We merely mention that hydrofluoric acid does not attack it, but on adding a drop of nitric acid the action sets in and continues with energy. In presence of a mixture of equal parts of the two acids the solution is complete, and there remains a rose colored liquid which, with ferrocyanide, gives an intense red brown color, but no precipitate. The mass some hours afterward coagulates to a jelly.

In a current of nitrogen at 1,200° molybdenum, whether in fragments or in powder, does not form a nitride.

It does not combine with phosphorus at the temperature of melting glass.

Boron combines with molybdenum at the temperature of the electric furnace, yielding an iron gray melted mass containing cavities lined with prismatic needles.

Under the same conditions, silicon yields a crystalline silicide not fusible before the oxyhydrogen blowpipe.

The action of carbon deserves to arrest our attention for a few moments.

Pure molybdenum, as above described, is a soft metal, which is easily filed and which does not even scratch glass. If we heat a fragment of molybdenum for some hours to a temperature close on 1,500° in the midst of a mass of charcoal in powder, it becomes cemented, takes up a small quantity of carbon, and its hardness increases so that it can scratch glass. If we then heat it to 300° and plunge it suddenly into cold water, it is tempered, becomes brittle, and hard enough to scratch rock crystal.

Inversely, if we take cast molybdenum containing 4 per cent. of carbon, very hard and brittle, and heat a fragment for some hours with molybdenum binoxide in a lined crucible, it becomes refined, and its surface may then be readily filed and polished.

I attribute this decarburization of the solid cast molybdenum at a temperature very remote from its melting point to the ready diffusion of vapors of molybdic acid through the metal. I consider that these properties may find applications in metallurgy.

If, in a metal saturated with oxygen, such as is obtained in the first period in the Bessemer converter, we wish to remove this oxygen, we add manganese, which is oxidized more easily than iron, and then passes into the slag (Troost and Hautefeuille). It has been also proposed to employ aluminum, which has given good results, because it is combustible, i. e., because it seizes on the oxygen, but which has the inconvenience of producing solid alumina. I think that molybdenum may be used under the same conditions; it would have the advantage:

1. Of yielding a volatile oxide, molybdic acid, which would be liberated immediately in the gaseous state, stirring up the whole mass.

2. Used in a slight excess it would leave in the bath a metal as malleable as iron, and capable of being tempered along with the latter.

The powder of molybdenum, which it has been attempted to use already, cannot render the same ser-

vices, because it burns rapidly upon the surface of the bath in contact with the air without having yielded any useful effect.

ANALYSIS OF PURE MOLYBDENUM.

	11.	12.	13.	14.
Molybdenum....	99.98	99.37	99.89	99.78
Carbon.....	0.00	0.01	0.00	0.00
Slag	0.13	0.28	0.08	0.17

Comptes Rendus, cxx, p. 1320; Chem. News.

[Continued from SUPPLEMENT, No. 1022, page 16341.]

THE USE OF HOT AIR IN DRYING.*

By E. M. COOK, New York.

THE methods of handling textile fabrics, etc., are comparatively simple, and are so well known that it is scarcely necessary to refer to them. Goods in considerable pieces may be stretched from side to side, or up and down, in a drying chamber, in some cases moving automatically, the drying currents having access to them; or they may be passed over revolving heated surfaces, as in the well-known form of paper machine. In handling materials in lumps, grains, or powder, the problem is more difficult, and, apart from revolving cylinders or fixed cylinders with revolving stirring devices, there are but few devices in practical operation. In the revolving cylinder apparatus and that with stirrers, the heat is ordinarily delivered directly from conducting surfaces; and, although air is sometimes used as an accessory, they are not really hot-air driers.

By far the most efficient device for moving material horizontally is the well-known "apron" drier. This consists of a series of superposed, endless aprons, having a slow, continuous motion, each alternate apron moving in opposite directions. Each apron projects slightly at alternate ends beyond its neighbor, and the material under treatment, being fed in a thin layer upon the upper one of a series, is slowly carried forward and deposited successively upon each in turn, and finally delivered at the bottom. The aprons are made of material suitable for the particular substance, and may be perforated; though this, in my opinion, adds little to their efficiency, as the air will always follow the lines of least resistance, which will not be through a layer of the material, however thin. To get a sufficient run, the aprons should have considerable length, and may be of such width as the weight and other properties of the material demand; by which considerations and that of space available, the number of aprons in a drier is controlled. I have recently inspected such an apparatus in practical operation, in use for drying a chemical product, which cannot be subjected to a high temperature. The aprons are eleven in number, spaced 16 in. apart vertically, and are each 50 ft. long and 6 ft. wide, giving a total length of 550 ft. They move at a speed of 150 ft. per hour, the substance being retained in the drier nearly four hours. They are made of cotton cloth, inclosed in a tight wooden casing, and supplied with air, moved by a fan blower over steam coils. The air enters at about 195°, and is discharged at about 135°. Its humidity at discharge is not measured, but from these figures, even making no allowance for losses by radiation, etc., its saturation cannot exceed about 0.18. Obviously this is not an economical application of heat, but as the material contains but little water, this may be of minor importance. The apparatus is considered a fairly satisfactory one, but there is no doubt that by the introduction of the recirculating system, both its economy and efficiency would be promoted.

Another drier of this kind is also in use in Brooklyn, N. Y., for drying brewers' grains. This material carries, fresh from the mash tub, from 75 to 80 per cent. of water. As the saturating liquor carries in solution a large amount of valuable food constituents, it cannot be pressed without sacrifice. It constitutes, when dry, a food of high economical and commercial value for cows and horses; the experiments of the New Jersey Agricultural Experiment Station show that for the latter its value is fully equal to that of the best oats, pound for pound. As a food for cows it is largely used wet; but, as it is subject to rapid fermentation and decomposition, in which condition the milk produced from it is exceedingly undesirable as a food, most of the States have stringent laws against feeding cattle with it in that condition; and, in consequence, much of it produced in summer, especially in the larger cities, is given or even thrown away to get rid of it.

It is obvious that with so large an amount of water to eliminate, and the comparatively low value of the dried grains, utmost economy in drying is imperative. The apparatus in question is on a large scale, having a capacity of about 150 bushels of wet grains per hour, which should produce something more than 2,000 lb. dry; this would require the evaporation per twenty-four hours of over 17,000 gals. (United States of America) of water. It consists of ten aprons, each 12 ft. wide by 50 ft. long, spaced about 24 in. apart, and contained in a substantial brick structure nearly 30 ft. high. The aprons are of wire cloth, varying from the uppermost to the lowest apron of the series, from 8 to 14 meshes to the inch. The motion is at the rate of 6 to 8 ft. per minute, giving from 75 to 90 minutes for the transit of the material, which is automatically fed in a very thin layer upon the uppermost apron. The gases, liberally tempered with air in the combustion chamber, are admitted to the drier at temperatures which, perhaps, vary at the different openings of communications, but was said not to exceed 300°, above which point grains are likely to be scorched. The discharge temperature varies under different conditions of the grains as to moisture, and of the atmosphere, but was said to average 160° to 170°; this indicates a low degree of saturation.

But in any attempt to move material horizontally, for drying, unavoidable drawbacks are encountered. Among the most serious of these are: First, the difficulty of controlling horizontal currents of hot air in a chamber of considerable dimensions, which is much increased by the presence of obstructions, moving or stationary. It is found that the current will be principally confined to the upper part of the chamber, and any material near the bottom will be but little

affected. This difficulty increases with the height and length of the chamber, and can only be partially remedied by especially locating the positions of the inlet and discharge openings, or by admitting air of different temperatures at different heights in the chamber. Second, the influence of the wind, which, when in an adverse direction, has a tendency to drive the current back, causes great irregularity in the drying, and occasionally almost entirely checks it. Third, the amount of power required to keep in horizontal motion a considerable weight of apparatus and material; and, lastly, and by no means the least important where land is valuable, the large space required for driers of this class.

In a vertical chamber or flue the tendency of an ascending current is to diffuse itself uniformly throughout its section; and the presence of obstructions favors and promotes this; also, if the chamber is of considerable height, the natural draught of a heated column will materially assist its ascent, and the direction of the wind will have little or no effect upon it.

The desideratum, then, for handling granular material successfully is a device by which it shall be caused to descend through such a chamber, by a regulated, methodical descent, at such a rate as shall suffice for its drying, and it must be divided into small portions, and frequently turned over, to allow of access of the drying current to all its particles. The material will descend by its own weight, and as we shall only have to control or retard its descent, the power required to do this will be inconsiderable.

In the apparatus which I have devised and constructed for embodying these ideas, the containing tower, T, is of brick, inclosing on the ground a space

of 10 ft. by 13 ft. and is about 80 ft. high; a considerable and perhaps unnecessary portion of the height being utilized for the automatic feeding bin, B, and a receiving bin, R, at the bottom for the dried grains. The drying chamber proper is over 40 ft. in height, and is furnished with 690 receptacles or trays for the material, arranged in 60 tiers, so placed that those in each tier break joint or alternate in position with those in the tiers above and below. These trays, t, shown in the enlarged detail, are 8 ft. long, made of galvanized

* A paper read before the Chemical Society, London, May 6, 1895. From the Journal of the Society.