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CONTENTS

FEBRUARY 1914

Page

High Head Hydro-Electric Power Development in the Sierra Nevadas 193

Briquets and Briquet Making 212

Microscopic Study of Electro Deposited Iron 218

Simple Gyroscopic Action 226

With the Alumni 234

Editorials 240

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VOL. XVIII FEBRUARY 1914, NO. 5

A HIGH HEAD HYDRO-ELECTRIC POWER DEVELOPMENT IN THE SIERRA NEVADA MOUNTAINS, CALIFORNIA.

WALTER E. JESSUP, '12.

At Big Creek, California, the initial development of one of the most interesting power schemes in the country is being completed. The interest is because of the very high head used, the large amount of power to be obtained from a comparatively small flow of water, the extreme length of the transmission line and the unprecedented height of the transmission line voltage.

Big Creek is an eight-mile tributary of the San Joaquin river which rises in the snow capped Sierras at an elevation of about 8,000 feet and is located in Fresno county seventy miles east of Fresno. The upper reaches of Big Creek flow through a mountain meadow, which by the construction of dams across each of the three natural outlets forms a basin or lake of nearly 125,000 acre feet capacity. The lake thus formed is about four and one-half miles long and one-half mile wide.

On the north and east of this basin the snow clad peaks rise to elevations varying from 9,000 feet to 11,000 feet enclosing a drainage area of eighty-eight square miles. The warm moisture laden winds from the Pacific Ocean striking this high barrier are here relieved of a large part of their burdens and this accounts for the high annual precipitation on this drainage area, usually amounting to over eighty inches. The run-off from this drainage area, a large part of which is heavily forested, is about fifty inches annually. The basin contains sufficient storage to develop 80,000 H. P. at fifty per cent. load factor for 180 days with no water flowing into it. The run-off records covering a period of several years show that with this storage sufficient continuous flow to develop 90,000 H. P. at fifty per cent. load factor can at all times be expected. The initial development of 80,000 H. P. requires approximately 240 second feet for peak load.

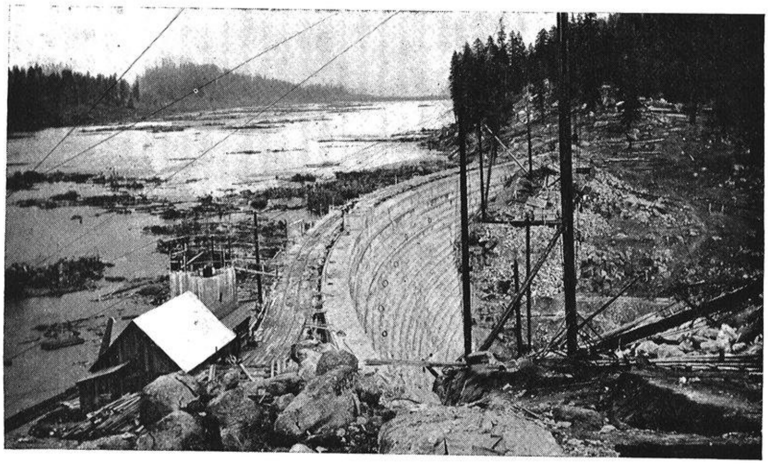


FIG. 1.—*Dam 3, the Basin Lake and the Intake Tower Leading into Tunnel No. 1.*

The site of this development is in a rough, rugged and wooded country fifty-six miles from the nearest railroad connection and the transportation of the 50,000 odd tons of cement, the machinery, materials and supplies presented the first big problem. The difference in elevation between the main line of the Southern Pacific R. R. at El Prado and the site of Power House No. 1 is some 4,400 feet. It was decided early that the usual methods of freighting in this district by twelve and sixteen-horse freight wagons was out of the question because of the difficulties, the length of time required to make a trip and the excessive cost. Winter conditions in the mountainous districts made the rate as high as $20 per ton. It was estimated that with a twelve-horse freight team arriving every ten minutes day and night on the site it would require four years to get the necessary freight in.

Accordingly a standard gage railroad was built from El Prado to the site of Power House No. 1 at Cascada. The railroad has been incorporated under the name of the San Joaquin & East-

Fig. 2.—*Hoist No. 1 Leading from Cascada to the Basin Maximum Gradient 85 Per Cent.*

ern R. R. as a common carrier under the laws of the state of California. For half of the distance the route leads through an easy rolling country where twenty degree curves and two and one-half per cent. grades are the maximum but after leaving this flat lower country at Auberry the railroad starts a rapid ascent as it enters the Sierra National Forest Reserve and follows the grade contour of the country very closely with sixty degree curves and five per cent. uncompensated grades for the maximums. Sixty-ton Shay locomotives of the geared type are required for the mountain division and have given very satisfactory service. This division might well be called the Route of a Thousand Curves and the natural scenery is of a tourist attracting beauty and grandeur. The time required for the building of the road, including the location surveys, the purchase of right of way, the arrangements for government permits and actual construction was but 165 days and probably sets a record for rapid railroad building in difficult country.

At Cascada a complete railroad yard was laid out and connected with a standard gage hoist which operates up the 2,000 foot hill to the basin above. The top of the hoist, nearly 5,000 feet long, is connected with a railroad of some seven miles of track, connecting the dams, the gravel pit, the saw mill and the various camps in the basin. Eight construction locomotives and a full equipment of dump, flat and gravel cars handled the material for the construction of the three dams located here.

The floor of the basin is at an elevation of 6,800 feet and the plans for the initial development call for a water elevation in the lake of 6,915 feet. Dam No. 1, the largest on the project, is built across the outlet through which Big Creek leaves the meadow and is 140 feet high at its highest point and 812 feet long. The central portion of the dam is arched upstream with a radius of 954 feet and connects the end sections or retaining dykes. The section is of the triangular gravity type with the upstream face vertical and the downstream face stepped and roughened to bond the concrete which will be added to the section when the dam is ultimately raised fifty feet higher. The added fifty feet of storage will supply the ultimate development at such time as the market for power demands it. This dam is constructed of mass concrete and large pudding stone and contains 59,000 cubic yards of concrete masonry. Three forty-two inch diameter sluice gates operated by hand from the top of the dam are placed so that the lake may be drained and were used to control the flow of Big Creek during the construction period. Dams No. 2 and 3, located across the two remaining natural outlets from the meadow, are of similar design. Dam No. 2 is eighty-one feet high, 1,015 feet long, arched upstream to a radius of 800 feet and contains 27,000 cubic yards of concrete masonry while dam No. 3 is 126 feet high, 450 feet long, arched to a radius of 625 feet and contains 31,000 cubic yards of concrete masonry.

The excavations for the dams were carried to solid rock formation found from twenty to ninety feet below the surface. Gravel was hauled in form a pit in the basin now covered by the lake, by locomotives on the railroad connecting the dams. Much of the large rock and stone used was taken from the sites of the dams and placed by stiff-legged derricks. Lumber for forms was cut in a saw mill built for the purpose, the pine trees cut in clearing the site of the lake being used. The motor-driven concrete mixers were located above the forms at an elevation high enough to deposit the whole mass by gravity. Wooden chutes led from the mixers to the space between the forms. The concrete plant was capable of depositing from 1,000 to 1,500 cubic yards of concrete daily, the work being carried on continuously. Provision was made in the tops of the dams for flashboards and they have been installed, raising the elevation of the lake to 6,920, five feet higher than the top of the spillways.

Below the meadow the course of Big Creek is very precipitous dropping 4,000 feet in six miles, all of which is available for power. This drop is divided by nature into two nearly equal parts, the first 2,100 feet and the second 1,860 feet, and a power house is now located at the base of each of these power drops, power house No. 1 being at Cascada, the end of the construction railroad, and the other five miles farther down stream.

Water from the basin lake is taken into the tunnel and flow-line pipe leading to the head of the penstocks of Power House No. 1 through an intake tower located near the west end of Dam No. 1. This tower is built of reinforced concrete with a twenty foot internal diameter and a height of 104 feet. To prevent debris from passing in with the water the entrance, extending from the top to the bottom of the tower, contains steel bar screens. The entrance screens are divided into three vertical sections seven feet, six inches wide and are to be kept free from clogging by debris by motor driven mechanical rakes designed to operate over the whole area of the screens.

A nine-foot diameter gate at the bottom of the tower and opposite the screen controls the flow into tunnel No. 1. The gate and its bearings are necessarily of heavy construction, the design calling for a gate to stand the pressure head produced when the lake level is raised to its ultimate elevation of 6,965, fifty

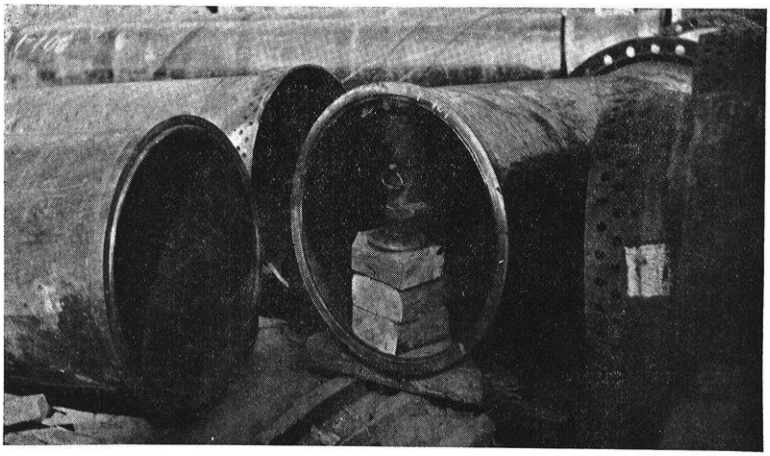


FIG. 3.—*Lap Welded Penstock Pipe Showing the Two Kinds of Joints, the Flange Bolted and the Bell and Spigot Riveted.*

feet higher than the level of the present spillways. This would produce a head of 140 feet on the gate and a total pressure of some 275 tons. The disk is operated by two stems and the operating machinery is designed to open the gate under this maximum unbalanced pressure. However the pressure on the two sides of the disk may be equalized by opening a twenty-four inch diameter by-pass valve located just above the main gate and discharging into a thirty-six inch diameter air shaft which leads from the top of the tower to the tunnel. A foot bridge from the top of the dam leads to the house on the top of the tower enclosing the rakes and gate operating machinery. The thirty-six inch air shaft provides for an entrance for air when draining the tunnel and a ladder in it gives access to the tunnel for inspection purposes.

The tunnel is twelve feet in diameter, 3,880 feet long and is driven on a grade of two feet per thousand through a solid granite ridge along the shore of the lake. The tunnel has a capacity large enough to drive six 20,000 H. P. Pelton wheel units under the 1,900 foot effective head available at Power House No. 1. The tunnel has been made this excessive size to provide for future installations in the power houses. After passing through the ridge the tunnel connects with a 108-inch diameter pipe, one-half inch in thickness, with double riveted longitudinal joints and single riveted circular seams, the connection being made 400 feet inside the portal. The pipe is securely anchored to the bore of the tunnel and concreted into place with a pressure tight joint. That part of the tunnel containing the pipe is lined with concrete and is large enough in diameter to allow inspection of the outside of the pipe. At the tunnel portal the 108-inch pipe branches into two eighty-four inch outlets one of which is closed, not being needed for the initial development.

From the other outlet an eighty-four inch pipe, capable of supplying four-2,000 H. P. pelton wheel units, leads around the grade contour of the mountain, 6,840 feet to the head of the penstocks. This pipe is laid on a grade of eight and four-tenths feet per thousand and as completed lies everywhere so that it has at least one foot of earth covering for protection against rolling rocks and freezing. Manholes for inspection purposes are provided at intervals of 2,000 feet. The thickness of plate varies from three-eighths inch at the upper end to one-half inch at the lower end as the pressure head increases. The longitudinal seams of the three-eighths inch plates are double and triple riveted as the stresses increase and the one-half inch plates are all double riveted. This pipe was furnished by the Willamette Iron and Steel Co.

The eighty-four inch pipe terminating at a point 1,942 feet above Power House No. 1 and 4,500 feet therefrom, divides here into four forty-four inch diameter outlets two of which are closed for the initial development. The remaining two outlets are connected through forty-two-inch hand and motor operated valves direct to the head of the pressure penstocks. These valves have electrical connection with the power house switch board below for remote control of the water leaving the flow line and entering the penstocks. Just below these valves twenty-four inch standpipes extend up the hill side a distance of 425 feet and terminate in thirty-six inch vertical surge tanks extending to an elevation equal to that of the water in the lake.

Just below the gate house for the two forty-two inch valves the two penstock pipes begin their descent in two parallel lines

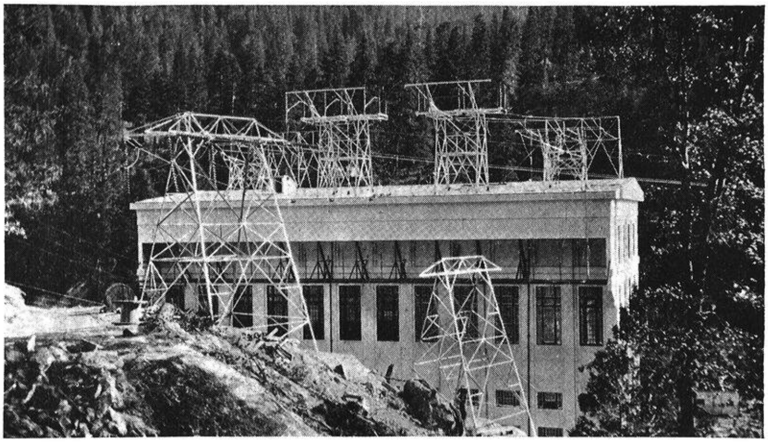


FIG. 4.—*Power House No. 1 Completed Showing the Beginning of the Transmission Line and the Tower Construction.*

seven feet apart, with varying vertical and horizontal angles to correspond to the topography of the steep and rocky slope to the power house. The maximum slope angle is about forty-three degrees, corresponding to a gradient of ninety-three per cent., and the minimum slope angle about five degrees corresponding to a gradient of nine per cent. The pipes are of lap welded steel tubes, manufactured and furnished by the Mannesman Rohren werke of Dusseldorf, Germany. No lapwelded pipe of this size and thickness has successfully been manufactured in this country to compete with that of German manufacture principally on account of the price of labor, and it was deemed unwise to use riveted pipe for the pressure produced by this extreme head.

Each tube is about twenty-six feet long and varies from forty-two inch diameter and three-eighths inch thickness at the top to twenty-four inch diameter and one inch thickness at the bottom. The sections vary in weight from three tons to seven tons according to the thickness and diameter. Up to a head of 1,460 feet the joints are of a bell and spigot type, the circular joint being made with a double row of rivets. For heads greater than this bolted flange joints of special design with a rubber gasket of five-sixteenth inch sectional diameter were used. For a given diameter of pipe the thickness increases with the head until the maximum allowable thickness of one and three-sixteenths inches is reached when the diamter is reduced two inches and this diameter used up to the maximum thickness again. This method was used down to the 36″x26″x26″ breeches joint, 800 feet back of the power house, where each pipe divided into two twenty-six inch pipes, one pipe leading to each of the two nozzles of a unit. Each pipe length was tested to one and one-half times the static head required before shipment.

Just outside the power house each of the four twenty-six inch lines connect into twenty-four inch hydraulically operated valves, this diameter continuing to the nozzles. These valves are designed for a pressure of 1,000 pounds per square inch but were tested out at 1,500 pounds per square inch without developing any weakness. They weigh 20,000 pounds each and were manufactured by the Allis Chalmers Company of Milwaukee. In order to facilitate the operation of these twenty-four inch valves with an unbalanced pressure of nearly 200 tons when the valve is closed, a four inch by pass is provided discharging into the pipe leading to the needle nozzle beyond the valve, thus equalizing the pressure on both sides of the main valve disk.

The power house is a reinforced concrete and structural steel building eighty-four feet wide, 171 feet long and 103 feet high. In it are built five floors and a basement, a stairway in the central portion of the building making all parts readily accessible. The room containing the main generating machinery extends the whole length and half the width of the building, extending upwards to the fourth floor. A 100 ton Cleveland electric traveling crane is installed in this room for placing the machinery and handling the apparatus. It was intended to use reinforced concrete as far as economical in the building but the great weight of the transformers, oil switches, buss structures and switchboard above the main floor required structural shapes for an economical design of the floors, and the concrete roof slab is supported on steel roof trusses. The present building is large enough to house three 20,000 H. P. units, two of which are now in place and has one end temporarily closed with expanded metal lath and concrete plaster to allow of future extensions.

Each generating unit consists of a fifty-cycle 6,600 volt generator mounted between and on the same shaft with two pelton type overhung water wheels, one wheel being mounted on each

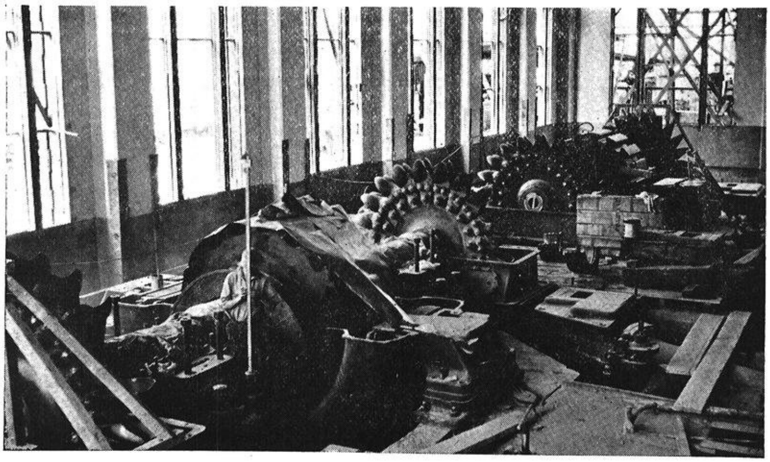


FIG. 5.—*The Interior of the Main Operating Room Showing the Two Units of the Initial Development Partially Installed.*

end of the shaft. The shafts are hollow forged nickel steel, twenty-seven inches in diameter at the rotor fit, twenty inches in diameter at the bearings and twenty-nine feet in length. The impulse wheels are ninety-four inches in diameter at the impulse circle and have nineteen cast steel buckets fastened to the nickel steel wheel disk by three pressure fitted bolts. These are the largest impulse wheels ever manufactured in this country and operate under one of the highest heads in the world. The generator rotor and the two wheels were pressed onto the shaft with a large hydraulic jack which screwed into the end of the shaft. The rotor, shaft and water wheels weigh over 100 tons.

The normal speed of the shaft is 375 R. P. M. and the unit generates 20,000 H. P. at this speed under the 1900 feet effective head. The rotating parts, however, are designed to stand a runaway speed of 750 R. P. M. For purposes of comparison it may be mentioned that the enormous turbines of the Keokuk plant are capable of generating but 10,000 H. P. each, and are of the same capacity as one single 94″ pelton type wheel of the Big Creek Project. Each generator has a continuous rating of 17,500 kva at any power factor from eighty per cent. lagging to a eighty per cent. leading current with an overload capacity of 21,000 kva for one minute and 25,000 kva momentarily. No larger generators of this type have been built.

The main shaft of a unit is supported on two self aligning babbitted bearings twenty inches in diameter and sixty inches long, one on each side of the generator and between it and the runners. The bearings are of the ring oiled water cooled type. The clearance between the stator and the rotor of the generator is so designed that while operating the electrical pull just about balances the dead weight of the revolving parts and the thrust due to the action of the jets on the wheels. When operating under full load the water issues from the nozzles in jets five and one-half inches in diameter and at a velocity of about 350 feet per second. It is difficult to realize the energy in a jet of this kind until one has had the opportuniy of seeing it in operation.

The nozzle is permanently fixed with respect to the bucket circle, and the needle, through the governing apparatus, regulates the size of the jet to suit the load on the unit. The governors, one for each unit, are of the automatic hydraulic oil relay and hand operated type of the latest design, the fly ball unit being enclosed and connected by belting to the main shaft. An electrical connection between the main switch board and the governors may also be used to adjust the jet diameter by operating the needle through the governor mechanism. The governors are arranged so that either wheel of a unit may be operated without the other although while generating more than 10,000 H. P. both wheels will be operating and will be regulated simultaneously and equally by the governing device.

Should the load on a unit be suddenly thrown off or "lost" the governor would suddenly close the jets and create and undue water hammer pressure in the penstock line. To protect the penstocks against this extreme pressure a pressure regulator is connected to the inlet pipe back of the nozzle and can either

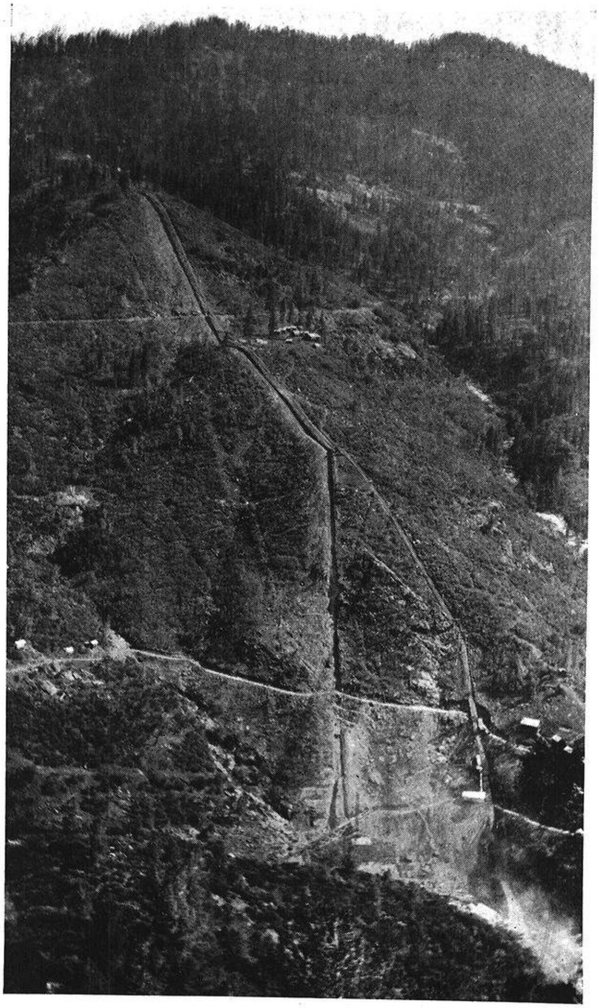


FIG. 6.—*Power Drop No. 2. The Hoist Line Appears on the Right and the Penstock Line on the Left Terminating at Power House No. 2 Located on the Creek Bank. Construction Camps Appear at the Top, Half Way Down and at the Bottom of the Hill.*

be operated by the governor direct or used as a synchronous by-pass. When acting as a by-pass the valve opens when the pressure rises beyond the danger point and automatically closes as it returns to normal. This type of regulating valve is of the same capacity as a nozzle and the velocity of the water issuing from it is absorbed by an energy absorber after which the water discharges into the steel lined tail race below the main jets.

The two D. C. exciters located behind the main units, are arranged for either water wheel or induction motor drive. They are of 350 H. P. capacity and operate at 750 R. P. M. and 250 volts. Each exciter is of sufficient capacity to excite both main units. These small water wheels are 47 inches in diameter and have twenty-four buckets bolted in place on the wheel rim. The nozzle is fixed and the jet is one and five-sixteenths inches in diameter. The speed is controlled either by operating the needle nozzle by hand or by an automatic governor control. For a sudden release of load the water jet is deflected from the buckets by a steel hood operated by the governing apparatus. The water to supply these wheels is taken from an eight inch header connecting the four penstock pipes just above the main twenty-four inch valves and is brought to the nozzles in six inch pipes.

The exciting generator is of the interpole compound wound type with the stunt winding arranged so that the two halves may either be connected in series for self excitation at 250 volts or in parallel for separate excitation by other regulating exciter sets called agitators. An agitator set consists of a small 250 volt motor driven generator connected differentially to a similar 125 volt generator to give 125 volts for normal excitation but with a regulating range down to 0 volts. There are two sets of agitators each of sufficient capacity to excite two main exciters.

In the basement beneath the main operating floor the oil tanks and pumps are located for the power house oiling system. The 2½ inch rotary oil pumps are either motor or water wheel driven, and take the oil from the main storage tanks and force it into the pressure tanks under a pressure of 200 pounds per square inch. This oil under pressure operates the valves and cylinders of the governors and then flows back through the filters to the storage tanks. The pressure system is also connected to the lower side of the main bearings through a reducing valve so that oil under pressure may be forced into the bearing before the shaft has gained enough speed for the ring oiling system to properly lubricate the bearing. This oil system also supplies the transformers and the high tension switches.

The high tension electrical equipment is of interest. The current is generated at 6,600 volts and stepped up to 150,000 volts for transmission. These step up transformers are made up of three single phase oil insulated and water cooled elements carrying 6,600 volts delta connected on the low side and 86,700 volts Y connected on the high tension side. Each of these elements are fifteen feet in diameter and twenty-six feet high and weigh when charged with the required 9,500 gallons of oil nearly eighty tons. The 150,000 volt switches consist of three single pole elements mounted in separate tanks of oil and are of the remote control, non-automatic, electrically operated type. Each switch complete occupies a space six feet by twenty feet ten feet in height and weighs fourteen tons.

Just above power house No. 1 Pitman Creek, a tributary to Big Creek, enters. It drains a small area adjacent to the basin lake and the runoff therefrom can be used to good advantage at Power House No. 2 since the operating head is some 200 feet less than at Power House No. 1 and will require, therefore, more water for the same sized generating units. This water is collected and together with the water discharged from the power house is diverted into tunnel No. 2 by Dam No. 4 which has been built in the Big Creek gorge some 300 feet below the power house.

The foundation of Dam No. 4 is on the exposed solid granite formation of the narrow gorge and the dam is constructed of mass concrete 73 feet high, 288 feet long and arched to a radius of 150 feet. It is not of the gravity section and depends on arch action for stability. The upper face slopes slightly upstream from the vertical and the section is triangular in shape. A seventy-two inch sluice gate is operated from the top of the dam and was used during construction to control the flow of Big Creek. Piers for supporting nine foot flash-boards are built on the top of the spillway and with the sluice gate control the flow of water going to power house No. 2 through the tunnel. The elevation of the water in this small reservoir at the spillway ele-

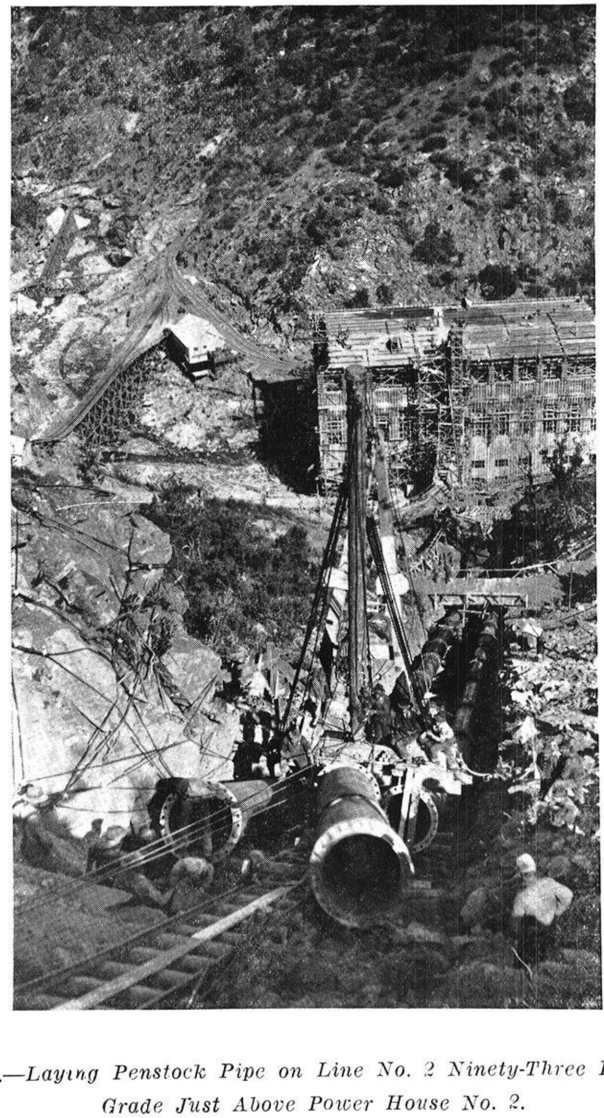


FIG. 7.—*Laying Penstock Pipe on Line No. 2 Ninety-Three Per Cent Grade Just Above Power House No. 2.*

vation of 4,814 feet may be raised to within five feet of the nozzles in the power house.

At the south end of the dam and on the side of the creek opposite the power house the entrance tunnel No. 2 is located. Steel bar screens are built into the concrete construction of the headworks and a large gate similar to the one at the entrance to tunnel No. 1 is provided. The tunnel is built nine feet in diameter, is 21,300 feet long and on a grade of three and two-tenths feet per thousand. It was driven from the two portals and each way from eight adits located about equidistant along the line of the tunnel. The tunnel is not straight but angles slightly at various points so that the adits would be as short as possible and still provide for at least 200 feet of cover at all points. It is unlined except at a few points where the rock formation was poor and there concrete lining was put in. The tunnel ends in a concrete lined surge chamber, thirty feet in diameter and 120 feet high, extending from the top of the tunnel to the surface of the ground. A nine-foot gate connects the surge chamber with a 108-inch pipe extending through a concrete lined tunnel for 250 feet to the head of the penstocks. The gate is provided with two operating stems and an equalizing by pass discharging into a thirty-six inch air shaft similar to the arrangement at the entrance to tunnel No. 1. The water entering the penstocks is controlled by two valves operated either by hand or electrically from the power house switch board and a stand pipe on each line extends vertically upward to an elevation equal to the top of the flashboards on Dam No. 4.

The penstocks to Power House No. 2 are exactly similar in design and construction to those leading to the other power house. The construction and equipment of Power House No. 2 is identical with that of Power House No. 1 except that the electrical equipment instead of being of General Electric is of Westinghouse design, and in order to get the same power with smaller effective head the amount of water and therefore the number of runner buckets must be increased. Instead of nineteen buckets there are twenty-one buckets on the runners of the Power House No. 2 units.

The San Joaquin and Eastern Railroad follows close to the line of tunnel No. 2 and a standard gage hoist 4,300 feet long

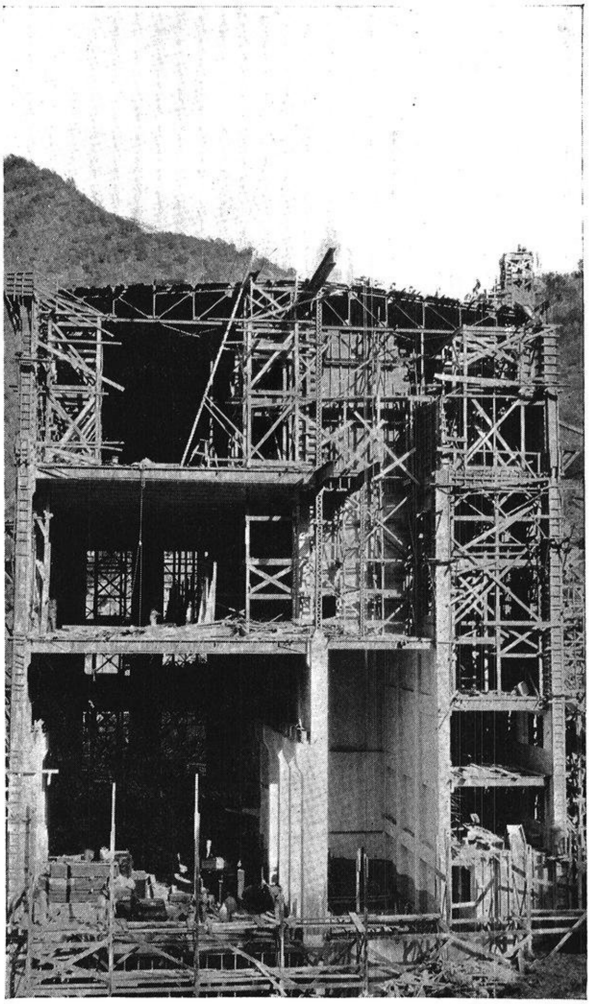


Fig. 8.—*End View of Temporary End of Power House No. 2 Showing Interior Arrangement. The Large Room Is the Main Operating Room.*

connects with the railroad at the west portal of tunnel No. 2 to carry materials and the machinery to the site of Power House No. 2. The maximum gradient on this incline is about eighty-five per cent.

The transmission lines lead from the power houses and after extending 240 miles in a southerly direction across two mountain ranges and a part of the Mojave Desert reach the main distributing station at Eagle Rock, nine miles from Los Angeles. There are two tower lines spaced eighty feet apart on centers in a cleared right of way 150 feet wide. The towers are built of galvanized structural shapes and are designed to stand the breaking of two conductors on the same side of the tower. Anchor and angle towers are designed to stand the breaking of all three of the conductors and the ground cable and a pull at right angles to the line large enough to allow the use of the tower to turn angles of sixty degrees.

The conductors are of aluminum and steel cable one inch in diameter, containing a central core of seven strands of plow steel with fifty-four strands of aluminum surrounding it. The conductors weigh 4,058 pounds per mile of single line. They are placed in a horizontal plane with a seven strand galvanized steel ground cable above, and are sagged for a minimum ground clearance of twenty-five feet, with a maximum stress of 7,500 pounds. Under normal conditions the span is 660 feet but in sleet country this is reduced to 550 feet. There are in all 3,400 towers and over 5,000,000 pounds of conductor and ground cable.

At Eagle Rock substation the current is stepped down to 72,-000 volts and 18,000 volts for transmission to Los Angeles and vicinity. The substation is of reinforced concrete and structural steel 168 feet long, 106 feet high and 131 feet wide similar in architectural treatment to the two power houses. The main transmission lines come in onto the roof and are taken into the building through a set of aluminum cup electrolitic lightening arrestors, to the main step down transformers. Two 15,000 kva synchronous condensors operating at 6,600 volts and 375 R. P. M. are installed here to regulate the power factor on the line and keep it as low as possible. These condensers are exactly similar in size and construction to the main generators at the power houses and are each connected up to the line through their transformers and operate under no load whatever, their only province being to induce enough leading current by proper regulation of its field excitation to offset the lagging current induced by the street car and city induction motor loads. They are arranged either for self excitation from an excitor on the shaft of each machine or from a separate exciter set.

The entire development belongs to the Pacific Light & Power Company of Los Angeles and the reported cost of $12,000,000 has been borne by them. Big Creek is but one of five other sources of power, steam and hydro-electric, owned by this company and they are able to write continuous service contracts with penalties added for all interruptions of service on all classes of work. The current is already being used to operate the street and interurban cars of Los Angeles and to relieve the overloaded condition of the local lines. The entire project has been designed and constructed by the Stone & Webster Construction Company of Boston in a little over two years.

BRIQUETS AND BRIQUET-MAKING

CHARLES A. MANN.

According to a recent report 50,000,000 long tons of coal have been recovered from "culm banks" in the United States in the last twenty-two years. In 1911 alone 94,647 long tons of coal were dredged from the bottom of the Susquehanna river, where it had been dumped as waste. These operations are indicative of greater economy of production and use of coal in the future. Many other materials generally considered wastes are now coming into use as fuels. All of these materials in the briquetted form have given more or less satisfaction.

In handling coal there is considerable breakage, so that much "slack," "fines," or "breeze" forms. If the coal in question is good coking coal no loss is hereby incurred as the coal is often reduced in size before coking. If the coal is a caking coal it may still be satisfactory in the fine condition because when caked it will not fall through the grates until it is completely burned to ashes. Another use for this fine coal or "breeze" is in powdered fuel burners which are now coming into more extensive use; but a good grade of coal is required in these burners. A means of handling this fine coal is by forming briquets of it by the use of some binding material and under pressure.

In order to use lignite satisfactorily it was necessary to form it into briquets. As the success of this method became known, briquetting was applied to almost anything of fuel value. Besides coal and lignite, peat, sawdust and bagasse are sometimes briquetted. A possible use for the large amount of tan bark from tanning industries is as a fuel after it has been briquetted.

Fuels to be used for briquets must be dry and in the form of a powder. It is the expense of drying that often prohibits the manufacture of briquets. This is true of lignite and peat, though lignite can be handled to greater advantage. Drying is accomplished by mere exposure to the atmosphere or by artificial means where this is practical. Breaking up is accomplished in some suitable jaw or roll-crusher and the material further reduced by means of a disk grinder.

Of greatest importance is the binder. Besides cheapness, a good binder must have the following properties:

1. It must bind strongly, producing a briquet sufficiently hard but not too brittle.
2. Under fire conditions it must hold the briquet together satisfactorily.
3. The briquet produced must be water-proof to such an extent that it will stand conditions of use.
4. It should not cause smoke or foul-smelling or corrosive gases.
5. It should not increase the percentage of ash or clinker.
6. It should increase or at least not decrease the heat units obtainable from a unit weight of fuel.

Binders in use and those proposed are divided into two big heads: inorganic and organic. A further division is (1) soluble, and (2) insoluble. The organic binders may be classed as shown below.

INORGANIC BINDERS.

1. Clay. 2. Lime. 3. Magnesia. 4. Magnesia cement (magnesium oxide and magnesium chloride). 5. Plaster of Paris. 6. Portland cement. 7. Natural cement. 8. Slag cement. 9. Water glass.

ORGANIC BINDERS.

A. Wood Products. 10. Rosin. 11. Pitch. 12. Pine wood tar. 13. Hard-wood tar. 14. Douglas fir tar. 15. Wood pulp. 16. Sulphite liquors (from paper mills).

B. Sugar Factory Residues. 17. Beet pulp. 18. Lime cake. 19. Beet sugar molasses. 20. Cane sugar molasses.

C. Starch. 21. Corn and potato.

D. Slaughter-house Refuse. (22).

E. Tar and Pitches. 23. Blast furnace tar. 24. Producer gas tar. 25. Illuminating gas tar. 26. By-products coke oven tar. 27. Coal tar creosote. 28. Various grades of pitches from different tars.

F. Natural Asphalts. 29. Impsonite. 30. Gilsonite. 31. Maltha. 32. Refined Trinidad. 33. Refined Bermudez. 34. Hard and refined asphalts.

G. Petroleum Products. 35. Crude oil. 36. Residum (asphalts, etc.). 37. Water gas tar. 38. Water gas tar pitch. 39. Wax tailings. 40. Acid sludge. 41. Asphalt tar. 42. Pintsch gas tar.

As all of the inorganic binders are non-combustible they increase the ash content of the briquet, which means increased cost in handling the ash as well as the payment of freight on non-combustible material. However, inorganic binders are not volatile and some of them when used with coal combine advantageously with the sulphur of the coal. Though sulphite liquors, starch, and some of the sugar residues are excellent binding materials, they have the disadvantage of solubility, which does not admit of exposing the briquet to moisture conditions. Most of the organic binders are satisfactory except that their cost prohibits their use. Also some of them cause excessive amounts of smoke, and usually this class of binder does not stand up well under pressure.

After the fuel material has been dried and ground to the desired size it is mixed with the binder. When a cold setting binder is used the material is molded cold and set aside to harden. When tars or petroleum residues or similar binders are used, these are heated to a flowing consistency, mixed with the fuel in a rotary mixer until all of the particles of the fuel are coated, and the mixture then molded and pressed. According to the materials used this pressure varies between 3000#/ sq. in. to 4000#/ sq. in., though sometimes going as high as 10,000#/ sq. in. It is interesting to note here that lignite needs no outside binder. The powdered lignite is forced into a cylindrical form under a pressure of about 10,000#/ sq. in., which develops enough heat to cause the pitchy hydrocarbons of the lignite to ooze toward the outside of the briquet. When this pitchy substance cools it forms an excellent binder. The objection to this method is the possible danger which may result from the explosion of the lignite powder under working conditions. This method may be adaptable to the briquetting of tan bark previously mentioned, as there is more or less oily and pitchy material remaining in the bark. Descriptions of the many briquetting machines, proposed and in use, would require more space than this article allows.

The shapes of briquets are of exceedingly great importance. In storing large quantities of briquets it is desirable to have regular shapes like cubes or prisms, as these can be compactly arranged and can be made conveniently into large sizes. By grooving these they can be broken up to any desired size. The disadvantage is that the edges are easily broken and form waste, which should never exceed five per cent of the original weight of the briquet. The cylindrical form is excellent, as it reduces breakage, and on a grate briquets of this shape lie so that the air passages through the mass are satisfactory. Briquets must not lie so close as to clog the grate or so far apart as to form flues. The best draft conditions are obtained from the ovoid shape, these briquets weighing about two pounds. Sometimes the rectangular shapes have holes through them which allow free passage of air. Certain shapes too are hard to ignite.

Briquets vary in density according to the materials used. Those from good coal may vary from 1.1–1.4, though 1.19 is give as standard. Besides hardness they must have coherence. This coherence is dependent on the size of grains of the fuel, the character and quantity of the binder and the pressure applied. No coal briquet should absorb more than three per cent of moisture. When soluble binders are used the briquet may be coated with a waterproofing material, but this is sometimes too expensive.

The ease of ignition of briquets is dependent on the size, density, mesh of fuel used, shape and binder. Large briquets and those with sharp edges are easily ignited. Dense briquets are hard to ignite while those made from the lump coal ignite better than those made from slack. If the binder is an organic one the increase in ash reduces the ease of ignition.

In America the use of briquets is still in its infancy. In Europe, however, where lignite has been briquetted successfully for a long period of time, the use of this kind of fuel is more general. Though data as to the total briquets manufactured is meagre, we can get from the following an idea of the extent of this business.

	Year.	Exports.	Year.	Imports.
Great Britain	1901	1,037,165 tons	1898	35,064 tons
Germany	1899	402,000 tons	1899	88,000 tons
Belgium	1897	6,239,499 tons		

Briquets of all descriptions are used on locomotives and on steamships. The briquetted lignite is a common domestic fuel. This class of fuel can be used for almost any heat or power installation.

The heating value of briquets is the sum of the heating value of the fuel used and the heating value of the binder. By the use of a fairly good binder an inferior grade of waste fuel can be made into satisfactory briquets. It is of interest to note that with peat the pressure used aids in raising its heating value.

Air dried cut peat.......	6,840	B. T. U./#
Pressed peat	7,290	”
Peat coke	12,676	”
Peat briquettes	13,330	”

In comparing the quantities of coal and patent fuel required per mile on a locomotive we find that it takes 27 pounds of patent fuel as against 31.5 pounds of coal from which this patent fuel was made. A similar ratio exists as regards its evaporative power.

Only such material should be briquetted as will result in briquets which answer to the requirements given in this paper. With coal, the locality, character of the coal, purposes briquets are intended for, cost and availability of binder and marketing facilities determine the practicability of manufacturing briquets. When slack is used, the combined cost of the slack and binder must not exceed the cost of the lump coal. Much depends on the binder. The cheapest binder is the heavy residum from petroleum available in California, Texas and adjacent territory. Four per cent of this binder is sufficient. Its cost ranges between 45 and 60 cents per ton of briquets. Water gas tar is next in order. Five to six per cent is required, making the cost 50 to 60 cents per ton. This material is available throughout the United States. Coal tar pitch to the extent of 6.5-8 per cent can be used. This increases the cost of briquets from 65 to 90 cents per ton. Excellent briquets are produced with pitch from producer gas tar, very little binder being required. This binder is not generally available, but it ought to be rather cheap when it comes on the market. Except for its solubility, starch would be an excellent and cheap binder. Only one per cent is required, making the cost per ton 20 cents. Other binders which are of less importance vary considerably in price according to locality.

Besides binder and coal cost, there is the plant outlay, labor, and overhead. This cost amounts to from 30 to 50 cents per ton in America; from 24 to 40 cents in France; 22 to 24 in Germany; and 24 cents in England. Not considering the coal, the cost of briquet making is about 90 cents per ton in America.

It is only the pressing need of economy that will bring about the cheaper and more extensive manufacture of briquets in America. Large sized plants in the proper localities would soon develop the manufacture of this class of fuels so that America would compare favorably with the European countries in the production of briquets.

A MICROSCOPIC STUDY OF ELECTRO DEPOSITED IRON

OLIVER W. STOREY.

The University of Wisconsin has the distinction of being the place where iron was first successfully electro deposited on a large scale. This distinction was achieved through the efforts of Prof. C. F. Burgess. Previous to his researches electrolytic iron had been known, but it could be deposited only in thin sheets owing to imperfections in the deposits.

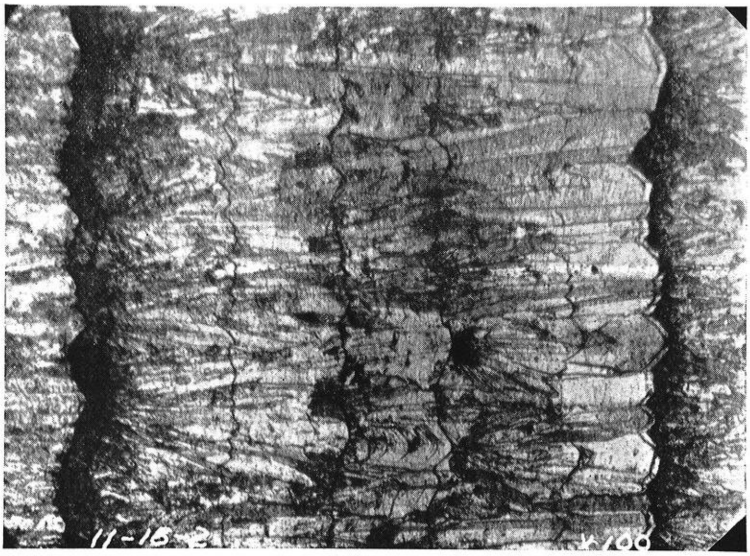


FIG. 1.

Professor Burgess first announced his solution of the problem in a paper given before the American Electro-chemical Society in 1904.* The importance of this discovery was not only in the successful culmination of a research problem but in that it opened up a new field in the mettallurgy of iron, since electrolytic iron is a source of pure iron in contrast to the purest of

* Burgess & Hambuechen, Tr. A. E. S. V, 201 (1904).

commercial irons which contain appreciable amounts of impurities.

This work was carried out at the Chemical Engineering Laboratories where the process is still in operation. During the ten years several thousand pounds of iron have been refined.

The refining of iron is carried out at present in stoneware tanks, each containing three sets of anodes, connected in parallel, between which are placed two cathode sheets, allowing the

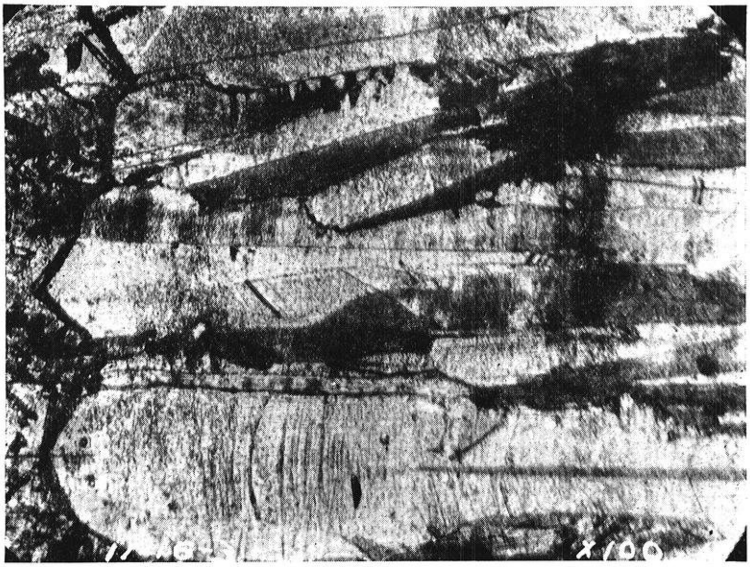


FIG. 2.

deposition to take place on both sides of the latter. The anodes first used were Swedish bar iron, though later American Ingot Iron has been used as a purer grade of raw material. With a current density of about ten amperes per square foot and an electrolyte consisting of an aqueous solution of iron sulphate and ammonium chloride, the deposition proceeds uniformly.

The electro deposition of iron presents difficulties not unlike those present in the deposition of various other metals. By varying the factors such as current density, temperature, circulation of solution, composition of electrolyte, and thickness of deposit, various kinds of deposits may be obtained.

Owing to these varying conditions, a large variety of forms of deposits have been produced, varying from dense to porous, and from smooth to nodular iron. With such a variety of structures this material offers an interesting opportunity for microscopic investigation.

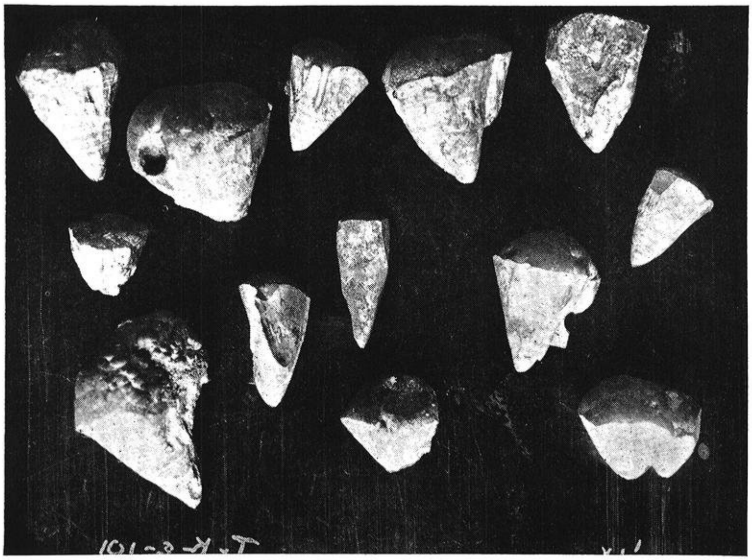


FIG. 3.

A typical analysis of the refined iron follows:

	Single refined	Double refined
Sulphur	0.001%	none
Silicon	0.003	0.013%
Phosphorus	0.020	0.004
Manganese	none	none
Carbon	0.013	0.012
Iron	99.963	99.971
Hydrogen	0.083	0.072

The double refining is accomplished by using an electro deposited material as anode.

The crystallization of electrolytic iron while being deposited is not unlike the crystallization of iron from the molten state. When iron or any other metal solidifies the solidification starts at crystal centers which grow until the entire mass is solidified.

In the electrodeposition of iron the deposition is started at a large number of centers on the starting sheet. But, unlike the liquid metal, the iron crystals can only grow in one direction, that is, perpendicular to the starting sheet.

The growth of crystals of electrolytic iron is shown in Fig 1. This micrograph shows a section of a coarsely crystalline deposit from near the starting sheet, at a magnification of 100 diameters.

As shown in the micrograph, the crystals grow from a large

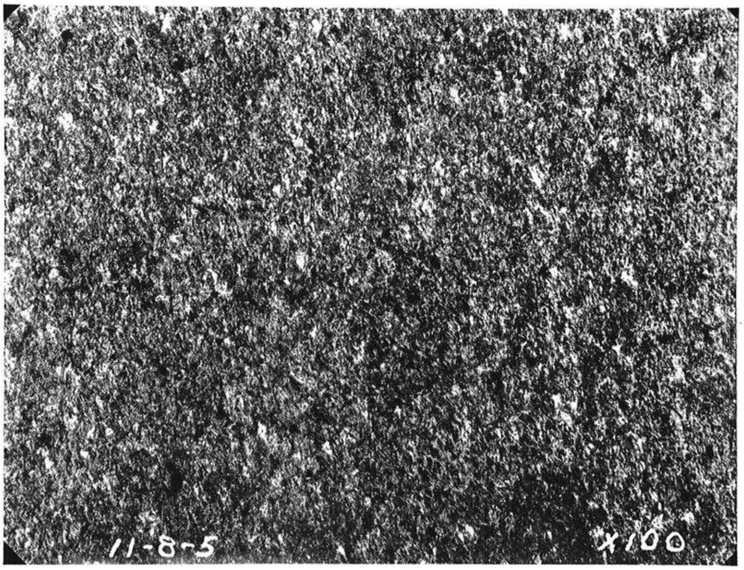


FIG. 4.

number of centers and deposit in the shape of a fan. These small crystals merge into each other forming larger crystals. In this manner the crystals continue to grow and may become as large as those shown in Fig. 2. This is the exterior part of the deposit shown in Fig. 1 and is also magnified 100 diameters.

These micrographs apply to a deposit which is coarsely crystalline and loose in texture. A dense deposit is often inclined to be nodular. In some cases these nodules may be removed by hitting the deposit a sharp blow with a hammer. Several of these nodules are shown in Fig. 3.

A specimen of one of these nodules or of a dense deposit fails to reveal any trace of the crystalline structure shown in Fig. 1

and Fig. 2. Instead a homogeneous surface develops showing only the outlines of the various nodules.

It has been stated that when the electro deposition of iron is started the crystallization is begun at a large number of centers. A micrograph of a thin deposit is shown in Fig. 4. Compare

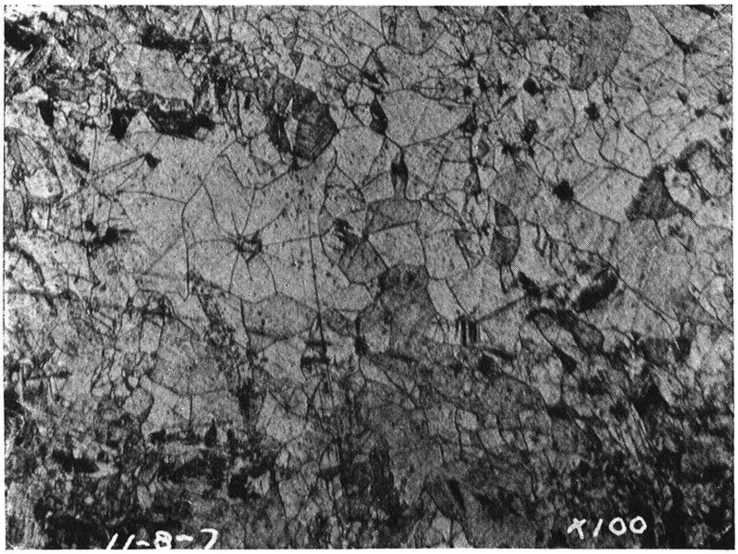


FIG. 5.

this to the coarse structure obtained on the exterior of a heavier deposit in Fig. 5. This again illustrates the growth of the crystals of iron.

Of what importance is electrolytic iron? It cannot be used as deposited where strength is needed since it is too brittle. It breaks easily and is devoid of tensile strength. The brittleness of the iron is attributed to the presence of hydrogen, which forms an iron hydride that is extremely brittle. By heating to between 500 and 600° C. the brittleness is overcome and the iron becomes ductile. During this heating operation hydrogen is driven from the iron.

It was thought that the removal of hydrogen would cause a change in structure of the iron which could be detected under the microscope. Several samples were heated from 500 to 850°

C. but no change in structure was apparent. Even at 769°, where iron becomes non-magnetic, no change in structure was apparent.

But by heating to 910° C. a structural change became noticeable. The fern like crystals were transformed into grains of metal which resembled that of a metal solidified from the molten state. This grain structure is shown in Fig. 6.

Why does the iron structure change suddenly at 910°? Iron resembles carbon in that it is subject to differences in its crystal-

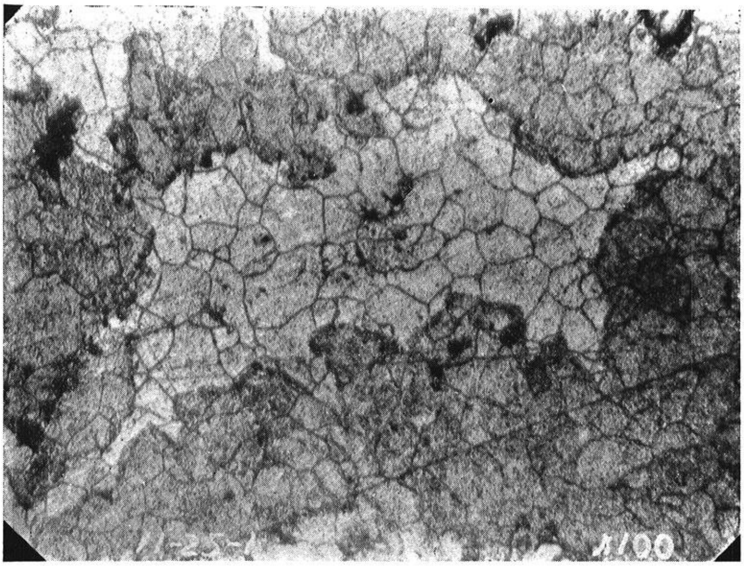


FIG. 6.

line structure, that is, it is allotropic. Carbon may also be obtained as graphite and as the diamond. These three forms are stable at the ordinary temperatures.

Iron, in the light of present day investigation, is known to crystallize in at least two different forms and possibly three, but only one of these is stable at the ordinary temperatures.

Pure iron below 760° C. is called alpha iron and is magnetic. The cube is the prevailing form of the alpha iron crystal.

At 769° C. there is a thermal change but there seems to be no accompanying crystalline change. Iron above 769° and below 910° C. is called beta iron.

At 910° C. a second thermal change is noticeable. The iron changes from cubic to octahedral crystals though still in the isometric system. This form of iron above 910° is called gamma iron.

The transformation of the deposited crystals of Fig. 1 to the grain structure of Fig. 6 is explained by this allotropic change which is accompanied by the changing of the cubical crystals to octahedral crystals.

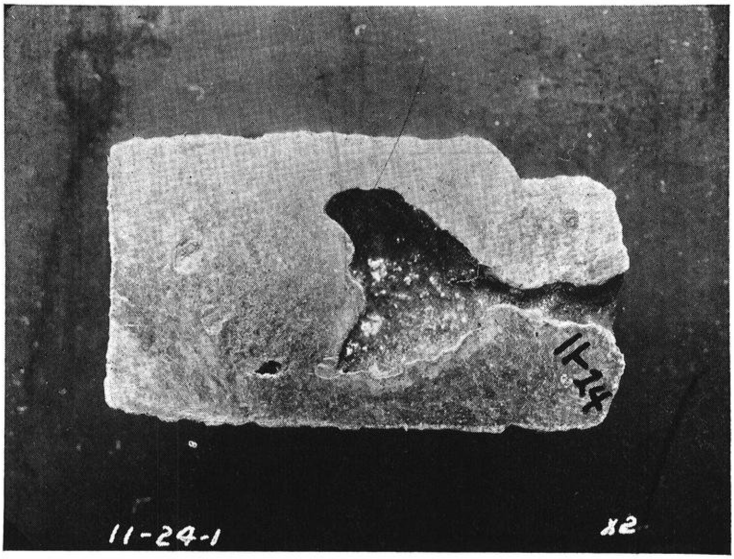


FIG. 7.

The porous coarsely crystalline electrolytic iron becomes granular with sharp boundaries, but the dense deposits, though granular, do not show definite boundary lines about the grains.

But by heating a dense deposit to nearly the melting point a well defined grain is produced as shown in Fig. 6.

Nearly the entire production of electrolytic iron at the Chemical Engineering Laboratories has been used in the production of alloys of iron with other elements to study their effect upon the various properties of iron. Electrolytic iron was especially adapted to this work since it furnishsed a source of pure iron.

When electrolytic iron is melted it shows defects similar to those of large ingots. Fig. 7 shows a small ingot of iron made in a vacuum furnace. While solidifying this iron was still giving off gases and in so doing carried some iron with it. This solidified as a collar of iron about the top of the ingot and left a cavity in the center. The gas given off at this high temperature is not known but it is probably hydrogen.

When electrolytic iron is melted and forged it is soft and easily worked in contrast to the hard brittle deposited material. It is granular and shows a grain structure similar to Fig. 8.

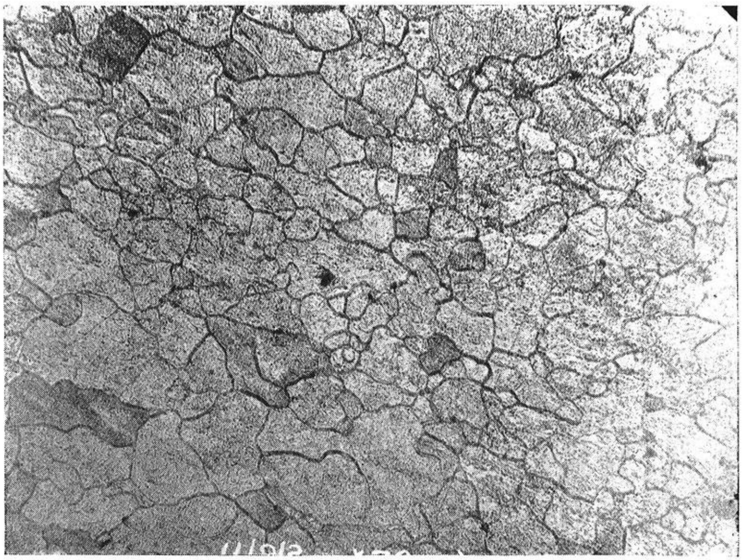


FIG. 8.

Electrolytic iron cathodes have been rolled directly into iron sheets which do not differ materially from the ordinary sheet irons of commerce. The microstructure of such a sheet iron is shown in Fig. 8, and is similar to that of any pure iron.

In conclusion, electrolytic iron is not only an interesting product because of its high degree of purity but it is also of interest to the metallographist. As deposited it shows the peculiar fern like crystals. Upon heating to 910° these crystals change to the grains of ordinary iron. This seems to show that the first crystalline change in iron takes place at 910° and not at 769° where iron becomes non-magnetic. It may be studied still further when melted as a source of pure material in the study of the crystalline growth of metals.

SIMPLE GYROSCOPIC ACTION.*

PROFESSOR EDWARD R. MAURER.

I. DESCRIPTION.

The words gyroscope and gyrostat are often used synonomously but sometimes a distinction is made, as follows: A gyrostat consists of a wheel and axle, both being symmetrical to the axis of the axle, and mounted so that they may be rotated about that axis; a gyroscope consists of a gyrostat mounted in a frame

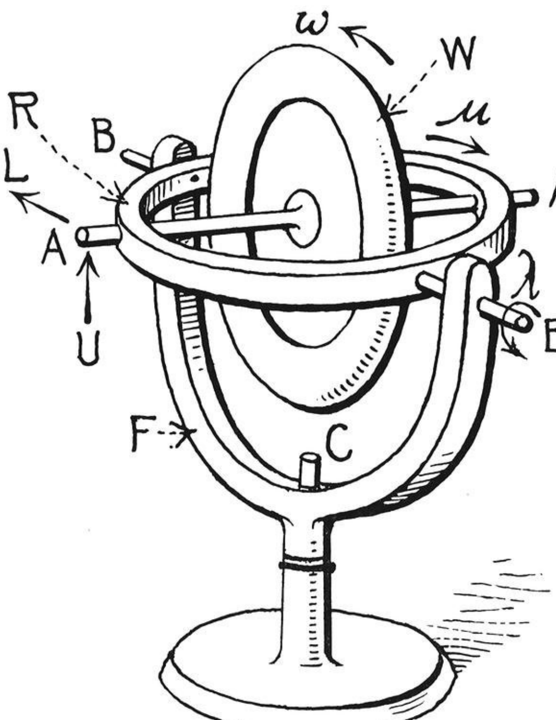


FIG. 1

* This article is a copy, except for abridgements and necessary modifications, of a portion of the writer's *Technical Mechanics* (rewritten edition).

which can be rotated. Fig. 1 represents a common form of gyroscope; the gyrostat (wheel W and axle AA') is supported by a ring R which can be rotated about the axis BB'; the axle BB' is supported by the forked pillar F which can be rotated about the axis CC'. Thus the wheel can be rotated about its center into any desired position. The gyroscope seems to have been designed for illustrating principles of composition of rotations. In 1852 Foucault (French physicist) made an interesting application of the instrument; by its means he practically made visible the rotation of the earth. More recently the gyroscope has been made use of in several connections,—to steer a torpedo, to serve as a substitute, unaffected by the iron of the ship, for the ordinary (magnetic) mariner's compass, to stabilize a mono-rail car, and to steady a ship in a rough sea; it has been proposed also to stabilize flying machines by means of a gyroscope.

When its wheel is spinning, a gyroscope possesses properties which seem peculiar to persons uninformed in the matter, inasmuch as it does not always respond as expected to efforts made to change its motion or position. For example, if a gyroscope like that represented in Fig. 1, well made and practically frictionless at all bearings and pivots, be grasped by the pillar and then moved about in any way, the axle of the wheel remains fixed in direction in spite of any attempt to alter it. The (gimbal) method of support makes it impossible to exert any resultant torque on the gyrostat (by way of the pillar) about any line through the center; and hence, as will be proved later, the direction of the axle cannot be thus changed. It is this property of permanence of direction of the spin-axis of a gimbal-supported gyrostat which is made use of ın the self-steering torpedo.

For another example, consider the effect of a torque applied directly to the gyrostat. A vertical force, say, applied at A would turn the gyrostat when not spinning about the axis B. But when spinning, that force *(U)* would rotate the spin-axis about the axis C, the direction of rotation depending upon the direction of spin. When the gyrostatc is spinning in the direction indicated by the arrow ω, then such force U would rotate the spin-axis about C in the direction indicated by the arrow μ. Again, a horizonal force applied at A say, would turn the gyrostat when not spinning about the axis C.. But when spinning, such force *(L)* would rotate the spin-axis about BB'; and in the direction indicated by the arrow λ if the spin is as indicated. This behavior of a spinning gyrostat under the action of torque is exhibited more strikingly by a gyroscope represented plainly in Fig. 2. The wheel may be spun on the axle *A;* the gyrostat and its frame may be rotated about the axis *BB′;* and all may be rotated about the axis *CC′*. *W* is the weight which can be clamped on the stem *A′* to balance or unbalance the frame with respect to the axis *BB′*. Now imagine *W* clamped so that the frame (with *W* and the gyrostat) is unbalanced. Then if the gyrostat is set spinning and the frame be released in the position shown, say, the frame will not rotate about *BB′* but about *CC′*. The direction of this rotation depends on the direction of spin and on the direction of the torque of gravity about *BB′*. If, for

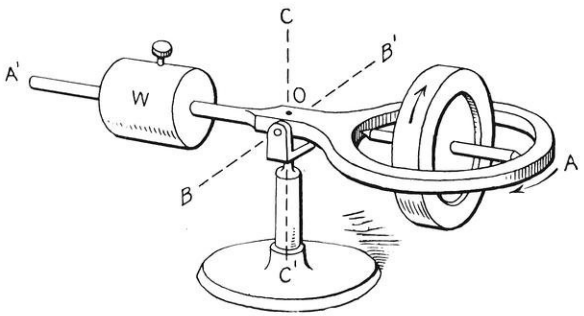


FIG. 2

example, *W* is clamped quite near *BB′* so that the torque of gravity is clockwise as seen from *B* and the spin is as indicated, then *A* rotates toward *B*. This rotation persists except insofar as it is interferred with by friction at the pivots, and air resistance. We might recite still other peculiar performances of a gyrostat but the foregoing suffice for our purpose. Professor Perry's book on "Spinning Tops" would be found interesting in this connection.

Any such rotation of the axis of a spinning gyrostat is called a *precessional motion* or a *precession* of the axis or of the gyrostat; the axis and the gyrostat are said to *precess*. It may not be clear from the foregoing examples of precession how to predict the direction of precession that would result by applying a given torque to a gyrostat with a given spin. The following is a simple rule for predicting; it is based on the dynamics of the whole matter as will be seen later: "When forces act upon a spinning body tending to cause rotation about any other axis than the spinning axis, the spinning axis sets itself in better agreement with the new (other) axis of rotation; perfect agreement would mean perfect parallelism, the direction of rotation being the same." (From "Spinning Tops".) Or, what amounts to the same thing, the precession is such as to turn the spin-vector* toward the couple or torque-vector.

There is another item of gyrostat behavior worth noting here. Suppose that the gyrostat shown in Fig. 2 to be precessing as already explained. If the precession be hurried, say by means of a horizontal push applied at A', the center of gravity of the frame (with gyrostat and weight) rises; if the precession be retarded, the center of gravity descends. This behavior is in accordance with the rule for predicting precession. In the first case there is a torque about CC'; the torque-vector is in the direction OC'; the spin-vector is in the direction OA'; and in accordance with the rule OA' turns toward OC', that is the center of gravity rises. In the second case there is a torque about CC' but the torque-vector is OC; and the spin-vector OA' turns toward that vector, that is the center of gravity descends. Thus we may state as another rule: Hurry precession, the gyrostat rises or opposes the torque which causes the precession; retard precession, the gyrostat falls, or yields to the torque which causes the precession.

Self-steering Torpedo.—The gyroscope of such a torpedo is linked to appropriate valves of a compressed air engine in such

* A *spin-vector* is a vector on the axis of spin, its arrow-head pointing to the place from which the spin appears counter-clockwise; or—what amounts to the same thing—the arrow-head points in the direction along which the axis would advance if it were a right-hand screw spinning (with the gyrostat) in a fixed nut. The length of the vector—immaterial in the present connection—represents the angular velocity of spin to some convenient scale. Likewise the couple-vector is a vector perpendicular to the plane of the couple, pointing to the place from which the rotation (which the couple tends to produce) would appear counter-clockwise; or—what amounts to the same thing—the arrow-head points in the direction along which the vector would advance if it were a right-handed screw turned by the couple in a fixed nut.

a way that any turning of the spin-axis toward either side of the torpedo causes the engine to turn the (vertical) rudder of the torpedo in the opposite direction. Prior to projection of a torpedo, the gimbals are locked so as to hold the spin-axis of the gyrostat parallel (or inclined at any desired angle) to the axis of the torpedo. During the discharge of the torpedo, the gyrostat is automatically set spinning and the gimbals are unlocked. During the flight, the spin-axis continues to point in its original direction; any deviation of the torpedo from its intended course changes the inclination of the spin-axis relative to the torpedo; simultaneously the gyroscope actuates the rudder as explained, and the torpedo is deflected back toward its proper direction.

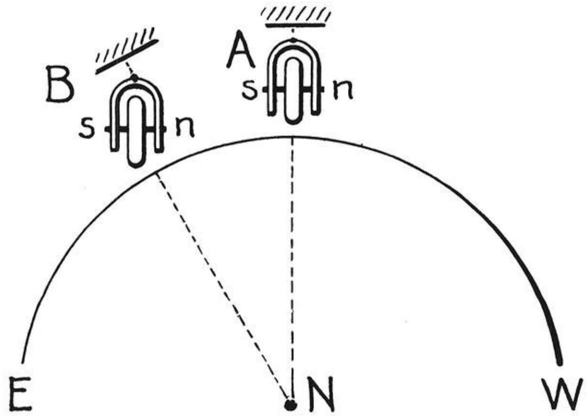


FIG. 3

Like a common pendulum swinging to its lowest position, the torpedo swings beyond a mean direction and is then swung back again by the rudder. And this oscillation is kept up during the flight so that the actual path of the torpedo is a zigzag, about two feet wide. A gyrostat (wheel and axle) weighing two pounds and rotating at 2,500 revolutions per minute has been made to serve the purpose just described.

Gyro-compass.—For our purpose we may regard a gyro-compass as consisting essentially of a gyrostat (wheel and axle), the axle supported in a ring or case, and the ring suspended from above. See *A*, Fig. 3. Such a compass, when the gyrostat is spinning, sets its spin-axis into the plane of the meridian at the place where the compass happens to be. Imagine such a compass to be set up at the equator with its spin-axis pointing east and west, and suppose that the direction of spin is counter-clockwise when viewed from the west. The rotating earth carries the gyrostat eastward; the spin-axis would remain parallel to its original position if the gyrostat were supported in frictionless gimbals, and would in time be positioned as shown at *B*. Now consider the gyrostat as shown at *B*, supported not in gimbals but suspended from above as in the gyro-compass. The supporting force (above) and the force of gravity would have a torque counter-clockwise as viewed from the north; thus the torque-vector would point toward the reader. The spin-vector points to the right; hence the torque would turn the end of the spin-axis marked *n* from the west toward the north.

Of course the action is not precisely as outlined above, that is the spin-axis does not remain parallel to its original position for a time and then yield to the influence of the torque mentioned. The action is really continuous; the slighest rotation of the compass with the earth from the position *A* induces the gravity torque, and the spin-axis begins to turn toward the meridian as described.

Though the restraint of the support (fine wire in the Sperry and mercury float in the Anschütz compass) is very small, the gravity torque is so small that the turning of the spin-axis into the meridian is very slow. Like a magnetic compass the gyro-compass swings beyond the meridian from a deflected position and oscillates for a time. In the Anschütz type the period of a free oscillation is about 1 hour and 20 minutes. Special damping arrangements reduce the oscillations to zero (from a deflected position of 40 degrees) in about one and one-half hours. The spin is maintained electrically, at about 20,000 revolutions per minute.

Mono-rail Car—A car on a single rail can be rendered stable even if the center of gravity of the car is above the rail by means of a suitable gyroscope apparatus. Fig. 4 represents the germ of one type of such apparatus. *AA′* is the spin-axis, *L* is a lever rigidly fastened to the axle *BB′* by means of which the gyrostat can be made to precess about *BB′*. Imagine the car to be standing or travelling in an upright position, the gyrostat spinning, and a man standing on the car so that he may grasp and operate the lever. Now suppose that the car is tilted, as by a wind against either side. The car exerts tilting forces on the gyrostat axle at B and B', the torque-vector of which is parallel to the rail; hence (see the stated rule) the spin-axis begins to set itself parallel to the rail, that is, it precesses about BB'. The axle BB' exerts (righting) reactions on the car but if the man will hurry the precession, the (heavy, rapidly spinning) gyrostat will rise against the tilting forces and carry the car back with it toward the vertical position. It is conceivable that a skillful operator could put the car back into its vertical position in one swing, but in general he would swing the car beyond the vertical, then back again and after a few oscillations, into its vertical position.

Gyro-stabilizers as now built automatically perform the function of the man of the preceding explanation, and they include two gyrostats, spinning in opposite directions, to enable the car to run on a curve. The gyrostat wheels of a certain Brennan mono-rail car (40 feet long and weighing 22 tons) are $3\frac{1}{2}$ feet

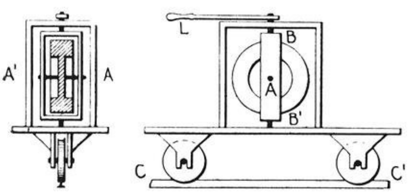


FIG. 4

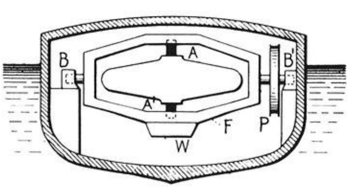
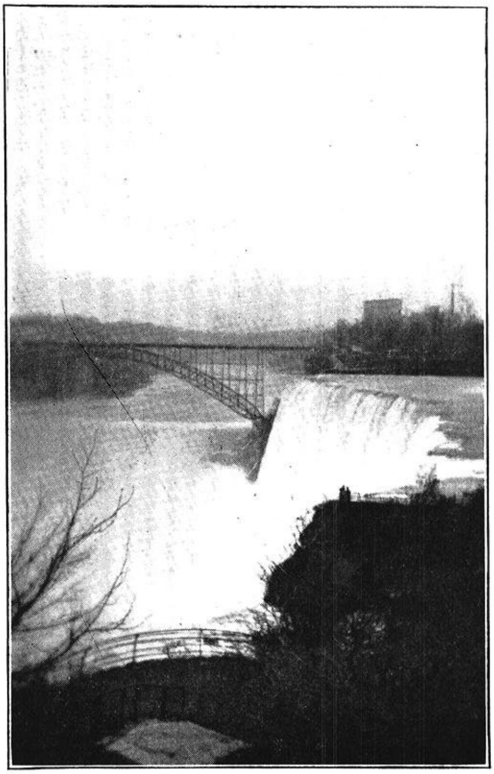


FIG. 5

in diameter; each weighs $\frac{3}{4}$ tons, and spins at 3,000 revolutions per minute (in a vacuum to avoid air friction). Such a car has taken curves of 105 feet radius at a speed of 7 miles per hour without appreciable disturbance of the level of the car floor. The spin is maintained by electric means; in fact each gyro-wheel is made the armature of a motor and this is driven by a generator on the car.

Schlick Gyro-stabilizer for Reducing the Rolling of a Ship.— This is represented in Fig. 5. The gyrostat is mounted in a rigid frame F which is supported in bearings B and B' fixed on the ship. Thus the wheel can be spun about AA' and the axle AA' can precess about BB'. P is a brake pulley by means of which this precession can be controlled. Explanation of the steadying action of this device is beyond the scope of this article. Such a stabilizer has been tried out in a ship 110 feet long, 12 feet wide and of 58 tons displacement. The gyro-wheel weighed 1100 pounds, was 1 meter in diameter, and was spun at 1600 revolutions per minute. In still water the ship would settle down from a heel of 20 degrees to one of ½ degree in about 20 single oscillations; the period was about 4⅛ seconds. The stabilizer produced the same extinction in less than three oscillations of 6 seconds period. (See London *Engineering*, Vol. 83, p. 448 (1907)).



WITH THE ALUMNI.

The work on the new directory of the Engineering Alumni is progressing rapidly and copies will soon be ready for distribution. At the time of this writing another circular letter will be sent out to those who have not answered to previous inquiries, and it is requested of all those alumni who receive the letters to reply promptly; thereby aiding the University to put out a very complete directory. The old directory was issued two years ago

and the changes that have occured since then are many. Therefore Alumni! if you haven't sent in your cards, do so NOW.

Howard B. Gates, '05, is Assistant Engineer of the Public Service Commission of New York City. He is at present in charge of subway construction under the Harlem river.

C. A. Hansen, '05, holds the position of Research Chemist in the research laboratory of the General Electric Company at Schenectady, N. Y.

John W. Lowell Jr., '11, is Assistant Engineer of the Portland Cement Company, at Chciago, Ill.

Owen W. Miller, '07, is at Chicago, Ill. He is editor of the "Railway List" and the "Railway Master Mechanic."

Edward A. Goetz, '04, is the Chief Engineer of the St. Paul Foundry Company at St. Paul, Minn.

Edward H. Keater, '10, holds an engineering position with the Mississippi River Power Company at Keokuk, Iowa.

The cards sent in by the Alumni show that a great number of the Wisconsin Grads are engaged in Municipal or Commission work. Some of them are:

Clarence M. Larson, '05, who is the Chief Engineer of the Railroad and Tax Commission of Wisconsin.

H. C. Zantow, '09, who is the Mechanical Engineering inspector for the Railroad Commission of the same state.

W. A. VanHook, '06, is Assistant Engineer of the Illinois Railroad and Warehouse Commission.

B. S. Thayer, '07, is with the United States Reclamation Service as an Assistant Engineer.

W. F. Hine, '07, is the Chief Gas Engineer of the Public Service Commission, 1st. District, New York City.

L. M. Hammond, '10, is Junior Engineer in the Reclamation Service. He is now located at Provo, Utah.

Joseph Shapiro, '08, is back again with the Railroad Commission of Wisconsin. He was with the Cutler-Hammer Mfg. Company last year.

L. D. Burling, '05, is an Invertebrate Paleontologist for the Geological Survey Commission of Canada.

S. M. Fisher, '09, is Assistant Engineer of the Panama Pacific Exposition with headquarters at San Francisco.

Other gleanings from the files are:

Horace M. Holmes, '08, is Superintendent of the Graff Construction Company at Seattle, Washington.

William H. Lieber, '07, is Patent Attorney for the Allis-Chalmers Mfg. Co., Milwaukee, Wis.

William E. Griffith, '12, is Assistant Engineer at the Lucas County Sanitary Engineering Department, Toledo, Ohio.

Julian E. Hart, '06, is Assistant Engineer of the Public Service Company, Chicago, Ill.

Lester M. Moss, B. S. '09, E. E. '13, is in the Development Laboratory of the General Electric Company Lamp Works at Harrison, N. J.

Fred J. Derge, '07, is the Light, Heat, and Power Manager of the Toledo Railways and Light Company at Toledo, Ohio.

Charles M. Scudder, '11, is doing engineering work on water power development with the Knoxville Power Company, Alcoa, Tenn.

William D. Moyer, '13, is an apprentice engineer at the Denver Gas & Electric Light Co.

William N. Murrish, '11, is with the Sierra & San Francisco Power Company at Modesto, California.

G. B. Code, '06, is manager of the Pocahontas Light & Power plant at Pocahontas, Iowa.

Ray W. Hart, '12, is in the United States Engineering service. He is at Rock Island, Illinois, at present.

Edward N. Stearns, '07, has taken the position of Bridge Engineer of the Western Maryland Railroad Company. His headquarters are at Baltimore, Md.

Earl N. Anderson, '13, is in the engineering department of the National Lamp Works of the General Electric Company, East Cleveland, Ohio.

Announcement has been received of the marriage on Dec 8, 1913, of Sydney H. Ball, '01, Mining Geologist, to Mary Ainslie, daughter of Mrs. Samuel Rutherford Ainslie of Oak Park, Ill. Mr. and Mrs. Ball are living in New York City.

Glen E. Smith, E. E. '11, L. '13, is a patent lawyer at Chicago.

Among those who are Consulting Engineers now are:

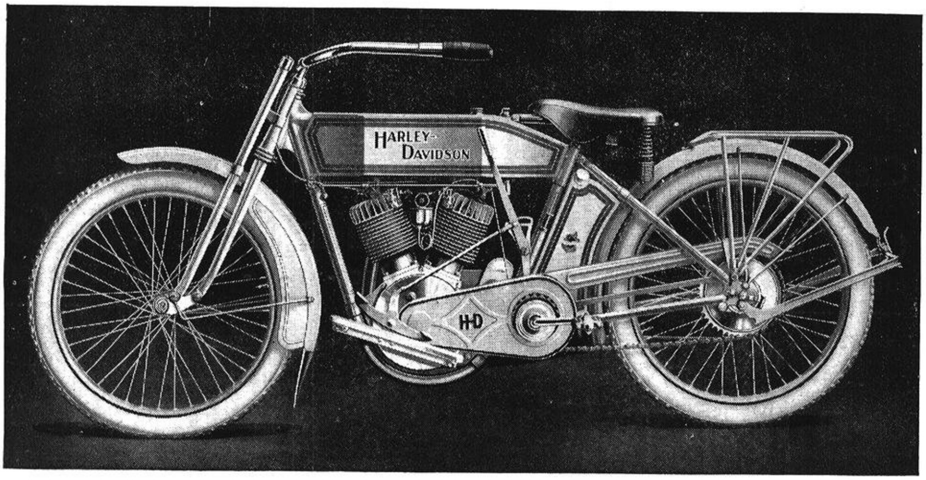
Weston H. Hall, '09, who is a Civil and Sanitary Engineer at Centerville, Ia.

E. L. Gross, '08, with an office at Chicago.

E. F. Weeks, '12, is a Heating and Ventilating Engineer at Spokane, Washington.

EDITORIALS.

We have had several inquires concerning an article on the "Manufacture of High Tension Insulation," which appeared in a recent issue. Mr. E. J. Arps, '14, is the author of this paper, and it was published with the approval of Mr. Kartak, who kindly checked it over for us. It is our policy to have the various articles submitted by students examined by men especially expert in the field with which the article deals. In printing this paper we inadvertently did not give any credit to Mr. Arps.



The 1914 Harley-Davidson

has every desirable feature to be found in the Motorcycle Field and in addition it is the only Motorcycle with Step-Starter—Double Clutch Control—Ful-Floteing Seat and Free Wheel Control.

The only Motorcycle with a Step-Starter

The Step-Starter in case of an accidental stalling of the motor, does away with the necessity of getting off in the mud or holding up traffic while the rider finds a level place on which to lift or lurch the machine onto the stand in order that he may pedal the motor to start it. Instead, the rider sits in the saddle and gives either pedal a downward push—when the Step-Starter does its work and the motor again begins to throb.

It is the only Motorcycle with Double Clutch Control

The clutch can be operated either by hand lever or by a pedal lever convenient to the foot. It is no longer necessary to remove either hand from the handlebars in order to operate the clutch, a decided advantage when negotiating sand, mud or rough roads.

It is the only Motorcycle with a Ful-Floteing Seat

A device which assimilates all the jars, jolts, and vibration due to rough roads, etc.

It is the Motorcycle with a Protected, Selective Two-Speed

A Two-Speed that the rider can shift from low to high or high to low or neutral at any time whether the machine is standing still or in motion. A Two-Speed that shifts only when the rider shifts it. A Two-Speed that is located in the rear hub away from dirt, dust or damage and withal the most efficient Two-Speed ever manufactured.

It is the Motorcycle with Automobile Control

The Brake, the Clutch and the Step-Starter can all be operated by the feet, leaving only the spark and throttle for hand operation making the control the same as that of the highest priced automobile.

Then there is the ***Free-Wheel Control,*** Folding Foot Boards, and nearly forty other refinements which help to make the Harley-Davidson the greatest motorcycle value ever offered.

We tell you all about these many improvements in our new advance folder which will be sent on request

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