the vertical plane by rudder action only, is also fully justified by tactical and construction reasons. It is obvious that a change in depth can be effected in the least time and by the least expenditure of energy, if the vessel be moved in the direction of least resistance; in other words, if she is steered up and down inclines by altering the angle of her longitudinal axis to the horizon. In order to be effective the turning moment used must be of considerable magnitude and under the most sensitive control, conditions best met by horizontal rudders, which have also the advantages of simplicity and economy of space, weight and power. Other things being equal the rapidity with which a submarine can rise for observation and dive again is a direct measure of its efficiency, since its chance of escape from observation or projectiles is in inverse proportion to the period of exposure. As pointed out below, a loss in this quality may be justified when balanced by a corresponding gain in the equally important tactical feature of speed, but in no other way; hence it may fairly be concluded that this feature also has come to stay.

The correspondence between the French and American designs extends also in a general way to the most important construction feature—viz., the power plant. For submerged work both have adopted the electric drive, and for surface work and recharging batteries, etc., both go back to the hydrocarbons, the American using the light oil gasoline, with an explosive engine while the French employ a heavier oil, petroleum, and transform its energy into steam instead of using it direct in an explosive engine.

American System Best.—From a purely theoretical point of view, the American system is better adapted to the purpose, involving as it does only one variable weight—viz., fuel, against two for the other—viz., fuel and feed water. This leads directly to simple and rapid compensating arrangements tending toward a reduction in the time necessary to pass from a cruising to the fighting condition, a tendency still further helped by the absence of the high temperature accompanying steam propulsion, as well as the slow working apparatus for the escape of the products of combustion. In general simplicity and economy of space the American system offers additional advantages. On the score of safety the advantage, if any, lies at present with the French. A less volatile oil is used in the first instance, and it is probably less difficult to secure the complete expulsion of the products of combustion. The advantage, however, is not important as the danger element in either case is well within permissible limits and will undoubtedly be still further reduced in future boats employing the American system by the use of heavier oils and the perfection of the apparatus for disposing of the products of combustion. The principal advantage of steam propulsion lies in the fact that the designer can avail himself of very complete data based on experience, whereas since the marine oil engine of the power now required is practically new in the field, the designer is hampered by lack of reliable data. Ultimately, however, the oil engine will probably displace the steam engine, since the development of the former offers the possibility of a single motive power for all conditions, which will be reasonably efficient in the submerged condition. Modern chemistry is already in a fair way to provide the materials for supplying the necessary oxygen in such form as to meet the conditions imposed in a submarine. In the meantime the growing field of the oil engine, both afloat and ashore, will supply the experience necessary for the development of the largest powers apt to be used in the submarine.

Electric Drive.—The remaining important feature common to both designs is the employment of the electric drive for submerged work. The storage battery and motor are admirable in some respects, but exceedingly inadequate in others, the principal objection being the well-known one of excessive weight and space in proportion to the power developed. When it is stated that a weight of 370 pounds per horse power hour is a fair average for a suitable installation, it is readily seen that there is much room for improvement. Another disadvantage of the battery lies in the care and attention necessary for its safe operation after sensible deterioration has set in. The difficulty which takes the shape of abnormal behavior with respect to "gassing" may, under certain conditions, result in an explosion, such as took place on the "Fulton" last spring, and more recently on the "Holland." Fortunately, however, this condition is not inevitable, and is susceptible of control when it does occur.

There is no particular quarrel with the motor, except as to the difficulty in fitting it with a suitable propeller, and the battery bids fair to develop faster in the future than in the past, on account of the increasing demand for a light, compact battery for automobile use. Its continued use may thus be expected until the appearance in practical form of a development of a heat engine similar to that hinted at above.

The principal difference between the French and American designs lies in the choice made of dimensions and proportions, which appears to be the direct result of different ideas as to the relative values of speed and maneuvering qualities. To attain the high surface speed desired the French designers have been forced to adopt a considerable displacement, great length in proportion to beam, the double hull with large tank capacity, and incidentally the steam engine and multiple rudders. As compared with the Holland boats, the increase in surface speed is gained by a sacrifice of efficiency in three directions: 1, As to simplicity; 2, as to the length of time necessary to pass from a cruising to the diving condition, and, 3, as to the necessary period of exposure for conning tower observations. No exact data are available as to the minimum observation period required by the French boats, but their extensive use of the periscope indicates a relative inferiority in this respect. In shallow water at least this result would naturally follow from the dimensions and form adopted, as it is probable that the rudders are then used to produce not only a turning moment, but also a vertical thrust.

While the limit of surface speed for a given displacement has not yet been reached for either type, further material advances are most apt to be made by further increases in displacement. The limit to this process is not set by construction reasons, but by the probable

use of the type, which for any one country is fixed by its geographical location and the nature of its coast and harbors. For instance, a submersible of the "Narval" type and dimensions is for France not only a defensive, but an offensive weapon, and the partial sacrifice of submarine qualities in the design is warranted by the possibilities for offensive use. The same boat transferred to America would become purely defensive and would not be so well adapted to the conditions here as is the American type. It is probable then that in countries situated like France, where the possible enemy possesses large ports and arsenals within easy striking distance, the submersible will eventually be increased in displacement to perhaps 300 tons, in order to obtain a vessel which shall be seaworthy in a large sense, habitable for considerable periods, self-supporting and capable of a fairly high sustained sea speed. Such a boat would be first and foremost a weapon of offense and only incidentally a weapon of defense, in which field its place would be taken by several smaller units. Whether these units should be of the submersible or pure submarine type depends upon the extent of the coast, the number of harbors, the internal water ways and the condition of the fixed defenses. As noted above, France has adopted for this purpose the submarine of the *Perle* type, a course which is probably justified by the small number of her harbors and her highly organized fixed defenses.

Turning now to the United States, her location with respect to possible enemies is such that there is no immediate prospect of the development of the large submersible into an offensive weapon; still the extent of her coasts, the number of her harbors and rudimentary character of her fixed defenses render this type preferable to the pure submarine for defensive purposes. The development of the best all round boat to meet the conditions is likely here also to lead to some increase in total displacement, which eventually, however, will probably not exceed 200 tons. As compared with the larger offensive submersible, such a vessel would be less seaworthy and would have less surface speed, better maneuvering qualities, and greater submerged endurance. The pure submarine would thus at first glance appear to be an undesirable type for the conditions prevailing in the United States, but this is only true so long as the sole aim is torpedo work. As a matter of fact, however, the usefulness of the submarine is not confined to this one function, as it affords to-day the best known means for the destruction of mine fields and cables and the reconnoitering of fortified harbors. The objective being far removed, it is essential that the dimensions and weight of this type of vessel be kept at the lowest limit in order to admit of transportation by battleships, armored cruisers and the larger class of scouts. In such a vessel some armament would be desirable for attack upon stationary shipping, dry docks, etc., but this feature should be subordinated to the features necessary for efficient bottom work. By taking full advantage of the latest developments in diving apparatus all the essential features, including efficient signaling apparatus, could to-day be combined in a maximum length of 35 feet and a maximum displacement of 25 tons. This appears to be the only possible guise in which the pure submarine may play an offensive rôle, and even here, in the author's opinion, means for recharging batteries are desirable and justifiable, as scout work might require a considerable radius of action.

CONCLUSION.

To sum up, it appears that the submarine boats of the near future will naturally divide themselves into four types and two main groups, to conform to the different conditions in the different maritime countries. Group 1 would be suitable for many of the European countries, and would include the large offensive submersible, self-supporting, with auxiliary bottom working features, and the small defensive submarine for torpedo work only. Group 2, suitable for the United States and similarly situated countries, would include the small offensive ground working submarine or submersible (with auxiliary armament) and the medium sized defensive submersible for torpedo work only. It appears, further, that the submarine qualities of the modern boats are based on sound principles, and that the future development of the four different types within the limiting displacements of each must be along the present lines, and in the direction of improvement in the tactical qualities of speed and practical radius of action. As pointed out above, improvements in these respects are largely dependent upon the general improvement of the power installations, and as compared with the corresponding feature in the main objective, the battleship, the improvement in the submarine bids fair to be the more rapid.

THE NAVAL WAR GAME "WAR."—VII.*

By FRED T. JANE.

AFTER THE BATTLE OF MANILA.

AFTER the victory of Manila the German fleet proceeded to blockade the bay, and a claim was put in for the capture of the American base. This the umpires disallowed.

The entire German military force was then landed, and a number of shore operations followed. To follow these in detail would be tedious, and it suffices to say that the net result was a falling back of the American army upon Cavite, which the Germans invested.

The working of the game about here was not eminently satisfactory to all those engaged in it, for reasons to be found below. The umpires deducted ten per cent of the German force for "sickness due to the effect of climate on troops worn out by a long sea voyage." This decision was hotly contested by the German players, as also was a second decision in which the umpires refused to allow the Germans any information as to the whereabouts of the American North Atlantic squadron, last heard of as steaming south off Rio de Janeiro. The reasons for this refusal were as follows:

* Prepared especially for the SCIENTIFIC AMERICAN by the well-known naval expert and inventor of the naval war game, with exclusive rights in the United States and Great Britain. This series was begun in the SCIENTIFIC AMERICAN SUPPLEMENT of December 20, 1902.

The American players put in that the North Atlantic squadron after passing Rio Janeiro, spread out, so that if sighted by any merchant vessels, one American warship and not an American fleet would be reported. In addition to this the "Maine" and "Missouri" were ordered to steam back toward Key West until they had been sighted thus by merchant vessels. This accomplished, they were to return again and pick up the rest of the squadron off the Horn.

The whole American situation was at this time precarious, for the second Kiel fleet was displaying considerable activity. Leaving Kiel, it steamed north, a formidable enough squadron consisting of the "Wettin," "Mecklenburg" (lacking her heavy guns), "Brandenburg," "Woerth," "Weissenburg," "Kurfürst Friedrich Wilhelm," "Baden," "Sachsen," "Württemberg," "Bayern," "Aegir," "Odin," "Heimdall," "Hildebrand," "Hagen," the new armored cruiser "Prinz Adalbert," the old cruisers, "Irene" and "Prinzess Wilhelm," with sixteen destroyers and six 25-knot torpedo boats. With it were several colliers. Ostensibly this fleet, of practically every available German ship remaining, was bound for the North American coast. The whole move constituted a very clever ruse, in the following fashion:

A trifling calculation showed that by far the greater number of these ships carried too little coal to cross the Atlantic, so the United States North Atlantic squadron proceeded toward the Philippines without regard to the new menace. Presently the (from the U. S. standpoint) expected happened, and the second Kiel fleet was heard of as having gone into various bays on the Norwegian coast. It was then ascertained that many ships were going back singly and more or less secretly to Kiel. The American side chuckled and went on chuckling till they heard that the "Wettin," "Mecklenburg," "Brandenburg," "Woerth," "Weissenburg," "Kurfürst Friedrich Wilhelm," "Prinz Adalbert," "Irene," and "Prinzess Wilhelm," accompanied by many colliers and with from twelve to fourteen destroyers in tow, were in mid-Atlantic. The ruse, in fine, was eminently successful.

We may here leave the second Kiel fleet for a time and return to events in the Pacific.

Off Manila, presently isolated and unable to cable, the Germans maintained a desultory blockade. Three of the "Kaiser" class ("Kaiser Friedrich III.," "Wilhelm II.," and "Wilhelm der Grosse") had gone to Kiao Chau to refit; the "Bismarck" also had gone thither for the same purpose.

All this while the U. S. S. "Ohio" had been completing for sea at San Francisco. When ready she ran south, intending to meet the North Atlantic squadron at Cape Horn. The Germans, having received information of her departure, dispatched the "Wittelsbach" and "Zähringen" to intercept her.

This reduced the blockaders to two ships of the "Kaiser" class and the "Hertha" and "Hansa." Learning this, the "Albany" ran the blockade and got away south without injury. The "Hertha" and "Hansa" chased her a little way, but were soon left behind.

The next night the "Brooklyn" essayed the same thing, but blundering into one of the battleships, was sunk by a short range fire.

The methods by which this blockade running was worked may be of interest. The blockaders were made to furnish a chart and full notes of their positions for the whole period. All movements and positions that could be observed from the shore were communicated to the Americans, and the course of any blockade runner compared with the positions of the blockaders at any given time. If this brought hostile ships within sighting distance, subsequent incidents were worked out by whatever orders had been issued by either side against such a contingency.

On the night that the Albany ran out, the battleships were some ten miles out, due west, the "Hertha" and "Hansa" being well south, the latter close inshore. Passing between these two ships, the "Albany" was sighted by the "Hertha," which fired rockets. Bearing inshore to avoid the "Hertha," the "Albany" came within 2,500 yards of the "Hansa," and shots were exchanged. These were ineffectual, and her high speed enabled the "Albany" to escape.

The "Brooklyn" the next night took an identical course, but when bending inshore from the "Hertha," sighted the "Hansa" without being seen. (These questions of sighting, being pure chance, were settled by dice throws.)

Seeing the "Hansa," she bore round due west. The player who acted as captain of the "Hertha" also sighted the "Hansa," and opened fire on her in mistake for the "Brooklyn." She then got out searchlights, and discovering her mistake, fired signal rockets. The battleships, acting on the prearranged orders, steamed in toward the lights, and it was umpired that, silhouetted against these lights, the "Brooklyn" would be seen before seeing the Germans.

One battleship opened on the American cruiser at once, the other bore round southwest, and this ship—the "Kaiser Barbarossa"—it was that sank the "Brooklyn."

The "Albany," once clear, went on south and fell in with the U. S. North Atlantic squadron without incident. This fleet, lacking scouts, found her extremely useful.

(To be continued.)

ATMOSPHERIC ELECTRICITY AND EARTH CURRENTS.

By E. O. WALKER, C. I. E.

ON the Nilgiri Hills, in India, Michie Smith found, on the edge of a dissolving mist, the potential to be lower than the normal, and, on the edge of a condensing mist, higher. On Ben Nevis Dickson noticed that when the summit was clear a current came up the mountain, and that the reverse was the case when the summit was enveloped in mist. Similarly, on Vesuvius, the observations of Palmieri go to show that during a fall of rain or snow the current is, in direction, downward, and when the mountain is clear, in most instances the opposite occurs.

Beyond the probability that vapor movements alter the atmospheric potential, there are other facts which ought to be considered in this relation. Kelvin has

shown that electrification of air is diminished by raising the temperature; so also has Warburg, and he thinks that the electrification is probably due to condensed water particles. He adds that air without dust is not electrified. That assertion has not been borne out by others; at the same time there is no doubt that dust profoundly modifies the electrical state. Palmieri finds that when the volcano is active the direction of current is downward. This is contrary to what occurs in a clear sky. Elster and Geitel assert that on mountain tops the density of the negative charge of the earth is greatest, but that there is a preponderance of positively electrified particles in the air. They add that in cloudy weather the condenser action of the clouds alters the conditions. In a broad sense, Schuster found in Switzerland, at high elevations, a high degree of positive electrification in the air, and a lowering of the same when the current blew off a glacier. Perhaps it may be said that cold makes vapor negative and heat makes it positive, and it is the movement of vapor, no doubt, which renders the distribution of potential below 1,000 meters in height very obscure. Chauveau, in France, finds that a disturbing influence, due to vapor, and strongest during summer, complicates the diurnal variations of the electric potential, which would otherwise have a simple oscillation.

Elster and Geitel suppose that the atmosphere contains an equal number of plus and minus ions; that fog destroys the mobility of the ions by attaching them to water drops; in the earth's electrostatic field the free ions undergo a partial separation. The positive ions round the mountain tops produce a discharge of negative electricity from them. An unimpeded acquisition of negative electricity takes place on the earth's surface wherever the negative ions penetrate below, as they practically do under the foliage of a forest. So the earth gets its negative charge. Cloud stops the ions and accumulates electricity, and disruption follows. Elster and Geitel appear to think with Lenard that the ionization of the air is caused by ultra violet light, more particularly in the highest strata of the atmosphere, which would account for conductivity in those regions and for luminous phenomena. A similar supposition is entertained by Ebert and Hoffmann. A body suspended above the surface of liquid air was found to acquire a strong negative charge, due to friction of minute particles of very cold ice in the vapor. The ice was positive to the body, especially so when cold and dry. Generalizing from this experiment, they attribute the electric effects of polar snow storms to this cause, and conjecture that, high up, where ice crystals are in suspension, the atmospheric electrification may be partly occasioned by friction between such crystals and cosmic dust, and that solar ionization shares in its production.

Arrhenius, on the other hand, thinks that auroræ are cathode ray phenomena. Near the poles, where the magnetic lines are vertical, these rays can penetrate more deeply into the atmosphere. Electric discharges, occurring on the sun, produce cathode and Röntgen rays. Cosmical particles projected by the sun, carry charges to other bodies; these are arrested in the high strata of the atmosphere, and produce cathode rays when discharged by ultra-violet light.

Regarding the sign of electrification in the upper regions, Elster and Geitel, by balloon experiments, have ascertained that negative discharge takes place quicker than positive up to 3,000 meters, and above that height the rate is more nearly equal. In dry, clear air the rate is nearly as great as near the earth, but in damp air the discharge is much reduced.

It is possible that difference in the potential gradient over land and over sea is productive of electric currents in the air and on the earth's surface. A large eddy, produced by the sun north of its path round the earth and another south, would account for the horizontal movement of the needle which is daily recorded in magnetic observatories, and would also be productive of the earth currents witnessed in telegraph lines and cables. These two phenomena are intimately connected, and it is hardly necessary to cite facts in support of such an assertion. But one not generally known may be quoted. From a number of observations made of the earth current from Belgum to Vingorla in India, some 20 years ago, it was found on quiet days that the rate of change of the force producing the current, whatever it was, varied from $\frac{1}{2}$ foot to 22 feet per hour.

If the daily variation in declination be due to a slight shifting of the magnetic axis of the earth under the sun's action, the north magnetic pole would, for India, be displaced to the eastward about 739 feet in seven hours, and then slowly return to the normal. This movement is at the rate of 106 feet per hour, and, within the limits of observation errors, the approximation in slowness of change of force in the two cases is very striking.

Adverting to the possible effect of differences in potential gradient in the atmosphere in production of currents, the figures given by several observers render this surmise significant. At Delhi the gradient is 127 volts (Mache). At Luxor, in Egypt, Exner found the maximum to be 128 volts per meter, at Bombay 64 volts, and in Ceylon 57 volts. At Jeur, in the Deccan, Ludwig found 150 volts, and made the interesting observation that the potential gradient fell from 150 to 120 as totality of the eclipse of 1898 was approaching, and went on falling to 89 volts for 30 minutes after it was over. He remarks that the potential gradient clearly does not depend primarily upon the temperature. Exner supposes that air-borne dust and vapor cause maxima and minima of potential gradient. Braun's theory that it falls with rising temperature is inconsistent with the above facts.

It was with these thoughts in mind that observations were undertaken by the writer in Ceylon. Earth currents in the telegraph lines are not present to any great degree, but the manifestations were similar to those in the south of India. Between Paumben and Manaar, where the shores are low and sandy, and the two stations connected by 16 miles of overhead wire and 35 miles of cable, no difference of potential was observed, greater than $\frac{1}{4}$ -volt. The atmospheric conditions of the two places seem to be too much alike to permit of any difference electrically, and the gulf waters, of considerable extent on both sides, assist to produce an electrical level. Again, with regard to any possible effect

by the earth's magnetic field, as no part of the line is elevated, no such effect could be predicted, nor did it come to light. Between Colombo and Kandy the case is different. The former is on the shore and at the sea level, and the latter on the hills at an elevation of 1,700 feet, distant about 70 miles east of Colombo. The end of the line, however, at Kandy is among thick and tall trees, and the town itself nestles among high hills; the Colombo end is very near the sea, but surrounded by high buildings, so that in both places effects due to atmospheric electricity would naturally be somewhat obscured. Observations of the earth current were taken between 7 and 9 A. M. It flowed generally from Kandy to Colombo, and the maximum was observed on a fine and sunny day. It would seem to have been due to a difference of potential between the two ends of the line of 1.5 volt. This was at 8:19 A. M., but, compared with other days and with different states of the sky, this difference of potential was not found to be the same. Once, when the sky was overcast at Colombo and clear at Kandy, the current flowed from the former to the latter, and showed only 0.5 volt. Between Belgum and Vingorla, in India, where the conditions are analogous, the average maximum difference of potential was found to be 1.5 volt, and the current was down the line, from the mountain to the sea shore, in the mornings.

These figures are too high to be attributable to thermal effects at junctions of earth plates with the soil, or to electro-chemical effects at the plates, and seem to be due to an influence external to the circuit of the wire, earth plates, and intervening earth. For instance, a small model was constructed with earth plates and mold similar to that actually occurring in the localities concerned, and the temperatures at the respective ends were artificially reproduced. The highest E. M. F. obtained was 0.03 volt. Again, in view to ascertain whether the different states of the iron earths were contributing to errors, a galvanized and a plain iron earth buried a little distance apart were tested and the E. M. F. obtained was 0.1 volt. Lastly, to prevent polarization due to signaling currents from affecting the measurements, earth connections quite distinct from the telegraph office earths were employed during the experiments.

In view to elucidate the cause of the earth current, observations were instituted at Colombo with a Kelvin quadrant electrometer kindly lent by the Technical College. The collector was a tinned disk suspended at 67 feet from the ground, on the roof of the building, and 13 feet above the latter. The lead was well insulated, and every part of the circuit insulated by blocks of paraffin where any contacts with the building were likely. The variations in the air potential were irregular. Generally, there was a slight increase of positive electricity when a gust of wind occurred. The direction of the wind at this season was south-west or west-south-west. On two occasions about 8 A. M., when heavy clouds prevailed and a light or gusty wind, sudden negative deflections due to 5 and 10 volts were respectively noticed. In fine weather, again, there have been sudden variations of 5 volts.

At Kandy, where some observations were also made, very slight variation was observed, hardly to the extent of 1 volt. The collector was also above the roof of the building. Once, in heavy rain and fitful wind, there was an increase of positive electrification of 10 volts. It would seem on the whole, in the early morning at Kandy that the air potential is more positive than that of Colombo, and has less variation at the season of observation, which was during the prevalence of the southwest monsoon. It is not impossible that on the mountains, the effect of solar radiation being greater in the less dense atmosphere, the ultra-violet rays may modify the earth's negative charge to a greater extent than at low elevations, and produce the result that is manifested in the earth current. As these rays must fall in different phases at different places there would also be present the conditions favorable to extensive electrical eddies in the air.—Electrician.

FISHING BY ELECTRIC LIGHT.

An electric-light equipment that will add to the interest of an evening's fishing, as well as to the length of the resulting string of fish, is described by a correspondent of Amateur Work. He says:

"The necessary materials are: a small incandescent

FISHING BY ELECTRIC LIGHT.

electric globe and porcelain base of about three-candle power and three volts; a dry battery for same, of the kind used in bicycle or night lamps; several yards of two-way flexible covered wire of small diameter, some rubber tubing to cover the flexible wire, a glass bottle with large mouth, and rubber cement.

"The neck of the bottle should be large enough to easily admit the porcelain base. Cut a circular piece of wood, B, from a cigar-box, large enough to cover the top of the bottle, and in the center bore a hole to admit the rubber tubing with a tight fit. The porcelain base, D, is screwed to the cork, C, with two screws which should be long enough to reach into the wooden piece, B. The flexible wire is then covered with the rubber tubing. An easy way to do this is to take a nail which will easily pass through the tubing, tie to it a strong thread, and from an upper window lower the nail into the tubing until it comes out at the other end. With the thread a string is then pulled through, and with the string the wire in the same way. Firm-

ly attach the string to the wire without any large knots, and also see that the ends of the wire are not likely to catch on the tubing. The wire on the lamp-end should extend about three inches to allow for connection in the bottle.

"Through the cork bore two holes from the center of the top side to the edges of the porcelain base. The wire and tubing are then put through the hole in the wooden piece, B, the end of the tubing being attached with bicycle or other cement to the underside of this piece. The two strands of the wire are then put through the holes in the cork and connected with the terminals of the lamp. The upper side of the cork is then covered with cement and pressed firmly against the piece, B. When dry, the water will not reach the wire when the cork has been inserted in the bottle. The other ends of the wire are, when ready to use, connected to the battery, and the lamp will then light. The battery is kept in the boat. The wire not in the water does not require to be covered with tubing. In use, the bottle is weighted so that it will sink to the required depth. The battery is then connected to light the lamp. The light will attract many kinds of fish. The fisher and a properly-baited line will do the rest."

THE ELECTRICITY WORKS OF SWITZERLAND AND WATER POWER.

OUR thoughts turn to Switzerland when we think of water power and hydro-electric installations. The statistics of the electricity works of Switzerland and the map of the network for the distribution of electric light and power which Professor W. Wyssling, of the Zürich Polytechnic, has recently published, however, do not appear to show the high figures and the general utilization of electric power with which Switzerland is often credited. But it must be borne in mind, however, that, as in the annual statistics compiled by the Association of Electrical Engineers of Switzerland and of Germany respectively, private installations, no matter how large, have not been included in these lists. The total electric energy which is utilized as power or light is thus considerably higher than it would appear from Dr. Wyssling's figures.

Dr. Wyssling's statistics are brought up to the end of the year 1901. When we glance at his map of Switzerland, we notice that there are four great power-distribution centers, whose mains frequently approach one another within a few miles, and, further, a number of more isolated centers. The great centers are Lausanne, with branches extending far up into the Rhône Valley on the one side and to the Lake of Neuchâtel on the other; the Jura Mountains, with Neuchâtel, La Chaux de Fond, Locle, and branches to Biel and via Solothurn to Langenthal and the Aar Valley; Berne, Thun, and Burgdorf; Zürich, Zug, Baden, Waldshut. More isolated are Basel, Lucerne, Glarus, St. Gallen and Geneva. Dr. Wyssling distinguishes between electricity works proper, which supply to customers; electric railways and tramways; and electric transmission of power by concerns which, while not serving the public, yet send their mains to some distance over grounds not their own. The electricity works proper are subdivided into primary power stations and secondary or distribution stations; the latter are generally provided with transformers, while customers are also joined directly to the primary generators. He counts altogether about 300 electricity works—namely, 235 primary and 61 secondary stations; 41 of the former are more of a private nature, while 194 serve the public directly or are operating railways. The primary power is water in 215 cases, gas or petroleum in 14, and steam in six cases. These latter figures do not comprise reserve power for the turbines; those reserves are formed by steam engines in 14, and by internal combustion motors in six cases. The available power of the hydro-electric stations fluctuates with the season. Counting only the minimum power always at disposal, Dr. Wyssling calculates that the total (minimum) capacity of the Swiss public electricity works is 110,000 kilowatts, or 160,000 horse power. When the big Zürich power scheme which has been talked about for some time has been executed, another 100,000 horse power will be added. The primary stations generate 103,200 kilowatts, 97,600 kilowatts being derived from water power, 3,100 from steam, and 2,500 kilowatts from gas, petroleum, or benzine; the private power transmissions represent 7,700 kilowatts (7,300 in steam, 200 in gas), the secondary stations 20,100 kilowatts. Thus 15 per cent of the total energy produced is consumed second hand, so to say, chiefly by electric railways, small motors, and lamps, while the large electrochemical works generally take their current direct from the primary stations.

Electric railways claim 13 per cent, lighting systems nearly 40, power 25, and electro-chemistry 23 per cent of the total power. A large portion of the power put down to the electro-chemical works is not utilized at present, owing to the depression in the calcium carbide trade. Of the 56 electric railways, seven are merely rope elevators. Thirty-seven railways obtain their power from other works; 19 have their own power plant; and eight of these latter sell light. As regards current system, we find 42 continuous-current and seven two-phase current plants for railways and tramways; triphase currents are also used on two of the rope lines. The towns of Zürich, Geneva, and Basel alone contain one-third of all the electric railways of the Confederacy.

Summing up, we see that, after all, comparatively little use only is still made of water power in Switzerland, and a rapid change in this direction is perhaps hardly likely. It is not so easy as it might appear to supply electric power to small works, when we have to rely on water as the primary power, however cheap that power may appear. The fluctuations in the water make the plants too complicated and expensive. The small manufacturer wishes to pay for current consumed, but not to submit to a minimum charge to be made in any case. Most hydro-electric stations have to insist upon a minimum payment, however; though in districts where the demand for light is constant and brisk, and relatively high rates are paid, special low terms can be offered for power. To overcome these