THE LOETSCHBERG TUNNEL THROUGH THE BERNESE ALPS.

By DR. ALFRED GRADENWITZ.

Soon after the completion of the Simplon tunnel, the construction of a tunnel through the Bernese Alps was begun, to establish a communication between Western Switzerland and France on the one hand, and Italy on the other. Through this new tunnel will pass a railway leading from Frutigen to Brigue at the northern end of the Simplon. This line is 33 miles in length, and comprises a considerable amount of tunneling in addition to the main tunnel $3\frac{1}{2}$ miles in length.

After leaving Frutigen, situated at an altitude of 2,560 feet above the sea level, the line continues along the eastern side of the Kander Valley. It then climbs up the valley side by means of a double bend and spiral tunnel, and at about the thirteenth mile reaches the entrance to the Loetschberg tunnel. The northern section comprises several short tunnels and a large number of bridges. The gradient averages about 1 in 37. The entrance to the main tunnel is situated at 2,935 feet above the sea level. The highest point of the line lies within the tunnel at a little more than 3.72 miles from the northern entrance, where the elevation of 4,594 feet is reached. The gradient in that portion of the tunnel is 1 in 443, and after passing the summit changes to a falling one of 1 in 263.

The northern entrance to the tunnel is at Goppenstein, at 4,000 feet above the sea level. The line then descends the Loetschen Valley, and just before reaching Giesch, bends, at right angles, toward the east, in order then to wind up the northern side of the Rhône Valley. It eventually crosses the river and joins the Rhône Valley line of the federal railways leading from Lausanne to the Simplon tunnel at Brigue. From Goppenstein to Brigue there are thirty-seven tunnels and twelve large bridges.

The construction work is controlled from the central office, located at Berne. The line was divided into four construction divisions, viz.:

- (1) The northern approach.
- (2) The actual tunnel work of the northern side.
- (3) The actual tunnel work of the south side.
- (4) The southern approach of the tunnel.

Each of these divisions has a separate installation of stores and tools.

All the machines and tools installed at Frutigen, which is the head station of the northern approach, are electrically operated, current being supplied at 15,000 volts from a central station at Spiez, and reduced to 250 volts. At the Kandersteg station, which is in charge of the second division, the plant includes a transformer for reducing the 15,000-volt current supply to 125 volts for lighting, and 500 volts for driving purposes. Four air compressors installed near the transformer station supply air for machine and drill working, as well as for the locomotives. Electrically operated centrifugal pumps and ventilation fans are likewise installed at this point, where there are, in addition, repair shops, explosives stores, and dwellings for the workmen. The Goppenstein plant, at the southern entrance of the tunnel, is quite similar to the former, three-phase current being supplied from a power station on the river Loetschen, at 5,000 volts.

In place of the older method of conveying all supplies by mule teams from the railroad station at Giesch, a construction railroad has been built. At Brigue, which commands the fourth division, is installed a plant, similar to the Frutigen installation, single-phase current, at 250 volts, being supplied by a local company.

The tunnel will be traversed by a double-track line which, however, at both ends is combined in a single track. The tunnel is lined, as rapidly as construction allows, with a concrete $1\frac{1}{2}$ foot in thickness; the extreme internal width inside this lining is to be 26 feet 3 inches. The height from the rail level to the center of the roof arch is 20 feet. A drain 2 feet square is provided at the base of the tunnel center.

A ventilating tunnel is built close to the western wall of the main tunnel; it will be rectangular in shape, tapering from the ends toward the center, and will have openings connecting to the tunnel proper, at frequent intervals. The twenty-four minor tunnels, situated along the construction railways, are all of small bore and single track.

According to reports by Mr. H. P. Kieffer, who recently visited the tunnel, the plant used in driving the main tunnel includes compressed-air drills of several types; the experience gained in the driving of the Simplon tunnel being amply utilized. The dump, as well as the workmen's cars, are handled by small compressed-air locomotives. The construction lines, leading from Brigue and Kandersteg to the tunnel portals, are of 9-inch gage, and are worked in the open by small four-coupled and eight-coupled steam locomotives.

The drills are set on a carriage consisting of a track with a wheel base of about 6 feet, which lies on the regular handling track. Mounted on this track, paral-

THIS LEDGE OF ROCK WILL EVENTUALLY SUPPORT THE MAIN LINE.

THE PERILOUS CHARACTER OF SOME OF THE PRELIMINARY WORK ALONG THE BRIGUE-GOPPENSTEIN LINE.

WHERE THE RAILROAD CROSSES A RAVINE.

PROFILE OF THE LOETSCHBERG TUNNEL.

SECTIONS THROUGH THE TUNNEL.

MAP SHOWING COURSE OF TUNNEL.

TIONS THROUGH THE TUNNEL.

DRILL CARRIAGE CARRYING SIX DRILLS USED IN THE BOTTOM TUNNEL HEADING, ONE OF THE DRILLS BELONGING TO THE LOWER SHAFT BEING OFF WHEN THIS PICTURE WAS TAKEN.

THE LOETSCHBERG TUNNEL THROUGH THE BERNESE ALPS.

SCALING A PRECIPICE ALONG THE SECTION FROM BRIGUE TO GOPPENSTEIN.

A GLIMPSE OF THE MOUNTAINOUS COUNTRY THROUGH WHICH THE TUNNEL PASSES.

lel to the longitudinal tunnel, are two I-beams, hinged to swing vertically. On the forward end of each of these beams, which are substantially reinforced, there is mounted a heavy shaft bar, set transversely, and pivoted to swing in a horizontal plane. At the opposite ends of the I-beams are counterweights. The compressed-air connections are controlled from a truck and fed from a line of hose at its rear. As the drills remain on the carriage at all times with the air connection intact, there is hardly any possibility for the dirt and grit to get into the movable parts of the drill and to impair its efficiency. The drills are of a large size, having a piston diameter of $3\frac{3}{4}$ inches. At Goppenstein there are two electrically-driven Ingersoll-Rand compressors, giving a pressure of from 90 to 110 pounds per square inch at the drills.

Acetylene lamps, carried by the workmen, are used for lighting the tunnel, each man being expected to purchase his own lamp and to keep it in repair. As, however, the blasting blows out every lamp in the tunnel, there are many periods of total darkness just at the time when the light is most urgently wanted. Electric light would, obviously, have been far safer and much more convenient and economical.

Owing, apparently, to the very careful study made of all conditions previous to beginning the actual work, the rate of progress in Swiss tunnels is remarkable indeed. The workmen on the Loetschberg tunnel (mostly Italian laborers) number at the present time about 3,500 at both headings. The work is done in three 8-hour shifts, each shift drilling about two rounds and shooting twice, which makes an average of 6 to 7 feet per shift, or about 18 to 21 feet per day. A liberal bonus is granted to the workmen for speed above a certain rate. The work on the northern side has been temporarily discontinued, after the terrible accident which occurred last year.

The bottom heading is from 6 to 8 feet high, and about 8 feet wide. Upraises are made from the bottom heading every 620 feet, and a small top heading is started from these upraises. The work of taking out the tunnel to its full section is, then, continued from this upper heading. Horizontal benches are worked ahead, and chutes are opened to the bottom heading, out of which to take the muck, heavy timbers reinforced by steel I-beams separating the upper headings and keeping the muck from falling on the workmen below and blocking the service line. The timbering is removed as soon as the top heading is applied, and placed further in the tunnel. Solid concrete is used to bring the tunnel to its exact section.

Before blasting, a heavy sheet-steel plate, about 7 by 4 feet, is laid down just ahead of the drill carriage, at a level with the track. When the blasting is completed for one round an entrance is rapidly made through the muck pile and down to the steel plate, and it is made wide enough to allow the arms carrying the drills to get through and into the top of the heading. Drilling is begun, and the dislodged muck is taken out while this work is in progress. Thus practically no time is lost in the progress except in leaving the drill carriage and blasting. Twelve holes arranged in four horizontal rows, about 4 feet deep and 2 inches wide at the base, are usually taken in each round. When the round is all drilled, the carriage bearing the six drills is run back to the last turn-out, and the blast fired. The charge is exploded by a fuse-and-cap method, the fuses being all ignited at the same time. Owing to a careful regulation of their length they are, however, not made all to explode at the same instant. Three fuses are placed in each hole in the bottom row, and two in the others, and though a large amount of powder is used for this method, it breaks the rock up very evenly. Electrically-fired exploders have not yet been found satisfactory enough to be adopted.

Mr. Kieffer's report on his experience in visiting the tunnel is exceeding well suited to give an idea of the extraordinarily trying conditions under which a gigantic work like this is performed.

"I spent the major portion of a day in the main tunnel and several hours at the headings to watch the operations of the drills, the effects of blasting, etc. I believe I have never in my life spent the corresponding number of hours on any other work which were as nerve racking as those in Loetschberg. I stood many times knee deep in water, in total darkness, and felt the awful precessive action of the blast as the rounds were shot. The air was filled with dust, and the fumes of explosives to a degree almost to suffocation. We would hear pieces of rock falling around us as they were dislodged from the tops of the headings.

"I thought every moment would be my last. This, combined with the knowledge that one is almost in the center of a mountain with solid rock above for thousands of feet, makes one feel that it is not the safest place in the world. Little streams of water would be opened in the sides and top of the headings during the blasting, and water poured out of the almost solid rock, incidents which do not add to one's comfort."

ELECTROCHEMICAL AGE.*

SCIENCE OF METALLURGY NOW ENTERING A NEW ERA.

BY ELMER E. CAREY.

FROM an examination of current scientific literature it is apparent that the science of metallurgy is now entering the electrochemical age. Copper has long been refined by electrolytic methods, and now copper sheets, tubes and wire are being made directly from copper ore by electrolytic deposition. Full accounts of this process have appeared recently in the SCIENTIFIC AMERICAN SUPPLEMENT. Electrolytic processes are destined in time to supplant all other methods in the reduction of metalliferous ores; the United Steel Corporation has adopted the electrolytic method of making steel rails, and it requires no prophet to see that the electric furnace will in time displace the various types of blast furnaces. Iron, tin, aluminium, sodium, and mercury are particularly adapted to electrical reduction; sodium is easily recovered from sea water by electrolysis. Aluminium will soon be as plentiful as iron when the various electrolytic processes now in use are brought to perfection; nitric acid is being manufactured from the atmosphere by electrical processes; feed water for boilers is being treated by the electric current to prevent scaling; drinking water is softened and purified; sewage disinfected, and the technical journals every month announce a new application of electricity or some new electrochemical process. All electrochemical processes are easily controlled; all the actions are positive; the character of the product may be altered at will; the resulting products are better in every way than those made by the older methods. Metals produced by electrochemical action are free from impurities; they are stronger, more tenacious, finer grained, and surpass the productions of the furnaces and smelters. Steel made by the electric furnace is far superior to Bessemer in every respect. The very acme of fine tool steel can be made from the black sands of the Pacific coast by means of the electric furnace, and here is the hint of an industry, now dormant, which is capable of being extended into mammoth proportions.

In the refining of gold, electrolytic methods are gradually superseding other methods; an electrolytic refining plant is in operation at the San Francisco mint. Electrochemical methods for the extraction of gold from ores were described some seventeen years ago, and during the last two years experiments have been conducted on this coast by various parties, and utility, value, and efficiency of electrochemical amalgamation and cyanidation fully established. Electrochemical action greatly increases the affinity of mercury for gold, and the action of KCN as a solvent is greatly hastened and intensified when electrochemical conditions are present.

"Within the last decade the problem of using electricity in a practical and efficient manner in the extraction of values in metallurgical processes has received the earnest attention of many investigators. It has long been known theoretically that the action of mercury and cyanide may be greatly intensified by the introduction of electrochemical conditions and inventors have been at work on the problem of constructing suitable apparatus to make practical use of the powerful aid of the electric current.

"One of the first applications of electrochemicals to modern metallurgical methods consisted in suspending a plate (cathode) in a cyanide tank and recovering the values thereon directly by electro-deposition. This slight improvement was found to give an improved extraction and it is strange that the matter did not receive more attention as this advance, slight as it was, pointed the way to still greater improvements, and was a hint that should not have been overlooked.

"The next step was to electrify the entire contents of the tank, thus reinforcing the cyanide with the powerful cleansing and reducing action of electrochemical forces; with proper electrolytic conditions it was found that the percentage of extraction is much higher and the time of treatment much shorter; and at the same time, as the values pass into the solution, they are simultaneously deposited on the amalgam plate by the electroplating action of the current, and the cyanide released for another cycle. The great efficiency of this system over the usual cyanide methods has been fully demonstrated; it is quicker, more positive, extracts a higher percentage of value, costs less to install and to operate, and in addition will extract values from pulp which is not susceptible to the action of ordinary cyanide solutions.

"Turning to amalgamating practice, it may be said that electrochemical methods may now be successfully used in connection with the usual battery plate. After

a long series of experiments, extending over a score of years, a very simple method of converting the standard plate into an electrochemical amalgamating device of remarkable efficiency has been devised. The electrochemical system of amalgamation is designed to extract from the sands or pulp all gold values not incased; it is entirely a new system of amalgamation, designed to do the work of the ordinary mill plate, including the treatment of slimes, and at the same time to extract values which cannot be saved by the usual mill practice and which otherwise would require cyanide treatment; to do all this in one single inexpensive and continuous operation, requiring practically no more outlay for installation and maintenance than the usual mill plate. The system also furnishes a method by which the Alaska beach deposits, black sands, hydraulic, placer, and dredge tailings, mill tailings, desert deposits, and many low-grade propositions can all be profitably worked. The broad claim made for the electrolytic system is that it will save all values not incased.

"*Preliminary Treatment.*—It may be sometimes necessary to grind ore or sands to 100, 150, or even 200 mesh, before the values are released, but after this has been done, the pulp is simply passed over the amalgamating device, and the electrochemical forces automatically extract the value to such an extent that usually no further treatment is profitable. In ordinary cases, values are recovered at 80 mesh. In certain cases where the ore is unusually refractory, base or rebellious, it may be necessary to treat the tailings for an hour or two by the continuous electro-cyanide process, which is an exceedingly simple and inexpensive operation, but withal very efficient.

"*Mode of Construction.*—The electrolytic method of amalgamating calls for a sluice box of suitable width, the length being 40 or 50 feet, or even longer according to conditions. In the bottom of the box is an ordinary copper plate acting as a cathode. Graphite anodes of suitable construction are arranged to conduct the low-voltage current into the water (electrolyte) passing over the device. Pulp of proper fineness, screened gravel or sand is passed into the apparatus by suitable means. Certain solutions are also added to the water. A critical low-voltage current of proper amperage is passed into the anodes; the water carrying pulp, etc., acts as an electrolyte, and makes the electric connection with the copper plate (cathode). In operation the water is at all times electrified and the copper plate is also constantly under electrical action. The device can be made of any desired capacity.

"*Essential Elements of the System.*—So far as the electrochemical actions and processes are concerned, there are five cardinal conditions or points to consider:

- "(a) The anodes.
- "(b) The flowing body of water, pulp, slimes, etc. (electrolyte).
- "(c) The copper plate (cathode).
- "(d) Certain solutions added to the water:
 - "1. Mercurial solution.
 - "2. Sodium solution.
 - "3. Hydrogen solution.
- "(e) Low voltage current.

"The anodes and cathodes are connected with a 5-10 volt generator in the usual manner; the usual volt meter, rheostat, and ammeter being in place. The current used has approximately the density of about five-tenths of an ampere per square foot of cathode surface."

In operating the mercury solution is mixed with water passing into the device. The amount of the solution, which is standardized, depending upon the values in the pulp. About the same amount of mercury is needed as in the ordinary practice. Practically all the mercury is recovered in the amalgam. Several chemical, electrical, and electrochemical processes are constantly and simultaneously in operation. When the machine is once adjusted for given conditions, these processes and reactions are synchronous, automatic, and mutually balanced, all of them combining perfectly to assist in the recovery of values. In this system the various powers, affinities, and laws of electrochemicals have been perfectly balanced and harmonized to produce certain desired results, and the system beautifully illustrates how natural laws may be used to serve mankind when intelligently adjusted and applied. A few more important reactions will now be mentioned.

"*Intensified Chemical Action.*—All chemical action is greatly intensified under critical electrical conditions. Amalgamation is a chemical action, and the affinity of

mercury for the metals is greatly quickened by the electric current. The chemical processes described below are much more rapid and effective under the electrolytic conditions than they usually are. In a similar manner the action of a cyanide solution can be greatly augmented and intensified; in electro-cyanidation values are recovered which are refractory in the usual solutions; and the time of treatment is reduced to one or two hours, while the gold is recovered by electro-deposition in the form of amalgam.

"*Deposition of Mercury.*—The even, constant and uniform deposition of virgin (nascent) mercury on the cathode plate is the crucial operation of the system. The mercury is deposited from the mercuric solution mentioned above by ordinary electrolytic action; an electro-plating process is in operation, and we have the cathode plate covered with a bright, uniform and chemically pure coating of nascent mercury, which remains in a perfectly "healthy" state as long as working conditions continue. The deposition of mercury and the character of the amalgam are at all times under absolute control of the operator. The mercury coating or plating adheres tenaciously to the copper plate, and the passing volumes of water, sand, pulp, etc., have no effect upon it. With proper adjustment, no excess of mercury is possible, and no "floured" mercury is discernible in panning the tails. This coating or plating of mercury above mentioned will stand the action of a heavy volume of running water containing a full load of pulp; even water carrying a full load of magnetic iron has no injurious effect upon it.

The mercury deposited by electrolytic action is nascent or virgin mercury; its affinity for metals and gases is far greater than usual; its amalgam forming powers are intensified to such a degree that rusty, greasy, or pyritic gold is instantly amalgamated; platinum is absorbed as quickly as gold when sodium is present in the amalgam (see Sodium Amalgam). Grease, talc, silicious coatings, or sulphurous conditions in connection with gold particles have no effect in preventing amalgamation, and "fouling" or "sickening" of the plate is impossible. The use of electrolytic amalgamation insures at all times a constantly bright, healthful, and powerfully active mercurial surface, impossible under the usual practice. The behavior of the mercury under electrolytic conditions is entirely different from its action in ordinary amalgamating practice; and conclusions based on the usual mill practice will not apply in the new method.

"*Nascent Hydrogen.*—Hydrogen at the moment of its liberation from a compound is known as nascent hydrogen; the gas in this condition has much more powerful affinities than ordinary hydrogen; nascent hydrogen has increased powers as a reducing agent; it destroys instantly organic, greasy, and foul conditions; it unites instantly with the oxygen of iron rust at ordinary temperatures, thus cleaning "rusty" gold; all impurities in the water are counteracted, and the action of nascent hydrogen on the mercury is such that fouling of the plates cannot occur. One authority states that in the presence of nascent hydrogen, mercury cannot "sicken" or oxydize or become sulphated.

The action of nascent hydrogen as a cleanser and reducing agent is used to advantage in the electrochemical amalgamator, and if the gold particles are unusually coated or rusty, additional volumes of hydrogen can be obtained through electrolysis by adding some inexpensive solution of potassium or sodium. Under the action of electrolysis, the mercury as fast as deposited, absorbs free hydrogen, which is occluded throughout the whole mass of mercury; large volumes of hydrogen are thus absorbed, and the gas is all the time exercising a powerful cleansing and reducing effect, and preparing the way for amalgamation. Mercury, which has absorbed hydrogen under these conditions is in the best possible condition to form amalgams.

"*Formation of Sodium Amalgam.*—When sea water is used in the electrolytic system of amalgamation, or when a solution of common salt, or some solution containing a sodium salt is mixed with the water entering the device, we have the deposition of nascent metallic sodium by electrolysis; nascent sodium is brought into contact with nascent mercury, and a sodium amalgam is formed, which is absolutely pure chemically; we may say sodium amalgam in its "nascent" state is formed, in which state it must always remain healthy; it also in this state has a much stronger affinity for the metals than the usual sodium amalgam of the arts. Sodium amalgam will hold free gold in any condi-

* The Los Angeles Mining Review.