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OF

JOHN TROWBRIDGE

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BY

EDWIN H. HALL

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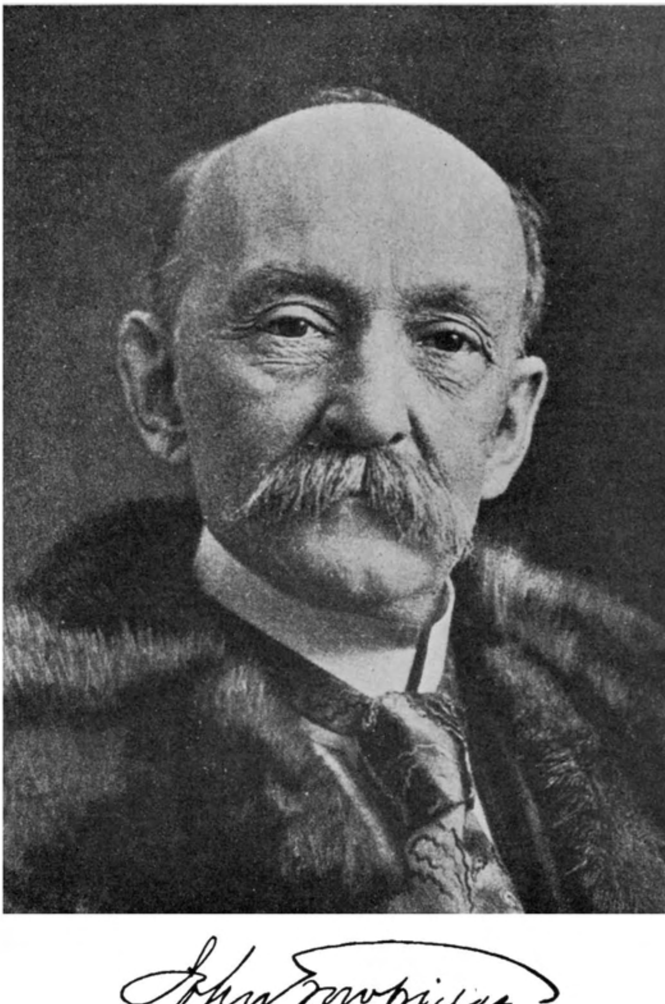

JOHN TROWBRIDGE

—— —, 1843—February 18, 1923

BY EDWIN H. HALL

Our colleague John Trowbridge was the sixth in succession of his family to bear the name John. Such persistence in the use of a given first name indicates family consciousness, if not family pride, and is perhaps the closest approach in this country to the inheritance of a title. It is true that the first Trowbridge to come from England to America was named Thomas, but his father, "a wealthy merchant and prominent citizen of Taunton, Somersetshire," was called John.

It appears that Thomas Trowbridge (1) and his wife, with two sons, came to Dorchester in Massachusetts about 1636. They are mentioned, it is said, in the records of the town and of the church as "Mr. and Mrs.," "a distinction confined at that time to persons of established gentility." Thomas Trowbridge removed to the plantation of New Haven, Connecticut, probably about 1638. He went back to England after a few years, and it appears that he never returned to America, though he left three sons permanently in this country, with enough property to be the cause of a good deal of trouble between the family and the steward in charge of the estate. Two of the sons, Thomas and William, remained in New Haven and established the family name in Connecticut, but a third, James (2), returned to Massachusetts and lived in Newton, or New Town, which is now Cambridge. He was a soldier in King Philip's War, being a lieutenant of the Cambridge village company of foot soldiers, and he was also a deacon of the church, evidently a man of note in his community.

A son of this James, Thomas (3), removed to Connecticut but left in Massachusetts two sons, Edmund and John. The former remained in Cambridge, and Trowbridge Street in that city is named for him. He was a noted lawyer and judge, a Tory during the Revolutionary War. The brother John (4) settled in Framingham, where he was "house-wright," farmer and selectman. His son John (5) also lived in Framingham, was farmer, tavern-keeper, selectman, a soldier in the French and Indian War, a lieutenant-colonel in the Revolutionary War. This John had a son John (6) who marched to Concord as a Minute-man, took part in the battle of Bunker Hill, was commissioned first lieutenant in 1779, and was town treasurer of Framingham for twenty-five years. His son John (7), born in Framingham in 1778, removed to Cambridge, engaged in trade and largely increased the property he had inherited from his father. The son of this John was given a middle name by way of innovation, being called John Howe (8). He entered Harvard College but did not complete the course. He graduated from the Harvard Medical School in 1835 but, having inherited a fortune, did not feel the need of practicing his profession. He was the father of our colleague, John (9), who was born in Boston in 1843.

This is an excellent New England family record and it accords well with the impression which Trowbridge made on everyone as of a man born to good conditions. The financial ease of his father did not, however, endure, and Trowbridge has told me that, while still a youth, he had to begin earning money. He had artistic talent and painted pictures which found purchasers. Possibly he began at this time the habit of literary composition which he continued for many years. The esthetic element was very evident in him; in addition to painting and semi-imaginative writing, he had music, the piano, as an accomplishment. It seems quite possible that, if he had been under no financial compulsion, he would have occupied himself permanently with art, in a leisurely way, rather than with science. It is my surmise that his career may have been determined to some extent by that of his contemporary and friend Edward C. Pickering, whose natural bent for science was unmistakable. The two graduated from the Lawrence Scientific School of Harvard University in the same year, 1865, with the degree of S. B. Each taught mathematics for two or three years at Harvard; each was afterward for a time in the physics department of the Massachusetts Institute of Technology; each returned finally to the service of Harvard, Trowbridge as assistant professor of physics in 1870, Pickering as professor of astronomy in 1876; for about forty years they were near neighbors in Cambridge. Pickering was, I think, the first American to write a laboratory manual of physics. Trowbridge was one of the first, if not the very first, of Americans to put students into the way of original research in physics.

It was his function to bring Harvard over from its old habit of set lectures, demonstrations, and strict textbook instruction, to the new habit of laboratory practice, research, and constructive thought. I well remember my first meeting with him, in 1877, when I was on my way to become a student under Rowland at Johns Hopkins. The routine physics instruction of that time was given in Harvard Hall, one of the older buildings in the "Yard," and the main body of the physics apparatus was housed there, as it continued to be for several years more; but Trowbridge had, for purposes of laboratory instruction and research, got possession of certain rooms in Lawrence Hall, domicile of the Lawrence Scientific School, then almost defunct. He had fitted up the main room on the first floor with large work tables, and it was there that I first saw him. My recollection of that first meeting presents him, a slim, graceful figure with thoughtful face and finely modelled head, standing beside one of these tables, on which was a certain electrical measuring instrument, such as none of his elders or predecessors at Harvard would ever have had use for, or perhaps understood.

I remember nothing else in the room and I think there was little else to be seen there. I was looking at the very nucleus, one man and one instrument, of the great laboratory of physics research which exists today at Harvard and of which all Harvard men should be proud. Trowbridge, more than any other man, was the creator of this laboratory. His own personal achievements in research were not so extensive as those of some other men, his juniors and mine, to whom he gave the opportunities they still enjoy; but he had the spirit of progress, he had a vision and constructive ability, he recognized and gave scope to the capabilities of other men.

For example, many years ago he planned, and employed the laboratory janitors to construct, a storage battery of twenty thousand small cells, housed in a great loft which had found no other use. For years not very much came of this installation, but after a time the course of research took such a turn that men had to wait for their opportunity to use it in rotation. The story of the "constant temperature room," at the base of the tower in the west wing, is somewhat the same. I don't know that Trowbridge ever did anything in this room, but he planned it and had it constructed. I used it for a year or so in experiments, on falling bodies, which attracted some attention, and Sabine made it famous by carrying on there some of his fundamental researches in architectural acoustics.

The earliest scientific publication by Trowbridge that has come to my attention is an account of a cosine galvanometer, devised by himself, in the *American Journal of Science* for 1871. He was an associate editor of this *Journal* for many years and made numerous contributions to its pages, including short notices of work done by others.

Another much used medium of publication for work done by himself or his students was the *Proceedings of the American Academy of Arts and Sciences* in Boston. His earliest paper in these *Proceedings,* presented, apparently, on January 9, 1872, dealt with the sources of error in attempts to show "the existence of electric currents in nerve and muscle." This paper, about 3 pages long, described experiments by the author and referred to the works of DuBois-Reymond and Matteucci. In volume 10 (1874-75) of the *A. A. Proceedings* he had a paper of about 4 pages "On a New Induction Coil." It describes experiments on the advantage to be gained by providing the ordinary straight core of the coil with an armature. "The iron core, with the armature, would then be in the form of a hollow square, one side of which is made up of a bundle of fine iron wires and the remaining three sides constitute the armature." The same volume gives evidence that Trowbridge's zeal for research was exerting a stimulating influence on his pupils at Harvard, for it contains research papers by two undergraduates, members of the class of 1876, B. O. Peirce and Lefavour.

Volume 11 (1875-'76) contains a paper in continuation of work on armatures for electro-magnets and another, of 3 pages, "On the So-Called Etheric Force," in discussion of a phenomenon, discovered in Edison's laboratory, which attracted considerable transient attention. This volume has also a paper, written by B. O. Peirce, describing work done under Trowbridge's influence. It is "On the Induction Spark Produced in Breaking a Galvanic Circuit Between Poles of a Magnet." This is a remarkable production for its time and place, and I have commented upon it at length in my Biographical Memoir of Peirce.

In volume 12 we find, by Trowbridge, a paper of 6 pages "On Vortex Rings in Liquids." It describes the rings formed by dropping liquids into liquids and makes a considerable display of mathematics.

These details, even if none of the papers mentioned proved to be of any great permanent importance, seem to me well worth recording, for they show conclusively the existence of a research atmosphere and the initiation of a research habit in the department of physics at Harvard a year or two before Johns Hopkins had opened its door for students.

In Volume 14 (1878-'79) is a paper, 8 pages long, appropriate to the time when dynamo-electric machinery was in process of rapid evolution, "On the Heat Produced by the Rapid Magnetization and Demagnetization of Magnetic Metals." Co-author with Trowbridge was Walter N. Hill of the U. S. Torpedo Station at Newport, R. I., and the research was probably carried on at Newport because of the dynamo equipment of the torpedo station. Iron, cobalt and nickel were studied, the "fine specimens" of the latter metals having been furnished by Mr. Joseph Wharton of Philadelphia. The work described was quantitative and careful. Currents, whether direct or alternating, were measured by means of an electro-dynamometer, constructed in general accord with the design of the apparatus described in Maxwell's "Electricity and Magnetism," Art. 725, but with some features which were, I think, due to Trowbridge.

Thus, the current did not traverse the wires or threads by which the inner coil was suspended, but entered and left the movable part of the instrument by means of mercury contacts which were cooled by running water. By means of this arrangement the apparatus was adapted to the measurement of fairly strong currents, which at that time were recorded in "webers per second," substantially the equivalent of present day amperes. Trowbridge had considerable facility in the design of apparatus, being endowed with that sense of spatial relations which goes with ability in free-hand drawing. Some years later, in volume 18 (1882-'83) appeared another paper by the same authors on the same general subject, the experiments now being limited to iron and steel. The conclusion drawn is "that heat developed by reversals of magnetization is probably due to induced currents, and not to molecular vibrations." The authors were doubtless correct as to the main portion of the heating they observed, but they overlooked or failed to make sure of the genuine hysteresis-loss of energy.

Going back to volume 14 we find another paper by Trowbridge, "Methods of Measuring Electric Currents of Great Strength; Together With a Comparison of the Wilde, the Gramme, and the Siemens Machine." It is in this paper that the electro-dynamometer, commented upon above, is described in detail with drawings. The dynamos, "dynamo-electric engines," tested were those of the Torpedo Station at Newport. Harvard, of course, had no dynamos, except those of a crude lecture-room type, at this time.

In Volume 15 (1880) we have "Simple Apparatus for Illustrating Periodic Motion," a short paper, with figures, and another on "Illustration of the Conservation of Energy." The latter paper discusses briefly, from the point of view indicated by its title, experiments, already referred to (volume 14), on heat generated by magnetization and demagnetization. It is interesting to note that in the original paper describing these experiments the term "conservation of force" is used. This was about 1878.

In volume 16 (1880-'81) we have from Trowbridge "The Earth as a Conductor of Electricity." This paper describes interesting experiments on the detection, by means of a telephone with grounded terminals, of time-signals sent out from the Harvard Astronomical Observatory. The conclusions are:

"1. Disturbances in telephone circuits usually attributed to effects of induction are, in general, due to contiguous grounds of battery circuits. A return wire is the only way to obviate these disturbances."

"2. The well-defined equipotential surfaces in the neighborhood of battery grounds show the theoretical possibility of telegraphy across bodies of water without the employment of a cable, and lead us to greatly extend the practical limit set by Steinheil."

"3. Earth currents have an intermittent character, with periods of maxima and minima, which may occur several times a minute during the entire day."

This was some years before the advent of electric street railways.

Volume 17 (1881-'82) contains no papers by Trowbridge but two serious ones by Charles Bingham Penrose of Philadelphia, who was working as a Harvard student in consultation with Trowbridge. The titles are: "Thermo-Electricity,—Peltier and Thomson Effects," "Thermo-Electric Line of Copper and Nickel Below 0°." Penrose, after taking the degree of Ph. D. at Harvard, quit the field of pure science and followed his distinguished father in taking up the study of medicine, which he was reported to find "easy" in comparison with research in physics. At any rate, he soon rose to eminence in his hereditary profession, though he never attained the popular fame of his brother, the Senator from Pennsylvania.

Volume 18 (1882-'83) contained a paper, already mentioned, on heat of magnetization and demagnetization. Volume 19 (1883-'84) had no paper from Trowbridge, who at this time was occupied with money-raising and plans for the Jefferson Physical Laboratory. Moreover, he was writing a book, intended for use in schools, "The New Physics," which appeared in 1884.

In Volume 20 (1884-'85), with Austin L. McRae, afterward Director of the School of Mines at Rolla, Mo., Trowbridge wrote on "The Effect of Temperature on the Magnetic Permeability of Iron and Cobalt," the paper being dated from the new laboratory. Another paper in the same volume was on "A Standard of Light," describing experiments on a strip of incandescent platinum as a standard light-source.

In the year 1886-'87 Professor C. C. Hutchins, on leave of absence from Bowdoin College, worked with Trowbridge, and the results of this partnership appear in two papers published in 1887-'88. This was one of the best working combinations that Trowbridge ever formed. Trowbridge had vision and enterprise; Hutchins contributed the skill of a master craftsman together with a habit of uncompromising thought and forthright speech. The title of the first paper is "Oxygen in the Sun." It examines by means of new experiments the evidence offered by Doctor Henry Draper and by Professor John C. Draper, respectively, tending to prove the presence of oxygen in the sun. One of these two distinguished authorities thought he had found coincidence between lines of the oxygen spark spectrum and certain bright lines in the solar spectrum. The other thought he had found coincidence with dark lines of the solar spectrum. Trowbridge and Hutchins reach a positive conclusion that neither of these investigators was right, though they are careful to state that they do not claim to prove the non-existence of any oxygen lines in the solar spectrum. Their finding relative to the work of the Drapers has been definitely accepted. It is, I believe, only within the last fifteen years that the presence of oxygen in the sun has been demonstrated.

The other paper is "On the Existence of Carbon in the Sun." The authors thought that they had found conclusive evidence of this existence; but I believe that, although carbon is now known to be present in the sun, it is doubtful whether at the date of their paper the theory of spectra was sufficiently developed to enable them to establish their conclusion.

In the same volume appears the first paper in which Trowbridge and Sabine collaborated, "Wave-Lengths of Metallic

Spectra in the Ultra Violet." Lines of metallic spectra produced in the laboratory by different methods, the arc method and the spark method, respectively, did not agree exactly in place with each other. The arc lines apparently coincided with the corresponding lines in the solar spectrum, but "when the electric spark with a large battery of Leyden jars was substituted for the electric arc, and the metallic lines obtained by the light of the spark were compared with those from the arc, occasionally a small displacement could be observed." After some speculation and experimentation we have the following: "It was difficult to believe that the displacement could arise from the noise of the spark. We believe, however, that it can be ascribed to this cause, and that the wave-lengths of metallic lines produced by burning metals in the electric arc or by vaporization in the electric spark are to one hundredth of a wave-length the same as those of the corresponding lines in the sun."

This statement is somewhat halting, but I believe that the main conclusion is in accord with present-day observation, which indicates that the difference in question may exist but must be very small.

This same volume 23 has another paper by Trowbridge and Sabine, "Selective Absorption of Metals for Ultra-Violet Light." One passage, perhaps the most significant, runs thus: "Here was a complete experimental proof that color [of the metal surface] in no way influences the selective absorption of metals for the ultra violet rays; for the copper mirror, which gave a strong yellow light by reflection, was as (sic.) capable of reflecting light of as short wave-length as the brilliant white surface of polished silver."

In volume 24 (1888-'89) Trowbridge collaborates with Samuel Sheldon, afterward President of the American Institute of Electrical Engineers, in two papers. The first is on "Neutralization of Induction," with especial reference to the protection of telephone circuits from disturbances due to neighboring electric railway systems, which were now rapidly coming into existence. "The best remedy for these disturbances is doubtless the adoption by either the power companies or the telephone companies of entire metallic circuits in which the earth plays no part. If this is not possible, a system of neutralization for the inductive disturbances might be adopted as follows:" etc.

The second paper was on "The Magnetism of Nickel and Tungsten Alloys."

Volume 25 (1889-'90) has a paper by Trowbridge and Sabine, "Electrical Oscillations in Air." It describes experiments on the oscillations of spark in the discharge of an air condenser. The "conclusions" begin thus:

"1. The electrical oscillations in the air between the plates of an air condenser shows a periodicity [the nature of this periodicity is not well described in the paper] extending through the entire range of the oscillations. We believe this periodicity is the analogue of the phenomenon of Hysteresis in Magnetism," etc.

This conclusion has not been sustained by subsequent observations, but it would be unfair to dismiss the paper with this remark. The research which it describes was one of great experimental difficulty and to compare the actual time of oscillation with the theoretical, in such a way as to attain a close approach to accuracy, was no small achievement. A revolving mirror was used to throw the light of the spark upon the photographic plate, and such was the speed of this mirror, and its distance from the plate, that the whirling spot of light was moving about a mile a second when it fell upon the recording surface. It is easy to believe the quiet statement of the paper that adjustment, timing, of the spark so as to make the revolving light-beam hit the distant target was a difficult operation. More than one revolving mirror burst under the centrifugal strain and, to protect life and limb of the observers, the axis of revolution was made horizontal, so that the movement of the mirror fragments, in case of explosion, would be confined to a vertical plane.

In the same volume is a paper, by Trowbridge alone, on "Motion of Atoms in Electrical Discharges." "The conclusion seems to be a strong one, that the electrical oscillations do not carry the atoms of metals with them in spark discharges."

In volume 26 (1890-'91) Trowbridge describes experiments on "Dampening of Electrical Oscillations on Iron Wires." Sabine's name does not appear at the head of this paper, but we find on page 23 this passage: "I wish to express my deep obligations to my assistant, Mr. W. C. Sabine, for his valuable suggestions and for his skill in the mechanical details of this investigation." I believe that Trowbridge intended and wished to have Sabine named as co-author of the paper; but Sabine for some reason was unwilling to approve this arrangement and he never, so far as I know, collaborated with anyone in publication after this.

For several years in the last decade of the nineteenth century Trowbridge published little or nothing in the American Academy *"Proceedings,"* but he was not inactive. Undertakings of a somewhat literary character must have engaged much of his attention at this time, for, as the appended bibliography will show, he produced a number of books, of a popular character, in rapid succession. He had undubitable equipment for productions of this sort, inventive imagination, an easy-going pen and a facile pencil. None of these books created any great excitement, but their very number shows that they must, as a whole, have had a considerable public. But literary production can hardly have been his chief occupation during this prolific period, for, with various collaborators he now published numerous papers in the *American Journal of Science.*

In fact, though frequently research papers published by Trowbridge in this *Journal* had been reprints or abstracts of articles appearing first in the Academy *"Proceedings,"* there were, as the bibliography will show, some, from 1871 on, that went directly to the *Journal.*

There was in the early 90's considerable doubt and discussion as to whether the magnetic property of iron is effective with rapid alternations of electric current along the metal. Hertz and also Lodge, on experimental evidence of a not very precise character, had given a negative answer to this question, and I believe that Stefan had supported this conclusion on theoretical grounds. As we have already seen, Trowbridge had in 1891 published in the Academy *"Proceedings"* a paper on the "Dampening of Electrical Oscillations on Iron Wires," and in 1894 he printed in the *American Journal* an account of his experiments on "Change of Period of Electrical Waves on Iron Wires." The alternations here studied were of such frequency as may occur in the discharge of a Leyden jar. About the same time, and apparently at Trowbridge's suggestion, Charles E. St. John was working in the Jefferson Laboratory on the same general subject by a different method. The results of the two studies were published in the same number of the *Journal,* and Trowbridge remarks, with characteristic courtesy, "My results confirm those of Mr. Charles E. St. John, who has shown by an entirely different method that the wave-lengths sent out by a Hertzian vibrator on iron wires differ in length from those transmitted on copper wires of the same geometrical form as the iron wires."

Soon after this Trowbridge and Duane, using, with some modifications, the apparatus of Hertz, measured the velocity of electric waves along wires. Their results were published in vols. 49 and 50 (1895) of the *Journal.* In the second paper the "average value of velocity" thus found is given as 3.0024×10^{10} cm. per second, the "generally accepted value for velocity of light" being at that time 2.998×10^{10} cm. per second.

Volume 3 (1897) of the *Journal,* 4th Series, contains a number of papers by Trowbridge in collaboration with T. W. Richards. The first is on "The Spectra of Argon," a study for which Lord Rayleigh furnished the material, "a portion of the purest preparation which had been used in his final determination of the density of the gas." The conditions under which the "red glow" and the "blue glow," respectively, occurred were carefully examined, by use of the Trowbridge storage battery consisting at this time of 5,000 cells. The second paper dealt with the multiple spectra of certain other gases, helium, hydrogen, nitrogen, and the vapor of iodine, the storage battery used having now 10,000 cells. The third paper is on "The Temperature and Ohmic Resistance of Gases during the Oscillatory Electric Discharge." This was before the recognition of atomic disintegration and the consequent existence of free electrons. The authors found that "a mass of gas at low tension contained in a capillary tube may act as though it opposed a resistance of only five or six ohms to the spark of a large condenser," but their speculations as to the causes of the phenomena observed did not, I think, go beyond the suggestion of disintegration of the gas molecules into free atoms. The last of the papers in which Trowbridge and Richards collaborated gave the results of experiments on the resistance of electrolytes to oscillatory electric discharges. They found that electrolytes, in contrast with gases, do not show any great change of conductivity with great change in the intensity of current.

In 1897 Trowbridge began to publish again in the American Academy *"Proceedings"* and for some ten or twelve years thereafter papers of research or speculation appeared under his name in both these *"Proceedings"* and the *American Journal of Science*.

Volume 32 (1896-'97) of the *"Proceedings"* contains "The Energy Conditions Necessary to Produce the Röntgen Rays." This gives a somewhat detailed account of the great storage battery, consisting now of 10,000 small cells, which had been used in many of the researches already mentioned and was an unique feature of the Jefferson Physical Laboratory equipment. This resource was due entirely to Trowbridge's initiative, foresight, and capacity for seeing the possibilities in other men; for it was constructed by employees of the laboratory, no one of whom, except a carpenter, was initially a skilled workman. This battery was used for producing the Röntgen rays, by means of the discharge of condensers.

A year later we find "An Inquiry into the Nature of Electrical Discharges in Air and Gases." This paper describes further experiments with the storage battery. The "conclusions" begin thus: "Beyond one million volts the initial resistance of atmospheric air to electrical discharges becomes less and less, and in certain conditions can be as low as one thousand ohms between terminals two or three inches apart." Of course, this still was before everybody knew about ionization of the gases in electrical discharge. Trowbridge was here occupied with an important subject, even if he did not completely penetrate its mysteries. Here, as in reviewing other undertakings of his, I am reminded of a remark I once heard from Rowland concerning some venture of his own: "If we succeed, we shall have made a great discovery. If we fail, we shall have tried to make a great discovery."

In volume 38 (1902-'03) of the *"Proceedings"* we have a paper of about eight pages on the "Spectra of Gases and Metals at High Temperatures," which contains but little of a conclusive character. The next two volumes contain no papers by Trowbridge, but the latter, volume 40, gives a paper "Resonance in Wireless Telegraphy," by G. W. Pierce, which may well be mentioned here, as Pierce began his research work at Harvard under Trowbridge's immediate direction.

"Slow Moving Electrical Luminous Effects" is the title of a paper in volume 41. This refers to work of Righi on the same subject, made by means of condenser discharges, whereas Trowbridge uses his storage battery directly, "without the interposition of a spark gap," to send discharges through tubes of rarefied gases. Mention is made of the "ionization theory of Townshend" as giving the best explanation of the effects observed, which Trowbridge thought might be related to the phenomenon of "ball lightning."

In 1907-'08 he was occupied with a "Longitudinal Magnetic Field and the Cathode Rays" and with "Positive Rays." In the first case he thought that the use of a magnetic field "has the advantage of producing the X-rays from a sharper focus and should, therefore, give better definition." In the latter his hope was "to measure the group velocity of the positive rays by producing a standing wave, or a stratum of maximum collisions in the space between the anode and the cathode."

In volume 45 (1909-'10) of the *"Proceedings"* we have "Discharges of Electricity Through Hydrogen." The first "conclusion" runs thus: "The striæ in Geissler tubes are analogous to waves set up in narrow channels by opposing pulsations of different periods."

I think that this was the last research paper published by Trowbridge, though in later years he made occasional informal communications at meetings of the American Academy of Arts and Sciences, of which he was President from 1909 to 1916.

For many years the *Philosophical Magazine* reprinted most of the research papers published in America by Trowbridge and his collaborators, copies in manuscript or in advance proof having been furnished in order to achieve approximate simultaneity of appearance in the different publications. I have discovered only two or three papers of Trowbridge in the *Philosophical Magazine* which are not duplications of those published in America.

In the early days of commercial development of the telephone Trowbridge was professionally consulted, and then or later he took out a number of patents relating to a telephone operation. He also, about 1895, was interested in a certain form of storage battery and secured or applied for a patent on a process for renovating such batteries. I am not aware that any of his patents proved to be commercially valuable.

It is a curious fact that Trowbridge, though he had so important a part in the construction and operation of the Jefferson Physical Laboratory, and though he was the chief instigator of its research activities, was not its first Director. Professor Joseph Lovering, a strongly marked personality of the old-fashioned professorial type, had this title from 1884 till his retirement, in 1888. This arrangement was a somewhat anomalous one, for I doubt whether Lovering, excellent lecturer and careful man of business as he was, ever performed a research experiment in the whole of his long life, including fifty years' occupancy of a full professorship at Harvard. When Trowbridge did become the Director, in 1888, the effect, so far as provision for research was concerned, was speedily apparent.

Trowbridge's habitual manner, outside the circle of his few real intimates, was quiet, gentle, and perhaps slightly depressed. He was courteous, generous, and possibly a little too yielding, but when he became aware of intentional opposition his sensitive nature was likely to feel aggrieved and then he could be tenacious. Moreover, he had a sense of humor which, though ordinarily concealed, could not safely be ignored. Things which he had seen or heard with an air of sadness he would afterward relate with tears of hilarity flooding his eyes.

He married, in 1875, Mrs. Mary Louise Gray (née Thayer), who died in 1907. There were no children of this marriage, but a step-daughter, Miss Alice Gray, afterward Mrs. Edmund M. Parker of Cambridge, was like an own daughter to him, both before and after the death of her mother. After his retirement from the Rumford Professorship he lived through several pensive and perhaps melancholy years, occupying himself with his rose garden and with that unfailing subject of human interest, the life work of Benjamin Franklin, especially with its scientific aspects. Fortunately he had, in his later years, ample financial means. He died February 18, 1923.

Two attempts have been made to put into one brief statement a summary of Trowbridge's character and life-work. One of these, written as the dedication for a volume of scientific research papers issued by the Jefferson Physical Laboratory about the time of his retirement, in 1910, has appeared more than once in print. The other, inscribed on a memorial tablet in the main lecture-room of the Laboratory, is this:

JOHN TROWBRIDGE
1843-1923
GENIAL AND GIFTED GENTLEMAN
LOVER OF SCIENCE AND ART
ONE OF THE FIRST TO INDUCT
AMERICAN COLLEGE YOUTHS
INTO THE DEVOTED FRUITFUL AND
BENEFICIENT LIFE OF EXPERIMENTAL
RESEARCH—LEADING SPIRIT IN THE
WORK OF FOUNDING EQUIPPING
AND DIRECTING THIS
PHYSICAL LABORATORY

PAPERS

Published in the "Memoirs" of the American Academy of Arts and Sciences

High Electromotive Force. *13* (1907), pp. 181-215.

Published in the "Proceedings" of the American Academy of Arts and Sciences

Remarks on Animal Electricity. *8* (1872), pp. 344-347.

On a New Induction Coil. *10* (1875), pp. 381-384.

On the Effect of Thin Plates of Iron used as Armatures to Electro-Magnets; On the So-Called Etheric Force; On a New Form of Mirror Galvanometer. *11* (1876), pp. 202-209.

On Vortex Rings in Liquids. *12* (1877), pp. 131-136.

On the Heat Produced by the Rapid Magnetization and Demagnetization of the Magnetic Metals (with W. N. Hill). *14* (1878), pp. 114-121.

Methods of Measuring Electric Currents of Great Strength, together with a Comparison of the Wilde, the Gramme, and the Siemen's Machines. *14* (1878), pp. 122-132.

Simple Apparatus for Illustrating Periodic Motion. *15* (1880), pp. 232-234.

Illustration of the Conservation of Energy. *15* (1880), p. 235.

The Earth as a Conductor of Electricity. *16* (1880-81), pp. 58-62.

On the Heat Produced in Iron and Steel by Reversals of Magnetization (with W. N. Hill). *18* (1883), pp. 197-204.

On the Heat Produced in Iron and Steel by Reversals of Magnetization (with C. B. Penrose). *18* (1883), pp. 205-209.

Influence of Magnetism upon Thermal Conductivity (with C. B. Penrose). *18* (1883), pp. 210-213.

Papers on Thermo-Electricity; No. 1 (with C. B. Penrose). *18* (1883), pp. 214-220.

The Electromotive Force of Alloys (with E. K. Stevens). *18* (1883), pp. 221-225.

The Effect of Temperature on the magnetic permeability of Iron and Cobalt (with A. L. McRae). *20* (1885), pp. 462-472.

A Standard of Light. *20* (1885), pp. 494-499.

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