ON THE ORIGIN AND DEVELOPMENT OF AMERICAN MECHANICAL "KNOW-HOW"

EUGENE S. FERGUSON

The term "know-how" appeared in the United States in the 20th century. It was invented to describe the peculiar set of constructive and organizational abilities that are essential ingredients in the building of an industrial complex. Although the term is new, it is fairly evident that the abilities it describes are not. But when we ask for particulars of the origin and development of "know-how," the only answers that have been formulated are couched in economic terms. The objection that complex and sophisticated tools and machines were required in order to build an economy of plenty is dismissed usually by a vague reference to Yankee ingenuity.

An examination of the rise of American technology reveals the need for more plausible explanations than we have been accustomed to. It is the purpose of this article to suggest the kind of question that might be asked and to point to what appear to me to be fruitful lines of inquiry.

The tradition of native American mechanical "know-how" was well established by the middle of the 19th century. Citizens of the United States were acutely aware of the mechanical prowess of their "go-ahead" country. The nation was, indeed, going forward. In Harper's Magazine, the Easy Chair Editor touched the dominant chord when, in 1853, he wrote "Our fast age is growing rapidly faster." The American "brag" was commonly remarked on both sides of the Atlantic. At the beginning of the same century--just fifty years earlier--however, the pace of material advance can only be described as halting. The seeds of know-how were present, of course; they had been imported from western Europe; but they had only just begun to germinate.

The contrast between the mechanical capabilities of craftsmen in 1800 and in 1850 is so striking that it would appear to demand an explanation. Yet little attention has been paid to this fundamental development which underlay the spectacular material achievements of these years. I have treated the subject in a personal and informal way because nowhere has enough information been assembled to make any final pronouncements, and because I should like to suggest the large number of variables that are involved in the increase and diffusion of mechanical knowledge.

First, let us look at the nature of the contrast just mentioned. In 1800, the Philadelphia waterworks were under construction. Designed by Benjamin H. Latrobe, an English-trained architect and engineer, the works required two steam pumping engines. One engine, located on the banks of the Schuylkill River, pumped water from the river to the second engine, which was in the main waterworks building in the Center Square, where City Hall now stands. The engines were of the conventional Boulton and Watt design; the largest engine cylinger that had to be made was just under 40 inches in diameter and about 6 1/2 feet long. The contract for building the engines was let to Nicholas Roosevelt, of Newark, New Jersey, whose machine works--called Soho Works, after the Boulton and Watt shops in Birmingham, England--were as advanced as any in the United States. The engines were completed; they operated satisfactorily for many years, but their construction taxed Roosevelt's shops to the limit. A visitor to his establishment during the summer of 1800 reported on the progress of boring one of the large engine cylinders.

The cylinder, of cast iron, had to have about 3/4-inch of material removed in order to obtain a smooth and true interior cylindrical surface. The boring mill, arranged horizontally, consisted of a boring head, driven by a water wheel, and a movable carriage to which the cylinder was fastened and which served to advance the cylinder against the boring head.

> Two men are required [wrote the visitor]. One almost lives in the cylinder, with a hammer in hand to keep things in order, and attend to the steelings [the cutting tools], the other attends to the frame on which the cylinder rests which is moved by suitable machinery; these hands are relieved, and the work goes on day and night; one man is also employed to grind the steelings; the work is stopped at dinner time, but this is thought no disadvantage as to bore constantly the cylinder would become too much heated; the work also stands whilst the steelings are being changed, which requires about ten minutes time, and in ten minutes more work they were dull again.... The workmen state that the boring was commenced on the 9th of April and had been going on ever since, three months, and about six weeks more will be required to finish it.[1]

In December, 1852, in New York City, the main propulsion engine of the caloric ship Ericsson had been installed on board, and last minute adjustments were being made for the trial run of the vessel, which occurred in the early days of 1853. The engine of the Ericsson, which was designed by the Swedish-American John Ericsson, was one that employed heated air, rather than steam, as the working medium. Ericsson expected that this "caloric" engine would make steam engines obsolete, and there were indeed some novel design features involved; but the most remarkable fact about the Ericsson's engine was its size.

Four cylinders, each 14 feet in diameter and perhaps 8 feet long (the working stroke was 6 feet), and four more cylinders, each 11 1/2 feet in diameter, were components of the enormous caloric engine. The cylinders were cast and bored at the machine works of Hogg and Delamater, which was one of several large mechanical firms located in lower Manhattan.

The details of this particular boring operation have not been discovered; but it is probable that the boring mill was arranged vertically and driven by a steam engine, that the cutting tools were greatly improved over those used fifty years earlier, and that the boring proceeded at a rate that would have amazed Roosevelt. A contemporary observer who was not inclined to be generous in his comments was Orson Munn, editor of Scientific American. He thought the "caloric" feature of the engine a humbug, but he had only praise for the mechanical design and machine work. Munn worte that "the designer and constructors of [the] machinery have shown themselves to have long heads, and skilful hands. We have never seen anything to compare with the castings."[2]

So far as I can learn, these were the largest engine cylinders ever attempted, anywhere, before or since. This kind of performance, involving construction on an heroic scale, was typical of the United States in the 1850's.

Returning now to 1800, we can look briefly at another kind of mechanical performance.

Eli Whitney, of New Haven, Connecticut, had engaged, on June 14, 1798, in a contract to supply 10,000 muskets to the federal government within a period of just over two years. He expected within the first year to build machinery that would enable him to use unskilled labor to produce muskets in quantity; but by the end of 1800 he had delivered no muskets, although his contract period had run out. The first 500 muskets were delivered late in 1801, and the contract was not closed until January, 1809. In no single year before 1806 did he deliver more than 1000 muskets.

Now this is the performance that is usually accepted uncritically as evidence of Whitney's role as the father of mass production industries. Upon closer examination it will be found that not only did other private gun contractors and the national amories at Springfield, Massachusetts, and at Harper's Ferry furnish many more muskets than did Whitney during this period, but that their methods were generally superior to those employed by Whitney. The idea of a system of progressive manufacture of interchangeable parts, using special-purpose machines to aid and, where possible, replace the skill of the operator, was present in 1800. The idea originated probably in France; it was known perhaps in England; but nowhere had it been effectively applied.

In 1853, on the other hand, the American inventor Samuel Colt was operating a pistol manufactory in London, using special-purpose machines that he had brought with him from the United States; and in 1854 a British commission, representing the Board of Ordnance, was in the United States to inquire into what the British called the "American System" of small-arms production and to purchase machine tools from American manufacturers in order to outfit the new British armory at Enfield, near London, which was to be operated on the "American System." Through the exhibits of Colt and the firm of Robbins and Lawrence (of Windsor, Vermont) at the Great Exhibition of 1851, in London, the idea of the "American System" had been brought home to English observers, with the results just indicated.

Thus we have examples that epitomize the mechanical "know-how" of Americans in 1800 and at mid-century, both in the production of large and small products. A number of distinguished studies have been made of canal, railroad, steamboat and manufacturing developments, but the concern has been with economic rather than technological development, and it is easy for a reader to assume that not much beyond Yankee ingenuity was necessary to build the locomotives, steamboats and manufacturing machines, so long as the money could be found to pay for them. Simple economic pressures and Yankee ingenuity are insufficient, however, to explain how a people could not only refine manual skills and improve upon machine tools that found their way to this country from the old world, but could strike out on a boldly original tack and, within a space of less than two generations, begin to export to England a manufacturing know-how and machine tools so different from those in England that the whole performance became known abroad as the "American System." Not only were manufacturing techniques and tools being exported, but in the 1840's American locomotives were being shipped to England, and American locomotive builders had gone to Russia and Austria to set up shops to build locomotives for the governments' railroads.

All of this occurred in spite of the fact that English machine-tool development started at least a generation ahead of American development. John Wilkinson's boring mill of 1775, which was a decisive factor in the success of Boulton and Watt's steam engine, was a much more sophisticated tool than Nicholas Roosevelt's boring mill of 1800.

When, in 1807, Robert Fulton wanted an engine to propel his pioneer steamboat, he imported a Boulton and Watt engine from England. It is significant, however, that an act of Parliament was required in order to export the engine, for an embargo on machinery of all kinds, intended to suppress foreign competition with English manufactured products which was not lifted until after 1840, was then in effect. This embargo, as well as the unavailability of British goods during the War of 1812, had a positive effect in encouraging the development of American tools and American machines, whose design may sometimes have departed from British precedent because the precedent was not at hand to be observed. The embargo was one factor certainly. But we ought to know something about the kind of people who were doing work in the United States, and about their sources of technical information and the ease with which it could be obtained. This has several ramifications, such as publications, technical societies, observations of travelers and so forth.

In trying a few years ago to learn something about what innovations actually occurred in the United States, I found this period to be a virtual wasteland, so far as actual source material on techniques and tools was concerned. The products of craftsmen and of machine tools could be traced without much difficulty, but the basic technical information was elusive and unsubstantial. There are, to my knowledge, no American machine tools of earlier than about 1830 in existence, with the notable exception of the Blanchard gun-stock machine of 1820, now preserved in the Springfield Armory Museum, and an incomplete device that looks like a milling machine, attributed to Eli Whitney but of quite uncertain origin. Nor have many drawings been preserved that can supply useful information. There are two reasons for this. First, many machines were built from full-size drawings on chalkboards or from no drawings, and second, even when drawings existed they were seldom considered suitable documents to be collected by libraries and historical societies.

At length, however, I ran across "An Interesting Letter from an Old Engineer" in the first volume of Machinery, of 1896. This letter, written by George Escol Sellers, led me back to a series of some 40 articles that Sellers had written for American Machinist between 1884 and 1893. These articles, "Early Engineering Reminiscences," began to fill the vacuum so far as information was concerned, and to bring the whole period alive and to provide plausible answers to many of the questions that I had asked. I will say that this was a most unlikely source, because it was written by a man who was past 75 before his first article appeared, and some of the events that he described so vividly had occurred before he was 10 years old. But I have tested the information, nearly line by line, and it has held up astonishingly well. In fact, I have thought enough of its value as source material to edit and annotate the series for publication.[3] It is in the process of checking Sellers' statements that I have been able to recognize the significance of fragments whose relevance would not otherwise have been evident.

George Escol Sellers was born in Philadelphia in 1808, about a block and a half from the old State House, now known as Independence Hall. One of his grandfathers was Nathan Sellers, who was the first maker of wire moulds for handmade paper in the United States. Nathan's son, George Escol's father, followed in the mould-making trade, but branched out into the manufacture of fire engines and, eventually, paper-making machinery. The other grandfather was Charles Willson Peale, portrait painter to the great federal generation of Americans and founder of the museum that became, in its way, an educational institution for American mechanicians.

George Escol grew up in a mechanical household, and he was at home in the shops of a remarkable group of able craftsmen who worked in Philadelphia during the first half of the 19th century. He attended the Friends' School on Fifth Street until he was 15 or 16 years old. His classmates included

Solomon and William Milnor Roberts, who became civil engineers, John Dahlgren, of naval ordnance fame, and John Trautwine, whose later civil engineering handbook became a classic in its field. Sellers attended a mechanical drawing class conducted by William Mason, a machinist and instrument maker, and he drew for John Haviland, the architect. He served no apprenticeship as such, but he became a competent machinist, profiting in every way by his associations with such fine craftsmen as Isaiah Lukens, Joseph Saxton, his uncle Franklin Peale, and an itinerant German aristocrat identified thus far only as Henri Mogeme.

The knowledge that a group of craftsmen, however competent, could impart to a pupil was limited. The existence and availability of printed information was important then as it is now. Oliver Evans (1755-1819), who was acutely aware of this need, figured in some of Sellers' earliest recollections.

Evans, a leading machine-builder in Philadelphia, was a friend of the Sellers family. A gifted innovator, Evans originated before 1800 an automatic flour mill which employed bucket conveyors, screw conveyors and automatic bolting equipment. Before 1810 he had built some of the first high-pressure steam engines in the United States and had invented a straight-line linkage that still bears his name throughout the world including Russia. He published the Young Mill-Wright and Miller's Guide in 1795, more than ten years before the first similar work appeared in England. The Guide went through fifteen editions, the last appearing in 1860. Nevertheless, the title of his 1805 book, Abortion of the Young Steam Engineer's Guide, reflected his frustration at the indifferent support he was able to command for a pioneering work on the steam engine which was issued before any similar work had appeared in England. Sellers told of Evans' concern over "the difficulties inventive mechanics labored under for want of published records of what had preceded them and for works of reference to help the beginner." The North American Review, in 1819, corroborated this deficiency:

> Books and instruments connected with the science and practice of engineering [are not] possessed by individuals in great numbers, and if any person seeks for them in the shops or book-stores in the United States, he will be disappointed. He must import them for his own use at great expense.[4]

Although there were two or three mechanical periodicals in England at this time and some issues at least were in the Philadelphia Library Company collections, it was not until the 1820's that any considerable amount of technical information became available. In 1824, the Franklin Institute was formed in Philadelphia for the exchange and dissemination of technical information. Mechanics' Institutes were formed in New York, Boston and Baltimore during this decade also, and in all four cities exhibitions of mechanical products, sponsored by the institutes, were held periodically. The Franklin Institute was easily the most important of the institutes, as measured by its influence upon the mechanical community. Its "Committee on Science and the Arts" acted as a clearing house for patent information and had the courage to judge the merits of individual inventions. Later committees on boiler explosions and their prevention published their findings for the benefit of all who would read. The Institute's Journal, which appeared first in 1825, was equal in quality to Newton's Journal and the Mechanics' Magazine, both of London, which preceded it by a few years. Also, in 1823 an American edition of Abraham Rees' outstanding English Cyclopaedia had been completed.

Whatever his sources of information, the native-born American mechanician made significant contribution to the American tradition during this period. We should know more about these men than merely their names, although it is sometimes difficult even to learn names. Person accounts are especially useful in putting flesh on bare bones. The Sellers reminiscences offer a delightful as well as plausible catalogue of the mechanics that he knew.

Jacob Perkins (1765-1838), of Newburyport, Massachusetts, was a prolific inventor who in 1815 came to Philadelphia. His head fairly rattled with ideas; he kept his head covered by a stove-pipe hat in which he carried all manner of notes, sketches and memoranda. In 1819 Perkins emigrated to England, seeking a wider field for his talents and to introduce there a system of bank-note engraving that he considered proof against counterfeiting. He took with him Asa Spencer, another native of Massachusetts, who had originated an ingenious geared scroll-lathe to produce the intricate scroll designs required for bank-note engraving plates. Perkins' inventions covered the mechanical field: extremely high-pressure steam engines and boilers, a hot-water heating system, a vapor-compression refrigeration system, among many other. Although Perkins remained in England for the rest of his life, he left in the United States a legacy of ideas and enthusiasm for innovation, and his influence upon later American visitors to England was not inconsiderable.

Perkins was characterized by Sellers as a bustling, quick, enthusiastic and excitable man of boundless energy. He had the faculty of keeping the mechanical world "in a feverish state of excitement.... It was never what he had done but what he was doing." The fact that few of his schemes ever actually succeeded seemed to matter little when he looked about for money to support some new venture. "To sum it all up," wrote Sellers, "he certainly filled a useful place in advancing improvements in steam engines, for his schemes set many level headed men to thinking in the right direction."

Contrasted with Perkins was the builder of fire engines, Patrick Lyon (1769-1829), who is known today mainly through John Neagle's handsome painting of "Pat Lyon at the Forge." Lyon was a careful, expert craftsman in the iron and brass work of fire engines. Incidentally, two of his fire engines can be seen on display in Independence Hall. One is attributed to an earlier maker, but the mechanical details are so similar to Lyon's work that the attribution is almost certainly in error, for Pat Lyon was never a man to copy blindly. He was independent, confident in his own solid ability. When questioned about tariff protection in the federal census of 1820, he replied, even though his business had fallen off in the depression of 1819, "I manufacture cheaper and better than the articles I manufacture can be imported. I do not want any additional duty laid for my protection." He represented the intelligent, systematic mechanician who advanced the art by small but sound improvements.

William Mason and Rufus Tyler were two machinists who set the tone for excellence of workmanship. Fine turning lathes, including rose-engine lathes, and machinery for engraving calico-printing plates and bank-note plates were made in their shop. When, around 1822, a Maudslay lathe slide-rest that had been smuggled out of England was brought to their shop, Mason and Tyler made changes and essential improvements, producing a sturdy and widely-accepted American version of the slide rest. As I have already mentioned, Mason taught youngsters how to use drawing instruments in mechanical drawing. Although Sellers did not tell whether Mason and Tyler had any apprentices in their shop, it is likely that they did.

Matthias Baldwin, world-famous builder of locomotives, was a Philadelphia mechanic who had served an apprenticeship with a jeweler and had spent many years as an engraver and fine machinist before a model that he was commissioned to build for the Peale Museum gave a new direction to his career. After the 1829 Rainhill trials of locomotives in England, Franklin Peale, at this time in charge of the museum, asked Baldwin to build for him a working model of the Novelty, the Ericsson and Braithwaite locomotive that had competed unsuccessfully with Stephenson's victorious Rocket. Why Peale chose the Novelty and not the Rocket as his model is not clear. However, it was for Baldwin but a step from the museum model to a full size locomotive for the Philadelphia and Germantown Railroad; and within a few years he was the leading locomotive-builder in America.

Franklin Peale was a good craftsman in his own right. He had served his apprenticeship in the machine shops of the Hodgson Brothers, located on the industrial stretch of the Brandywine Creek just north of Wilmington, Delaware. The Gilpin paper mills, the Young cotton factories and the DuPont powder mills were among the Hodgsons' customers. Peale spent about two years in Europe for the U. S. Mint, studying the metallurgy and mechanics of minting processes throughout Europe. An extensive report of his is in the

National Archives, but the hundreds of working drawings that he prepared from actual machinery in Europe apparently were not saved.

William Norris was a locomotive builder who was an organizer rather than a craftsman. After a short career as a dry-goods merchant, Norris set up a shop to build a locomotive designed by Stephen Long, an Army engineer, and earlier the discoverer of Long's Peak in Colorado. The trial of the first Long and Norris locomotive was described years later by Norris: "Gentlemen, I can, on my honor, assure you that we ran four miles and a-half in seven hours and a quarter, and running all the time at that."[5] Norris soon obtained the necessary mechanical help to eliminate his difficulties, and within a few years he built a locomotive that attracted attention in Europe as well as at home by climbing an inclined plane while pulling a loaded passenger car.[6] Until this feat was accomplished, it was assumed that locomotive engines would pull a load only on nearly a dead level, and that considerable changes in elevation would have to be overcome by inclined planes, employing stationary engines to pull cars up. The idea had been imported uncritically from England where it had been stated by George Stephenson, one of the pioneer builders.

Norris locomotives were soon being exported to England; and it was Norris who in the 1840's went to Vienna to organize locomotive and car shops for the Austrian state railroad.

In the United States, a considerable number of English locomotives were imported for the early railroads. Given the demand for locomotives, however, specialized machine shops came into existence in Philadelphia, New York, New Jersey and in Massachusetts. George Escol Sellers and his older brother Charles built two locomotives for the Philadelphia and Columbia Railroad. Seth Boyden, of Newark, New Jersey, was a versatile inventor who turned to locomotive building. John Brandt, a Lancaster, Pennsylvania blacksmith who was concerned with the Sellerses for a time in building a textile-card making machine, went on to become master mechanic of the Erie Railroad and eventually to set up a successful locomotive works in Lancaster.

The know-how of the mechanicians just described was supported not only by the scanty technical literature available and specimens of English machines but also by immigrants who brought with them needed skills. Sellers' account of an incident that occurred in the 1820's, when his father was running an extensive fire-engine manufactory is revealing. A German workman came to the shops one day looking for work. After George Escol's father had told him that he had nothing for him, the German stood about for some time watching the work being done in the shop. At length he said, to no one in particular, "I see no coppersmith's bench or tools." Sellers said, "We have that work done out." The visitor countered, "Better work, better fits if done here."

The result was that the German, who gave his name as Henri Mogeme, built himself furnaces and tools required for a small brass foundry and fitting shop, and in the course of his work he found time to instruct George Escol in the art of brass-founding and brazing. Sellers said later, "I never went into his shop that I did not learn something. Mogeme was a capital teacher: when explaining anything to me it would be as if I was entirely ignorant. He would say, 'No understand without beginning right'."

Mogeme was an itinerant craftsman, but with this difference. He apparently was of noble birth, had attended a German technical school and had worked in various shops on the continent and in England before coming to the United States. He returned home after a few years in America; but he left the country richer so far as mechanical skills were concerned. I have not heard of other such itinerants in the United States; but as I mentioned earlier the whole technical background of this period is very imperfectly known.

Still another source of know-how which is not generally realized is the American mechanician who went abroad in search of know-how on the spot. In 1832, when he was not quite 24, George Escol Sellers went to England to learn what he could about the building of paper-making machines and their use. The first paper machine in the United States was the one that had been installed in the Gilpin mill, on the Brandywine, in 1815, after both of the Gilpin brothers had visited England and after an English paper-maker, Lawrence Greatrake, had been induced to emigrate to America. The Gilpin machine was a copy of John Dickinson's English cylinder machine, patented in 1809. The Sellers shops had been for several years building a much-simplified version of the Dickinson cylinder, which enabled small paper mills to increase production with a trifling capital expenditure. In the late 1820's, however, an English Fourdrinier machine was imported and installed in a mill in upstate New York. The idea of the Fourdrinier machine had originated in France, but the machine development had been financed by the Fourdrinier brothers, London stationers, and the actual development work had been largely in the hands of Bryan Donkin, also of London. To see Donkin's shop was one of George Escol's primary objectives in going to England.

Sellers was entertained and treated with unusual openness by some of the outstanding mechanicians of the day, and he was thus able to visit several prominent shops and mills and to compare English with American practice. Although he was but a young man, the relative ease with which he gained the confidence of and obtained information from such cautious men as John Dickinson and Bryan Donkin suggests that Sellers was an intelligent--even expert--listener to detailed technical descriptions, and that the information that he had brought with him from America was of great interest. Since George Escol's sister was engaged to marry a man who had come from Birmingham, England, the bridegroom's brother took Sellers in hand when he arrived in England and opened several doors for him; and his good friend Joseph Saxton, a Philadelphia mechanician who had been in England for some time, was his constant companion in London, introducing him to his circle of acquaintances.

Sellers was greatly impressed by Donkin's accomplishments. He noted that while he was in his company, one day, Donkin received word of a Fourdrinier machine that had broken down. Taking spare parts from the shelf, Donkin dispatched a workman to get the machine back in order, predicting that it would be making paper again before midnight. The idea of an interchangeable spare part for a musket was gaining general acceptance by this time in the United States, but a spare part for a machine as extensive and complex as the Fourdrinier paper machine was unheard of.

On the other hand, the weight of traditional practice sometimes blinded the great English craftsmen to the value of American improvements. Donkin was interested in what Sellers told him about mechanical developments in America, but he could not understand how machine works could be successfully run without a strict division of labor, as in England, where each workman mastered only a single operation, such as turning, filing or wielding a cold chisel. "I told him," wrote Sellers, "that he must bear in mind that America's start in mechanical art was at the point England had reached and without her prejudices." One example that Sellers cited was England's rejection of the American cut nail, and the prejudice of English carpenters and patternmakers for the hand-made tapered wrought nail, of "the best possible form that could be devised to split the wood it was driven into, without first boring a hole to receive it." Another example was the pointed wood-screw, which originated in the United States. The Birmingham hardware makers would not consider taking orders for such screws, because the old square-end screw was good enough for them.

Sellers had also an opportunity to visit and inspect at leisure the celebrated shops of Maudslay, Son and Field, machinists and engine builders. Henry Maudslay, the pioneer machine-tool builder, had died in 1829; the works were being carried on by his partners. Sellers was taken first by his host to see the boring machine on which the largest steamboat engine in England was being machined.

"Here," wrote Sellers, "I must confess a feeling of great disappointment, for the cylinder struck me as a mere pigmy compared with the cylinders of the North River and Long Island Sound boats of that period.... There were at that time boats on the American rivers with condensing engines, whose cylinders would cover two of the one on the boring machine.... The workmanship on them appeared to be of the highest possible character. This astonished me, after having seen the lathes and other machine tools, none of which lacked in care or accuracy in their construction, but totally inadequate for the character of the work they had to do, as to weight, strength, and firmness." Moreover, none of the lathes he saw was as large as the one his father, his brother and he were then (in 1832) building in their Philadelphia shops.

The British, however, were by no means unaware of American advances, and an opportunity to look at American development from an English viewpoint is afforded by British Parliament inquiries concerning machinery--one in 1841 regarding the operation of the machinery embargo and another in 1854 regarding the making of muskets.[7]

An American who was in London in 1841 answered a question about the use of English tools in the United States. "There are not a great many English tools imported into the country," he said, "but the English have furnished us with some important patterns to build by. The planing-machine we first obtained from England, and I believe the first imported into the United States was smuggled from this country, from the manufactory of Messrs. Sharp, Roberts & Company, of Manchester."

An English witness noted, on the other hand, that the "entirely new inventions; not improvements in machines, which are still mostly made here; come now from abroad, especially America."

Another Englishman, who had been in the United States, recalled that the machinery there was "tolerably well finished, such as we should call second-rate machinery in our own country."

In answer to the question: "Are the Americans as skilled as the English?" this same witness replied, "It is not possible that they can be, without more experience than they have had at present."

"Are the Americans aware of their inferiority?"

"They will not allow it," responded the witness.

David Stevenson, Scottish engineer and uncle of Robert Louis Stevenson, had reported elsewhere[8] that he had seen in the Baldwin locomotive works in Philadelphia "no less than twelve locomotive carriages in different states of progress, and all of substantial and good workmanship. Those parts of the engine, such as the cylinder, piston, valves, journals, and slides, in which good fitting and fine workmanship are indispensable to the efficient action of the machine, were very highly finished, but the external parts, such as the connecting rods, cranks, framing, and wheels, were left in a much coarser state than in engines of British manufacture."

In 1854, when the "American system" was being discussed by a Parliamentary committee, Samuel Colt was called in to testify. He had much to say about the "American system," but he managed to express the American position in a sentence: "There is nothing [he said] that cannot be produced by machinery."

While Joseph Whitworth, a leading English engineer and mechanician, could see no particular advantage in the "American system" of manufacture, another prominent engineer, James Nasmyth, was generous in his praise of the system as it had been carried out in the Colt pistol factory. "The first impression," he said, "was to humble me very considerably....In those American tools there is a common-sense way of going to the point at once, that I was quite struck with; there is a great simplicity, almost a quaker-like rigidity of form given to the machinery; no ornamentation, no rubbing away of corners, or polishing; but the precise, accurate, and correct results."

Whitworth, who had visited the United States in 1853, said elsewhere that the thing that had impressed him was the ready acceptance of labor-saving tools by the workmen as well as the proprietors.

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A number of the elements of answers to questions implicit in the title of this article are contained in the sources and lines of inquiry that I have suggested here. The catalogue is by no means complete, but I have ventured to give a fragmentary account at this time in the hope that others will perhaps be provoked to pursue the subject further.

I close with a few tentative conclusions, about which argument or discussion are invited.

First, the information that came from Europe was essential, and it was used freely and without prejudice. Next, the stream of travelers going to Europe to obtain mechanical and engineering information was important, but its magnitude is not known with any precision. I suspect that it was perhaps five times as great as the best-informed scholars today would estimate it to be.

Third, and this I have not illustrated because it is adequately covered elsewhere, the geography, unlimited natural resources, economy and political climate of the new country all had a powerful influence upon mechanical developments. Governments at all levels were permissive but not, as we have been generally taught to believe, passive. Patent laws, corporation charters, government subscriptions to stocks, and direct subsidies have served to promote the common good (at least in the production of material wealth) by encouraging individual ingenuity and enterprise.

Fourth, the intelligence, ability and self-reliance of the mechanics mentioned here--and there were many hundreds of others like them--was certainly an important factor in the development of the tradition of "know-how." These men, while often short on principles, possessed a highly developed intuitive sense of fitness, as well as an integrity that insured an honest product of good value. There were a few catalysts, such as the Perkinses and the Ericssons, who added suggestion if not direction to the mainstream of engineering advance.

A final ingredient, found in the United States but not in Europe, was the freedom with which knowledge was shared and exchanged. Closed shops and mills seem to have been few and far between in the United States. To show conclusively that this "open door" policy was completely general will require more information than I now have; but when the factors that underlie the rise of American mechanical "know-how" are ranked in order of importance, I think that this one will be close to the top of the list.

Iowa State University

Footnotes:

[1] Quoted in Greville and Dorothy Bathe, Oliver Evans (Philadelphia, 1935), p. 70.

[2] Scientific American, VIII (January 22, 1853), 149. Quoted in "John Ericcson and the Age of Caloric," United States National Museum Bulletin 228 (Smithsonian Institution, Washington, D. C., 1961), pp. 41-60.

[3] Now in press, to be published by Smithsonian Institution.

[4] North American Review, VIII (1819), 15.

[5] As reported by Sellers in his reminiscences.

[6] The Norris locomotive George Washington exhibited no radical departures in design. Norris simply questioned, albeit in a dramatic way, the currently-accepted design concepts. Sellers, in mentioning the incident, assigned it no particular significance; but in this I think he was mistaken. I say "I think": there is need for a systematic study of the evolution of ideas about tractive effort and adhesion, both in England and in the United States.

[7] Great Britain, Parliamentary Papers (House of Commons, Sessional Papers), 1841, Vol. VII and 1854, Vol. XVIII.

[8] David Stevenson, Sketch of the Civil Engineering of North America (London, 1838), pp. 258-259.