gine; the great improvement and development of the typewriter; the casting of chilled car wheels; the Birkenhead and Rabbeth spinning spindles; and enameled sheet iron ware for the kitchen. Next the phonograph of Edison appears, literally speaking for itself, and reproducing human speech and all sounds with startling fidelity. Who can tell what stores of interesting and instructive knowledge would be in our possession if the phonograph had appeared in the ages of the past, and its records had been preserved.

The voices of our dead ancestors, of Demosthenes and Cicero, and even of Christ himself speaking as he spake unto the multitude, would be an enduring reality and a precious legacy. In this decade we also find the first electric railway operated in Berlin; the development of the storage battery; welding metals by electricity; passenger elevators; the construction of the Brooklyn bridge; the synthetic production of many useful medicines, dyes, and antiseptics, from the coal-tar products; and the Cowles process for manufacturing aluminum.

In the last decade (1886-1896) inventions in such great numbers and yet of such importance have appeared that selection seems impossible without doing injustice to the others. The graphophone; the Pullman and Wagner railway cars and vestibuled trains; the Harvey process of annealing armor plates; artificial silk from pyroxyline; automobile or horseless carriages; the Zalinski dynamite gun; the Mergenthaler linotype machine, moulding and setting its own type, a whole line at a time, and doing the work of four compositors; the Welsbach gas burner; the Krag-Jorgensen rifle; Prof. Langley's aerodrome; the manufacture of acetylene gas from calcium carbide; the discovery of argon; the application of the cathode rays in photography by Roentgen; Edison's fluoroscope for seeing with the cathode rays; Tesla's discoveries in electricity, and the kinetoscope, are some of the modern inventions which still interest and engage the attention of the world, while the great development in photography, and of the web perfecting printing press, the typewriter, the modern bicycle, and the cash register is beyond enumeration or adequate comment.

Looking at this campaign of progress from an anthropological and geographical standpoint, it is interesting to note who are its agents and what its scene of action. It will be found that almost entirely the field lies in a little belt of the civilized world between the 30th and 50th parallels of latitude of the western hemisphere and between the 40th and 60th parallels of the western part of the eastern hemisphere, and the work of a relatively small number of the Caucasian race under the benign influences of a Christian civilization.

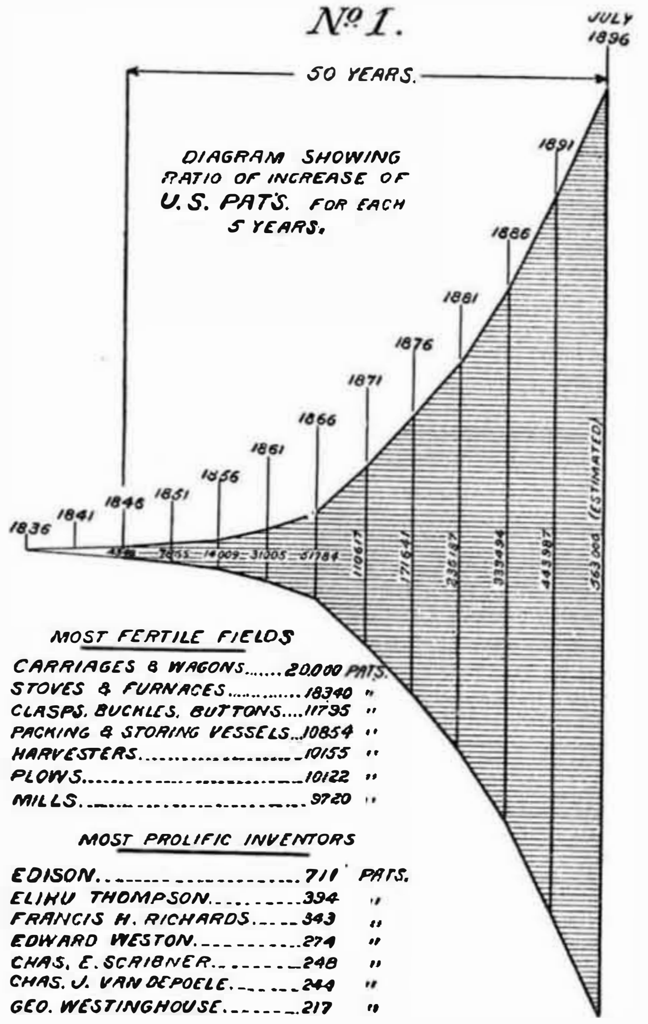
Remembering, furthermore, that most of this great development is of American authorship, does it not appear plain that all this marvelous growth has some correlation that teaches an important lesson? Why should this mighty wave of civilization set in at such a recent period, and more notably in our own land, when there have been so many nations far in advance of us in point of age? The answer is to be found in the beneficent institutions of our comparatively new and free country, whose laws have been made to justly regard the inventor as a public benefactor, and the wisdom of which policy is demonstrated by the growth of this period, amply proving that invention and civilization stand correlated—invention the cause and civilization the effect.

This retrospect, necessarily cursory and superficial, brings to view sufficient of the great inventions as milestones on the great roadway of progress to inspire us with emotions of wonder and admiration at the resourceful and dominant spirit of man. Delving into the secret recesses of the earth, he has tapped the hidden supplies of Nature's fuel, has invaded her treasure house of gold and silver, robbed Mother Earth of her hoarded stores, and possessed himself of her family record, finding on the pages of geology sixty millions of years existence. Peering into the invisible little world, the infinite secrets of microcosm have yielded their fruitful and potent knowledge of bacteria and cell growth. With telescope and spectroscope he has climbed into limitless space above, and defined the size, distance and constitution of a star millions of miles away. The lightning is made his swift messenger, and thought flashes in submarine depths around the world, the voice travels faster than the wind, dead matter is made to speak, the invisible has been revealed, the powers of Niagara are harnessed to do his will, and all of Nature's forces have been made his constant servants in attendance. We witness a new heaven and a new earth, contemplation of which becomes oppressive with the magnitude and grandeur of the spectacle, and involuntarily we find ourselves asking the question, "Is it all done? Is the work finished? Is the field of invention exhausted?" It does seem that it is quite impossible to again equal the great inventions of this wonderfully prolific epoch; but as these great inventions, which now seem commonplace to us, would have seemed quite impossible to our ancestors, we may indulge the hope of future possibilities beyond any present conception, but onward and upward in the great evolution of human destiny.

Rejoicing in our strength and capabilities, the new light of man's power and destiny breaks more clearly over us, and content with the infinite quality of mind and matter, the teachings of philosophy, and the facts of evolution, we rest in the assurance of positive knowledge that all that has been done in the past is merely preliminary, that human ingenuity knows no limit, and so long as man himself remains hedged about with the limitations of mortality and the conditions of growth, so long will his strivings and attainments be infinite.

BETA.

No. 1.



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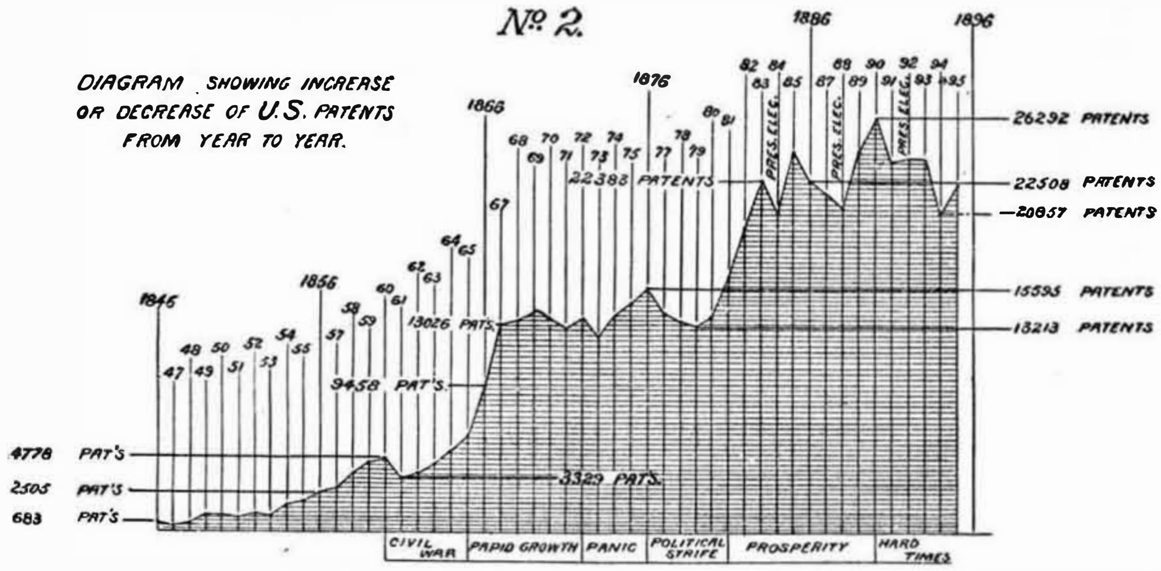

STEEL.

The term steel signifies iron containing a small percentage of carbon, and in modern times the term has become extended so as to indicate iron containing an almost infinitesimal amount of carbon, provided the metal is produced by the open hearth or Bessemer process. In the early ages of the world meteoric iron, a close representative of modern nickel steel, was used by the ancients. The art of producing iron in the primitive fining hearth, analogous to a blacksmith's forge, goes back to an early date. Then the blast furnace was invented, and cast iron, containing a larger percentage of carbon than steel contains, was produced. In the intense heat of the blast furnace, with its prolonged contact with the fuel and gases of combustion, the iron absorbed over two per cent of carbon. Such iron is termed cast iron.

With the exception of some special processes, the majority of steel in early days was produced from wrought iron. The latter was made from cast iron by the puddling process. The cast iron in the form of pigs was melted on the hearth of a reverberatory furnace in contact with iron cinder and iron ore, accompanied by constant stirring of the melted metal. The carbon was gradually oxidized, and wrought iron quite free from carbon was produced. This, after being worked down into shape by hammers and rolls, was inclosed in cases with shavings of horn and similar material and heated to a high heat for many hours. The metal absorbed carbon for the second time, and when removed from the boxes showed a blistered surface, and was termed blister steel. It was worked over to produce spring steel and shear steel, or was broken into pieces and melted in crucibles to produce cast steel, the crucibles holding from thirty to fifty pounds of steel.

Puddling involved a constant stirring and working of the metal with a pokerlike tool termed a rabble. This seemed to involve much labor, and many attempts were made to get rid of it. Various forms of mechanical puddling machines were manufactured, and about 1870 a great deal of attention was attracted by the American Danks rotary puddling furnace, the proof of which is given in the fact that it was elaborately examined in 1871 by a committee of English iron masters, who actually imported 40 tons of pig iron from England to test it with. This is cited to show the importance attached at so late a period to the old puddling process. It seemed obvious that, by puddling cast iron to a point when a portion of the carbon only was removed, steel might be directly produced; and the iron and steel world of the later sixties was intensely interested in the production of puddled steel, which then offered the only prospect of producing steel in large units. Many minor inventions were made in the production of steel until the world was ready to receive the monumental one, termed the "Bessemer process."

Sir Henry Bessemer early began his experiments on the production of steel from pig iron by the use of an air blast. His work was done principally in the fifties, and as evolved and developed by constant experiment, it took the shape of the following steps: Cast iron was melted in a cupola or a reverberatory furnace, and then was run into a vessel near whose bottom or in whose bottom were a number of blow holes, and through which, before the introduction of the metal, a blast under heavy pressure was maintained. The hot iron was run in, and as the blast was forced through it, its carbon and silicon were burned out and its temperature rose enormously, the carbon and silicon of the iron forming the fuel. The original idea was to withdraw the metal when the carbon was sufficiently reduced. This, however, proved impracticable, except with exceedingly pure iron, although this process has been successfully carried on for many years in Sweden. The least trace of phosphorus impaired the quality of the steel very greatly, and eventually the system was adopted of blowing the metal to the complete exhaustion of the carbon and of then adding a weighed quantity of ferro-manganese or of spiegeleisen, which were practically cast irons containing a large portion of manganese and carbon. By varying the proportions of these materials added, steel of any required percentage of carbon could be produced. As the Bessemer process gradually came into use, it was seen that the manufacture of steel was revolutionized. It was introduced into this country, and Holley, newspaper reporter, mechanical engineer, and metallurgist, found it a fertile subject for his genius, and developed the mechanical features of the process by the introduction of the most perfect hydraulic machinery for operating it. The converter in which the metal is treated is now an egg-shaped vessel, mounted on trunnions, and of size to treat at once from one to fifteen tons of melted iron. Its bottom is full of holes for the blast. It is turned down on its side to receive the charge, the blast is turned on, and it is brought into an upright position for the blow. As the air passes through the melted iron contained in it, a vivid flame issues from its mouth, and the carbon and silicon are burned out of the iron. It is next turned down to receive the carbonizing charge of ferro-manganese or spiegeleisen, and the effect of any phosphorus present is partly overcome by the manganese thus added. The steel, which is as liquid as water under the intense heat, is poured into moulds, and by hammer and roll is worked into any desired shape. The old steel processes treated steel in units of a few pounds weight. The Bessemer process increased the units to many tons.

Something still was wanting; very pure iron had to be used, phosphorus being ruinous. In 1878, only seven years after the visit of the English metallurgists to America to examine the Danks puddling furnace, an announcement was made by a young man, Mr. Sidney Gilchrist Thomas, who stated that by the use of lime he had succeeded in reducing the phosphorus in the Bessemer steel process. After exhaustive experiments the following basic Bessemer process, as it is termed, was evolved, Thomas being associated in the work with his cousin Gilchrist. The Bessemer converter was lined with special bricks consisting largely of lime and of magnesia. After being heated up by a coke fire, a quantity of lime was thrown into the converter and was further heated.

The charge of iron was then introduced and the blow given with a period of some minutes of after-blow or of blast after the carbon was all gone. Spiegeleisen or ferro-manganese was added to give the carbon and the metal was poured. The effect of the after-blow in the presence of the basic material removed the phosphorus almost entirely and proved the greatest advance yet made in the Bessemer process. This brings us down to recent times. Incidentally it may be mentioned that the slag produced in this process is so rich in phosphoric acid that it is used to an enormous extent as a fertilizer.

In 1856 Sir William Siemens explained a steam engine of his invention to the Royal Institution, an invention representing ten years of experimental researches. It was an attempt to apply the regenerative system for saving heat. It was found to be without practical utility, because the high heat destroyed the machinery. A year later his brother Frederick suggested the employment of the system in a furnace. The hint was sufficient. Extensive experiments were at once begun and the Siemens regenerative furnace was the result. It was practically perfected about 1860, and Michael Faraday's last lecture in 1862 was devoted to it. In the Siemens furnace the fuel is burned in a gas producer. By the admission of insufficient air for complete combustion, a combustible gas, termed producer gas, is produced. The gas is admitted to the hearth of the furnace and burned there with heated air, the gas also being heated on the way to the furnace.

The essence of the Siemens invention lies in the way in which this heating is effected. The gas from the producer and the air for its combustion are caused to pass through chambers filled with intensely heated fire brick piled up loosely. The products of combustion before they leave the furnace pass through two other such chambers, thereby heating them. At short intervals, by the manipulation of valves, the course of the gas and of the air is changed, so that the products of combustion go through the chambers which have just been utilized for heating, thereby bringing them up again to a higher temperature, while the chambers already heated are used for the passage of the gas and air. By this process a sort of cumulative effect is produced. A most intense heat can be developed, and the economy effected is very large. Applications of the Siemens or open hearth furnace to making steel at once became obvious. By the Martin process, pig iron and wrought iron were melted together on the hearth, producing a steel of any desired percentage of carbon; by the Siemens process pig iron and iron oxide are used to produce steel on the open hearth, and in the Siemens-Martin process both methods are combined. The product of this operation is the famous open hearth steel.

The tendency of the present day is to produce open hearth and Bessemer steel of low carbon percentage, the metal from the chemist's standpoint being rather wrought iron than steel. It is produced in enormous quantities and the great ships and buildings of our days, the age of steel, are due to four great inventions of which three belong to the last half century. The hot blast for blast furnaces, invented in 1828 by James Neilson, doubled the output of the blast furnace without any extra fuel; in 1855 the Bessemer process was announced and the second of the inventions began to be applied; seven years later, or 1862, may be taken as giving the date of the third invention, the Siemens furnace; and the fourth invention, which we have placed in 1880, is the Gilchrist-Thomas or basic process of making steel from iron containing phosphorus. All other inventions in the metallurgy of iron and steel, ingenious as they were, practical as they were thought to be, with all their promise of great usefulness, sink into comparative obscurity when compared with these four epoch-making inventions which have so inconceivably modified our everyday life.

DISTINGUISHED INVENTORS.

Samuel Finley Breese Morse, the American artist, and the inventor of the electric telegraph, was the son of an American geographer; he was born at Charlestown, Mass., in 1791, and died in New York, April 2, 1872. In 1810 he graduated from Yale College, and in 1811 went to England with Washington Allston to study art under Benjamin West. In 1815 he returned to the United States, and in 1826 he was chosen as the first president of the National Academy of Design, which he was instrumental in founding. He was very fond of discussing electrical matters with his friend Prof. J. Freeman Dana; and while on a voyage from Havre to the United States in 1832, Morse conceived the idea of making not only an electric telegraph, but also an electro-magnetic and chemical recording telegraph, substantially as it now exists. Morse made some drawings on the steamer, which he afterward elaborated, but it was not until 1835 that he first exhibited a telegraph in operation, when he put a half mile of wire in coils around a room. In 1837 he filed a caveat in the Patent Office and also exhibited his new system in the University of New York. He asked Congress for aid to build a line from Baltimore to Washington, but nothing resulted. He went to England, where a patent was refused him. His French patent was worthless. It was not until March 4, 1843, that Congress finally granted $30,000 for his trial line. In 1844 the work was completed and Morse was able to show the practicability of his system of electro-magnetic telegraph. His patents were promptly infringed, and he was quickly engaged in an interminable succession of patent suits. At last these were decided in his favor, and he was able to reap the just reward from his great invention. Honors without number poured in upon him. Foreign nations vied with one another to give him medals or to confer decorations, and in 1858 the representatives of France, Russia, Sweden, Belgium, Holland, Austria and other countries met at Paris to decide on a collective testimonial, and $80,000 was voted to him. It is believed that he had the original idea of submarine telegraphy; he also made the first daguerreotype in the United States.

Elihu Thomson was born in Manchester, England, 1853, and at the age of five came to this country with his parents, who settled in Philadelphia, where he was educated, graduating from the Central High School in 1870. He experimented a great deal during his boyhood in electricity and chemistry, photography and similar subjects. Graduating at the age of seventeen, he spent six months as an analytical chemist in a laboratory, and was then appointed assistant professor of chemistry and physics in the high school, and was promoted to the chair of professor of chemistry and mechanics in 1876. He frequently lectured and continually experimented during this period, in the Artisans' Night Schools, Franklin Institute and elsewhere. He was associated with Prof. Edwin J. Houston in some patents relating to dynamos, and upon these and other inventions based the American Electric Company, since called the Thomson-Houston Electric Company, organized in 1880, and became chief electrician of the company. His invention of electric welding and brazing has been fully described in the columns of the SCIENTIFIC AMERICAN and SUPPLEMENT. His remarkable experiments in alternating current induction have done much to win for him an international renown. The air blast applied to switches and commutators for blowing away destructive arcs is a type of his practical way of reaching results. Like Edison, he holds a great number of patents.

Capt. John Ericsson was born in the province of Wermland, Sweden, in 1803, and died in New York in 1889. His father was a mining proprietor, so in his youth he had ample opportunities to watch the operation of machinery. He learned to draw, and entered the corps of Swedish engineers, and at twelve years of age was engaged in the construction of canals. He afterward entered the army and rose to be a captain at seventeen. During this time he made a small heat engine, which was the precursor of the hot air engine which he afterward successfully developed. His inventions in relation to locomotives were also important. Capt. Ericsson early began to make experiments on the screw propulsion of vessels, especially for war vessels, with the arrangement of the screw and all the machinery under the water line. He came to the United States in 1839, and in 1841 he became engaged with Commodore Stockton in building the United States frigate Princeton, said to be the first successful propeller war vessel with all its machinery under the water line. In 1833 he brought out the first practical hot air engine. He was also among the earliest constructors of steam fire engines. During the thirteen years that Capt. Ericsson lived in England he is said to have made forty new inventions. In 1828 he applied on the Victory the principle of condensing steam and returning the water to the boiler, and in 1832 he gave to the Corsair the centrifugal fan blowers, now generally used in American steam vessels. In 1830 he introduced the link motion for reversing steam engines on the locomotives King William and Adelaide, and in 1834 he superheated steam in an engine on the Regent's Canal Basin. Undoubtedly, the greatest of Capt. Ericsson's achievements was the building of the Monitor in 1861. This little iron gunboat, with revolving turrets, was so successful in the historic naval engagement at Hampton Roads in 1862 that it changed the whole course of naval construction throughout the world. Among his later inventions were torpedo boats and sun motors.

Elias Howe, the inventor of the sewing machine, was born at Spencer, Mass., in 1819, and died in Brooklyn, in 1867. He spent his time until 1835 on his father's farm and mill. He then went to Lowell and was employed in a manufactory of cotton machinery. He afterward worked in a machine shop in Boston. Here he developed his invention of the sewing machine. The first of his machines was made in May, 1845. He patented it September 10, 1846. After constructing four machines, he visited England in 1847, and remained there two years. From his return until 1854 he was involved in tedious lawsuits, but at last his rights were acknowledged and the former infringers paid him handsome royalties. He is said to have realized $2,000,000 from his invention.

Nikola Tesla was born at Smiljan, a small place on the Austrian border, and he is now 39 years of age. His education was received at Carlstadt in Croatia; he, too, showed the experimental bent and eventually entered the polytechnic school in Gratz, Austria. Here he studied engineering and devoted his spare time to studying electricity; on graduation he entered the engineering department of the telegraph at Buda-Pesth, and in 1881 took up the electric light and the construction of dynamo machines as his especial work. He is said to have been greatly impressed by the drawbacks incident to the employment of the commutator and collecting brushes on dynamos and motors. His efforts resulted in the production of an alternating system of power transmission, in which these drawbacks were done away with, and which is now universally introduced under the name of the "polyphase system." This work was presented in a lecture before the American Institute of Electrical Engineers, in May, 1888. But his recent work and that which has brought his name more prominently before the world than ever before has been with alternating currents. Employing a dynamo giving 20,000 alternations in a single second, he has produced what may be properly termed the most remarkable experimental results recently attained by electricity. With these alternations used in the production of the most beautiful lighting effects, he succeeded in showing or at least in indicating the possibility of producing light by means of a single or without any conductor whatever. Several striking features were brought out in his experiments in this line. He showed the nature of the brush discharge and demonstrated the necessity of excluding air and gas in general from induction coils and condensers. Many other effects of high frequency currents were pointed out, which have thrown novel light upon electrical phenomena. In recent years he has devoted his attention to the perfection of a method of lighting and other inventions, notably a method of conversion to currents of high frequency and the mechanical oscillators, which were first shown in an experimental lecture before the Scientific Congress at the World's Fair, Chicago, in August, 1893.

Alexander Graham Bell was born in Edinburgh, Scotland, March 3, 1847, being, therefore, almost the same age as Edison. He was educated at the Edinburgh High School and University. He came to the United States in 1872. His father and grandfather were both language teachers, and the young Bell's attention was directed to language by the course of studies prescribed by his father. The synthesis of artificial speech, by Helmholtz's method, is said to have early engaged his attention, and he resolved to pursue one of the outcomes of his studies, multiple telegraphy, to a practical conclusion. It has been said that all this