[Continued from SUPPLEMENT No. 1558, page 24976.]

IRON AND STEEL HULL STEAM VESSELS OF THE UNITED STATES.—V.*

By J. H. MORRISON, Author of "History of American Steam Navigation."

STEEL SHIPBUILDING IN UNITED STATES.

THE manufacture of steel in this country dates from a very early period, but it met with very indifferent success. It was used mainly for tools and agricultural implements. During the period of the civil war in this country, the Bessemer process of steel making was first introduced in the United States. An experimental plant was established in 1862 at Wyandotte, about ten miles below Detroit, Mich., on the Detroit River, by E. B. Ward, adjacent to his extensive Wyandotte Rolling Mills, subsequently called Eureka Iron Company, for the making of steel ingots to roll into rails. The process here used was one invented by William Kelly, of Eddyville, Ky. On account of the delays incident to all new departures in manufacturing, and other causes, the machinery was not completed for the operation of the works until September, 1864, when the first steel made in this country, under what was practically the Bessemer process, was produced. This mill made but a small amount of steel when it ceased operations, and as the experimental steel works under the Bessemer patent commenced operations but a few weeks later, they found it to their mutual interests to form a consolidation in 1866 as the Pneumatic Steel Association. The original Bessemer steel mill under the Bessemer patents in this country was started at Troy, N. Y., by Winslow, Griswold & Holly, and their first conversion of steel took place on February 16, 1865.

The open-hearth process in the making of steel under the Siemens-Martin patents was introduced in this country a few years later, and was attended, like the introduction of the Bessemer process, with its many discouragements and trials attending a new departure in any process of manufacturing. This process for making steel was first introduced in 1868 by Cooper, Hewitt & Co., of Trenton, N. J., and some time after a few other manufacturers adopted its use. The first plant that was built for the exclusive manufacturing of steel by this process in this country was the Otis Iron and Steel Company, of Cleveland, Ohio, in 1874.

The first vessel built in this country having steel plates in her construction was the propeller tugboat "Sport," of 65 x 14 x 9 feet 6 inches, in 1873 at the Wyandotte shipyard of E. B. Ward and Frank Kirby. The shapes in the vessel were of iron. The steel plating used in the vessel was rolled from some of the ingots left at the time of the closing down of the experimental steel plant at Wyandotte, as previously mentioned. David Bell, of Buffalo, N. Y., plated three small steam yachts he built in 1875 with steel plating rolled at a plate mill in Buffalo.

Steel plate of American manufacture was used at this period for several marine boilers. The first built was in 1870 by the People's Machine and Boiler Works, of Baltimore, Md., for the U. S. revenue steamer "North-erner." In 1873 the owners of the steamboat "Mary Powell," of New York, had two steam boilers constructed of steel for the vessel by Alex. Cauldwell, of Newburg, N. Y.; and the same year Murphy, McCurdy & Warden, of New York, built one boiler of steel for the steamboat "Shady Side" for New York waters. All of this steel was made by Park Brothers Co., of Pittsburgh, Pa. The braces, tubes, and rivets were of iron.

The first marine boiler built in this country of steel was that for the steamer "William G. Hewes" of Morgan's line in 1860, by the Morgan Iron Works, of New York city, of English plate steel. The machinery of the vessel was built at the Morgan Iron Works, and the iron hull by the Harlan & Hollingsworth Company.

in their construction, though there were many builders who withheld their approval of its use at the time. There were some severe criticisms in our technical papers, also, of the use of steel of such a high tensile strength for the purpose. Their construction received but a scanty indorsement in the trade at the time.

These vessels were all built by James Rees & Sons Company, of Pittsburg, Pa., and with two exceptions were for South American waters. The first built was the "Francisco Montoya," contracted for in May, 1878, for service on the Magdalena River in South America.

THE SOUND STEAMER "PURITAN."

It was a stern-wheel vessel, having dimensions of hull of 149 feet by 29 feet 9 inches by 4 feet, with two high-pressure engines, each having cylinders of 15 inches by 5 feet stroke. The angle iron used in the hull was made by Lewis, Oliver & Phillips, the channel iron by the Carnegie Steel Company, and the iron for bulkheads by Moorhead, McClean & Co. The hull plating was of crucible homogeneous steel of 70,000 pounds tensile strength, made by Howe, Brown & Co., Pittsburg, Pa. The bow plates and the knuckle plates were 3/16 inch thick, and the balance 6 pounds to the square foot, single riveted with 5/8-inch rivets. The hull was sent out in sections and re-erected at Barranquilla, and the vessel was completed ready for service under steam in February, 1879.

The "Victoria" was contracted for late in 1879 by the same company as the former vessel, and completed early in the next year. This vessel was 157 x 33 x 5 feet hold, being somewhat larger than the "Francisco Montoya," and with more power for propulsion. The angle iron was furnished by the Carnegie Steel Company. The hull plating was of the same kind of steel as used in the first vessel, and made by same steel company.

The Zulia River Navigation Company, of New York, contracted with the same builders in June, 1880, for a steel-hull stern-wheel steamboat named "Venezuela," to open navigation on the Zulia River in Venezuela. The hull was 120 x 24 x 3 feet deep. This was the first steam vessel built in the United States to have steel angles and floors, and of unequal legs, being 2, 2 1/2, 3.7 pounds per foot. The rolls were made especially for this angle steel to secure the weight. This vessel may be said to be the first all-steel vessel built in this country. The angle steel was made by the Carnegie Steel Company. The steel of forward keel and bow plates was No. 8 gage, knuckle plates No. 7 gage, and balance of hull plating No. 10 gage; all of crucible homogeneous steel, made by Howe, Brown & Co. The six bulkheads were of No. 12 steel plate made by Moorhead, McClean

the previous named vessels. The bow and knuckle plates were 8 1/2 pounds, bottom and sides 7 1/2 pounds per foot; all double riveted. There were at the same time three steam launches built for the same board, each 37 feet long, and having steel plating of No. 16 gage.

The steamer "Chattahoochee" was contracted for in June, 1881, for service on the Chattahoochee River in Georgia, and was the first all-steel steam vessel built in the United States for service in American waters. The length on deck was 155 feet, beam 31 1/2 feet, depth

of hold at knuckle 4 feet 6 inches, shear forward 30 inches, with 30 inches guards. Frames 2 x 2 1/2 inches by 4 pounds spaced 18 inches centers; deck beams 2 x 3 inches by 5-pound angles, of steel, made by the Carnegie Steel Company. The steel plating of the hull was made by Howe, Brown & Co., of homogeneous crucible steel of 70,000 pounds tensile strength. The forward plates and the knuckle plates were of No. 6 gage, and the balance of the plating No. 9 gage, all double riveted. The bulkheads were also of steel plate. The motive power was two high-pressure engines, each having cylinders of 15 inches diameter and 5 feet stroke, and three boilers, each 20 feet long and 42 inches diameter. It was a stern-wheel steamboat, having a waterwheel of 18 feet diameter. This vessel was run on the Chattahoochee River, then taken to the St. Johns River in Florida, and run there for several years, and subsequently was in service from Vicksburg on the Mississippi River to Greenville, Miss. She was destroyed by fire while lying up at Vicksburg for repairs on December 6, 1893. Estimated value of vessel at time of destruction, \$40,000.

The Pusey & Jones Company, of Wilmington, Del., built for the Magdalena River in South America, late in 1879, two steam vessels about 130 feet long, having steel hull plating rolled by Hussey, Brown & Co., of Pittsburg, Pa. They also built a stern-wheel steamboat 120 feet long in 1881, and in 1883 another of the same type of 150 feet in length, both for South American waters, and having steel plating. In all, they constructed ten vessels in four years, both steam and sail, that were constructed partly of steel. If not in error, one or two of these vessels had imported steel plate used in their construction.

The manufacture of steel plate for shipbuilding purposes was still in its experimental stage for some years after the building of the "Sport" in 1873. It was at the time Congress was taking some action toward the improvement in our naval vessels, during their searching inquiries into the questions of the best means and material to be used in the construction of the proposed vessels, that the doubt of the advisability of using steel in the construction of the vessels came before them, both from those in private professional life, as well as those in the naval service. There was a marked difference of opinion on the subject among the members composing the first Advisory Board of the Navy, and that may have had some influence, through Congressional action, in having a second board appointed. There is no doubt but at this time most of the owners of steam vessels and builders of iron vessels in this country did not feel warranted in adopting the use of steel plate in the construction of vessels, mainly from the cause that this metal had not in the past given the best results in its use for other purposes. The manufacturers of steel in this country were at the time most persistent in their assurances that they could produce a uniform grade of steel suited to the wants of shipbuilding, and in quantities to meet all the demands of the constructors in this country at the time. There is no question but that they were one of the main factors in the rapid development of our steel shipbuilding. With them it was a question of an increase of business for their large plants. In 1882 there were eight steel mills in this country that were able to produce rolled steel plate, each of 20 tons and over per day, composed of the Otis Iron and Steel Company, of Cleveland, Ohio, the largest producer; Singer, Nimick & Co., Hussey, Howe & Co., Park Brothers & Co., Schoenberger & Co., Juniata Iron and Steel Works, Spang Steel and Iron Company, and Linden Steel Company, of Pittsburg, Pa., and the Bay State Steel Mills, of Boston, Mass. By 1884 there had developed among the constructors and builders more confidence in the use of steel, though at first there were several merchant vessels, built but partly of steel. More all-steel vessels began to take form after 1886. The adoption by the Navy Department of the use of steel in the construc-

THE FIRST ALL-STEEL RIVER STEAMER "CHATTAHOOCHEE."

Was intended for service in Gulf of Mexico. Boiler was a flue-return tubular type.

The opening of the experimental stage of steel in shipbuilding in this country may be said to date from the time of the permanent adoption of steel for shipbuilding in Great Britain. The vessels constructed were small in comparison to those built of steel in the United States a few years later, but it showed a confidence on the part of the builders in the use of steel

& Co. There were steel transom and engine beams, with deck under engine beams of steel. During the same year the builders constructed for the Magdalena River, Republic of Colombia, the steamer "Roberta Calisto," and the "Irma" for service at Greytown, Nicaragua, both having steel plating like the former vessels. They were each 110 feet long. At the same time they built the "H. H. Benner" for the National Board of Health of the United States, having hull dimensions of 112 x 18 x 4 feet. The steel plate of the hull was made by the same manufacturers as that furnished for

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

tion of the first vessels for the new navy had its effect in the use of steel in the building of new vessels for the merchant service.

There was not at first any merchant vessel in this country built wholly of steel, as that metal at the time was to the designer and builder too much of an unknown quantity to be used wholly in the construction

The Lighthouse Board had built in 1887 at Baltimore, Md., by H. A. Ramsay & Co., the twin-screw tender "Zizania," having a steel hull complete. This vessel was the second steam vessel having *two stern-posts* and two rudder-posts. The first one was built by J. H. Dialogue at Camden, N. J., for service at Galveston, Texas, a few years before. The motive

We must remember that the lines of the coastwise steamers, as well as those on the rivers along the coast, had been for about ten years before the opening of the steel era laying aside the wooden-hull vessels, and building new vessels having iron hulls, so that when the subject of steel for construction began to be agitated, there was a large percentage of the new vessels on the coast of iron. On the lakes it was different. They had but very few iron-hull vessels; probably not more than fifteen in the passenger and freight business in 1882.

The large demand that was now made for material of steel in construction of steam vessels, bridge building, and steel framing for large buildings, was such that the owners of the steel mills had prior to this time become interested in the opening of new mines of ore in the Lake Superior mining region, and steamship companies were formed by those in interest, who had new vessels built on the lakes for the transportation of their own raw material. This brought about a boom in shipbuilding in 1886 of steel vessels that has continued to almost the present day, with but little change, except enlarged size of vessel. At the same time the Navy Department entered upon a plan for the further enlargement of the fleet of naval vessels, that called for the production of hundreds of tons a year of steel for their construction, and this increased the demand for lake tonnage to supply the raw material for the making of the finished steel. What increased the demand a few years later still further, was the successful operation of the armor-plate mills, in producing the armor for the United States naval vessels. So in the course of a few years the use of iron was turned aside, and steel adopted in its place, in the building of vessels on the lakes. It is thus seen there was more than one cause for its rapid growth on the lakes. They have also made marked advances in the methods of construction, and it was but a few years before the builders on the lakes were in the front rank in their methods of construction. As the shipbuilding plants were mostly all new in 1886, they had the advantage of the equipment of their plants with all the improved and up-to-date power and labor-saving machines, that gave them much advantage for the time over the older and longer established builders on the coast.

The use of mild steel for the hulls of the modern type of steam vessels on the northern lakes was first made use of in two vessels built at the Wyandotte Shipbuilding Company's yard. These were the "Albany" and the "Syracuse," propellers of 1,900 tons each, built for the Western Transit Company, of Buffalo, N. Y., and were *entirely of steel*. The "Albany" was completed in September, and the "Syracuse" in October, 1884. The former was sunk in collision with the "Philadelphia" on November 7, 1893. These vessels had fore-and-aft compound engines built by the Detroit Dry Dock and Engine Works. The same builders launched in April, 1885, the twin-screw propeller "Mascotte," of 112 x 22 x 8 feet, having part steel hull and two high-pressure engines.

The propeller "William Chisholm," of 1,500 tons, was launched by the Globe Iron Works Company August 7, 1884, having iron and steel plating and steel angles in the hull, and fitted with a compound engine.

The "Tioga," of 2,080 tons, was completed in July, 1885, at Buffalo, N. Y., by the Union Dry Dock Company, having the larger part of the hull constructed of steel, and having steeple compound engines, for the Union Steamboat Company.

The first *all-steel* hull built by the Globe Iron Works Company was the "Spokane," of 2,350 tons, for the

THE HUDSON RIVER STEAMER "C. W. MORSE."

of a vessel. The steel manufacturers having every confidence in the mild steel plate they could make for structural work of shipbuilding and bridgebuilding, as equal to the better grade of iron plate for similar purposes, soon had its effect in inducing some of the builders to use the steel plating for some of the vessels. It was not eagerly sought by consumers from its first introduction for all-steel vessels, but had to work its way into favor on its merit, from the designers and owners of vessels, and this took three or four years.

About the earliest of these part-steel steam vessels was the "Alaskan," built by the Delaware River Iron Shipbuilding and Engine Works for the Oregon Railway and Navigation Company, launched August 7, 1883. It was the shell plating only that was of steel in this vessel, all other plates, shapes, etc., being of iron. The "Olympian," a mate to the "Alaskan," having steel plating also, was completed for the same company but a few weeks after the "Alaskan," by Harlan & Hollingsworth Company. The "Chicago," "Atlanta," "Boston," and the "Dolphin," then building at Chester, Pa., were all-steel even to the rivets. The "Atlanta" was launched October 9, 1884, the "Boston" on December 4, 1884, the "Chicago" December 5, 1884, and the "Dolphin" April 12, 1885.

At the time these Pacific coast vessels were completed the Harlan & Hollingsworth Company had two large steam yachts under construction; the "Electra" having angles, bulb T beams, and shell plating of steel, the balance of the hull structure being of iron. This vessel was launched in April, 1884. The "Nourmahal" was almost wholly of steel, but very little iron being used in building the hull. This vessel was launched in May, 1884. They also built the "City of Palatka" for Florida waters, partly of steel, that was finished late in 1884. There were a few ferryboats, tugs, and comparatively small steam yachts, their hulls being in whole or in part of steel, built during the same year at the yards on the Delaware River and on the Hudson River. The large steam yacht "Alva," built entirely of steel, by Harlan & Hollingsworth Company, was launched October 14, 1886.

The steel hull was now recognized as being the advanced type of vessel. At first, it was not adopted for another reason, on account of the increased cost of steel plate over iron plate, but in a very few years the price of ship steel was reduced to so near the price of iron plate that it was adopted more generally, and at once on the northern lakes, where a large demand was being made for increased tonnage.

Of the early *all-steel* vessels for the merchant service built on the Atlantic coast, may be named the "Puritan," of the Fall River line, launched July 25, 1888; "Iroquois," of the Clyde line, in 1888; "Leona," of the Mallory line; "Yumuri" and "Orizaba," of Ward line, in 1889; the "Yucatan," for the Ward line, and the "Seguranca," for the New York and Brazil line, in 1890; "El Rio," for Southern Pacific Company, in 1892.

There were 43 steam vessels built on the Atlantic coast, in whole or in part of steel in the construction of the hull, from 1884 to 1890, consisting of coastwise steamships, steam yachts, and ferryboats, of an aggregate of 31,183 net tons. The largest of these vessels was the "Seguranca." There were equally as many built in same time of iron entirely.

The first steel vessels of later years built in Great Britain were constructed in 1878 of mild steel:

	Iron. Tons.	Steel. Tons.
1878.....		4,470
1880.....	459,994	35,373
1885.....	303,825	162,641
1890.....	42,069	957,894
1895.....	7,789	862,595
1897.....	9,206	763,766
1901.....		1,438,700

power of the "Zizania" was a fore-and-aft compound engine operating each screw. On account of the contractors becoming financially involved before the vessel was launched, the board was compelled to finish the vessel themselves. They also had built the same year two steel-hull light vessels at Marcus Hook, Pa., by Woodbridge & Hutton. These vessels were built on the "combination" system, having a complete steel hull, the outside of the hull plating having a layer of tarred hair felt, this being covered with yellow pine planking fastened with iron bolts, and the hull then sheathed over the planking with hard-rolled zinc sheathing.

NORTHWESTERN LAKES.

The development of iron shipbuilding on the northwestern lakes was of very gradual growth, for it is found that in twenty years after the building of the "Merchant" in 1862, there were but 49 steam vessels built of iron for the lake service. The demand for larger vessels was met by the limited depth of water in parts of the Detroit River and St. Clair River. The "Cuba" and the "Java," built in 1872, were about the largest vessels on the lakes for over five years. The competition with the railroads, and the supply of oak timber for building wooden vessels running short at this period, were other causes that brought about in a few years the more general adoption of the iron-hull vessel. This change in favor of iron-hull vessels had no more than been fully recognized by the builders and vessel owners on the lakes, than the Navy Department decided to adopt the use of steel in the construction of the new vessels for the navy. This brought before the marine interests of the lakes another radical change in the material for construction, just at a time when they had proposed a marked ad-

THE HUDSON RIVER STEAMBOAT "NEW YORK."

vance in the building of their vessels. Having the raw material for the making of steel, in the shape of the ore and the coal at their own doors, and the steel rolling mills so close at hand, they very soon adapted themselves to the change, and it was but a few years before they were building more steel-hull vessels on the lakes than were under construction on the Atlantic coast. They were now making up lost time.

There were causes for this apparent backwardness on the part of the vessel owners on the Atlantic coast, in adopting the use of steel to a larger extent at first.

Wilson Transit Company, having fore-and-aft compound engines, and launched in July, 1886.

The first *all-steel* hull by the Union Dry Dock Company was the "Susquehanna," of 2,780 tons, having three-cylinder compound engine, for the Erie and Western Transportation Company, launched September 4, and completed in November, 1886. This vessel was designed as a larger carrier, and to be more economical in operation than the "Onoko," that was hardly fulfilled in all particulars when in service.

The next year the Globe Iron Works built the *all-*

steel propeller "Ira H. Owens," of 1,750 tons, for the Owens line, having compound engines.

To this time all the steel-hull vessels on the lakes had been equipped with compound engines, but the triple-expansion engine had been built for merchant vessels on the Atlantic coast for a few years past, and their economy in operation over the compound engine had been generally recognized. The operation of many of their steam vessels on the northern lakes with high-pressure steam, or as non-condensing engines, had been the practice for many years, so the change to the compound engine, and then the triple-expansion engine, did not involve such a radical change in the working steam pressure that it had in the steam vessels on the Atlantic coast, where the low-pressure condensing engine was the general type of marine engine, even in most of the propeller engines. The first engine of the triple-expansion type on the lakes was in a steam yacht named "Peerless," built by the William Cramp Shipbuilding Company, and sold to parties on the lakes in 1885 or 1886. The first of that type of engine built on the lakes was placed in the wooden-hull steamer "Roumania," built in 1887 at West Bay City, Mich., and the engine by S. F. Hodge & Co., of Detroit, Mich., and the same year one was placed in the iron-hull steamer "Cambria," built by the Globe Iron Works Company. It was not until the next year that the modern type of steam vessel, having the steel hull and the triple-expansion engine, was adopted, when the "Carona" and the "E. P. Wilbur" were built by the Globe Iron Works Company, and the six vessels for the Northern Steamship Company, by the same company, and the "Scranton" by the Cleveland Shipbuilding Company. This was the opening stage of the boom in shipbuilding on the lakes.

There were built in 1891, 29 iron and steel steam vessels having an average of 1,671 net tons.

In 1893, 25 vessels, average 1,990 net tons.

In 1896, 25 vessels, average 2,544 net tons.

In 1900, 26 vessels, average 3,700 net tons.

In 1902, 33 steel vessels, average 3,265 net tons.

In 1904 there was a total gross tonnage built on the lakes of steam vessels of 152,773 tons.

In 1898 there were 216 iron and steel steam vessels, having a total gross tonnage of 407,908 tons.

In 1904 there were on the northern lakes 421 iron and steel steam vessels of a gross tonnage of 1,088,960 tons, and 30 iron and steel sailing vessels of a gross tonnage of 100,633 tons.

The periods of the changes to the advanced types of steam vessels may be stated:

The "Philadelphia," built by David Bell in 1868, of 1,463 tons; the "Onoko," by Globe Iron Works Company in 1882, of 2,164 tons; the "Globe," by the Globe Iron Works Company in 1894, of 2,995 tons; the "Victory," by the Chicago Shipbuilding Company in 1895, of 3,774 tons; the "North West," as a passenger steamer, by Globe Iron Works Company in 1894, of 4,244 tons; the "S. F. B. Morse," by F. W. Wheeler & Co. at West Bay City, Mich., in 1898, of 4,936 tons; the "Douglass Houghton," by Globe Iron Works in 1899, of 5,332 tons; and "James C. Wallace" in 1905, by American Shipbuilding Company, of 6,684 tons.

There was a breaking away from the old form of vessel when the Union Steamboat Company had constructed in 1887 at Buffalo, N. Y., two steel-hull vessels of 1900 tons each, named "Owego" and "Chemung." They were modeled after our coastwise steamers, having finer lines than the more modern lake vessels, intended for higher speed, and were fitted with triple-expansion engines built in New York. While they made better time than the usual type of lake vessel, they were more expensive to operate, and smaller carriers of freight for their dimensions. The "Owego" is credited with having made the trip from Buffalo to Chicago in May, 1889, in 58 hours, and in the next month the "Chemung" over the same route made the trip in 54 hours. The "Owego" made the round trip in June, 1890, from Buffalo to Chicago and return in 5 days 5 hours and 3 minutes, going light, and returning with 85,000 bushels corn. At this time the "Harlem" and the "Hudson" were considered the most modern and profitable vessels to their owners, of those on the lakes.

The lake shipowner and the shipbuilder both have peculiar conditions to meet in connection with the draft of water and load to be carried. Originally the St. Clair River had seven principal mouths, and these were obstructed by sandy deposits, reducing the depth of water from 2 to 6 feet, and the Lime Kiln crossing in the Detroit River could not be depended upon for more than 13 feet of water. So here were the restrictions that bound the designer for years until 1870, when there was a depth in the canal of 13 feet at St. Clair Flats, that was further increased in 1873 to 16 feet, and in 1893 to 18 feet depth over the bars and through the canal, and at the present time 21 feet has been obtained; and over the Lime Kiln crossing the same depth of water has been found. Taking the depth of water, kind of freight that is mainly transported, and they have designed a vessel of a peculiar but thoroughly efficient type. The vessels have a moderate draft of water, fair speed, and economy of operation, with unrivaled facilities for loading and unloading their cargoes at their docks.

The most novel production of late years in steel shipbuilding in this country has been the whalebacks of the northern lakes, constructed by the American Steel Barge Company at West Superior, Wis. They were the invention of Alex. McDougall. Their first steam vessel was the "Colgate Hoyt," of 276 x 36 x 22 feet, that was completed in the fall of 1890. The "Joseph L. Colby," of about the same size, and having

a fore-and-aft compound engine of 28 and 50 inches by 42 inches stroke, and operated by 120 pounds steam, was completed in November, 1890, and sent to the Atlantic coast. In the following month the "C. W. Wetmore" was sent from the lakes with 95,000 bushels of grain through the canal, and arrived at Quebec July 5, 1891, and shortly after left for Liverpool. She was reported at New York on August 14, and shortly after cleared for the Pacific coast, and passed San Francisco in 76 days from Philadelphia, Pa. She was lost on the Pacific coast. The "E. B. Bartlett," a duplicate of the "C. W. Wetmore," but having a triple-expansion engine, was finished in 1891. The "Colby," "Bartlett," "Wetmore," and "A. D. Thomson" were the only steamers sent to the Atlantic coast. There was one passenger whaleback steamer built in 1893, named "Christopher Columbus," having accommodations for 5,000 passengers that ran from Chicago to one of the lake ports. There have been sixteen steamers and twenty-four barges built of this type on the northern lakes in fourteen years.

(To be continued.)

THE DISTRIBUTION OF POWER.*

By W. E. AYRTON.

PROBABLY, like myself, you have heard vague comparisons made between the power of the Victoria and the Niagara falls. Now, what is the true comparison? The flow at Niagara varies at different times of the year from 62 to 104 million gallons per minute. At the Victoria Falls the flow can be one-twelfth of the smaller number—for it is so now and some authorities, well acquainted with the spot, say that at the end of another three months the flow will only be half of even that. The mean available drop at Niagara is about 160 feet; at the Victoria Falls 380 feet. Hence, while the minimum Niagara flow represents about 3,000,000 horse-power, the present Victoria flow represents about 580,000 horse-power, or only about one-fifth of the preceding. Further, if those who predict the flow of the Zambesi sinking to something like two and a half million gallons per minute in November are true prophets, the Victoria Falls will then only give out about 300,000 horse-power, or, say, one-tenth of the minimum that Niagara produces. In all that precedes I have taken the full power of the direct drop in each case—that is, I have assumed in each case the intake to be close to the main drop, and I have deducted nothing for inefficiency of machinery.

Now, how exactly does the efficiency in the electric transmission of power depend on (1) the pressure, (2) the power transmitted, (3) the length of the transmission line, (4) the resistance of the conductors composing it?

The very simple approximate formula connects these quantities:

$$\left\{ \begin{array}{l} \text{Percentage} \\ \text{loss of power} \\ \text{on the road.} \end{array} \right\} = \left\{ \begin{array}{l} \text{Horse power transmitted} \\ \text{3 (thousands of volts)}^2 \end{array} \right\} \times \text{miles} \times \left\{ \begin{array}{l} \text{Resistance per} \\ \text{mile of all the con-} \\ \text{ductors in parallel.} \end{array} \right\}$$

This formula tells us that as long as the electric pressure is limited to some 10,000 or 11,000 volts, a pressure boldly used as early as 1897 by the Rand Central Electric Works and at the Moodie mines, near Barberton, but the one that is still the maximum sanctioned in Great Britain, it will not be possible, even with a pair of conductors of good copper, and each as thick as three-quarters of an inch in diameter, to transmit more than about 6,000 horse-power, or to transmit that power more than about ten miles, without the loss on the road exceeding ten per cent. The actual efficiency will, of course, be less than ninety per cent, since there will also be losses in the machinery at each end of the transmission system. Not only have various successful 60,000-volt transmission schemes been carried out, but the Kern River Power Company, in California, is constructing one for transmitting 4,020 horse-power over 110 miles at 67,500 volts. When the new railway—Brakpan to Witbank—is completed, 110 miles will be twenty more than will separate the Rand from the coal fields at Witbank—fields that produce such good coal that the Central South African railways have contracted to purchase 84,000 tons during this year at 6s. (\$1.44) per ton at the pit's mouth. Now, if six wires were used like those now employed by the Rand Central Electric Works, then, at 67,500 volts, 9,000 horse-power might be put in at Witbank and only five per cent lost on the road; that is, about 8,950 horse-power delivered on the Rand. But the insulators would have to be placed much farther apart than on the existing Rand posts to prevent the starting of a brush discharge between the wires.

You will now grasp why in 1895, ten years ago, it was a bold and pioneering policy to equip the Rand Central Works for 10,000 volts and to use 13,000 volts during times of full load, and why in 1905 the recommendation of some advisers to distribute power at only 10,000 volts to the proposed substations of the contemplated fifty-seven miles of electrified railways—Springs to Randfontein—is most retrograde of those advisers to the railway. In 1879 a firm of electrical contractors, well known then and equally well known now, told me that they had been asked to tender for the construction of an electric transmission system to convey a comparative small amount of power ten miles. But since they considered that they could not possibly hope to deliver more than half, while, in practice, they feared that they would only succeed in delivering much less, the proposal had to be ranked with the exploits of Gulliver and Baron Munchausen, and so even that

* Abstract of a lecture delivered at the meeting of the British Association, Johannesburg.

firm declined to tender. To-day, twenty-six years later, electric power is, from an engineering and from a business point of view, being successfully transmitted 232 miles.

Next I come to a very important question, and one that merits far more consideration than it has yet received. There are two kinds of electric current—direct current and alternating current. Now which kind of electric current should be used for the distribution of power over long distances? Practically, every electrical engineer will at once reply: alternating, of course. Well, I am going to preach heresy.

The alternating current has undoubtedly the great advantage that a motor can be constructed with no rubbing electric contacts, every wire may be permanently soldered in position, a condition of considerable importance in dusty places like mines. Another advantage possessed by an alternating current is that an alternating-current dynamo can be constructed to produce a large horse-power at a high voltage; and further, this alternating voltage can be transformed into a still higher one without the use of moving machinery. Contrasted with this, no single large direct-current machine has ever been constructed to generate more than about 3,500 volts, and no means is known for efficiently converting a direct-current voltage into a higher or a lower one without the use of moving machinery.

So far, then, my case seems weak. The advantages of using great electric pressures we have seen. Are there any disadvantages? This is a disadvantage—the risk of piercing the insulation. See how thick the insulating material has to be on cables, how far apart the conductors have to be placed, even when the cable is intended for only 10,000 volts. But does this consideration supply any argument for, or against, the use of one kind of current rather than the other? Small current and high pressure must be used for the economical transmission of power over long distances, whether the current be alternating or direct, I agree, but, I submit that, while from the point of view of economic transmission, 60,000 volts alternating means exactly the same as 60,000 volts direct, from the point of breakdown of the insulation, 60,000 volts alternating is as bad as 85,000 volts direct, indeed, may be worse than 100,000 volts direct. For an alternating current consists of waves like the waves of the sea. In a storm the waves may be running mountains high, and yet the average depth of the sea remains the same as in a calm. The mean electric pressure may not be very large, and yet the crests of the waves may be so high, and the troughs so low, that its strength can not stand the electric tossing.

But there are other disadvantages in the use of alternating current. One of them is the increased drop of pressure in an inductive circuit when supplied from an alternating source of supply instead of with direct current. This self-inductive effect, as it is called, is small, if the going and return conductors be straight, short and near together. But, if the distance over which the power is to be transmitted be long, the wires obviously can not be short, and if, to obtain economy, high electric pressure be used, the wires cannot be put very near together, since that would lead to a brush discharge through the air from one conductor to the other, producing leakage.

But that is not the whole indictment against the use of alternating current for long-distance transmission. Leakage from wire to wire can be rendered small, but still if the current be alternating, it always flows along the wires, even if all the apparatus at the distant end be entirely disconnected from them. The very first thing that struck Ferranti, the Brunel of electricity, when he commenced transmitting power with alternating current at 10,000 volts pressure from Deptford to London was that the current flowing into the system at Deptford was as large during the day-time, when practically no lamps were turned on in London, as during the evening, when many were glowing. And, in the case of the 150 miles transmission at 50,000 volts, by the Bay Counties Power Company, in California, it was found that to charge even the aerial lines as a condenser required forty amperes, so that the current flowing into the system remained practically unchanged when the useful load was decreased from several thousand horse-power down to nought.

Now, this is the very opposite of the effect we previously noticed, for in that case it was the alternating pressure that failed to send the current into the transmission system. Surely, then, the one effect is a correction of the other. That is so, and I will give you a practical illustration.

[The lecturer then showed experiments illustrating the neutralizing effects of capacity and inductance, and showed how resonance is established in electric circuits.]

Much damage has been done to electric cables used for the distribution of power by the unexpected high pressures produced by resonance in alternate-current circuits. A cable may have been tested at twice or thrice the working pressure and passed as satisfactory. But if there is a liability of a pressure being applied, which, as you see, may in somewhat extreme cases be twenty or thirty times the working pressure, what avails it, there being a factor of safety of two or three—disaster must follow.

Now, with direct current for long-distance transmission, there is no question about the electric pressure at the top and bottom of a wave being much greater than the mean pressure, no question about self-induction reducing the current—no objection, therefore, to putting the conductors as far apart as the risk of