9.945 gross tons iron ore Duluth to Conneaut.

The "Wolvin" in her last trip to Conneaut established what is likely to be the unloading record for ore for some time. Her cargo of 9,945 gross tons was unloaded in precisely 4 hours and 30 minutes by four Hulett clam-shell machines and four Brown electrical machines working together. The "Wolvin" had been at Conneaut since Friday night, but was compelled to wait her turn until Monday morning. At 7:20 o'clock Monday morning the eight buckets began working upon her and at just 11:52 o'clock the last bucket was hoisted from the hold and the whistle of the big steamer signaled for a tug. She had been completely unloaded without any hand labor whatever. No such work has ever been done before on the Great Lakes. The nearest approach to it is the record of the "James H. Hoyt," when 5,200 tons of ore were taken from that steamer by the four Hulett machines in 3 hours and 52 minutes. The "Hoyt," like the "Wolvin," has her hatches spaced 12-foot centers.—Marine Review.

THE MODERN STEAM LOCOMOTIVE.*

By Prof. W. F. M. Goss.

IN the early development of American railroad systems, locomotives were used which, with few exceptions, were of a single type. As the extent of track increased, it was equipped with locomotives of the "American type." It made no difference whether the service was freight or passenger, or whether the locomotives were for use on heavy grades or level track, the fitness of the type was rarely questioned. The extent to which the design was duplicated is disclosed by the fact that in the early eighties a single establishment supplying many different railroad companies, and building in one year 600 locomotives, employed but a single man as draftsman.

As a response to early conditions, the type was almost perfect. By the exclusion of other types the problems of the builder were simplified, and the cost of manufacture was kept down; and when track mileage was increasing at enormous bounds this was important. As the same patterns were used over and over again every detail was proven in service upon hundreds of locomotives, hence cost of maintenance was low. The design was well adapted to the rough track common in pioneer work and considering the character of the service rendered the type was and still is remarkably efficient as a power plant. But while the type still has an important place in service, few locomotives of its kind are now being built. Its decline is due to the fact that as a type it cannot take on proportions which the modern locomotives must possess. One reason for this is to be found in the fact that it will not admit a grate of sufficient size for present-day requirements, and another is in its limited tractive power. The grate of the locomotive lies very near the source of its power, and if restricted then the power of the locomotive cannot expand. Originally the firebox of the American type locomotive was limited in width by the space between the side frames and in length by the distance between the driving axles. In locomotives common in the eighties, the width of the grate was not more than 34 inches, and the length generally less than 72 inches. Various means have since been employed to increase its size. The spacing between the driving axles was increased in order that the firebox might be made longer; the boiler was raised to allow the firebox to rest on top of the frames, instead of between them, allowing the width of the two side frames to be added to the width of the grate, and in some cases the grate was inclined upward and allowed to extend back over the rear driving axle. By means such as these the American type locomotive of 1876 came to be the American type locomotive of 1893, greatly augmented in proportions and power; but nevertheless defining severe limitations to be met by the designer.

The second limitation affecting the American type concerns its tractive power. Assuming adhesion, or, better, the coefficient of friction between wheel and rail to be equal to one-fifth of the weight on drivers, the American type engine of the eighties, carrying from 14,000 pounds to 16,000 pounds upon each driver, was capable of exerting a tractive force of from 10,000 pounds to 12,000 pounds. Wheel loads have since so increased that the modern engine may be depended upon to develop a tractive force of 5,000 pounds per driver, or a maximum of 20,000 pounds for the American type locomotive.

Until harder materials can be had for rails and tires, it is not likely that wheel loads can be further increased, so that greater tractive power must involve more than four-coupled wheels, and therefore a departure from the American type. With these facts in mind it will be of interest to inspect a few modern types, and to note the manner in which they have been developed from the original.

Turning to the process which goes on within the firebox, it will be found that under favorable conditions, each pound of coal burned will sustain 1 indicated horse-power for a period of from 12 to 15 minutes. Within certain limits the power developed is nearly proportional to the amount of coal burned. In the development of the modern locomotive, grates have been enlarged and heating surface extended that larger amounts of fuel may be burned. In one direction only has the designer found the way blocked against his ingenuity. He has not been able materially to augment the strength of the fireman, and consequently, when running under constant conditions, the power of the modern engine has not increased in proportion to its dimensions. A laborer is working at a fair rate when, in unloading coal from a gondola car, merely dropping it over the side, he handles 6,000 pounds of coal per hour. At the limit, a locomotive fireman will handle an equal amount, standing on an unsteady platform, placing it upon some particular part of the grate, and usually closing the door after each scoopful. This rate will serve to develop approximately 1,200 indicated horse-power, and cannot be exceeded under sustained conditions of running, though for short intervals the rate of power may outrun the rate of firing. Because of the limitations upon the strength of the fireman it is probable that further growth in locomotives will probably await the coming of an automatic stoker which will serve to remove its operation from dependence upon the physical condition of a single man.

The amount that a locomotive will pull at the drawbar depends upon its speed. At slow speed, the maximum pull is limited by adhesion. After the point in the speed is reached for which the adhesion is sufficient to permit the development of the full power, the pull, assuming no loss of power between cylinder and drawbar, is inversely proportional to the speed. For a locomotive capable of developing 1,200 horse-power the pull at 25 miles is 22,500 pounds, while at 80 miles the pull is 7,000 pounds. The loss between the cylinder and drawbar, however, which in an actual locomotive must always occur, reduces the maximum actual pull at 80 miles to about 5,000 pounds.

The discussion of grate areas and fireboxes suggests the question as to whether there are not other forms of boilers than those commonly in service which would serve the locomotive better. The Vanderbilt boiler, having a cylindrical firebox, is one answer to this question. Again, the extensive adoption of water-tube boilers in stationary and in marine service leads naturally to speculation concerning the application of this type to locomotive practice. Indeed, designs of water-tube locomotive boilers are not wanting, but none are of great promise. Among several that have been proposed is that of Mr. Drummond, of the London and Southwestern, the important feature of which is a high flue of large diameter across which water-tubes extend. The boiler of Mr. Drummond, while technically a water-tube boiler, is practically a shell boiler representing an unusual arrangement of tubing. In considering the possible success of any water-tube boiler it will be well to remember that the present locomotive boiler is not much heavier than the best of the water-tube boilers of similar capacity, and the fact that the boiler shell is depended upon to serve as a part of the framework of a locomotive, makes it impracticable to abandon the present shell without greatly increasing the weight of the frames. The side frames are tied to the boiler at frequent intervals, and such important details as guide yokes are in many cases as much dependent upon the boilers for their support as upon the frames. All this increases the difficulty in applying a water-tube boiler to a locomotive.

Closely identified with problems of boiler design is that of front-end arrangement. The front end includes the extending shell of the boiler forming the smokebox, and in general all mechanism therein contained, such as steam and exhaust pipes, nettings, diaphragms, draft pipes and also the stack. The office of the front end is to draw atmospheric air into the ashpan, thence through the grate and fire; to draw the furnace gases through the tubes of the boiler, thence under the diaphragm and into the stack, and to force them out into the atmosphere. In order that this movement may take place a pressure less than that of the atmosphere is maintained in the smokebox so that when the locomotive is working there is a constant flow from the atmosphere along the course named and back to the atmosphere again. The difference in pressure between the atmosphere and the smoke-box is spoken of as the draft, and under normal conditions of running is usually represented by from 4 inches to 6 inches of water. The draft thus expressed, however, is approximately three times greater than that to which the fire is actually subjected. Thus, a third of the total draft is required to overcome the resistance of the ashpan and grate, together with the fire thereon. Another third is required to overcome the resistance of the tubes, and another third to overcome the resistance of the diaphragm. These facts serve to explain several things which ordinarily are not well understood.

In the design of the front end, practice has wobbled badly. The front end was first short, surmounted by a diamond stack, containing the netting. It was then extended to constitute a cinder trap. It was afterward discovered that the front end as a cinder trap was unnecessary and undesirable, and it is now in the process of being shortened again that it may not hold cinders, but may become entirely self-cleaning. While this portion of the locomotive has been the subject of a considerable amount of patient study, and while great progress has been made, much yet remains to be done before the whole problem of the front end is completely solved.

Passing now from boiler to machinery, mention must be made of the recent and very general substitution of steel for iron in all cast parts. Such castings as wheel centers, axle boxes, and rocker boxes, which were formerly of iron, are now cast in steel, with the result that the engine machinery has been lightened, and weight thus saved has been added to the boiler. The form of each individual part of the machine has been carefully studied with reference to the service it is to perform. For example, in an attempt to diminish wear and to reduce the chance of failure in valve gear, the width of links and the length of rocker and saddle pins have been made to occupy the full width between the frames of the engine. Piston valves, with their superior balance, have largely superseded flat valves. By the use of wheels of larger diameter and reciprocating parts of better design, the problem of counterbalancing driver wheels has been so simplified that extremely bad work in counterbalancing is now rarely found, except, perchance, representing combinations which are patented. I am often asked why it is that so much difference exists in the valve gears of American and foreign locomotives. First of all, it is but proper to note that whenever a practice becomes settled there is somewhere a reason for it. The Stephenson link motion has generally been used in this country because it is a good device, and because it is easily worked into the general lines of the American locomotive. In English practice, where inside cylinders are common, that portion of the main axle which lies within the frame is largely occupied by the cranks. There is no room for four eccentrics, and consequently the Joy gear, which takes its motion from the connecting rod, is much used. This gear seems on the whole admirably adapted to the condition described, though English designers complain that by its use the motion of the valve is considerably disturbed by a low joint or other irregularity in the grade of the track. Other gears are used in England, though none, perhaps, to the same extent or with as good reason as the one referred to. The Germans make very general use of the Walschaert gear, which takes its motion from a single eccentric and the cross head of the engine, while the French designer may choose any of the types mentioned, or if occasion seems to demand, may produce an original gear. The choice of a gear is in most cases doubtless made from practical considerations rather than from theoretical. In working out the general lines of the design of a locomotive one or another form adapts itself to the purpose better than others. Of course, this is not true in all cases, but assuming the choice of gear to be controlled by proper limits, it might be so, for it is not a difficult thing to secure a distribution of steam within a locomotive cylinder which will give results approaching maximum performance. A chief requisite in any valve gear is a degree of stiffness and an absence of lost motion which will make the movement of the valve positive. These qualities are especially necessary in the gear of a locomotive, for in this type of engine the port opening at running cut-off is frequently not over ¼ inch or ⅜ inch, so that even a slight defect in any of the mechanism between eccentrics and valve produces large proportional effects upon the time and extent of the port opening. Ten years ago light and poorly designed gear were common defects in the American locomotive. Then it sometimes happened that the steam distribution depended quite as much upon the oilcan as upon the position of the reverse lever, and reports are current of an engine which would run well under a partially open throttle, but would stop if the throttle were fully opened, the mechanism being insufficient to move the valve when the pressure was heavy upon it. But the valve gear of the modern locomotive is not of this sort. With its heavy and direct connection, its double suspended link, and with the light weight of the valve to be moved, a marvelously good steam distribution is secured even at the highest speeds. Those who, seeing but one side of the really complicated problem, believe that locomotive valve gears ought to be revolutionized, should investigate carefully before they proceed. They should remember that the modern locomotive under ordinary conditions of running rarely requires more than 32 pounds of steam per indicated horse-power, while under favorable conditions it requires less than 25 pounds. Few simple stationary engines exhausting into the atmosphere, with their more complex forms of valve gears, are doing better than this, which is evidence of the narrowness of the margin limiting possible improvements in this direction.

With progress toward higher ideals in locomotive design, there has been a steady increase in steam pressure. During the past twenty years pressure has gone up from 130 pounds in 1880, to above 200 pounds in 1900, and this increase is responsible for many changes in the details of locomotives. Boilers have, of course, become heavier, and where power has not increased, cylinders have become smaller and lighter. In other words, by virtue of the higher steam pressure, the dimensions of the engines of the locomotive have not increased in proportion to their increase in power. The higher steam pressures are chiefly responsible for a very general adoption of the piston valve. The extent to which they have affected the economy of the engines cannot be definitely defined. From a purely thermo-dynamic point of view, each increment in pressure should bring its return in increased economy, but as the scale of pressure ascends, the economy increment diminishes while radiation and leakage losses increase. The range of pressure now common in locomotive service is so high as compared with that employed in other types of engines as to fairly raise the question as to whether economical limits have not already been reached or even exceeded. The practical question can best be defined somewhat as follows: An opportunity is presented whereby the boiler of a proposed locomotive may be 5,000 pounds heavier than that of an existing class. Should this additional weight be utilized in making a stronger boiler that a higher pressure may be carried, or should

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* A paper read before the American Society of Mechanical Engineers.

it be utilized in making a larger boiler that the rate of evaporation may be reduced? Either course should result in increased economy in operation, but which course will prove most economical and where the limits lie, cannot be stated. It will, I am sure, be of interest if I add that the whole question of locomotive performance as affected by boiler pressure and extent of heating surface is one which is now being carefully studied in connection with the locomotive testing plant of Purdue University under the patronage of the Carnegie Institution.

With steam pressure upon simple engines approaching 200 pounds, the advisability of using compound cylinders began to be considered. In the early nineties the compound locomotive became a subject of much interest in this country. The advantage of compounds as an abstract proposition was not doubted. The problem was to build up a mechanism which, while meeting the requirement of correct theory, would at the same time be sufficiently strong and simple to justify its use under the severe conditions of locomotive service. At first, all efforts were directed to the development of a 2-cylinder type, the impression being that to succeed, a compound must have no more parts than a simple engine. But as time passed and all locomotives grew in size, the problem of the 2-cylinder compound became one of increasing difficulty, until now the clearance in tunnels and past station platforms is on many roads insufficient to allow passage of the large low-pressure cylinder. Meanwhile, the Vauclain 4-cylinder type has come into extensive use, and 4-cylinder tandem-compounds are being introduced, until now the tendency is strongly toward a 4-cylinder type. In all this there has necessarily been much experimentation, and experimentation sometimes leads to troubles and disappointments as well as to promise and success. In some cases the compound locomotive has proven expensive to maintain; in others, ill adapted to the service expected of it. Compounds should not often be used under conditions requiring frequent starting and stopping, or when changes in the grade of the track are such as to require frequent changes in the conditions of running. It is on the long, steady pulls that they will show their largest gains over the efficiency of the simple engine. Another fact of great importance in any discussion of the economic performance of the compound as compared with the simple, and yet one which is rarely taken into account, is that which concerns the proportion of the total coal used which is burned while the engine is advancing its train over the road. In the freight service of the average road not more than 80 per cent of the total coal burned is effective in the generation of steam for the cylinder of the engine. The other 20 per cent represents fuel used in firing up, in keeping the engine warm while standing, or remains in the firebox at the conclusion of the run. Obviously, no change in cylinder arrangement can reduce the amount of coal thus consumed. A compound locomotive, therefore, which upon test shows a fuel saving of 10 per cent over that required by a simple engine will, when put into regular freight service, have a chance to save but 1-10 of 80 per cent of the amount of coal which the simple engine uses. These are facts which should be fairly faced in any discussion of the compound problem. They in no wise discredit the usefulness of compounds, which without doubt are to have a large part in the future service upon American roads.

Having now seen that American practice in compounding is committed to the 4-cylinder type, it will be of interest to consider a design which theoretically at least must be regarded as the highest development of that type. I refer to the design of the De Glehn balanced compound which was first brought out in 1886, and which for several years has been the standard for all new passenger power on several of the larger roads of France. An examination of the drawing suggests great complication, but I shall attempt to show that the design embraces very little that is objectionable, and that it presents certain advantages which no other design has compassed. I can perhaps forestall criticism by saying that many American engineers, who have had an opportunity to observe its action, have expressed their admiration with enthusiasm. The fact, also, that the Pennsylvania Railroad is at great cost importing from France an engine of this type for experimental work on its lines; that the American Locomotive Company is building a large engine upon this general design, and that both of these will be tested upon the locomotive testing plant of the Pennsylvania Railroad Company at St. Louis this summer, should give additional interest to the De Glehn balanced compound.

In the De Glehn design, the two low-pressure cylinders of a 4-cylinder compound are placed side by side between the frames, and connect with inside cranks, which are set quartering on the forward driving axle. The details of these cylinders and surrounding parts are similar in every respect to those of all inside-connected engines. Thus placed, the low-pressure cylinders are well protected from radiation, and they connect with exhaust passages which are both short and direct. The high-pressure cylinders are placed outside the frame and connect with outside cranks in the wheels of the second driving axle. These cylinders are not in the same cross-section with the low-pressure cylinders, but are carried back on the frames a distance which is substantially equal to the spacing of the driving axles, so that the main rod of the outside cylinder connecting with the second driving axle is no longer than the main rod of the inside cylinder connecting with the first driving axle. The side frames between the high-pressure cylinders are strengthened in substantial cross-bracing in the form of a casting, not shown in the sketch, which, so far as the frames are concerned, serves the purpose of a false saddle at this point.

The two or more pairs of driving wheels are connected by coupling rods, the several cranks being so arranged that the pins for the coupling rods in the front drivers are set diametrically opposite the inside cranks of the axles carried by these wheels. When one of the outside pistons moves forward, an inside piston moves backward, the reciprocating parts of each high-pressure cylinder being balanced by the reciprocating parts of its neighboring low-pressure cylinder. If, under these conditions, each wheel is perfectly balanced for its revolving parts, and if the reciprocating parts of the high-pressure engine have the same weight with those of the low-pressure engine, the machine as a whole will be balanced, both horizontally and vertically. So far as the action upon the track is concerned the balance will be practically perfect.

It will be seen that the machinery of these engines, as compared with that of an American 2-cylinder engine, involves nearly double the number of parts. Thus, the French engine may have the same number of axles and wheels, but all other machine parts, such as pistons, cross heads, main rods, valve motions, and valves, are in duplicate. Each cylinder is treated as a complete unit, having its individual cross head and its individual main rod. There are four sets of cross heads instead of two, as in American practice, and four main rods instead of two. But these apparent disadvantages are more than compensated by the increased lightness of the parts involved, and by the possibility of a higher character of design. In American practice, the two main rods of a modern engine must be designed to transmit from 800 horse-power to 1,000 horse-power. That this may be accomplished rods have become enormously heavy, and crank pins have grown to be as large as axles were ten years ago. Moreover, the forces to be transmitted often exceed the ability of the fixed portions of the machine to withstand properly, hence parts strain, journals and brasses fit badly, and hot pins and boxes result. An American locomotive, if designed after the De Glehn type, would have four rods, each transmitting from 400 horse-power to 500 horse-power, and the rods themselves would be light. The pins, while comparatively small, would afford liberal bearing surface without exceeding a convenient limit in size, and concentrated stresses upon all fixed parts would be reduced. In such a case, who shall say that the duplication of parts, when offset by such obvious advantages, increases the chances of failure. Is it not conceivable that under the conditions which have been described a large number of parts may even involve fewer chances of failure?

Another objection often regarded as insurmountable by the American designer, is that the inside cylinders necessarily connect inside of the frames, and, hence, a crank axle is necessary. When this objection is analyzed, it is found to be based in part upon the extra cost of a crank axle, and in part upon experiences of long ago. Early American engines which were fitted with crank axles were very flexible, and were frequently run over exceedingly rough track. The record shows that in such engines there were numerous failures of axles. We, therefore, said, and for years have continued to say, that we will not use the crank axle. Our modern engine, however, is less flexible than the earlier one, and is less subject to strains through inequalities in the track. Our advantages in this respect are at least equal to those of other countries. If England and France can run crank axles, why may we not do the same? The fact that these countries do use them, and meet with few failures, would indicate that the American objection is largely historic.

But the French compound presents another side to the axle question, too important to be overlooked. The problem of transmitting 1,500 horse-power or 2,000 horse-power through a single locomotive axle has in American practice led to the adoption of axles of very large diameter. In spite of this fact, axle failures on heavy engines are by no means unknown. With steam pressures and cylinder diameter still tending upward, where is there sign of relief? Here, again, we can well afford to look with favor upon the French compound, for by its design the total power of the engine, instead of being transmitted through a single axle, as in American practice, is divided between two. The inside cylinders connect with the forward axle, and the outside cylinders with the rear axle. By the adoption of the De Glehn type, no single axle of our modern engines would be called upon to transmit as much as 1,000 horse-power, and present diameters could be materially reduced, and at the same time allow a wider margin of safety. The balanced-compound, therefore, instead of introducing axle troubles, may reasonably be expected to lead to a betterment in present conditions. The advantages of the French type may be summarized as follows: It solves completely the difficult problem of balancing drive wheels, it constitutes a satisfactory system of compound cylinders, it avoids the concentration stresses in frames, it divides the total work of the cylinders between two axles instead of concentrating it in one, and the dimensions of the details of its machinery are such as will permit them to be well designed. The work of the De Glehn has had a marked influence on locomotive design in many countries, as is to be seen in the building of balanced compounds in Germany, England, and in the United States, as well as in France.

Quite recently a rival of the compound has appeared. While Americans have been rigidly orthodox in their application of principles, contenting themselves with such progress as may appear in the better design of machine parts and in the choice of better materials from which to construct them, and while the French have been busying themselves with the problems of their balanced compounds, German designers, under the leadership of Herr Wilhelm Schmidt, have been experimenting with superheated steam. Encouraged by his success in stationary practice, Herr Schmidt has extended the application of his system to locomotives, with the result that there are now four or five locomotives of the Schmidt type running and still others building. These engines are in service on the State Railroads of Prussia, and it is claimed that their performance is 25 per cent better than that of similar engines using saturated steam. The Schmidt system involves no material changes in the exterior form of the locomotive boiler, but the tubing is modified and the smokebox design is so changed as to accommodate the superheater which is located therein. A flue 10 inches or 12 inches diameter extends from firebox to smokebox along the lower portion of the barrel of the boiler. This displaces from 20 to 30 of the small tubes which would otherwise have its place. Its purpose is to deliver to the smokebox a considerable volume of furnace gases at a high temperature, in the accomplishment of which purpose the tube serves well. To give room for the superheater, the diameter of the smokebox shell is somewhat greater than the barrel of the boiler.

The pipes of the superheater occupy a space lying between the outside shell of the smokebox and the interior partition sheet, a cross section of this space having the shape of a horseshoe, the toe calk of which may be assumed to be at the bottom of the boiler. The construction is such that the gases discharged from the small tubes are free to pass directly up the stack, having thus no contact with the superheater, all as in an engine of usual construction. The gases discharged from the large flue, however, pass into the space occupied by the superheater at a point near the bottom, and sweeping around on either side, are discharged into the smokebox space on either side at points near the base of the stack. The length of this annular space in the direction of the axis of the boiler is almost equal to the diameter of the boiler. It is filled with the pipes of the superheater. The pipes start from a header near the stack on one side, and pass around to a similar header near the other side, the extent of the superheating surface thus provided equaling 25 per cent of the direct heating surface of the boiler. The headers are so arranged that steam passing the throttle of the engine goes to one of the headers, thence by one-half of the whole number of pipes to the opposite header, thence by the remaining pipes back to the first header, from which it is conveyed to the cylinders. In this passage and re-passage of the pipes, the temperature of the steam is raised to 500 deg. and 600 deg. Fahr., which is from 125 deg. to 225 deg. above the temperature of the saturated steam at usual boiler pressures. This steam is conveyed directly to the cylinders. Published reports of the performance of the Schmidt locomotive show a gain in efficiency which is generally stated to be equal to 25 per cent, and the absence of all trouble in respect to cylinders or superheaters. These statements if true are full of significance.

Examining the design more in detail, we shall find in the Schmidt locomotive a condition more favorable to the use of a superheater than any which has ever been tried in this country. The installations with which we have hitherto dealt have served in stationary or marine practice. The superheater of these plants has either been a separate boiler-like device in which no water was carried, or has been so combined with the boiler as to be always in close communication with its furnace. Under these conditions, when the engine throttle is closed, the circulation of steam within the tubes of the superheater ceases and the metal of the tubes, together with the entrapped steam within them, remain exposed to the undiminished intensity of the furnace action. In this manner, the tubes are often heated to a very high temperature, a result which, when often repeated, leads necessarily to a failure of the superheater. Again, when after an interval of inactivity, the engine is started, the steam which has been held back within the superheater until it has been raised to an enormously high temperature, passes on to the engine, oftentimes retaining enough of its heat to burn the lubrication and sometimes the rod packings. But all difficulties of this class, which to a greater or less degree have appeared in the operation of every stationary plant using superheated steam, are doubtless avoided in the Schmidt locomotive. In this machine, as in other locomotives, the rate of combustion varies with the volume of steam used. When the throttle is open, the fire burns brightly; when it is closed, its activity is at once suppressed. When there is no steam passing within the tubes of the superheater, the gases circulating around the tubes are comparatively low in temperature, and when the conditions are so changed that the temperature of the gases becomes maximum, the volume of steam passing the tubes is greatest. Just as the draft responds to the varying demands which are made upon the boiler, so the volume of heat which is available for superheating varies with the quantity of steam which is to be superheated. The details of the design provide that when the glower is on, dampers are closed which prevent the circulation of gases in the superheater so that it is only when the throttle is open that the superheater does work. This would seem to make impossible any overheating of the superheater. In view of the highly favorable character of all these conditions, it is likely that it will be found easier to maintain a superheater of the Schmidt design on a locomotive than in connection with any other type of engine, and, moreover, that the superheating in locomotive service may be a pronounced success, while in other classes of service its future is still problematical.

I would add that it is expected that two superheating locomotives of German manufacture are to be tested at St. Louis during the Fair by the Pennsylvania Railroad Company.

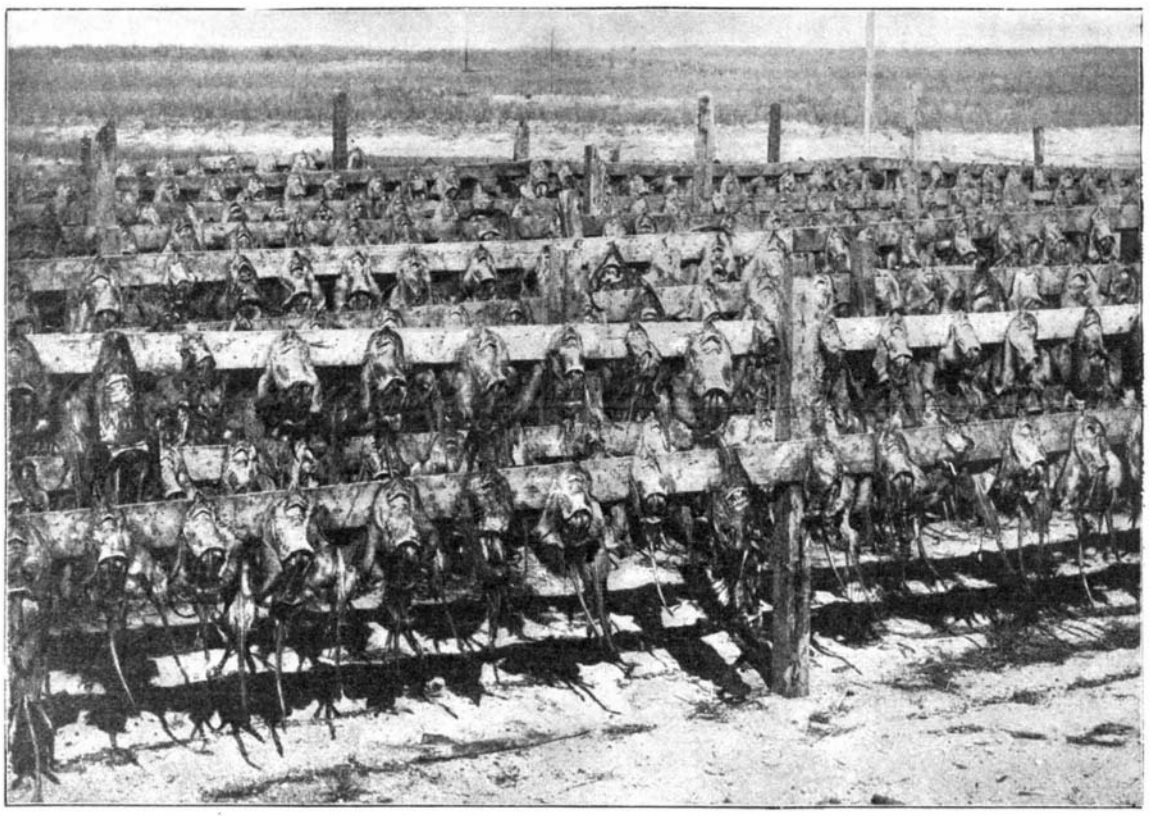
AQUATIC PRODUCTS AS FERTILIZERS.*

By Charles H. Stevenson.

A fertilizer is any substance added to the soil for the purpose of producing a better growth of crops. The food required by plants is supplied in part from the atmosphere, but principally from the soil. If the supply of any one of the necessary ingredients be deficient, a small crop is the result; and the purpose of fertilizers is to supply the plant-foods lacking in the soil.

The general use of fertilizers is of comparatively recent origin, yet the preparation of these substances supports an extensive industry, employing a large amount of capital and many thousands of men. Compared with the immense quantities of barnyard materials, phosphate rocks, etc., the use of aquatic products for fertilizer is relatively small, yet it is by no means unimportant in the fishery industries.

Fish, seaweed, shells of mollusks and crustaceans, and various other aquatic products have long been known to possess rich fertilizing properties. All kinds of fish can be used for this purpose but, owing to the greater value of choice species as food, only the non-edible ones and the waste parts are utilized. The menhaden is the only fish taken in great quantities in this country especially for conversion into fertilizer. The output of this species is very large, amounting to 30 per cent of the total catch of fish in the United States, and its capture maintains one of the most extensive and vigorously prosecuted of the American fisheries. Compared with that from menhaden, the quantity of fertilizer made from other fish is small, and only such are used for this purpose as cannot be profitably employed in any other way.



DRYING SKATES FOR MANUFACTURE INTO FERTILIZER, OPPOSITE PROVINCETOWN, MASS.

The original use of fish for fertilizing purposes was in a fresh or green state, and they were added to the soil directly after their capture, although, of course, no special effort was made to preserve their freshness. Before the advent of the colonists in America, the Indians were accustomed to manure their small crops of corn by placing one or more fish in each hill or by spreading them broadcast over the field, and this practice was followed by the early settlers. Owing to the original richness of the soil and the limited agricultural operations, the use of fertilizers was of comparatively small extent until the latter part of the eighteenth century. It appears that fish were then employed for this purpose all along the Atlantic seaboard from Maine to North Carolina wherever they were obtainable in sufficient quantities.

Fresh fish contain usually from 65 to 80 per cent of water and from 1 to 16 per cent of oil. Neither of these has any value as a fertilizer. On the contrary they decrease the portability and storage qualities of the constituents, and the presence of the oil is prejudicial to the decomposition of the fertilizer when applied to the soil.

Early in the nineteenth century the fishermen occasionally extracted the oil from the fish when the latter were unusually fat, thus removing an injurious ingredient, for which valuable uses were found. This resulted gradually in the establishment of factories for removing the oil, and likewise most of the water, so that the fertilizing substance might be in better condition for transportation. At present most of the fish used for fertilizer are treated in this manner, even the farmer-fishermen finding it more profitable to sell their catch at the factories and purchase the scrap; but large quantities of fish in a fresh state are yet used precisely as was the custom three hundred years ago.

Owing to its great abundance, combined with its non-edible qualities, the menhaden is the principal fish used for fertilizer in this country, and the quantity used annually is about 800,000,000 in number, or 240,000 tons round or live weight. Of these fully 99 per cent are handled at the factories, and the remainder are used in a fresh or green state. With the menhaden are taken some skates, sea-robins, bellows-fish, and other waste fish. Aside from a few that may be taken with the menhaden, and occasionally some river herring or alewives, no other fish are captured in the United States especially for fertilizer to any great extent.

Formerly nearly all waste produced in dressing fish for market was thrown away as useless; but in recent years, in the fisheries as in other industries, the utilization of waste material has been made a subject of careful investigation, and many substances formerly considered refuse are now found to contain elements of commercial value. The dressings at the fish markets and at the fishing centers, the refuse of canneries and boneless-fish factories, and even the carcasses of whales are turned to account in the production of fertilizer. In addition to these materials, the farmers use large quantities of seaweeds, horseshoe crabs, oyster shells, clam shells, etc.

The total annual product of menhaden fertilizer in the United States according to the latest returns amounted to 85,830 tons, for which the producers received $1,539,810. It is difficult to approximate the quantity of other fishery products used for fertilizer, but it is estimated that the waste fish of all kinds amount to about 20,000 tons, worth $200,000; horseshoe crabs, shells of shrimp, etc., 800 tons, worth $16,000; shells and agricultural lime, 60,000 tons, worth $150,000; and seaweeds, 250,000 tons, worth $312,500, making a total estimated output for this country per year of 416,630 tons, worth $2,118,310.

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* From United States Fish Commission Report.

CONTEMPORARY ELECTRICAL SCIENCE.*

Charge of an Electron.—J. S. Townsend compares the various values found for the charge of an electrolytic ion and an electron, and finds that the difference lies well within the limits of the probable experimental error. If E is the charge on a hydrogen ion or atom in a liquid electrolyte, N the number of molecules per cubic centimeter of a gas under normal conditions, then, since a known volume of hydrogen is evolved at the negative electrode when unit quantity of electricity passes through the liquid, the formula

$$N \times E = 1.22 \times 10^{10}$$

is established, E being measured in electrostatic units. In this formula the most probable value for N, according to Lord Kelvin, is 10^{20}, and 1.22×10^{-10} is not improbably an upper limit to the value of the charge in electrostatic units. Of the values determined from electrons liberated by Röntgen rays that of H. A. Wilson is probably the most reliable. By the method which he used he avoids the necessity of finding the number of drops in the cloud formed by the expansion of the conducting gas, and a very uncertain quantity is thus eliminated from his calculations. He concludes from his experiments that "it may be considered established that e lies between 2×10^{-10} and 4×10^{-10} electrostatic units." The lower limit is in fair agreement with the value 1.2×10^{-10} found for E by taking $N = 10^{20}$. Therefore, the value 2×10^{-10} does not differ by more than the factor 2 from the most probable values which can be obtained from the electrolytic and electron methods. —J. S. Townsend, Phil. Mag., March, 1904.

Physiological Effects of N-rays.—A. Charpentier has observed that N-rays exert a direct effect upon the human ear, and increase the sharpness of hearing while they act. On the other hand, the newly-discovered N′-rays diminish the sharpness of hearing, and generally have the opposite physiological effects to the N-rays. Some human tissues emit N′-rays, such as a muscle kept in a state of tension without actual contraction. It may be supposed that all physiological activities give rise to N-rays and N′-rays, and that in some of them one species predominates and in others the other species. This is the physiological analogy to the mixture of N-rays and N′-rays given out by a Nernst lamp. —A. Charpentier, Comptes Rendus, March 7, 1904.

Physiological Action of N-Rays and Conducted Rays.—A. Charpentier has discovered two additional effects of N-rays. If a strong source of N-rays is placed about 4 centimeters behind the top of the skull, and a little above it, not only are faintly luminous objects perceived with greater brightness and detail, but in absolute obscurity a faint luminous cloud is perceived, evidently due to a slight excitement of the visual nerve center. The effect is distinctly shown when a copper wire is used to "conduct" the rays from the source to a small copper plate placed at the point indicated. The second new effect is objective, and consists in the enlargement of the pupil when the conducting plate is placed over the seventh cervical vertebra. The dilatation observed varies from ½ millimeter to 1 millimeter. The apparent increase of luminosity previously mentioned is, however, not due to this enlargement of the pupil, as it remains the same if the objects are viewed through pinholes.—A. Charpentier, Comptes Rendus, February 1, 1904.

An Optical Analogy to Hertz's Grating Experiment.—F. Braun has succeeded in producing with ordinary light waves the effect produced by Hertz with a grating of parallel wires, which was found to reflect electric waves vibrating in a plane parallel to the wires while it freely transmitted those waves which vibrated at right angles to the wires. An attempt to discover this effect in the optical sphere had already been made by Du Bois and Rubens, who found a certain amount of polarization, but a greater transmission of parallel than perpendicular waves. But this is due to the fact that the finest gratings at the disposal of those physicists consisted of wires 0.01 millimeter thick. The author has succeeded better with wires disintegrated on a glass plate by means of a powerful electrostatic discharge. The disintegrated wire, usually of silver, showed a clear central line where it had lain on the glass. On each side of that there was a narrow band of metal. Outside that again, there were fine metallic needles in the form of very pointed isosceles triangles. Outside those, there was a zone of finely-divided metallic dust. On the border between the needles and the dust, the author discovered portions where light vibrating across the plane of the needles was transmitted more freely than light vibrating parallel to the needles. The author hopes to render the phenomenon more amenable to quantitative measurement by destroying a set of thin plates of a complex organic compound of gold in such a manner that only the gold remains. That ought to give a very fine and regular grating, which might be studied by means of Siedentopf and Szigmondy's ultra-microscopic method.—F. Braun, Sitzungsber. Akad. Wiss., Berlin, January 21, 1904.

New Kind of N-Rays.—R. Blondlot has found that besides the kind of N-rays already described, there exists another kind which reduces the luminosity of a feebly luminous surface instead of increasing it. The new kind, which he designates by N′, is specially abundant in the least refrangible part of the N-ray spectrum. On re-examining that part by means of an aluminium prism having a refracting angle of 60 or even 90 deg., he found an alteration between the two different kinds of rays in the spectrum. The following is a table of refractive indices (for aluminium) and wave lengths:

	Index.	μμ
N′	1.004	3.0
N	1.0064	4.8
N′	1.0096	5.6
N	1.011	6.7
N′	1.0125	7.4
N	1.029	8.3
N	1.041	8.1

On plotting these results in a diagram, it is found that the first five values lie close together on a simple curve. Certain sources appear to emit N′-rays only, or predominantly. Among these are wires of copper, silver and platinum. Bichat has found that ethyl ether, brought into a state of forced extension by Berthelot's process, emits N′-rays. When that state is ended, either by a slight shock or spontaneously, the emission of N′-rays ceases instantly. N′-rays, like N-rays, may be stored up. Thus, if a piece of quartz is brought near a stretched copper wire, it emits N′-rays for some time after.—R. Blondlot, Comptes Rendus, February 29, 1904.

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* Compiled by E. E. Fournier d'Albe in the Electrician.