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NATIONAL ACADEMY OF SCIENCES

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BIOGRAPHICAL MEMOIR HENRY MARION HOWE

1848-1922

BY

GEORGE K. BURGESS

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1923

Henry Marion Stone

HENRY MARION HOWE

By George K. Burgess

A very beautiful memorial service was held at the Episcopal Cathedral of St. John the Divine, New York City, at 5 o'clock on the evening of October 25, 1923, in honor of the late Henry Marion Howe, who was a vestryman in an Episcopal church of that diocese. Dr. Michael I. Pupin, professor of electro mechanics, Columbia University, was the speaker on this occasion, his theme being "The power of coordination" as exemplified by Doctor Howe in his life and works. This service coincided with the date of the fall meeting of the American Iron and Steel Institute and there were gathered in that quiet and peaceful corner many of his old friends and associates to do honor to the man whose life was so worthy and fruitful in his endeavor to be of service to mankind.

Henry Marion Howe was born March 2, 1848, in Boston. His death occurred in the seventy-fourth year of his life at his home in Bedford Hills, N. Y., on May 14, 1922, of an illness from which he had been suffering, acutely at times, for some 15 months. He is survived by his wife, Fannie Gay Howe, whom he married in Troy, N. Y., April 9, 1874, and also by two sisters, Mrs. Laura E. Richards, of Gardiner, Me., and Mrs. Maude Elliott, of Newport.

In order to have a proper background for such a life as was that of this eminent scientist and teacher, it is of interest to note that his father, Dr. Samuel Gridley Howe, American philanthropist, and son of Joseph N. Howe, a shipowner and cordage manufacturer, and Patty Gridley, one of the most beautiful women of her day, was educated at Boston and Brown University, taking his degree in medicine in Boston. However, he was no sooner admitted to practice than he abandoned all prospects of following his chosen profession. With Byron as an example, his enthusiasm carried him to Greece, where he joined the army and spent six years in the midst of scenes of warfare. After this, in turn, he established a relief depot near Aegina, and formed another colony of exiles on the Isthmus of Corinth, writing meantime a History of the Greek Revolution, which was published in 1828. After his return to America, in 1831, he began receiving a few blind children at his father's house in Pleasant Street, and thus sowed the seed which grew into the famous Perkins Institution for the Blind. He was the director, heart and soul of the school; he organized a fund for printing for the blind—the first done in America—which gained for him the title, "Cadmus of the Blind."

His mother, Julia Ward Howe, American author and reformer, daughter of Samuel Ward, a New York banker, and Julia Rush (Cutler), a poet of some ability, when 16 years of age began to contribute poems to New York periodicals. Among her many works of art, undoubtedly the most popular is her poem, "The Battle Hymn of the Republic," written to the old folksong associated with the song of "John Brown's Body," when Mrs. Howe was at the front in 1861, published in the Atlantic Monthly. Her children were Julia Romana Anagnos, 1844–1886, who, like her mother, wrote verse and studied philosophy, and who taught in the Perkins Institution, in the charge of which her husband, Michael Anagnos, succeeded her father; Florence Marion Howe Hall; Henry Marion Howe, the well-known metallurgist, and subject of this biography; Laura Elizabeth Richards; and Maude Howe Elliott, wife of John Elliott, the painter of a fine ceiling in the Boston library, both these daughters being contributors to literature.

Henry Marion Howe, the only son of these two illustrious personages, was in his early childhood trained by tutors in the persons of Polish and Greek refugees to whom his father's beneficence was well known to many. With these for teachers, and in the atmosphere of a home such as was his, young Howe was surrounded throughout his childhood by the very

essence of culture and learning which laid the foundation upon which was built the man so fittingly described by Albert Sauveur when conferring upon him the John Fritz medal in 1917:

> Lover of justice and humanity;
> Public servant and public benefactor;
> Master of the English language;
> Loyal and devoted friend;
> Untiring and unselfish worker in an important field of science;
> Stimulating teacher, inspiring investigator and generous collaborator;
> Voyager in realms but dimly perceived by fellow workers;
> Lone explorer of fields destined to yield rich harvests to future generations;
> Man of genius, honored and loved the world over.

As a boy, young Howe attended the famous Boston Latin School, from which he graduated in 1865, then entering Harvard, where he remained until graduation in 1869, at the age of 21. During these years of his early education he seems to have followed his natural inclinations toward sport and gayety. He was debonair, devoted to music and dancing, full of fun and mischief; "he was never known to drink, or smoke, or consort with light company—his fun was of a different order." One characteristic, which followed him all through his life, was his love of playing practical jokes upon his friends and all who came in contact with him. After being rusticated in his sophomore year at Harvard because of a boyish prank "the faculty thought not appropriate," however, he began to realize he was wasting the great opportunity of education, and from then on his time was not lost. In the fall of 1869 he entered the Massachusetts Institute of Technology and there first revealed his capacity for hard work in the field of science in which he was to become so distinguished in his later years. In 1871 he graduated with the degree of "graduate in the department of geology and mining engineering," for which the institute substituted a few years later the title of "bachelor of science."

With this liberal education as a basis, it was necessary for him to lay yet another foundation—that of acquaintance with practice—and so we find him next in Troy, N. Y., a student in the steel works. Here he worked hard, but it was not all drudgery, for his high spirits and sense of humor soon made him a favorite in a place full of gayety such that his presence was always in demand.

When his practical studies in Troy were over, he began the work of his career as superintendent of the Bessemer Steel Works, Joliet, in 1872, and of the Blair Iron & Steel Co., 1873–74. For the next five years he devoted himself to the metallurgy of copper, and improved copper smelting in Chile for the heirs of Augustus Hemenway, and then designed and built the works of the Orford Copper & Nickel Co., at Capeltown and Eustis, in the Province of Quebec and at Bergen Point, N. J., 1879–1882. This latter year he was manager of the Pima Copper-Mining & Smelting Co. of Arizona. As a result of his practical studies during these years in the field of improved copper smelting, there appeared from time to time technical papers on the subject, culminating with his first book, Copper Smelting, published in 1885.

It was while with this last-mentioned company that Doctor Howe made a rather startling decision. With prospects for a singular success financially, for becoming a leader in the industrial world, he deliberately chose, at the age of 35, to turn away from the practical to the theoretical side of his profession. He must have realized, from questions arising out of his practical work, that there was a real need in the metallurgical world—that of bringing cosmos out of apparent chaos of nonrelated facts.

So he made the change by establishing himself in Boston as a consulting metallurgist and at the same time a lecturer on metallurgy at the Massachusetts Institute of Technology, where he remained until 1897, when he was called to the chair of metallurgy at Columbia University in New York City. In 1913 he retired from active work at Columbia and became professor emeritus, when he declined as far as practicable all professional business, devoting himself exclusively to research in Green Peace Laboratory which he established at his home in Bedford Hills and maintained until his death, with the aid of one assistant.

The year 1893 also was marked by his election to the presidency of the American Institute of Mining Engineers, an honor and a task given only to men of distinction and accomplishment

in the mining and metallurgical fields. His presidential address, "Our possibilities," showed him to possess keen analytical powers in showing what we might expect in the future, for many of his predictions have been verified. Howe was one of those who believe in yeoman service to the cause he represents, and he was always ready to serve in the arduous work of directing the policies of the technical societies to which he belonged.

He had a gift for organization which was to stand him in good stead when the call came in 1917, of which more later. He had also a farsighted vision as to the possibilities of future usefulness to the community of societies that had not yet found themselves, as illustrated in the case of the American Society for Testing Materials, of which he accepted the presidency, or chairmanship, as it was then, in the early days of its formation in 1900. As stated by one of the founders, Mr. William R. Webster:

> On looking over the American Society for Testing Materials records you will find that we made very little progress during the first few years of our work, and that it was not until after Doctor Howe was elected president of the society that our work was systematized and real work accomplished.

It was during Doctor Howe's stay in Boston after establishing himself as a consulting metallurgist that he began what was later to become the true mission of his life. Already Howe had established his position as an acute observer and reasoner, imbued with the love of investigation and scientific research, expressing himself with a fine clearness, not only in his writings, but also in his lectures to his students and in technical papers presented at scientific meetings.

In 1891 there appeared The Metallurgy of Steel, the great book which constituted the principal foundation of Doctor Howe's fame. Up to this time steel making was only a practice, not a science. It was a series of operations resulting in the production of a material which was not always satisfactory in quality; nor were the defects understood, nor had the use of the microscope been known generally in the making of steel. Metallography was practically a new science. Therefore, since a quarter of a century had elapsed after the appearance of Percy's classical work on iron and steel, and meanwhile there had appeared merely handbooks, including the really admirable books of Bauerman and of Ledebur and the masterly discussion of Bell in connection with the metallurgy of iron, and especially with the blast-furnace process, it seems to have been a fitting time to offer in accessible form, and more fully than these distinguished authors had, the data which made up our then present knowledge of the metallurgy of steel, and, above all, to discuss these data and seek their true teachings. This book, embodying the results of a comprehensive study of the literature on the subject, marks a new era in the history of steel metallurgy. With astonishing clearness Doctor Howe collected and collated all known facts, either in English, French, or German, in such a comprehensive and full, but concise, manner that it no longer was necessary to consult previous literature on the subject for information relating to the metallurgy of steel, although the author, in seeking to lighten the labor of others who might wish to examine the matter in greater detail, or who might wish to verify his statements, has given many references which it would profit most readers but little to examine. In the words of Dr. Rossiter W. Raymond, this "was an amazing accumulation of reported facts tabulated, verified, and explained as far as was then practicable."

In 1902, beside many professional papers of importance, there appeared Dr. Howe's Metallurgical Laboratory Notes, translated into French, a book containing information on various laboratory practices in the field of metallurgy. Immediately following this, in 1903, came the book entitled, "Iron, Steel, and Other Alloys," translated into Russian. This was a contribution to metallurgical literature for the benefit of not alone the various classes of students, but also to meet the needs of practitioners by giving them a systematic account of the condition of the metallography of iron at that time. Other important works which should at least be mentioned briefly here are the article on "Iron and steel" in the new volumes of the tenth edition of the Encyclopædia Britannica, appearing in 1902, and a later article on the same subject for the eleventh edition of the same work. These are comprehensive but brief statements of the history of iron and steel up to the time of the publication of the treatises.

No attempt will be made here to give a summary of the monumental series of contributions to science and technology from Howe's pen. We may mention one or two items in which he maintained an active interest and to which he was constantly reverting in his writings; such as the nomenclature of steel and the soundness of steel. Howe's logical mind rebelled at a commercial classification of steel and he sought persistently to have adopted generally a rational classification, beginning with an early paper published in 1876 and ending with his last book in 1916. He was keenly disappointed that the International Association for Testing Materials would not adopt his views. To the question of the "soundness" of steel he returns again and again in his experimental work and writings, and this subject may be said to be the underlying theme of all his work. His numerous papers on metallography as related to iron and steel, of which science he was one of the creators and most able expounders, constitute a masterly series of monographs.

This brief mention of Howe's principal works brings us up to the publication, in 1916, of the results of his best creative genius, The Metallography of Steel and Cast Iron. While it was not possible, or practicable, in his first book, The Metallurgy of Steel, to more than make a start upon the interpretation of the facts contained therein, he was able, through his own experience and research, and the results of that of others, to include in his last book his personal observations and conclusions, the object being not to state already soundly established principles of a new science, but to open before the workers in that science new fields for thought. He believed the true task of a teacher is to excite thought, and this, I believe, he could not have better accomplished than he did in this masterly book.

This volume, consisting of two distinct parts, an introduction to the new science of microscopic metallography as applied to steel and cast iron and an extended study of the very new branch of that science, the mechanism of plastic deformation, was the first of a series of monographs the completion of which was undoubtedly interrupted by Doctor Howe, then at the age of 70, in order to serve during the World War as an active member and later chairman of the engineering division of the National Research Council, devoting his entire time and thought to the problems under way at such a crisis in the history of the country. For this purpose he spent the winter of 1917–18 in Washington, where his counsel in matters metallurgical was much sought after and valued.

Doctor Howe was made a member of the National Research Council February 26, 1918; made member of the division of engineering March 11, 1919, and chairman April 1, 1919. He was appointed scientific attaché in the American Embassy in Paris April 15, 1919, and delegate to Brussels meeting June 17, 1919. Resigning as chairman August 12, 1919, he was appointed honorary chairman of the division of engineering October 14, 1919, to serve for the year 1919 to 1920, and again appointed honorary chairman on April 25, 1920, for the year 1920 to 1921.

This chronology, however, gives no glimpse of the great work he was really doing in orienting and stimulating effective research looking to the improvement in metallurgical practice and products of military importance and in bringing together groups of men most skillfully chosen who could aid in carrying out much-needed investigations. Thus, under his direction, there was formed a general committee of the research council on metallurgical research with several offshoots, in the work of several of which he took an active part, including committees on pyrometry, alloy steels, body armor, steel ingots, improvement of metals in the "blue heat" range, and heat treatment of carbon steels, which last committee he consulted freely in the work of his own laboratory at Bedford Hills. For he also found time to engage in experimental work himself during 1917 and 1918, especially in relation to helmets, special steels for various purposes, the explanation of serious and puzzling imperfections such as "flaky" steel, and the improvement of open-hearth furnace practice on which technique the quality of our steel output depends. Among the objects of his visit to Europe in 1919 was to see what could be done in reviving and maintaining the international relationships among scientific men, and naturally he was concerned with the fate of the International Association for Testing Materials, of which he had been one of the bulwarks in this country; but he found the time not come, nor has it yet, when this important international body could be revived.

The period immediately following the war was a very fruitful one for Doctor Howe and is reflected in the several important contributions from his pen, usually in association with

others. The last three years of his life he was also working on a treatise relating to steel manufacture which he was not permitted to finish.

In 1918, he accepted the position of consulting metallurgist on the staff of the Bureau of Standards, which he held until his death, and he also had a similar relation with the Bureau of Mines. He wanted no remuneration, but merely facilities for productive work at his laboratory. The product of these connections is given in the last writing to bear his name, published after his death under the title, "Influence of temperature, time and rate of cooling on the physical properties of carbon steels."

It was not, however, merely in Howe's formal writings that he was listened to by all interested in the subjects of which he treated, but if one will examine the printed discussions of the many technical meetings he attended one will be surprised at the wealth of suggestive and clarifying material he would offer spontaneously. It was a delight to all present to hear him in a scientific meeting, clear, concise, witty with homely, trite, and often epigrammatic comment, always courteous, always thorough, and unerringly pointing out the weak spots, yet never forgetting to give commendation where merited and occasionally unstinted praise. No man could better summarize another's work than he.

He gave his advice very freely and completely in correspondence with his friends and professional colleagues, and some of the letters I have seen are in themselves models of composition and exposition, and each evidently formed the substance of a portion of some scientific paper in preparation. By thus communicating his ideas in advance of publication he was able to fortify himself and reap the benefits of preliminary friendly discussion. All his published work gives evidence of the greatest care in preparation; he considered all the alternatives possible; and in a subject such as metallography, singularly prone to awake controversy, he was generally able to put forth facts and conclusions that were not seriously questioned.

One of the most charming of his traits was his interest in and the encouragement of the younger men at scientific gatherings. He never failed to say the right word to stimulate further effort, and well I remember the profound impression he made on the occasion of my first paper before the mining engineers by his statement, "We can hardly overestimate the importance of the entry of the Bureau of Standards into our field." Many others have mentioned this trait, which is well described by Mr. A. A. Stevenson, himself a steel maker and a friend of 30 years or more standing:

> Much may be said about what Doctor Howe has done for the steel industry and what he has written, but so far as I am concerned, I feel the greatest legacy Doctor Howe has left is that of his influence on the younger men with whom he came in contact.

Another characteristic was his indomitable persistence and will to work together with an optimistic outlook and cheerfulness as illustrated by the last year and more of his life, when he writes to his sisters:

> As for me I am getting on after a fashion. I am so thankful to be spared most of the pain which usually goes with this ailment and continue to be of real service, and so busy with my readings, and writings, tho they are all done on the bed, that I have no time to be bored, and I think no inclination to grumble, especially when I think of those who voluntarily brought far greater hardship on themselves in the service of their country.
>
> I have just practically finished an important professional paper, "practically finished," because I am now engaged in revising the section and page numbers. I expect a collaborator here the last of next month to take up another important paper with me, and I am making substantial progress on a book.
>
> So it might be worse, incomparably worse, and we may still hope that it will be better.

Doctor Howe had a fine sense of patriotism intensified by his sense of the Nation's as well as the individual's duty, often expressed when occasion offered, and he even made the occasion, as when receiving the John Fritz medal on May 10, 1917, he stated:

> To prolong thanks is so thankless that I might well now hold my peace were it not for the world crisis, ever in our consciousness. This so presses for our best thought that attention to other matters suggests fiddling while Rome burns. For Rome truly is in flames. We are as a family in a burning home. Democracy itself is at stake.
>
> Our problem at the end of the war will be to prevent future wars, to prevent the actual employment of the enormously enhanced destructive powers sure to evolve, to force the nations to keep the peace as we have forced individuals. To say that we are inherently incapable of preventing our own annihilation; that because the less developed past did not learn to prevent its little wars, killing their tens of thousands, the more developed future must ever remain impotent to prevent its wars with their far higher order of havoc, killing their millions, is to betray a fatalism, a pessimism as unworthy of Americans as it is foreign to our nature. To me it seems an insult to the mothers who bore us, nay, to the God who made us.

Among the many honors conferred upon this greatly honored, yet modest man, a member of almost every technical society having to do with iron and steel both here and abroad, he received the degree of A.M. in 1872, and LL.D. in 1905, from Harvard; the degree of LL.D. also from Lafayette in 1905; and that of Sc.D. from the University of Pittsburgh in 1915. He was made a Knight of the Order of St. Stanislaus (Russian) and a Chevalier of the Legion of Honor of France. For his work he received five gold medals from leading technical societies of the world: The Bessemer medal of the Iron and Steel Institute of Great Britain, as mentioned elsewhere in this biographical sketch; the John Fritz medal of the American Institute of Mining Engineers; the Elliott Cresson medal of the Franklin Institute of Philadelphia; that of the Verein zur Befoerderung des Gewerbfleisses of Berlin; and the gold medal of the Société d'Encouragement pour l'Industrie Nationale of France. He was elected president for one term of the American Institute of Mining Engineers, and the International Association for Testing Materials, and for four terms of the American Society for Testing Materials, being among others an honorary member of the Russian Technical Society, Russian Metallurgical Society and the Société d'Encouragement, American Society for Testing Materials, American Society for Steel Treating.

As a teacher, Doctor Howe gave one of his greatest services to humanity. Not only was he the leader, he was also the comrade and friend. The student never felt restraint in asking advice of this kindly gentleman, who in turn was most generous to the deserving, often helping in a material way as well. In the laboratory, as well as in the classroom, he was most patient even in cases where his suggestions had been taken amiss. Owing to his delightful clearness of thought and expression, and simple, logical presentation, Professor Howe's courses were considered the easiest in school. He was endeared in the hearts of his students, and all who came in contact with him, by his wonderful smile and sympathetic manner, and those receiving his recognition considered themselves honored indeed.

The inspiration of Doctor Howe's leadership, it has been the desire to perpetuate, and two societies with which he was intimately associated have sought to commemorate his name. The American Institute of Mining and Metallurgical Engineers have established "the Henry Marion Howe lectureship," and very appropriately Prof. Albert Sauveur, a life long friend and himself with Howe one of the pioneers and outstanding authorities in the subject of metallography, is the first lecturer under this foundation.

There has also been established, in honor of Doctor Howe, the "Henry Marion Howe gold medal," by the American Society for Steel Treating, the first medal being awarded in October, 1923, to Dr. Emanuel J. Janitzky, a replica in bronze being given to Mrs. Howe, in recognition of her aid as a coworker of Doctor Howe, a most devoted friend and companion, accompanying him in all his travels. It is of interest here to note the rules governing the award of this newly established medal as follows:

The board of directors of the American Society for Steel Treating has established a fund to be known as the Henry Marion Howe medal fund, the proceeds of which shall be used annually to award a gold medal to be known as the Henry Marion Howe medal. The award will be made as follows:

(1) The medal will be awarded to the author of the paper which shall be judged to be of the highest merit. All papers in order to be considered must be published originally in the transactions of the society during the 12 months ending August 1 of the year in which the medal is awarded.

(2) The competition for the Henry Marion Howe medal shall be open to all.

(3) The award shall be made by the board of directors.

(4) The award may be withheld at the discretion of the board of directors.

When Howe was elected to the National Academy, in 1917, he had been recognized for years by his colleagues as the dean of American metallurgy. Howe's preeminent position is strikingly set forth at the presentation to him of the John Fritz medal in 1917 in the addresses of Dr. R. W. Raymond, Pres. I. N. Hollis, and Prof. A. Sauveur. We have already quoted the estimate of Sauveur and we are also indebted to much in Doctor Raymond's account of Howe's accomplishments. We may close by quoting from his student, associate, and successor at Columbia, Prof. William Campbell:

In short, we can say of him that he was a kindly gentleman, thoughtful of others; a great scientist, greatly honored and yet most modest; a remarkably clear writer with a gift of simplicity of thought and diction; and lastly he was undoubtedly the greatest of all the steel metallurgists.

THE RECORD OF HENRY MARION HOWE

I. BIOGRAPHIC DATA

Born March 2, 1848, at Boston, Mass.
Graduated from Boston Latin School, 1865.
Graduated as A. B. from Harvard College, 1869.
Graduated (degree corresponding to B. Sc.) from Massachusetts Institute of Technology, 1871.
Received degree of A. M. from Harvard College, 1872.
Student in steel works at Troy, N. Y., 1871–72.
Superintendent of Bessemer works of Joliet Iron & Steel Co., 1872.
Superintendent of Blair Iron & Steel Co.'s works, Pittsburgh, 1873–74.
Married Miss Fannie Gay, of Troy, N. Y., 1874.
Improvements in copper smelting in Chile for heirs of Augustus Hemenway, 1877–78.
Designed and built the works of the Orford Nickel & Copper Co., at Capelton and Eustis, in the Province of Quebec, Canada, and at Bergen Point, N. J., 1879–82.
Manager of Pima Copper Mining & Smelting Co., Arizona, 1882.
Consulting metallurgist, with office in Boston, and lecturer on metallurgy at the Massachusetts Institute of Technology, 1883–97.
Professor of metallurgy in Columbia University, New York, 1897–13, and professor emeritus from 1913.
Chairman, engineering division, National Research Council, 1919.
Consulting metallurgist, Bureau of Standards; Bureau of Mines.
Deceased, May 14, 1922 at Bedford Hills, N. Y.

II. DISTINCTIONS RECEIVED

HONORARY MEMBERSHIPS

Royal Swedish Academy of Sciences.
Russian Imperial Technical Society.
Russian Metallurgical Society.
Cleveland Institution of Engineers, England.
Société d'Encouragement pour l'Industrie Nationale of France.
Dallas Historical Society, Texas.
Alumni Association of the School of Mines of Columbia University.
American Iron and Steel Institute.
Institution of Mining and Metallurgy, England.
American Society for Steel Treating.
National Research Council, honorary chairman engineering division.
American Society for Testing Materials.

FELLOWSHIPS, ETC.

National Academy of Sciences (Member).
New York Academy of Sciences (Fellow).
Washington Academy of Sciences (Non resident Member).
American Academy of Arts and Sciences (Fellow).
American Philosophical Society (Non resident Member).
American Academy of Engineers (Charter Member).

PRESIDENCIES

American Society for Testing Materials (four terms, 1900–02, 1909–12).
American Institute of Mining Engineers, 1893.
International Association for Testing Materials, 1912.
Alumni Association, Massachusetts Institute of Technology (three terms).
Jury of Awards, Mining and Metallurgy, Chicago Exposition of 1893.

HONORARY VICE PRESIDENCY

Iron and Steel Institute of Great Britain.

LIFE MEMBERSHIP OF COUNCIL

International Association for Testing Materials.

ORDERS

Knight of the Order of St. Stanislaus, Russia (second order, with star of first order).
Chevalier of the Legion of Honor of France.

MEDALS

Bessemer medal, Iron and Steel Institute of Great Britain.
Eliot Cresson medal, Franklin Institute of Philadelphia.
Gold medal of the Verein zur Befoerderung des Gewerbfleisses, Berlin.
Gold medal of Société d'Encouragement pour l'Industrie Nationale of France (1916).
John Fritz medal, American Institute of Mining Engineers, 1917.

HONORARY DEGREES

LL. D., Harvard, 1905.
LL. D., Lafayette, 1905.
Sc. D., University of Pittsburgh, 1915.

III. PUBLICATIONS

In this incomplete list of writings of Henry M. Howe the following abbreviations are used:
A. I. M. E.—Transactions of the American Institute of Mining Engineers.
A. S. M. E.—Transactions of American Society of Mechanical Engineers.
A. S. T. M.—Proceedings of the American Society for Testing Materials.
I. A. T. M.—Proceedings of the International Association for Testing Materials.
J. I. S. I.—Journal of the Iron and Steel Institute.
E. & M. J.—Engineering and Mining Journal.

PRINCIPAL WORKS

The metallurgy of steel. Scientific Publishing Co., New York, 1891. Translated into French.
Metallurgical laboratory notes. 1902. Translated into French.
Iron, steel, and other alloys. 1903. Translated into Russian.
Metallography of steel and cast iron. 1916.
Article on iron and steel in the new volumes of the 10th edition of the Encyclopædia Britannica. 1902.
Article on iron and steel in the 11th edition of the Encyclopædia Britannica, vol. 14, p. 801, 1910.

PROFESSIONAL PAPERS

Improvement in processes and furnaces for reducing and smelting ores; one-half assigned to Mr. Howe by William E. C. Eustis. U. S. Patent No. 209554, November, 1878.
Blast-furnace economy. A. E. M. E., 3, 1874–75.
What is steel. E. & M. J., Aug. 28, Sept. 4, Sept. 11, Sept. 18, 1875.
Thoughts on the thermic curves of blast furnaces. A. I. M. E., 5, 1876–77.
The nomenclature of iron. A. I. M. E., 5, 1876–77.
A direct process of copper smelting. A. I. M. E., 7, 1878–79.
Two new processes for the extraction of nickel from its ores. A. I. M. E., 9, 1880–81.
On comparative efficiency of fans and positive blowers. A. I. M. E., 10, 1881–82.
Contributions to the metallurgy of nickel and copper. A. I. M. E., 10, 1881–82.
A suggested cure for blast-furnace chills. A. I. M. E., 11, 1882–83.
A systematic nomenclature for minerals. A. I. M. E., 12, 1883–84.
The patience of copper and silver as affected by annealing. A. I. M. E., 13, 1884–85.
Note on the contraction of iron under sudden cooling. A. I. M. E., 14, 1885–86.
Attainment of uniformity in the Bessemer process. A. I. M. E., 15, 1886–87.
Smelting cupreous pyrites. E. & M. J., March, 1879.
Bessemerizing sulphides. E. & M. J., May, 1879.
Bessemerizing matte in a reverberatory furnace. E. & M. J., March, 1883.
Bessemerizing copper matte. E. & M. J., April, 1883.
The Bessemerizing of copper matte. E. & M. J., May, 1883.
The Hunt and Douglas copper process. E. & M. J., December, 1885.
Rose Polytechnic Inst., annual scientific address, 1885.
Copper smelting. Bulletin 26, U. S. Geol. Survey, 1885.
The Clapp-Griffiths Bessemer plant. Science, 1885.
Bad rails. E. & M. J., May, 1886.
The attainment of uniformity in the Bessemer process. E. & M. J., June, 1886.
The effect of slag on the fibrousness of Avesta steel. E. & M. J., September, 1886.
The Elizabeth copper mine, Vermont. E. & M. J., November, 1886.
The manufacture and cost of coke. E. & M. J., November, 1886.
The quality of steel for guns. E. & M. J., January, 1887.
Modern manufacture of steel. E. & M. J., 1887.
Two conditions of phosphorus in iron. A. I. M. E., 16, 1887.

Momentary depression of the elastic limit at two critical temperatures. Tech. Quarterly, December, 1888.
Heat treatment of steel. Cornell University lecture. Scientific Amer., 1888–189.
Special report to the U. S. commissioner on mining and metallurgy at the Paris Exposition, 89.
An electric-resistance magnesia crucible furnace for laboratory use. A. I. M. E., 31, 1901.
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