THE PROGRESS OF THE MECHANICAL ARTS IN THREE-QUARTERS OF A CENTURY.

BY COLEMAN SELLERS, E.D.,
Professor of Mechanics, Franklin Institute.

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Mr. President, Members of the Mechanical Section of the Franklin Institute, Ladies and Gentlemen:

I have listened with interest to the remarks of the President of this section, Mr. Wilfred Lewis, in regard to the advantages which have resulted from the formation of the several sections within the society, by which those members forming the respective sections can associate and effect an exchange of opinions on matters of common interest, apart from the regular meetings of the society at large.

In looking back to the time when the Franklin Institute celebrated the first half-century of its life, I recall the speakers on that occasion, and regret exceedingly that some are unable to take part in the present celebration. I had the honor at that time to be President of the Institute and presided at the meeting held in Musical Fund Hall. Among the speakers was Mr. Frederick Fraley, who delivered the historical address, he being one of the two survivors of the original founders of the Institute. Mr. Fraley is still with us, and is now the only survivor of those few men who had the good of the mechanic and craftsman at heart when they established what has proved to be among the most successful in its practical results of all institutes of the kind in the world. I regret that the condition of Mr. Fraley's health prevents him from being able to address you at this time, but I know that in heart he is with us, as he has been for the past three-quarters of a century.

The scope of the subject upon which I have been asked to address you merits careful preparation in order to pre-

sent it in a sufficiently comprehensive shape for the limits of a single address. I regret extremely that I have not had an opportunity for such preparation, and can offer, therefore, some informal remarks only, covering a few recollections and observations on the progress of the mechanic arts during the past seventy-five years. The records of the Franklin Institute are the records of much of the progress made during the whole of this time, and in the volumes of its *Journal* you will find abundant evidence of the good work of the earnest mechanics, engineers and teachers who have come together for mutual benefit and in the interest of this society. You will find no better place to note the progress of the mechanic arts than in the account of the work of these citizens of a great manufacturing city in the reports of the committees of the Franklin Institute, and especially the Committee on Science and the Arts, which for many years performed gratuitously what is now largely confided to paid experts. These men did this work of the Institute, and are still doing it, for the common good, without any expectation of other reward than the satisfaction of unselfish interest in mechanical progress.

The greatest advance in mechanics has been manifested since the advent of the locomotive. It so happens that the birth of the modern railroad system is coincident with my own birth. At that time the first railroad was put into operation in England, which development, taken in connection with the advent of the steamboat which preceded it, was certainly the exciting cause of the great industrial advance that has since been made. Previous to 1827 wooden rails had been laid to form roads over which ore was hauled from the mines, and coal was transported in the same manner by animal traction to better advantage than over common roads. Oliver Evans in our own country, and other engineers abroad, had conceived the idea of the high-pressure steam engine, and, with the full understanding of its value, a practical traction engine to use on roads, was one of the first examples of its application. It was after the invention of the road engine that the locomotive upon rails became possible.

The traction engine applied to the railroad was the basis of our present wonderful system of inland intercommunication, and its development has given an impetus to all trades. In fact, the wants of the railroads taken alone would have been sufficient incentive for what has since been done in the mechanic arts, engaging, as it has, the attention of engineers to produce the labor-saving tools required for the improvement and preservation of the railroads and equipment, including the great iron and steel works that supply the rails, bridges and buildings.

Special machinery has been constantly needed to render possible such industries as iron ship-building, bridge and structural work, and the appliances which have been introduced in place of hand labor throughout the industrial world.

The progress of the single industry of machine tool building has, therefore, a most important bearing on this subject, and traced through the many stages of its rapid growth, the development of this one industry would be sufficient to illustrate the progress in mechanic arts during the period in question, and especially what has been accomplished in this country.

The important relation which tools and implements bear to the mechanic arts and, in fact, to all arts and crafts, forms the subject of an interesting tradition which was published in the *Journal of the Institute* by the late Mr. Joseph Harrison, Jr. In his home at Philadelphia he exhibited a painting by Schusselle representing a blacksmith seated at the right hand of King Solomon's throne in his great temple, to illustrate a hypothecal event during the feast given in Jerusalem at the completion of the edifice. To this feast had been bidden the various artisans who had been engaged upon the construction and decoration of the building, those who had helped to shape the gold and silver and carve the ivory and weave the costly hangings that decorated its walls. There also came, unbidden and unrecognized, the swarthy smith, who, forcing his way through the courtiers and the guard to the throne of the king, claimed recognition as the one man to whom was due the creation

of the entire work, for it was he who had forged the tools without which the other artisans could have done nothing. The wise king, recognizing the justice of the claim, gave to the smith the seat of honor.

Antedating the smith of King Solomon's day and the mechanics of all times, the progress of civilization can be traced by the study of the implements used in the daily life of different races of man, and prominent in the progress of the mechanic arts must be counted the tools with which work has been accomplished.

As one instance of progress from primitive methods during the period under consideration, it may be of interest to refer to the construction of one of the first large engines that were built for the city water works in Philadelphia. There is probably no one present who can recall the fact from actual memory, but where our Public Buildings now stand there was once a smaller structure, on top of which was a tank into which water was pumped, and this water was distributed through the then small city below Broad Street by means of wooden pipes of comparatively small size. The engine used in this work was, I believe, of the Oliver Evans type of high-pressure engine, the cylinder of which was cast in New Jersey. The boring bar used in boring out the cylinder was of the crudest character, operated by hand by means of levers attached to it, so that men walking around the cylinder could propel the cutting tools, and gradually force the cutters on the boring bar, through the cylinder, until it had been turned out approximately true. After that the inner surface had to be filed to a sufficient degree of smoothness. Probably a month was consumed in this operation of boring the cylinder. As I shall take occasion to mention, the subsequent improvements in machine tools have changed the process of cylinder boring from an effort of days to the work of a few hours.

It may be of interest also to note that when the engines were erected and the boilers put in their place at this Center Square Station, the latter were found upon test to be insufficient for their purpose. Oliver Evans had specified

the length of the grate bars and the width of the furnace to be used, as also the length of the boilers, which were of the plain cylinder type, but the wise men of the city government believed that they could do better by making the boilers much longer than he had suggested, and they were so constructed. Upon their failure to do the work, Oliver Evans, who was in New York, was sent for in haste to correct the difficulty. His message to those in charge, enforced by his presence afterwards, was that they must cut off 10 feet from the length of each boiler. This seemed a strange proceeding, but he soon explained to them that the extra length which they had added to his prescribed dimensions was acting as a condenser to re-convert steam into water, inasmuch as the heat of the furnace could not extend the whole length of the boilers as they had been built. Upon cutting the boilers down to their proper size so the heat could extend over their whole fire surface, they proved sufficient for their work, and continued to operate as long as this primitive water plant was in existence. I have this story from those who were living at the time.

I hope I may be pardoned for alluding here to some events in my own experience as a mechanic in order to justify my authority as a historian. From earliest childhood my interest has been led in the direction of the mechanic arts. My first knowledge of physics came from my father, through his instructions and experiments for my benefit before I had fairly passed out of the stage of infancy, for I was but seven years old when I lost so able a teacher. As a schoolboy most of my holidays were spent in his machine works at Cardington, near Philadelphia, where I had abundant opportunity to not only know what was being done at that time, but I had from my seniors the history of what had immediately preceded my personal observation.

My acquaintance with the rapid advance in the railroads of America, and in the motive power on the roads, dates from the time when the building of locomotives was undertaken in my father's shops, immediately after Matthew Baldwin had started his works in Philadelphia. When I was 19 years of age I accepted service as draughtsman

in a rolling mill in Cincinnati, where rails were being made for the roads then projected through the Western States. The rails used at that time, which were called strap rails, were flat bars of iron about $3 \times 1\frac{1}{4}$ inches in section, with oval depressions rolled into the face to receive the head of the spikes driven through the rail to fasten it to string pieces of wood. They were punched at each one of these depressions, which marked the location of the spike hole. At that time the most common accident on the railroads was one unknown now, namely, "snake heads," as they were called, when the strap rails, by the action of the wheels upon them, would curl up, drawing the spikes from the wood, and often piercing the bottom of the car, and not infrequently killing or injuring passengers.

After my experience in the rolling mill, where I acquired a knowledge of the wants of the railroads, I was engaged for seven years in locomotive building, first in constructing engines for the Panama Railroad, in connection with one of my brothers who was the inventor of a locomotive for ascending inclined planes. The late John C. Trautwine was the Consulting Engineer of the Panama Railroad, and it was on his recommendation that these engines were ordered, in the belief that some heavy inclines would have to be overcome in passing from the Atlantic to the Pacific Ocean at Panama, although these inclines were avoided, and the engines eventually used in the construction work merely.

Subsequently I entered the locomotive works of Niles & Co., of Cincinnati, as foreman for five years until 1857, when I accepted service as Chief Engineer for William Sellers & Co., of Philadelphia, then, as now, engaged in building machine tools. Thirty years' active experience in machine tool building enables me to speak from a full knowledge of this industry and what machine tools have done for the advance of the mechanic arts. When engaged in locomotive building in Cincinnati, I introduced a number of improved methods, but was hampered continually for the want of machine tools powerful enough to do the work as I desired it done, as well as for the want of special tools

not then available. At that time in the Eastern cities certain machine tools were being built with success and were doing far better work than it was then possible with tools built in a branch of the locomotive works where I was engaged. The firm of Niles & Co. had, however, some reputation even then as builders of machine tools and sugar machinery, but it was not until the retirement of the original founders of the house that the works became devoted wholly to the machine tool business. At the time I speak of, slotters, horizontal boring machines and lathes of various kinds and quality were built in America after the introduction of the planing machine, the first one of which was probably introduced into the city of Philadelphia some time about 1830.

The early machine tools were of the crudest workmanship, and most of the lathes were made partly of wood. In fact, the transition from wood to iron in the construction of machinery was in progress during the early part of this century, and the formation of the tools themselves and much of the machinery built at that time involved the conversion of structural shapes required for wooden machines into similar shapes in metal. In the first change from wood to metal, architectural shapes and ornamentation were considered desirable to make machine tools and other machinery meet what seems to us now the rather barbaric taste of those who were to use them. The same might be said of locomotives, which almost up to the sixties were elaborately decorated with paint, polished brass and scroll work. England gave us the first good machine tools, and set the example which has tended to simplicity in design. To that country we owe much that is valuable, not only in the direction of self-acting machine tools, but also in the various appliances for improving the character and quality of work to be accomplished. Thus, Sir Joseph Whitworth, one of the earliest makers of superior machine tools in England, aimed at utility and not ornamentation in the improvement of his products. It was he who introduced surface plates for producing other plane surfaces by means of the scraper; that is to say, after a surface had been made

comparatively true on the planing machine, it had yet to be brought to a commercially true plane by a process of scraping off the higher projections, until, when tested by one of the Whitworth surface plates, it seemed to touch at intervals of not more than $\frac{1}{4}$ inch.

After scraping had come to be recognized as the only means of making true plane surfaces, there followed, unfortunately, a form of deception that exists, I am sorry to say, not only in America, but still more prominently in some of the copies of American machine tools produced abroad, namely, the practice of scraping the surface without any special regard to the purpose for which the operation is intended, but rather to give it the appearance of having been carefully fitted, and the surface so produced was very aptly called by the late Mr. William B. Bement, of Philadelphia, "bedquilt scraping." The parts touched by the scraper in this imitation work are very often not irregular in design, but constitute a set figure or pattern which cannot deceive the eye of those familiar with good work.

Long before the time of the International Exhibition of 1851, America had begun to take her place in machine tool building, under a clearly distinct line of thought that was for a long time not appreciated in other countries. When visiting England, in 1884, I was shown a copy of an American planer adapted to planing the stub ends of connecting rods for locomotives, there being two sets of uprights and two cross-heads with four tool-holders adjustable in position to enable both ends of two connecting rods to be planed simultaneously. The American tool from which the idea was taken has its cross-heads facing one another, and the table is speeded to run back and forth at the same rate of cut. By this means the machine is made to take a cut at each forward and backward movement of the table. The English machine had its tool-holders facing in one direction, and all four cuts were taken at one and the same time only when the table was running forward, no work being done on the back stroke. The power of the American machine was therefore double that of its English copy, all other things being equal, and the maker was astonished when this was pointed out to him.

This one example shows how difficult it is to copy the machinery of another country if the copyist does not grasp the controlling idea of the mind that gave life to the original. Instances of this are found in many other directions where American contrivances, having obtained a world-wide reputation, are less efficient in the foreign copy than in the original production.

The planing machine is an invention well within my own experience. In the beginning it had the platen, upon which the work is fixed, dragged backwards and forwards by a chain. The first planer that William Sellers & Co. purchased and put into use was one of this chain pattern, and one was introduced in my father's shops when he undertook to build a locomotive in 1834. At the time of the Vienna Exposition, where machine tools from Philadelphia were exhibited, the engineers sent by the British Government to Vienna to note the progress that was being made noticed the broad feed cut on all the planing machines, lathes and tools that came from all parts of America, and remarked upon it as "producing good effect," as "looking well," etc., as if it were for appearance only, not knowing that it was a principle that had been established in America, thoroughly understood not only by the managers of the works, but by workmen all over this country, and universally adopted as necessary to good work.

I have already referred to the slow process of boring cylinders for pumping engines. When the early locomotives were built, for example, in the Niles Works, in 1856, the boring of the cylinders was done on a 36-inch lathe with a horizontal boring bar, and without any knowledge as to the theory of boring in order to produce the best results. It always took two days to bore the cylinder of a locomotive of the size in use at that time, and I think the largest cylinders were not over 15 inches in diameter. In Philadelphia, when Baldwin's had advanced to a very large establishment, they still bored the locomotive cylinders in the same way. It was not until shortly before the Centennial Exhibition of 1876 that attention was turned towards the utilization of a theory that had obtained in

limited practice some years before as to the improvement in boring metals, the idea being that the quickest and best work can be done in boring by making the roughing cut with a fine feed, removing as much metal as possible by depth of cut, and making the finishing cut with a very broad feed but light cut that would let the cutter pass through the hole to be bored as quickly as possible so as not to wear the cutting edge in passage. That principle was first introduced when Mr. Asa Whitney, of this city, discovered that chilled cast-iron car wheels could be made to compete with the best wrought-iron ones and do a greater mileage. If the wheels cast in an iron mould were not allowed to cool naturally, but taken red hot from the chill, were put into the annealing furnaces and brought up to a heat a little below the melting point, and then allowed slowly to cool, they were found to be free from all internal strains, while wheels taken red hot from the mould would burst into three or four pieces in cooling, showing that there was violent internal strain in metal cast in that way under the tension of the heavy chill on the outside of the tread of the rim. The problem of boring chilled wheels was solved by taking advantage of the fine roughing cut and coarse finishing feed. Mr. Whitney desired to have wheels made interchangeable in their fit on the standard axles, so that when a wheel was fitted on an axle at a workshop in Philadelphia, another wheel could be furnished to fit that same axle at any future time, and just as well as the first one.

When the late Mr. Hudson had charge of the Rogers' Locomotive Works he applied to the firm of William Sellers & Co., to have a special locomotive cylinder boring machine designed and built, saying that he had seen a boring machine designed by Mr. Grant, of the Grant Locomotive Works, capable of boring a 19-inch cylinder in nine hours. The matter was referred to me, and when I came to calculate the theoretical time required for boring a cylinder of the size named, on the supposition that the speed of 16 feet per minute might be used in making the cuts, with a fine feed and a deep cut for the roughing cut, and a shallow cut and a much wider feed for the finishing cut, I found that the

estimated time amounted in all to only three hours, and named three and a half hours as not only possible, but what might be guaranteed as the productive output of such a machine. An order was given for this machine, it being understood that it was not only to bore the cylinders, but to counterbore the ends for the clearance of the piston, to cut off the sinking head and face up the flanges at each end of the cylinder. When completed, the first test was made with a 19-inch cylinder of hard close metal. This was bored in three hours and twenty minutes, exclusive of the time of setting the cylinder, which was not much on account of the peculiar arrangement of the machine, and the facility with which the cylinder could be put in place for boring. In this case the cylinder stood still, while the boring bar travelled lengthwise, carrying the cutter head with it, and upon the two face plates of the driving heads of the machine were arranged automatic slide rests that faced off the flanges. In this design there was no guesswork, as the principle of fine feed and deep cut on roughing, with very coarse feed and shallow cut for finishing, was in common use in all operations of boring, turning and planing metals, with exact knowledge as to what result was obtainable when the possible speed of cut per minute had been predetermined for the hardness of the metal to be toolled.

Since the time when I first related the incident of the rod planer in a paper published by me in the *Engineering Magazine*, in 1892, even this tool, useful as it is, has been superseded almost wholly in locomotive works by improved milling machines. It is not my province to detail step by step the advance that has been made in machine tool building, but, as stated at the outset, I wish to make this industry illustrate the advance in the mechanic arts, and in connection with it I must call attention to the relative condition of the skilled workmen in America and in other countries. We owe much of our progress to our common school system, to our freedom from precedent and to our just patent laws. I do not wish in the slightest degree to decry what has been done abroad, for I myself have been a close stu-

dent of the progress of the mechanic arts the world over, and have been only too glad to recognize and avail myself of all that is good and worth adopting, assuming at the same time that improvement is possible and absolutely necessary in many cases to adapt the machinery designed abroad to the conditions that obtain in American workshops. The tendency to standardize everything is peculiar to this country. Builders of locomotives in America adopt standard sizes and types of locomotives, and are thus able to manufacture such to great advantage. Railroads in America are willing to take from the builders what has been shown to be good and effective, and when the same kind of machine is to be duplicated many times, the maker can afford to invest heavily in special gauges and special tools that decrease the amount of manual skill required in laying out the work or working to drawings. The first time a piece of work is done, whether it be small or large, simple or complex, more time is spent upon it than after the workmen have become familiar with its construction, and certainly more time than would be required after special appliances have been invented and made to cheapen the product, especially when the men are paid for their work according to the quality and quantity turned out, and not by a fixed wage per diem. I allude to this because I know it is the custom of foreign railroads to submit to builders in England and America specifications for engines that cannot compete in economy of construction with those that are built in quantities in the way that I have just mentioned. It is the recognition of this fact that is now opening the markets of Europe to American locomotives as they are built and as they are used in America. A celebrated builder of locomotives in England told me that the rules of the Board of Trade and Parliamentary regulations for the safety of the people crowded their locomotives with useless appliances. A close observer of railroad machinery, who is familiar with the principal railroads in the world, has stated that if a locomotive builder abroad is given a new problem, such as to construct a hill-climbing freight engine, or a goods engine as it is called abroad, or even an express passenger

engine for mountain districts, a completed machine may be the result that is a model of strength and durability, but inaccessible in the extreme when ordinary repairs are required. It is easier to take out the cylinders in an American engine and replace them with new ones than it is to reset the valves on the type in general use abroad, where the valve chests are crowded together under the smoke-stacks as though they would never require adjustment or resetting. The persistency evinced in adhering to the crank axle in English engines, in spite of its weakness, is one of the matters not understood in this country. Give accessibility to the valves, and ready access to all the parts, and the whole engine will be better cared for by those in charge of it.

It has been the scientific methods introduced by the managers of the railroads, aided by the skill and perfect equipment in their workshops, that have made those great railway systems what they now are. They must exercise the utmost caution in all that they undertake; every alteration or deviation from adopted standards involves so many pieces that must be changed. In regard to the simple matter of making brakeshoes for the cars, and boxes for axle journals, I know from my own experience that it was not until the introduction of machines for moulding these pieces accurately that the best results could be obtained and the parts made exact and perfectly interchangeable. Every invention, whether it be in the foundry or in the machine shop, is cumulative, and has its effect upon other trades, and through our ingenuity and progress we have now reached a point when the whole world looks to America for certain work which it seems cannot be done to equal advantage in other countries.

Dr. John Anderson, then in charge of the Woolwich Arsenal, England, was sent to this country to visit the Centennial Exhibition in 1876, and besides acting as one of the judges of the machine tool exhibit, he made an official report as British Commissioner to both houses of Parliament. Prominent in these reports there will be found one on "Machines and Tools for Working Metal, Wood and

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Stone at the Philadelphia Exhibition," in which the following statement occurs:

"Great Britain certainly can claim the credit of having been the birthplace of modern machine tools, and has done wonders in raising the mechanical standard of perfection, and her influence for good in the advance of civilization thereby is incalculable; but when we consider the enormously greater area of the American continent, it is a matter of vast importance that tools have taken such a hold of the American mind, which will influence the civilization of the Western world for ages to come, and will exercise a powerful effect, not only on that continent, but on Australia, China and the world generally." This, therefore, has a profound significance which can scarcely be over-rated. Again he said: "The display of machine tools made by the United States was so vast that only the more salient points can be noticed in a brief report. It showed certainly that the past century has not been passed in idleness, and, judging by the enormous stride made by them during the past few years, it showed that they have been intelligent students of the best European authorities. It is true to say, however, that the Americans, as a rule, are not copyists; the inventing of clever devices and tools for saving labor seems to be their natural forte, and worthy of the old stock, probably quickened by the peculiarly favorable circumstances under which they live. It was the display made in this section which most conspicuously brought out the enormous strength of America as a producing power. More than a hundred exhibitors had each a large exhibit that commanded the admiration of all who took the trouble to examine them in detail. In this vast array were machines for all purposes, small arms, ammunition, sewing machines, clocks, watches, and all the branches of machine-making and engineering, and almost all were finished in a style superior to that of any former exhibition."

In the engineering practice of the first quarter of this century, scientific methods did not obtain. There was little technical literature to help the designer, and the best results which have made American ingenuity appreciated the

world over were brought about through careful experiments and earnest effort on original lines. The history of the steam engine, so far as the American types are concerned, was clearly not the outcome of the books, for what is thus taught under the head of thermo-dynamics is really a description of what had been accomplished, rather than the cause of the development. The need of technical education was early felt, but the want was not supplied until the generosity of individuals rendered the foundation of technical schools possible. The Government cannot be looked upon to aid in such institutions in the United States as it can in England, yet up to 1884 in London there was no technical school in existence that in any way compared with those at Hoboken and Boston in this country, besides which engineering is now taught in our universities. At a dinner given to the members of the Institution of Civil Engineers, in 1884, Sir Lyon Playfair, in responding to the toast of "The Universities of Scotland," after those of England had already been discussed by able speakers, astonished his audience by refusing to speak to the toast directly, and entered a strong plea for technical education in England such as existed at that time in the United States. He said they should not look to Germany and France for the examples of technical schools, but across the Atlantic, where those speaking their own language had already put into practice what England had so long needed. While the speaker was doubtless correct as to the wants at that time in Great Britain, the technical school of South Kensington was then being organized, and the guilds of London had contributed freely toward its support. Good work had been done by this and other schools, and by the trade schools that have been established in various parts of England.

We are long past the period of empirical work. The steel makers and iron founders now depend upon metallurgists to guide them, while every well-equipped machine shop in the country must have its staff of educated men who are able to reinforce the practical knowledge of those engaged in manufacturing by exact mathematical methods

that in the early stages of our profession were limited to simple arithmetic.

As indicative of the necessity of education on the part of the working classes, I have known instances in which labor-saving machinery that was cheapening the output in a particular class of hardware, when introduced in America, into England, failed entirely and brought discredit to the member of the firm who had advised its purchase. A gentleman interested called upon me afterwards and solicited letters enabling him to visit some of the industrial establishments in the United States. Upon his return from these places he told me that all that had been said about the character of the work done by the machinery in question, not only had been confirmed, but that its merits had been underestimated. He said, however, that in his opinion, it was impossible to utilize it to advantage with the workmen in England, owing to trade prejudice and trades union regulations. What the peculiar conditions were I am unable to say, but what I wish particularly to impress upon my hearers in this respect is that in his opinion the difference in the character of our workmen and workmen of the same trades in England is wholly due to the better education of the Americans, who are fully two generations ahead of those abroad. It is perfectly evident that it is impossible to raise the standard of work by means of labor-saving machinery unless the workingmen themselves will see the advantage derived from their ability to do more and better work, and thereby obtain better wages. This is particularly the case when they are called upon in this country to operate machines that do not require constant attention, but where it is possible for one man to attend several machines and earn higher wages than he possibly could if compelled to stand idly watching a machine that required but a small portion of his time to operate. There would be no inducement to contrive automatic machinery unless those who use such machinery are able without prejudice to take advantage of the saving in labor attainable thereby.

Ship-building all over the world, since the first iron vessels were launched, shows by the constantly improved out-

put the wonderful progress in scientific knowledge, and in manual as well as technical skill. The great fighting machines for the ocean have been improved with astonishing rapidity. This year our own output in that line has for the first time been tested and found good, when handled by men of whom we as a nation may feel proud. The nations have been increasing the power of their fighting ships year by year, adding new improvements in machinery, new means of resisting attack from other ships, new guns and newer projectiles to pierce the new armor plate, and let us hope with decreasing opportunity to bring the results to actual test in battle. In our own recent experience, practice at great cost found our trained marine force better equipped for the operation of these fighting machines, and in the far East and in the West Indies our guns swept a maritime power out of existence with upon our part scarce the loss of a man.

In working iron and steel the introduction of the Whitworth forging press marked an important advance compared with the costly steam hammers, and hydraulic presses became absolutely essential in perfecting the American type of link and pin bridge construction. Some of the forgings required for the 5,000 horse-power dynamos needed by the Niagara Falls Power Company could not have been executed by means of any existing steam hammer in this country or elsewhere, and the Bethlehem Steel Company were the first to introduce this system of forging on a large scale. Forging by pressure in place of impact by hammers enables the force required to cause a given deformation of metal to be accomplished with the least expenditure of power and greater exactness, as was soon manifested in the readiness with which hollow shafts were produced. About 1893, the work at Niagara Falls called for steel rings of absolutely uniform density, having an outside diameter of 11 feet 4 inches, with a width on the face of approximately 50 inches, and a thickness of over 5 inches, which necessitated the use of a press of greater capacity than any heretofore erected. The press at Bethlehem, combined with the Whitworth system of compressed steel ingots, was taxed to its utmost to make what

was needed in this case. It is interesting to note that this work was the first product of machinery introduced mainly to furnish armor plates and the massive steel forgings needed for our modern ships of war.

The plant of the Niagara Falls Power Company offers evidence enough of the remarkable progress that has been made, not only in the mechanic arts, but in the high scientific ability required to design machines that had no precedent in size or in exact requirements as expressed in the specifications predetermining each requirement as to the results to be accomplished. Thus the designers of the dynamos were called upon to guarantee an output from each unit of power with so high an efficiency that all the magnetic and electric losses in the machine would not amount to over $2\frac{1}{2}$ per cent. This requirement was fulfilled, and when subsequent machines were installed, the result was even more favorable than in the first instance. The final result is the crucial test of all progress, and certainly we have in those of our industries which require mechanical skill sufficient evidence of the marvellous progress that has been achieved during the past seventy-five years.

As I have taken occasion to mention the work at Niagara Falls, which has engaged so much of my attention, it may interest those who are not familiar with the results of this undertaking to hear something further in regard to it. At Niagara Falls we had for the first time to construct a tunnel that would be adapted as a tail race to the development of 100,000 horse-power. The International Niagara Commission had decided that 5,000 horse-power was to be the unit, and the plant was accordingly laid out on this basis. It was assumed that water-wheels could be made of that capacity and could be placed 150 feet below the level of the dynamos to be operated, where, as one of the Commissioners suggested, the length of shaft would be about the same as between the propeller and engines of an ocean steamship. In the practical solution of this problem we were obliged to have similar thrust bearings to guide the shaft, but the construction of the turbines is such that the water under the upper wheel of the two in the case is made to support

the whole mass of about 160,000 pounds. The dynamo at the upper end of the shaft, therefore, practically spins on a cushion of water with only a pressure of 3,000 more or less on the thrust bearing rings, according to the variations in the velocity as the power developed is increased or decreased.

It is too large a subject to permit me to refer in detail to all of the work that had to be done at Niagara Falls, but I want to say that, while our constant effort has been to interest the manufacturers of machinery to make designs that they could guarantee, a great deal of designing has been necessary by the engineers of the company, most of which was experimental, and that no failures should have been experienced is most satisfactory, when I realize how little precedent we had to guide us, and the risk attending the solution of the problem as it was presented to me.

The first three turbines that were installed in accordance with the design of the builders had to be materially altered, and I have introduced improvements of my own invention to enhance their efficiency as far as the shaft transmission is concerned. These modifications were made in the five units that were subsequently installed, and without any change in the water-wheels, the efficiency was increased so that they delivered 5,500 electrical horse-power each, instead of 5,300 horse-power, which was the output before the changes were made.

As now constructed, all the electrical and magnetic losses in each of the dynamos aggregate but $2\frac{1}{2}$ per cent., and you can judge what the efficiency of the water-wheels must be when those which, at 75 per cent. efficiency, would give 5,300 horse-power, are now driving dynamos that deliver 5,500 horse-power without any changes in the wheel, but only such alterations in seemingly immaterial parts as the design of the connection between the water-wheels and the dynamos.

As regards the utilization of the power being developed at Niagara Falls, it may interest you to note that we hope shortly to have ten dynamos running, each of 5,000 horse-

power nominal capacity, but actually capable of delivering over 5,000 horse-power each.

The first industry established in connection with the plant was a paper company, which required 7,200 horse-power, but it installed its own wheels on land of the Power Company, and utilized the latter's tunnel and canal facilities. Next followed the Pittsburg Reduction Company, which takes 8,550 electrical horse-power for the manufacture of aluminum. The Carborundum Company, for making abrasives, takes 1,030 electrical horse-power. The Union Carbide Company, 5,000 electrical horse-power, for the manufacture of carbide of calcium. The Niagara Electro-Chemical Company, making peroxide of sodium, that is, metallic sodium, takes 400 electrical horse-power. These and other works now in operation or being installed will utilize, possibly by the first of next year, a total of 41,000 horse-power. Most of these establishments are electro-chemical or metallurgical in their processes, and have sprung into existence with the development of hydro-electric power, although they are based upon principles which were discovered years ago. The metal sodium, for example, is made commercially by practically the same process as was employed by Sir Humphrey Davy when he first began experimenting with the galvanic battery for the reduction of metals. The alternating current that has been adopted in the machines that generate this electricity is the alternating current as studied by Michael Faraday. The change in the potential from 2,200 volts at the machine to 11,000 volts in transmission is effected by the transformers that were discovered by Faraday, and were formerly used chiefly in Ruhmkorff coils and other philosophical instruments. The principle as known then became useful for lighting purposes when the alternating current took its place in the lighting of cities.

In the problem presented at Niagara Falls we had to provide for direct current to operate railroads and for electro-metallurgical purposes. This power is developed as alternating current, and transformed from 2-phase into 3-

phase by an invention of Mr. C. F. Scott, of the Westinghouse Company.

It is a noteworthy fact that, since the first wheels were started in 1895, there have been no stoppages of more than an hour or two at the most. The plant has been in operation night and day, carrying on processes that permit of no interruption on account of the loss which would result.

I regret that I cannot discuss this subject at greater length, for the machinery and appliances installed at Niagara Falls, as well as the industries which have resulted from the development, have made the enterprise one of the important achievements of the period we have under consideration.

Reviewing the century's progress, one cannot but be impressed with the tendency to specialize all industries. It has been truly said that jobbing shops are and always will be a necessity, but that manufacturing establishments will lead in the march of improvement. Trades are becoming more diversified, and time, talent and capital are being expended upon individual machines and appliances as special which were formerly but a part of the output of single establishments. To this concentration of the best thought upon special branches of all industries we may attribute much of the progress in the mechanic arts made during the past seventy-five years, which has opened the markets of the world to the products of our industry. The influence of the Franklin Institute has played no small part in this progress, and as one long identified with its work, I extend my greeting to its members, hoping they will continue to advance the usefulness of an institution which worthily bears the name of one of the greatest philosophers that America, and the world, has produced.