sion of an instantaneous occurrence, or else at appreciable intervals. Whereas one cross was very luminous, the second as a rule was weaker, and so on with diminishing intensity. The relative position of the various bright crosses as well as their succession showed the greatest variability. The impression was frequently produced of the disk rotating in the direction of the hands of a clock, while it really rotated in the opposite direction; or it would appear pendulating.

3. In connection with an extremely sharp powerful cloud lightning, an eightfold cross would appear brilliantly for a moment, all the arms lying at the same distance, while one of the crosses had a somewhat greater intensity than the remaining.

From the above it is inferred that Walter's statement of the extreme variability in the discharge phenomena of lightning flashes is correct.

The time which actually elapses between the partial discharges can be computed only if the images appear for a moment, as according to physiological investigation on the duration of "after-images" (Nachbilder), the duration of the phenomenon cannot be upward of 1-50 of a second, i.e., the duration of one rotation. From other observations it is inferred that the duration of a discharge is about 1-1000 of a second, whereas the lightning referred to under No. 3 evidences a discharge phenomenon including at least eight partial discharges of equal intensity and succeeding each other at regular intervals of about 1-1000 second each.

In connection with the lightning referred to under No. 1, the visible discharge must have come to an end after less than 1-35000 to 1-40000 second, and the partial discharges mentioned under No. 2 must have been of the same short duration.

A determination of the duration of lightning is the more important, as it will give a means of ascertaining the time of oscillation, provided the lightning really constitutes an oscillating phenomenon. The period of discharge would thus be less than 1-30000 second.

THE IMPENDING EXHAUSTION OF THE WORLD'S IRON SUPPLY.

Several months ago the chief of the Swedish geological survey, in pursuance of a resolution adopted by the Swedish parliament, prepared a report showing the extent of the known deposits of iron in the world, and the rate at which such deposits are being consumed. While there has been some dissention as to the exactness of certain details contained in the report, it may be accepted as a substantially accurate investigation of a subject of vital importance to the world. Most disquieting in this report is the conclusion that we are likely to run short of iron within a single century if the present rate of consumption is maintained.

The world has only 10,000,000,000 tons of iron ore available. Of these Germany has twice as many tons as the United States. Russia and France each have 400,000,000 tons more than this country. Our annual consumption of iron is placed at 35,000,000 tons, which is more than a third of the world's total consumption. Commenting on the known and generally-accepted facts of the situation, the Iron and Coal Trades Review in one of its recent issues stated: "We would seem to be within a little more than half a century of an absolute iron famine. This fact raises problems of serious consequence to the world's iron industry and to the outlook of civilization itself."

The efficient consul-general of the United States at Paris, Mr. F. Mason, has analyzed with considerable astuteness the problems involved in this threatened industrial catastrophe. From an elaborate report of his we abstract the following facts:

It is well known that the high-class ores of the lake district in America will, at the present rate of consumption, be exhausted within less than fifty years. The Mesaba deposits, with the present annual output of 12,000,000 tons or thereabouts, will not outlast twenty-five years, and it requires only a simple calculation to demonstrate that a continued yearly consumption of 35,000,000 tons of ore by the iron and steel industries of the United States will, within the lifetime of many persons now living, eat away entirely the 1,100,000,000 tons which, according to the Swedish report cited, constitute our country's entire workable supply as at present known. Inasmuch, therefore, as the United States possess but about one-ninth of the world's ore deposit and yet consumes more than one-third of the total annual output from all countries, the conclusion is direct and unavoidable that the future economic policy of American iron masters should be to secure by all practical means, the largest possible ore supply from the mines of other countries. How can this be most economically and effectively accomplished?

The problem is largely one of transportation, in which the item of marine freight rates plays a dominant part. An economic long-distance ocean rate for heavy, low-class merchandise, involves necessarily two conditions, viz., vessels specially adapted to the trade, and return freights that will bear an equal or higher charge for transportation. The ship that brings ore from Spain, Sweden, and other European countries to the United States, must have each trip an eastward-bound cargo that will be more than ballast and yield a regular and definite profit. There is but one material which will meet the requirements of the case, and that is coal.

It is in respect of quantity and quality of coal supply that the advantage of North America over European countries is decisive and overwhelming. Whatever may be the facts concerning ores, the known coal measures of the United States render their fuel supply secure, abundant, and of excellent quality for centuries to come. There are hundreds of thousands of acres of gas and coking coals of high quality in the Appalachian region—to say nothing of other fields—which have as yet been hardly scratched by the pick and drill of the miner. New coal deposits of greater or less extent and value are being discovered from year to year. With what is now known the present enormous annual output of 280,000,000 tons of bituminous coal can be maintained for hundreds of years without exhausting the available supply. In Europe, on the contrary, the years of adequate coal provision are definitely numbered. In England experts estimate the duration of the workable coal measures to be from sixty to one hundred years. Germany has a somewhat longer lease of industrial life dependent on coal supply, but already the subject is so acute that a heavy contract for the delivery of German coal to France, for iron and steel works, is understood to have been canceled recently at heavy loss to the sellers, because, it is definitely understood, the imperial government objected to the depletion of the national coal supply for the benefit of neighboring countries. France has native coal for a generation or more, but the mines are deepening, the cost of production is gradually increasing, and economists are looking with growing apprehension to the future. Twenty-five or at most thirty years hence, the question of an adequate fuel supply will be a serious problem for France.

In 1903 France consumed 42,694,100 tons of coal, of which 34,217,661 tons were the product of French mines, while the remaining 8,476,439 tons were imported. Cardiff and Belgium coals are delivered at Havre at prices varying, in ordinary seasons, from $4.63 to $5.21 per ton. This is the competition which American coal would have to meet, since from that port of debarkation, common to all imported coals, the costs of duty and freightage to the interior would be the same.

The railway freight rate on coal from Havre to Paris is 70 francs per carload of 10 tons, or $1.35 per ton for a haul of 143 miles. The rate by the River Seine, which is open to navigation practically the entire year, is from $1.05 to $1.10 per ton. Add to this the import duty of 26 cents and it will be seen that the Belgian and Welsh coals can be landed in ordinary times at the docks outside the walls of Paris for about $6.36 to $6.50 per ton. The wholesale price charged by importers to local dealers for bituminous coal is at present, slightly more than $10 per ton. Is there not in the margin of $3.50 and $3.64 between these figures an opportunity for American coal, provided the whole transaction, including mining, railway and ocean transportation, and transshipment at seaports, is so organized and managed as to develop a large trade and reduce expenses per ton to a minimum? In other words, can American bituminous coals of the grades adapted to gas manufacture, domestic use, and general industrial purposes, be delivered in large quantities at Havre for a cost not exceeding $5 per ton.

It remains to consider the correlation between these conditions and the future ore supply of the United States and certain European countries, as described in the first section of the present report. Coal imported into France pays a duty of 26 cents per metric ton. In respect to duty, freight up the Seine to Paris, and other charges American coal would be on the same basis as Belgian and British coals, which come into France principally by that route.

The demand for foreign coal will increase with the gradual exhaustion of the French mincs, and the consumption will be augumented in proportion to whatever reduction can in future be made in the present high cost of fuel. There are millions of tons of good coking and gas coals in the Allegheny and Cumberland districts of the United States which can be produced with profit at the mouth of the mine for an average price of $1 to $1.25 per ton. When the railroads now projected or under construction are finished and in operation it should be possible to carry such coals to tide water for a freight rate not much, if anything, in excess of $1 per ton.

When in 1902 the project of exporting American coal to Europe was actively discussed, it was the consensus of expert opinion that the successful development of such a trade would require the construction of a special class of vessels which would do for the ocean-going coal traffic what they had done for the ore and coal trade of the Great Lakes, namely, steel barges of 10,000 tons burden, stanchly built, with quarters for a crew of ten to fifteen men, and engine power sufficient for a speed of 8 or 10 knots per hour, which would give steerageway sufficient for safe handling in all weathers. Given a fleet of vessels, with loading docks for coal along the Chesapeake Bay or Atlantic coast, and a reliable return freight, and the problem of a large and expanding coal export to Europe, which depends primarily on an ocean freight rate not exceeding $1.25 to $1.50 per ton, would be practically solved.

As return freights, the potash minerals of Germany have been suggested, but they are limited in quantity and restricted by various conditions, so that there remains but one available resource, and that is iron ores of Spain, Finland, and the Scandinavian Peninsula, three countries which, together, now mine about 14,000,000 tons per annum, but which, for want of cheap and abundant fuel, smelt not more than one-third or one-fourth of that amount. The time will doubtless come when most, if not all, European countries will prohibit the export of native coal, except to their own colonies. The imported fuel supplies of France, Italy, Spain, and Scandinavia will then have to come mainly from beyond the Atlantic. It will be strange indeed if American foresight shall fail to recognize the opportunity which time will ripen and the laws of demand and supply will offer to American enterprise.

THE EFFICIENCY OF THE GAS ENGINE.

What becomes of the heat in the fuel which goes into a gas-engine cylinder? Part of it, usually about 25 per cent, is converted into work, about 40 per cent is absorbed by the water jacket, and about 35 per cent is lost by radiation and through the exhaust pipe. If we can reduce the amount which is wasted, the percentage turned into work will obviously be increased. Other things being equal, the amount which is absorbed by the water jacket depends upon the amount of surface exposed during inflammation. The higher the compression the less the surface surrounding the unit of compressed charge. Hence, more heat goes into the work. The Lenoir engine, firing at atmospheric pressure, requires nearly 100 cubic feet of gas per B. H. P. hour, while with a compression of five atmospheres an engine of the same horse-power will do the same work on 20 cubic feet of gas.

In a paper read before the Western Society of Engineers, Mr. C. E. Sargent presents a keen analysis of these losses, which it seems well worth summarizing in the following paragraphs:

The higher the compression within the limits of the pressure necessary for premature ignition, the greater will be the efficiency, but the kind of fuel governs the degree, and the compression necessary to ignite kerosene vapor, while not so volatile as gasoline, will not cause ignition. Natural gases can be compressed to 150 pounds absolute, alcohol to 190 pounds, and blast furnace gas to 210 pounds, and still require an electric spark for inflammation.

In considering the heat which is lost by way of the exhaust, it must be remembered that, when a cylinder full of gas and air is compressed and ignited, the reactions during combustion raise the temperature of the gases enormously, and that for every degree F. of rise in temperature, there is a corresponding increase of 1/490 of the volume of the gases even though with a proper mixture the combustion is not instantaneous.

If a full cylinder of combustible mixture is compressed from atmospheric pressure and temperature and heated further by chemical action, then, when the volume is constant, the pressure is increased. When the exhaust valve opens this pressure causes the familiar "sea-lion" bark apparently inseparable from the gas-engine. This is the second loss of the internal combustion engine, and when we consider that from 35 to 40 per cent of the heat is wasted in this way, is it any wonder that engineers have tried to minimize the loss? We all know the efficiency of the direct-acting steam pump and the gain by a more complete expansion even though we obtain a lower mean effective pressure, and consequently less power from the same cylinders. To utilize the heat and pressure in the exhaust, compound gas engines have been suggested, tried, and in a few cases with some success.

The working fluid of the internal combustion engine, unlike steam, is practically a perfect gas, so that the efficiency of the gas engine may be increased if we can expand the burnt gases to a greater volume than before compression. As in a steam engine there is a limit to the degree of expansion desirable. When the pressure equals the power required to overcome the friction, a further expansion reduces the efficiency of the engine. Hence the decrease in efficiency as the load is lightened.

In a single-expansion steam engine it has been found that a terminal pressure of about four pounds above the atmosphere is the most efficient pressure of release, while on account of the lower mechanical efficiency of the gas engine a terminal pressure of from 6 to 8 pounds seems to give the greatest economy.