THE KOBUSCH-WAGENHALS STEAM MOTOR COACH.

IN the effort to meet the present imperative demand for a satisfactory railway motor coach a rather large number of constructions have been developed of late. Through the courtesy of the St. Louis Car Company we are enabled to present a steam motor coach which has just been completed in its Baden plant. This is a steam coach, and an inspection of its construction as well as observation of its performance in operation gives one the impression that it is just about what is being sought for.

The design and arrangement of its motive power features have been developed by Mr. W. G. Wagenhals, who, in partnership with George J. Kobusch, president of the St. Louis Car Company, has been attending to the first construction which has just been completed. The accompanying photographic reproductions afford a very good idea of the essential points, drawings of which we hope to present later on.

Regarding general particulars first; the coach is 82 feet 6 inches in length and has a total weight of 178,560 pounds, 115,600 of which is at the motor truck end. Height, from rail to top of stack, 15 feet 2 inches; width, 10 feet over all. The underframing is of steel and the body construction and fitting is that usual with high grade railway coaches so far as the passenger and baggage compartments are concerned. That portion of the body which incloses the boiler and "motoneer's" compartment, however, is constructed of steel. The coach seats fifty-two persons in the main compartment, and twelve in the smoking compartment. Ahead of the latter is a baggage compartment ten feet in length, while the remaining twelve feet is assigned to motive power uses.

In this latter compartment a marine type, water tube boiler occupies the space immediately ahead of the baggage compartment and over the motor truck. This

a box guide through which is passed a bar, curved to the radius of the distance to the truck center. This bar is pivoted at one end and at the other end attaches to the lower arm of the reverse lever. This arrangement provides a positive control of the link motion entirely unaffected by any movement of the truck with respect to the car body.

The most striking feature of the car, however, relates to the motor truck, the arrangement of which is not only most unique but has been so cleverly worked out as to create a most favorable impression of the idea. Instead of following locomotive precedent Mr. Wagenhals has really taken street car precedent and practically merely exchanged a steam motor for the electric motor which is geared to one axle. Side rods have been added to utilize all four wheels and an inspection of the cuts will show simplicity and workmanlike character of the essential arrangement. A double cylinder, piston valve, 11 by 12 inches, 275-horsepower engine has the frame of its cylinder end hung on a single point spring suspension just back of the truck center casting. At the other end, the engine frames are extended beyond the crank shaft so as to rest on and be supported by the axle of the forward wheels. This affords a three point suspension for the engines, while a still further extension of the engine frames enables the two to be rigidly connected by means of the heavy shouldered bolt. A pinion on the crank shaft meshes with a gear wheel on the axle, in the same manner as is practised with electric motors. Both engines are inclosed in crank cases so as to be self-oiling as well as protected from dust, etc., and the gears also run in a case. The oil cups of the other parts are located outside the truck frame and reach their particular bearings by means of small pipes. The wheels are 42 inches in diameter and with the present size of pinion and gear a tractive effort of 8,000 pounds, or a speed of 40 miles per hour is secured. The exhaust is used to heat the coach and the fuel oil, though it is

elongated solid of revolution but some prefer a cylindrical, some the tear shape used by Santos Dumont and Lebaudy. This form, or in general a form, with a blunt bow immediately followed by a gently tapering after part, is suggested by the forms of birds, fishes and ships. Some even recommend imitation of the bird's flight. It would be as sensible to build an automobile in the form of a mechanical greyhound. Before blindly imitating nature we should consider whether our object is the same as hers. The strongest and hence the broadest part of a bird's body is at the place of attachment of the wings, and a fish needs a gently tapering, flexible after part, in order to employ its caudal fins effectively. In the airship both of these considerations are subsidiary to the requirement that the cross section shall be as small and the internal capacity as large as possible. Water waves travel about 4 meters (13 feet) per second, as may be ascertained by noting the time which the swell of a boat at a known distance occupies in reaching the shore, or by observing how the swell runs ahead of the slowly-moving swan, falls behind a fast steamer, and keeps even pace with a boat going about nine miles an hour. Now, the shorter the bow of the fast steamer is, the smaller is the number of such overtaken waves that impede its progress, and the longer the portion tapering from the maximum cross section to the stern is, the more numerous are the waves which, so to speak, squeeze it forward. Until ten years ago, therefore, the belief prevailed that a long amidship section with parallel sides involved loss of speed.

Helmholtz, however, has pointed out that the air which envelops an airship, unlike the water surrounding an ordinary vessel, can escape in every direction, and that, furthermore, the speed of the airship is so small in comparison with the velocity of sound (i. e., of air waves) that difference in the density of the air may be neglected. How Helmholtz was able to pass from this explanation of the essential dissimilarity

THE KOBUSCH-WAGENHALS STEAM MOTOR CAR.

boiler is of the square, torpedo boat type, measuring 77 inches in width and breadth. It has 1,215 square feet of heating surface, 43.5 square feet of grate area and carries a working pressure of 250 pounds per square inch, though it is built for a cold water test of 500 pounds. It is fired with crude oil through five burners of a special design. One thousand gallons of this oil are carried in a tank underneath the car body. In this tank the oil is heated by a portion of the exhaust steam and a pressure of air, obtained through a reducing valve from the main reservoir of the brake system, forces the oil up to the burners, where it is sprayed by either steam or air, or both, as may be desired. Owing to the high steam pressure as well as the desirability of easy feed control a marine type boiler feed pump is used instead of an injector. Two thousand gallons of water are carried in two tanks also under the body of the car and the feed water passes through heating coils at the top of the boiler before entering the boiler proper. In addition to the boiler and its attachments, the compartment contains a Westinghouse 9½-inch pump and a complete E-T brake equipment. The throttle and reverse levers are located most conveniently for the motoneer, while the other controlling devices, such as that of the feed water pumps, etc., are all within easy reach.

The main steam pipe runs from the boiler (overhead) to the front of the compartment, where it is turned down and runs through the floor to a casting which is the female part of a flexible joint. A similar joint is near the forward end of the motor truck center casting. In the length of pipe which connects these two flexible joints is an expansion joint. Trial has shown this arrangement to be most satisfactory, as there is no escape of steam under any condition of swiveling and there appears no indication of any weakness developing. The guide just ahead of the end sill provides for retaining the reach rod to the link motion in line during the rises and falls of the truck with respect to the car body. The forward end of this reach rod is merely

directed out the stack when not required for these purposes. The truck center casting and frames are of cast steel and the 7 by 10 inch axle bearings are equipped with locomotive type boxes and cellars. The trailer truck is of the standard M. C. B. four-wheel type, with its center 53 feet from that of the motor truck.

In operation one is struck particularly with the entire absence of vibration due to the working of the engine. This is, of course, due to the divorce of the motor truck from other than a center casting connection with the car. Also the large boiler capacity enables the engine to be worked to its full capacity under all conditions and the engines are of a size which lifts the car into speed in a surprisingly quick manner. Another point which impresses one is that only three or four easy disconnections are necessary to enable the truck to be run out from under the car for repair or exchange with another truck. Within a few days the car will be sent on a demonstration trip around the country, in the course of which it will be placed on exhibition in the depots at the large railway centers. Following this the present car will be put into regular service on the Missouri Pacific Railway.

DIRIGIBLE AIRSHIPS.

By COUNT VON ZEPPELIN.

A BALLOON that is motionless with respect to the surrounding air shares all the latter's movements, which are not small. In a calm the air is moving with the resultant of the earth's velocity in space and the rotational velocity of its surface and a hurricane represents only a comparatively slight deviation from this average velocity.

A dirigible or automobile airship can propel itself through the surrounding air at a speed limited to the velocity at which the effective propelling force equals the air resistance, which depends on the size and shape of the vessel.

All designers agree that an airship must be an

of the conditions of motion of airships and ordinary vessels to the conclusion that the two are identical, is more than I can understand, but he did so, and the advocates of the "tear shape" are supported by his great authority. I advocate the cylindrical form for airships for the very reason that their velocity is insignificant in comparison with that of air waves, yet I feel confirmed in my view by the fact that during the past ten years the straight amidship section of ocean vessels has been continually lengthened with great advantage, although the waves of displacement do affect the speed in this case.

The shape of the bow should be such that the air will be displaced by a large surface presenting no concavity in order to reduce the compression to a minimum. A semi-ellipsoid is better than a paraboloid because it is tangent to the cylinder behind it and presents no angle to increase the resistance. The stern should be shaped like the bow, because the withdrawal of a body from the air develops a resistance similar to that which opposes progression.

The carrying power of a cylindrical airship is proportional to its length and the square of its diameter. Large vessels are faster than small ones because the increase in carrying power permits the employment of motors more powerful than would be required to overcome the increased resistance even if the resistance were proportional to the surface.

But it is not. The resistance per unit area diminishes as the total surface is increased. I deduced this law from observation in 1895-6.* In 1903 Hergesell confirmed this law by experiments with pendulums having spherical bobs of various sizes. Ritter has recently attempted to disprove the law by mathematical demonstration supported by a single experiment in which only small surfaces were used. In view of the danger of falling back into the old erroneous assumption that the resistance is proportional to the

* Zeitschrift des Vereins Deutscher Ingenieure, 1895. Zeitschrift für Luftschiffahrt und Physik der Atmosphäre, 1896.

area of the surface, let us devote a little attention to the true law of resistance, which is not to be overthrown by old traditions, mathematical reasoning or the experiments of Ritter, Lössl, and Canovetti which, though otherwise admirable, were made with too small surfaces.

An air current striking a surface must be deflected to its boundaries. The succeeding particles of air encounter this deflected current so that they do not exert their full force against the surface or the air cushion that covers it, but are carried away in a direction and with a velocity which correspond to the resultant of the arriving and the deflected currents. The larger the surface is, the more rapidly is the initial mass of air forced outward, the greater is the deflection of the succeeding particles and therefore the smaller is the pressure exerted by them on the surface.

Or, let us compare two disks of 10 and 100 square inches, each divided into rings of equal area, say 1 square inch. The outer ring of the large disk is narrower than that of the small disk, consequently the particles which strike the outer ring are more readily deflected outward and the reaction is less in the first case than in the second. Hence the increase of pressure due to unit increment of area must be less for the large disk than for the small one, or the total pressure must increase less rapidly than the area.

In designing an airship the danger of sinking must be guarded against as securely as in designing an ocean vessel. Many inventors solace themselves with the knowledge that if the airship is compelled, by failure of the machinery or otherwise, to descend, it can sink slowly and land safely, like an ordinary balloon. This is sufficient for the experimental stage, but airships will be of little value until they can travel long distances over wooded, mountainous, and densely populated districts and over the sea, where the gentlest descent may be fatal, as well as over the enemy's territory, where landing means captivity. As there is no motor which is not liable to frequent stoppages, the airship should have at least two independent motors.

air pipe leaks the airship changes in form, refuses to obey the helm and is in a dangerous plight.

Another source of danger is the single gas bag made necessary by this maintenance of internal pressure. A bullet or a branch of a tree may tear the bag, let out all the gas and cause a catastrophe.

Flexible airships can serve only for sport, or for military or scientific purposes which justify the taking of risks. In war they would be very useful, notwithstanding their small radius of action. But the employment of flexible airships of only twelve or even twenty-four hours' flight in field operations—as distinguished from sieges—necessitates the assignment to each vessel of a company almost equivalent, in officers, men, horses, and wagons, to a field battery, and consequently entails great expense. For naval operations such airships could be used only near the coast.

The only representative of the rigid system is my own airship. It has a rigid hull, the shape of which is not affected by the degree of distension of the gas cells which it contains. This construction does away with the objections mentioned above and, in particular, it allows a second system of propelling mechanism to be placed at such a distance from the first system that they do not interfere, without necessitating any increase in the cross-section of the hull and, therefore, without increasing the resistance to progression. I reached this result in the following way:

In the first place, I calculated how long an approximately cylindrical hull of very small diameter could be constructed that would sustain its own weight and the weight of its car, crew, and machinery. The limit of length is reached when a further increase involves an increase in weight (used in stiffening the long cylinder to prevent bending under the load on the middle point) greater than the increase in buoyancy given by the added length. If this limit has been reached and a second motor, etc., are then added the additional volume of gas required to sustain them can be accommodated only by increasing the diameter of the cylinder and consequently diminishing the speed. To avoid this I connected, end to end, two such cylin-

between the stopping of the motors and the landing of the airship at a point 19 kilometers (nearly 12 miles) distant, and was found to be at least 15 meters per second. When the airship was driven by the motors alternately instead of together, the speed was computed to be about 12 meters per second (39 feet per second or 26.7 miles per hour). To allow for possible error I take the speed with both motors as 14 meters per second or 50 kilometers (31 miles) per hour, and the speed with one motor as 11 meters per second or 40 kilometers (25 miles) per hour.

With a load of 3,090 kilogrammes (6,800 pounds) in addition to its own weight, the airship rose to a height of 850 meters (2,800 feet) above sea level. Hence 4,300 kilogrammes (9,460 pounds) could have been carried at the sea level. If 500 kilogrammes (1,100 pounds) are deducted for possible error and the consideration that the start would sometimes be made from an elevation of several hundred feet, and 800 kilogrammes (1,760 pounds) for crew, provisions, etc., 3,000 kilogrammes (6,600 pounds) are left for fuel. As each motor consumes 25 kilogrammes (55 pounds) per hour, the airship, using both motors, could travel 60 hours at 50 kilometers (31 miles) per hour, or 3,000 kilometers (1,860 miles). With one motor it could travel 120 hours at 40 kilometers (25 miles) per hour, or 4,800 kilometers (3,000 miles).

The objection is often made that these long flights are theoretical and have not been actually accomplished. I reply that trial trips of moderate length prove the feasibility of the longer journeys. A new ocean steamer starts confidently for China after making comparatively short trial trips.

But there is one great difference. The steamship has officers and men trained by experience in similar ships, while I am the only man who has commanded a large rigid airship, and my experience is limited to four flights of an aggregate duration of three hours.

The management differs greatly from that of a small, flexible airship. The heavy masses are not easily moved or stopped, and as the resistance offered by them to the air varies with their position in the vessel, they cause oscillations which must be checked

TRUCK OF THE KOBUSCH-WAGENHALS STEAM MOTOR CAR.

LEAD END OF KOBUSCH-WAGENHALS STEAM MOTOR TRUCK.

The most effective means of propulsion is the screw propeller. Experiment has disproved the old theory that very large slowly-turning propellers give the best effect. More than ten years ago I had a (water) boat built to be driven by air propellers, in order to test my propellers and motors. I found that properly constructed propellers, which impose on the motor exactly its full normal load, show equal efficiency whether they have long blades and turn slowly or have short blades and turn rapidly, also whether they have two, three, or four blades. A speed not very different from that of the motor is advisable, because it simplifies the transmission. Small propellers are preferable because they save weight and space and need only short shafts.

Whether the airship shall be small or large, rigid or flexible, will depend on the nature of its employment and the corresponding requirements in regard to safety, speed, load and radius of action.

Lebaudy's war airship, the best representative of the flexible system, attained in 1904 an average speed of 11 meters per second (36.1 feet per second, or 24.6 miles per hour) and a maximum speed of 11.8 meters per second (38.7 feet per second or 26.4 miles per hour) carrying sufficient benzine for 11 hours. As each Lebaudy is larger than the last with a relatively lighter motor it appears probable that a 12 hours' flight with four men at a speed of 12 meters per second (39.4 feet per second or 26.8 miles per hour) will soon be accomplished. Major von Parseval may possibly achieve such a result still sooner. What of it? A flexible airship of this type is too uncertain to attract many aeronauts. Above all, it has only one motor and the addition of a second independent motor with its propellers would necessitate an increase in size that would seriously affect the speed and duration of flight.

Furthermore, the shape of the gas bag can be preserved only by keeping the gas under constant pressure by means of an inner bag, or "ballonet," inflated with air by a pump driven by the motor or preferably by an independent motor. If the motor stops or the

ders, each carrying its own car and machinery. Thus I doubled the length of the airship without enlarging its cross-section and provided it with two entirely independent propelling systems, either of which could be used alone for moderate speeds.

The requisite rigidity is given by a series of rings, stiffened by transverse braces. This construction necessitates the division of the gas capacity into a number of cells which, like the water-tight compartments of a ship, insure safety because the rupture of one does not affect the others.

The outer skin is of waterproof fabric, stretched over a metal frame. An interval is left between it and the gas cells so that the latter are not immediately affected by the unequal heating of the skin by the sun's rays and the buoyancy is fairly uniform. Variations in buoyancy cannot be entirely avoided as the airship is lightened by the consumption of benzine and made heavier by rain, snow, and hail. In the rigid system the compensation of these variations by expenditure of gas and ballast and by oblique flight can be avoided by the addition of horizontal rudders acting as aeroplanes. A great advantage of the rigid system is the possibility of fixing the propellers at the level of the center of resistance and thus avoiding the waste of energy involved in the struggle to maintain horizontal flight.

The probable speed of my airship was calculated in 1903 by Prof. Müller from the most reliable formulae of resistance and the experimental data of Renard and others. The result was 14 meters per second with two motors, each of 50 horse-power. The speed attained in my flight of January 17, 1906, using 170 horse-power, was about 15 meters per second (49.2 feet per second or 33.5 miles per hour) which agrees well with Müller's figures.

This speed was determined from the observation, made simultaneously from the ground and both cars, that when the airship was steered approximately to windward, it remained nearly over the same point and was never driven backward. The velocity of the wind was estimated from the time which elapsed

by special devices. Vertical motion must be effected by power, to save gas and ballast and prolong the flight. Experiments with double aeroplanes like my lifting rudders have given an upward pressure of 13.1 kilogrammes per square meter (2.68 pounds per square foot) for a speed of 12 meters (39.4 feet) per second and an inclination of 15 degrees. Therefore, with my rudders, aggregating 26 square meters (280 square feet) total pressures of from 340 to 680 kilogrammes (750 to 1,500 pounds) can be obtained.

Usually only one motor would be used, to lessen the danger of both failing simultaneously and also increase the length of flight. Both motors would be used only to gain a moderately distant point as quickly as possible, or against strong head winds, to overtake a hostile airship, etc.

As the travel over the ground is the resultant, in direction and velocity, of the wind and the proper motion of the airship, the progress of the vessel, like that of a sailing ship, depends upon the wind. The sailing ship, unlike the airship, however, can beat to windward against the strongest gale, though it is motionless in a calm, when the airship goes ahead at full speed.

On the average, wind favors the progress of airships for these reasons: First, during half of the time the wind is directly favorable; secondly, very often when the start is made with an unfavorable wind an opposed current can be found above or one side of the straight course; thirdly, in many cases a favoring wind may be expected to spring up during the flight.

Therefore meteorologists can render immense service to aeronauts by increasing the number of observing stations, promptly disseminating information and extending the system of wind charts to the continents and to elevations of 200, 500, 800, and 1,200 meters. The knowledge of the maximum height of fog, the aeronaut's worst enemy, in different latitudes, would also be very valuable.

There is no difficulty about obtaining bearings while in sight of land that can be identified on the chart. Over the ocean the direction and rate of resultant mo-

tion may be obtained by dropping a float by day or a piece of potassium, which inflames on contact with water, by night and measuring the inclination of its apparent direction as seen from the known elevation of the airship at measured intervals of time. The speed and direction of the proper motion of the airship being also known, the velocity and direction of the wind can be deduced and the course laid accordingly. I have devised a simple instrument and a table which gives the required figures and compass points at a glance. The latitude and longitude can easily be obtained astronomically with Marcuse's quadrant, which has been tested in the Wegeners' balloon voyages.

As it appears from the above that airships similar to mine will soon be available for flights of 3,000 miles, the question arises, of what use will they be? To the sportsman a flight across the Atlantic, taking advantage of the trade winds, will not appear too hazardous. Other persons will properly demand an assurance of safety equal to that of an ocean liner. The safety and certainty of the voyage depend upon the force, frequency and duration of opposing winds. A careful study of wind charts has convinced me that—in central Europe at least—a head wind blowing for 48 hours with an average velocity of 6 meters (19.7 feet) per second represents the greatest obstacle to be overcome. As my airship has a relative speed of 11 meters (36.1 feet) per second it would travel against such a wind at the rate of 5 meters (16.4 feet) per second or 18 kilometers (11.2 miles) per hour. It would travel about 850 kilometers (528 miles) in 48 hours, or 1,700 kilometers (1,056 miles) in four days, and still have fuel enough for another day's journey. Hence, in the most unfavorable conditions, it could go 1,000 miles, or 500 miles and back.

If additional persons, extensive apparatus, mails, etc., are carried the quantity of fuel and, consequently, the length of the flight, must be decreased.

Airships with a radius of action of 800 kilometers (500 miles) would be very useful as movable wireless telegraph stations. In war, airships would be valuable as spies in constant wireless connection with headquarters, and possibly as armed cruisers and torpedo boats.

But the most important characteristic of the rigid system of construction is its capacity for development. It requires great dimensions and, as with the ocean steamer, speed, safety and relative economy in first cost and operating expenses increase with its size. An airship only slightly smaller than mine would be useless and an increase of 1 meter (3.3 feet) in diameter with a corresponding increase in length would give an additional buoyancy of 3,000 kilogrammes (6,600 pounds). Such an airship could carry fifty passengers for short trips. It could reach the north pole by easy stages, establish communication between East and West Africa and carry food, water and ammunition to our troops, or rise above the clouds for the observation of a solar eclipse.

THE ELECTROTHERMAL METALLURGY OF IRON.*

By MAJOR E. STASSANO

It is well known that in ordinary furnaces only a small part of the calorific power of the combustible materials used for heating is utilized. Moreover, the quantity of heat really used varies with the construction of the furnace and the mode of heating. On the average, the thermal efficiency of industrial fuel is only 2 to 3 per cent for a forge fire; 5 to 10 per cent for apparatus in which the heating is produced through walls of refractory material, as in crucibles; from 10 to 20 per cent in furnaces with hearths and in small blast furnaces; finally, an efficiency of 30 to 50 per cent, and even 70 per cent, is obtained in cupolas and large blast furnaces.

The very small thermal efficiency obtained in industrial furnaces is due in a great part to the fact that the necessary element for combustion, viz., the oxygen of the air, being so much diluted by the inert gas, nitrogen, which, during the combustion, absorbs a great deal of heat, lowering the temperature, and necessitating large dimensions for the combustion chamber. Apart from this, a great deal of heat is lost by radiation from the walls, and also by convection. It is, then, readily understood why a high efficiency can be obtained by the use of electric energy for the production of the heat, for the reason that this source of heat is not due to combustion and that the most important causes of loss inherent in the use of a combustible can be avoided.

In taking 20 per cent as the mean thermal efficiency of industrial fuels used for heating metallurgical furnaces, and in putting the thermal efficiency of electric heating at only 50 per cent, it is easy to determine the limits within which the substitution of electric heating for heating by combustion may be realized industrially, and with what resulting economy. The mean calorific power of industrial fuels is 6,500 calories,† while the transformation of 1 E.H.P. hour into thermal energy produces 635 large calories. Taking into account the efficiencies already mentioned, it follows that

$$\frac{6,500.20}{100} \div \frac{635.50}{100} = 4.22 \text{ E.H.P. hours, transformed into thermal energy, produce the same thermal work}$$

* Paper read at the Sixth Congress of Applied Chemistry at Rome, May 1, 1906 (translated).

† Theoretically, the calorific power of fuels has a greater value than 6,500 calories, but if humidity, which is always rather considerable, is taken into account, as well as ash and other impurities, we find in practice that the calorific power is not above the value indicated.

as that obtainable by burning 1 kilogramme of combustible in an industrial furnace.

The greater number of hydro-electric generating stations produce an electrical horse-power year at a price not exceeding \$8.* Under these conditions, if one can utilize 50 per cent of the heat produced in the transformation of electric energy into thermal energy, an electric furnace worked from a generating station which makes use of large water power can work under the same economical conditions as are possible by the use of coal costing 21 fr. (\$4.20) per ton.

It may be remembered that in the preceding calculations the thermal efficiency of combustibles in an industrial furnace has been given a higher value than is obtainable in practice. The supposition has also been made that in new electric furnaces only 50 per cent of the heat produced would be utilized, and the cost per electrical horse-power hour has been arrived at by considering only 8,000 hours' running per annum, whereas in reality a hydro-electric installation is used during 8,760 hours per annum, i.e., without interruption.† Further, it must be remembered that in many metallurgical operations it is indispensable that certain special combustibles should be employed, such as coke, which, on account of its manufacture, costs more than natural coal. It must also not be forgotten that the price of coal tends rather to rise than to fall. Under these conditions it will be readily understood that

is a carbide of the metal, more or less rich in carbon, containing in addition numerous impurities and other metals and metalloids arising from the total or partial reduction of the different compounds found in the ore that is used. This result, which cannot be avoided in the different processes at present used in the reduction of ores by coal, necessitates the first product being submitted to a number of successive refining operations, so as to obtain the metal finally in the required degree of purity. Further, during the operation of reduction, certain impurities contained in the industrial combustibles, and even in the air which is necessary to maintain the combustion, mix with the metal, modifying its composition and give rise to parasitic actions which are generally harmful from the point of view of the success and economy of the succeeding operations.

The electrothermal process depends on a source of heat necessitating neither combustible nor atmosphere to maintain combustion, and its use does not bring with it any of the inconveniences which have just been mentioned. Nor is this all. It is known that the thermal efficiency of a given metallurgical operation is the higher the greater the difference of temperature between the source of heat and the material to be heated. Similarly, the more the surrounding atmosphere is at a high temperature the more active are the chemical reactions which are produced.

Finally, it may be added that the electric energy

FIG. 1.—VERTICAL SECTION OF THE STASSANO ROTATING FURNACE.

the employment of electric furnaces is a matter of importance in localities where hydro-electric power can be utilized to carry out some of the reactions under economical conditions identical with those which would allow of the use of coal costing more than 21 fr. (\$4.20) per ton.

The preceding very approximate calculations do not allow the importance of the problem to be realized exactly, because there is another reason not less important which increases the expense when combustibles are used, and which somewhat militates in favor of electrothermal processes. In metallurgy generally the coal does not serve merely, directly or indirectly, as the reducing agent, but also as the source of heat. It is for this reason, notably in the metallurgy of iron, that when the ore is in contact with the combustible during reduction, it is not possible to determine exactly the quantity of coal absolutely necessary to effect the reduction of the ore and that which is necessary for the production of the required temperature. It follows, therefore, that it is necessary to employ an excess of combustible, an excess which is partly absorbed by the metal, according as the ore is reduced. Under these circumstances, the product obtained after the first operation of reduction of the ore is far from containing the only metal which one wishes to extract. The product

used for working electric furnaces being generally produced by hydro-electric power, in order that the apparatus should work under the best conditions, it should be installed for continuous working and always fully charged. It is evident that in realizing these conditions fairly completely, the advantages presented by electrothermal methods will be considerably increased. The new processes will permit the metallurgical industry to be installed not only in localities deprived of natural fuels and possessing important water power, but will also admit of certain special applications, even where the fuel can be obtained at low prices, and where it would seem at first sight that practical application cannot be realized.

To sum up, it can be shown that, in order to utilize the heat produced by the transformation of electric energy into thermal energy under industrial conditions, chiefly in metallurgy and particularly in the metallurgy of iron, it is sufficient that the apparatus employed should fulfill the following principal conditions:

1. That the inclosure in which the transformation of electric energy into heat is carried out, and also the metallurgical operations necessitating this heat should be protected from the direct action of the atmospheric air and constructed of materials absolutely inert from the chemical point of view.
2. That the heat developed by the transformation should be produced at as high a temperature as possible.

* At Terni, the retail price per electrical horse-power-year is only 27 fr.

† The Commission sent to Europe by the Canadian Government to study electrometallurgical installations admits in its report the utilization of 8,760 hours per annum.