CHAPTER 5

The Life of Harry Brearley (1871–1948)*

"The reader will observe that my early work on high chromium steels was not inspired by any intention or hope on my part of discovering a stainless steel."
Harry Brearley, Torquay, 1929

BREARLEY'S AUTOBIOGRAPHICAL NOTES were written in 1929, when he was 58 years old and convalescing from an illness at Torquay, a seaside resort in Devon. The papers were bound and sent to his only son, Leo. In 1988, at the time of the 75th anniversary of Brearley's discovery of stainless steel, British Steel Stainless planned a commemoration and began collecting memorabilia concerning Brearley and his work. Brearley's notes were found in Australia in the possession of his grandson, Basil. The notes were published as *Harry Brearley—Stainless Pioneer* by British Steel Stainless and the Kelham Island Industrial Museum in time for the 75th anniversary celebration.

Readers will discover how Brearley's early life and experience led him to become a self-trained chemist and metallurgist. Outokumpu Sheffield (a successor company to British Steel Stainless) has kindly granted permission to quote portions of Brearley's autobiography.

The Early Years

"I was born on February 18, 1871, in a backyard off Spital Street, Sheffield, in what was called a 'House, Chamber and Garret' dwelling.

*Permission granted by Louise Fairweather, Outokumpu-Sheffield (successor company to British Steel Stainless), to use excerpts from *Harry Brearley—Stainless Pioneer*, published by British Steel Stainless, 1988

The house would be less than twelve foot square. How we lived I do not know, and I do not know how my mother managed to keep us reasonably clean.

"I am the eighth child of John and Jane Brearley's nine children and the youngest of five sons. My elder sister had gone into domestic service before I began to take notice. My earliest recollection was of my crying myself awake. After comforting me my mother took me to take back some washing. My mother did other people's washing to help keep the home going, wonderful woman.

"I should be about five years of age when we moved from the back-yard in Spital Street into a front house in Marcus Street. Instead of playing in a crowded court we had the run of a quiet street and plenty of spare land running steeply down to the railroad sidings. This was for some years a wonderful playground, ample, varied and stocked with raw materials for every game we knew or could invent."

Harry's Schooling. "I began to go to school about this time, going with my brothers, but all I can remember of these earliest school days is that we marched towards the school exit at noon singing 'Home to dinner, Home to dinner, There's the bell, There's the bell, Mash a tater in a can, Ding dong bell, Ding dong bell.'"

At a very early age, Harry expressed a keen interest in the working of metals. "I learned many things in those early days as I made my roundabout way home. I spent hours watching pocket blades forged, files ground, lead toys cast and metal buffed and burnished to shining brightness.

"I have no idea of how I learned to read. My father and mother and brothers were readers of novelettes and blood and thunder stories. But there were no books at home, absolutely none. Although I had less than average schooling as a child I never clamored for more. As a child I was delicate. I remember hearing my schoolmistress telling my mother I was delicate. I didn't know what it meant but I realized that it was some disadvantage which might prevent regular attendance at school."

Harry describes the work of his father and grandfather in the metal trades and ironmaking. "My grandfather was a country blacksmith and my father was a steel melter. I suppose I had heard my father and mother talk about smithy work and hardening steel by cooling it off in water.

"Home lessons for the next day's school had no terrors for me. I did no home lessons. I was caned occasionally but that was no penalty for the freedom of the streets which I enjoyed. Neither my father nor my

mother ever mentioned home lessons; it would have been an impractical proposal. There really was no room indoors for the family, to say nothing of a vacant table. There was not even a chair apiece. As a child I never thought of sitting on a chair. We youngsters stood round the table at meal times and disappeared out of doors as soon as meals were over, wet or fine, summer or winter.

"Since I 'got on' I find myself constrained to do many things which are not worthwhile, and one of them is to sit in a stiff chair when I would rather squat on the floor.

"My mother had six months of schooling as a girl but she could read and write. Whatever driving force there is in me came from my mother. My father was a dreamer, strong, industrious and able at his job or at anything to which he turned his hand, but entirely lacking in ambition and the considered use of his talent for the support of a large family. We were always poor even when my father had regular work. We never starved in the sense that we wanted bread, but it ran to bread and butter on Sundays only."

Harry's First Jobs. "It was a great time when I was able to add a copper or two to my mother's purse. I began regularly to do so by bundling sticks. A few boys and girls in Marcus Street were allowed to bundle sticks after school hours. We were paid a penny per dozen bundles but we often had to chop our own sticks. The owner of the stick shop was a timber yard labourer who made and sold bundled sticks as an extra.

"Before I was eleven years of age I had passed the 6th standard and was entitled to leave school. First began the job at Marshland's Clog Shop. My job was to do nothing in particular but everything I was asked to. My job was fetch and carry. The day began at eight and finished at eleven. My next job was at Moorwood's Iron Foundry where I was warehouse boy. Having the run of the works was full of interest—put black varnish on kitchen stoves—had to leave when found to be below factory age.

"My next job was as cellar lad in the crucible steel-making furnaces. I was a slim, fair-haired, blue-eyed boy and altogether too frail, the workmen thought, to make a cellar lad, much less a steelmaker. My father never expected me to be a steelmaker, as he believed I was not strong enough. I ceased being a cellar lad because I was below the minimum age regulation of the Factory Act."

Harry Becomes a Bottle Washer. "In October, 1883, when I was just twelve years of age, a newly-appointed chemist took charge of the laboratory at the Norfolk Works of Messrs. Firth & Sons. The new

chemist, James Taylor, was a dark, thin, pale man, thirty-five years of age. A few weeks after he arrived he wanted a boy to wash up and I was chosen. The first day I spent with Taylor left an impression I never shall forget. I had never been in a lab before. In fact, I had never heard the word 'laboratory' and had no idea what purpose the place served once I got inside it. There was so much glassware about I thought it might be a room where something to drink was prepared.

"The first days in the lab were unspeakably dreary. Taylor was not the kind of person to arouse interest and confidence in the undisciplined boy. During the second week Taylor asked me what I read and I said 'Boy of England, the Comic Journal and Jack Harkaway.' He appeared not to have heard of these papers. Eventually I worked diligently at whatever book Taylor suggested to me. The first was 'The Irish National Arithmetic.' With this little book I began at simple addition and worked to the end. Taylor was pleased with my industry and I was pleased because he would talk about arithmetic, although he had nothing to say about 'Jack Harkaway.'

"In 1885, when I was fourteen, Taylor bought me a copy of 'Todhunter's Algebra,' a large book of about 600 pages which cost 7/6 d. I was touched that anyone should think it worthwhile to give a book costing so much money. I can see myself proudly taking it home and showing it to my mother who was swilling down the pavement after a load of coal had been delivered. I still have that book.

"Taylor suggested that I should attend night school and study math. Whatever he suggested I attempted, he was my king and could do no wrong or think it either. I attended night school two or three evenings as week and worked at my books until I was driven to bed.

"I was a bottle washer to Taylor and two assistants. It was an easy job with spare hours I could devote to school work which consisted mostly of math and general physics. One of the lab assistants was Colin Moorwood. I owe a great deal to him. He sang snatches of opera in the lab and recited bits of poetry. He smiled when I asked if Shakespeare was an Englishman, but understood sympathetically the depths of my ignorance. He understood the Sheffield dialect but taught me to speak English and I learned from him the music of words and some verses full of high aim and chivalry. Colin was a gent who taught me by example and has remained one of my best friends. He had been brought up in a comfortable home. I knew his home, first as a boy when I would take a message and receive a chunk of sweet cake from his dear mother, and later when, being neither man nor boy, I was learning to feel at home among 'educated' people.

"I learned gradually to make whatever pieces of apparatus might be required. Taylor gave me my first lessons in glass blowing and, in time, I learned to do it better than he. I made a habit, before work in the lab commenced, of working with the joiners and plumbers so that by the time I was twenty, although I had no trade, I was quite at home working with many handicraft tools."

Brearley Becomes a Laboratory Assistant. "I had become an assistant in the lab before Taylor left England and I lost my mother about the same time. My mother's death caused our home to be broken up and I found myself in lodgings with my brother Arthur and, as usual, he was keeping an eye on me. I became interested in the girl who ultimately consented to marry me, and whose feet now adorn the fender on which mine are now resting. I had attended a bible class at the Sunday School. It was one means of meeting Nellie but it had other attractions. Some of the young men were very wide awake. They were interested in talking and a few of them talked of strange books. There was a mutual improvement class on Saturday evenings where good speeches would sometimes be made. I was so much attracted by some of Ruskin's books that I neglected everything else to read them and to read some of the intelligible Carlyle. Ruskin's 'Unto the Last' was a revelation. Ruskin's 'Analytical Economics' and Todhunter's 'Algebra' are the two books that I prize above all others. This excursion into literature excited an appetite which will never be satisfied. But I saw no living in it and I was really equally greedy to understand some of my work from which interests I had temporarily separated myself. There was some prospect of becoming an analyst which I could not afford to neglect."

Brearley Rises to Analytical Chemist. "I decided to understand chemical analysis thoroughly and began reading about the determination of manganese in steel. I attacked one steelmaking interest after another, until at the end of six years I knew my special subject backwards and forwards. I was so poor I had to provide a week's lunches out of 18 p—a brown loaf and dates costing 4 p half penny would serve for two days. It was a regular B. Franklin existence, but my teeth were good."

"At twenty-four I thought about getting married, now earning £2 a week. Had I been asked how I proposed to keep a wife I should have shown my hands and said, after Abernathy, 'with these and a determination to use them.' We were a practical couple with no expensive habits, who were very much in love with each other and delighted to be in the country away from town life.

"After the excitement of marriage I settled down again to reading chemistry. I began to write about the analysis of steelworks materials. Between 1895 and 1902 I contributed scores of articles to *Chemical News* and other journals. Taylor wrote me from Australia in 1897 offering me a position in the assay lab dealing with gold and silver and the lead-antimony-tin alloys generally known as white metals, but I was to study the assay and analysis of the metals before going. I decided to turn it down."

Brearley's First Book. As a young man of 31, Brearley was working as a chemist at Kayser Ellison's steelworks in 1902. "I was their first chemist and Mr. C.W. Kayser kindly allowed me to do some private analytical work. They were in the tool steel business. Whilst there I wrote, with Fred Ibbotson, my first book, *The Analysis of Steelworks Materials*. The actual writing was done in six or eight weeks, but I was so full of the subject and wrote easily, so long as I ignored tenses, moods, split infinitives and other niceties of composition of which I had no real knowledge. Ibbotson thought the English of that part of the book that I wrote was imperfect but he said there was blood in it. This was almost literally true. When I was finished I felt exhausted; I felt as a woman must feel after giving birth to a wanted child—exhausted and triumphantly glad."

About this time, Brearley became involved in a part-time venture with Colin Moorwood, which they called Amalgams. Brearley had discovered how to produce a certain claylike material that a large company would buy from him. "Every evening and every weekend I worked for the Amalgams Company, sometimes in the workshop and sometimes at home. One room of our house was littered with experimental bits and pieces and packages of the material; and then it was improved so much out of recognition as to be a new material. Within two years the business warranted the engagement of a man to look after it; I had other things to do."

Brearley Becomes a Chemist at the Riga Steelworks. "At about this time Firth's bought a partly erected steelworks at Riga to which John Crookston, their Odessa agent and a naval architect by profession, was appointed manager. Crookston and Moorwood met in Riga to consider how the partly built works should be completed and started. On Moorwood's recommendation, Crookston offered me a job as the chemist of the Riga Works. I accepted the job and prepared to leave for Russia in the new year of 1904. I was then thirty-three years of age. About the middle of January Colin and I traveled overland to Russia."

Brearley busied himself setting up an analytical laboratory and buying the various chemicals and pieces of glassware needed. The place was unheated, and because it was in the dead of winter, he worked in an overcoat, a dressing gown, and a long pair of rubber snowshoes. He had a portable, smelly, paraffin stove that he moved from place to place as he worked.

The Russo-Japanese War had been declared by the time Brearley reached Riga, and this war directed the attention of the Salamander Works to the manufacture of armor-piercing projectiles. Billets were to be imported from Sheffield, forged to shape, annealed, machined, and hardened and tempered. The factory was ill equipped and had no experienced men.

Firth's sent out a man from Sheffield named Bowness, who was said to know all about hardening shells, but he proved to be incompetent. His shells failed at the firing tests at St. Petersburg, and Bowness was promptly sent back to Sheffield. Brearley was then offered the job of shell hardening, which he accepted without hesitation. Brearley's brother, Arthur, who was overseeing the building of the melting furnaces, took over the laboratory. When back in Sheffield, Harry had trained his brother in the art of analyzing steel.

Brearley is Promoted to Heat Treater and Then to Works Manager at Riga. Harry needed to test samples of the shell steel that were hardened at different temperatures to find the ideal hardening temperature, but there were no thermocouples or any other pyrometric devices. The temperature of the hardening furnace could only be determined by eye. Harry thought it might be possible to find some salts that would melt at different temperatures. By mixing chemicals in the laboratory, he finally found three metallic salts that melted at approximately what they thought might bracket the hardening temperature. Each of the three mixtures was melted and cast into small cylinders that were then coated with brown, green, or blue wax to identify them and protect them from moisture. They called the little cylinders "Sentinels" or "Sentinel Pyrometers."

Harry sent the formulae for the three Sentinels to his Amalgams Company in Sheffield and said that his little invention resulted in the production and sales of thousands of the Sentinels.

Under Brearley's supervision, and while using the Sentinels, the first batch of shells that was heat treated passed the firing test, and they never again failed to pass the test. After his success with shell hardening, Brearley was promoted to Works Manager. It had been just one

year since his arrival in Riga. He spent three more years in Riga, leaving for Sheffield in 1909.

Brearley Becomes Manager of Firth Brown Research Laboratories

In an unusually cooperative spirit, Thomas Firth & Sons and John Brown & Company, two neighboring steelworks in Sheffield, decided to set up a research laboratory that they would operate jointly. When Brearley returned from Riga, he was offered the position of research director. Brearley accepted the job, although he had other options. He still owned the Amalgams Company and had some other ideas about doing private consulting. He was then 38 years of age.

Before accepting the job, however, Brearley thought to have a clause in his contract stating that "any discovery and patents resulting from his work shall be the property jointly of the Company and Brearley."

By now Brearley was a skilled analytical chemist and a self-trained metallurgist, by virtue of his experience as Works Manager of the Salamander Plant at Riga. However, he admitted that he knew least about the physical changes taking place during the heating and cooling of steel. The little he did know related to the influence of heat treatment on the mechanical properties as determined by tension testing and "nicking and breaking." He admitted to being completely ignorant of the microstructure of steel and more than a little confused.

Brearley was given free reign on his research projects and was even given the option of turning down any job in which he was not interested. He set about studying heat treating and became much involved in Izod notched-bar impact testing, ordering two of the earliest machines. He went on to study armor plate. He wrote a book, *Tool Steel*, and another, *The Case Hardening of Steel*, that even had a German edition. He thought his finest work was the book *Ingots and Ingot Moulds* that he co-authored with his brother, Arthur.

In May 1912, Brearley visited the Royal Arms Munitions factory at Enfield to investigate the erosion and fouling of rifle barrels. He had worked with steels containing 5 to 6% chromium and thought steel with more chromium content might be a solution to the rifle problem, particularly because of the high melting point of chromium. At that time, chromium steels were already being used for exhaust valves in airplane engines.

Brearley made a number of different melts of 6 to 15% chromium with varying carbon contents, using first a crucible process and then

an electric furnace. The first steels later to be recognized as stainless were melted in August 1913. At this time, Brearley was still trying to find a steel with more wear resistance. However, he then discovered that the new steel strongly resisted chemical attack, after samples of the steel were polished to a mirror surface and etched with a nitric acid solution (as part of the process to examine the crystalline structure of the steel at high magnification).

Brearley Discovers Stainless Steel. On August 20, 1913, Brearley made a cast of steel (No. 1008) having 12.8% chromium, 0.24% carbon, 0.44% manganese, and 0.20% silicon (as noted by Dr. K.C. Barraclough in his account of the 75th anniversary of Brearley's discovery). This was the first commercial cast of what came to be called stainless steel. An ingot was forge cogged to 3 inches square and rolled to a 1½ inch diameter bar. Twelve sample gun barrels were forwarded to the arms factory.

Although Brearley's steel did not prove useful for gun barrels, he described the moment of his actual "discovery" of stainless steel as follows:

> "When microscopic studies of this steel were being made, one of the first noticeable things was that the usual reagent used for etching the polished surface of a microsection would not etch or etched very slowly. I found, moreover, with both the usual reagents, that different pieces would etch and some would not etch. I was satisfied, therefore, so far as corrosion with the etching acids was concerned, that merely to specify the composition of the material was not sufficient, because from the same bar of steel I could cut a piece and then a second piece and a third piece, and in different conditions of heat treatment some of them would etch and some would not. The significance of this is that etching is a form of corrosion, and the specimens behaved in vinegar and other food acids as they behaved with the etching reagents."

Brearley also noticed that cut samples of the steel left in the laboratory did not rust. He described his remarkable discovery 16 years after the event in a rather matter-of-fact manner. He also made the very significant discovery that the chemistry and heating and processing of steel are all equally important.

From the end of 1913, Harry Brearley talked of his idea of producing cutlery. Until that time, cutlery had been made of carbon steel. The town of Sheffield also had been the center of the cutlery industry

in England for 300 years. Brearley recognized that his new steel had definite advantages over the 25% nickel steel formerly used to resist tarnishing, because it could be softened for machining and subsequently heat treated. However, the making of cutlery out of his steel was not easily accomplished. Two Sheffield cutlers by the name of George Ibberson and James Dixon, who were originally sent bars from the first cast, reported that it was almost impossible to forge, difficult to harden, and dirty when polished.

There also was definitely a prejudice against the idea of producing cutlery blades that would not rust. One of the foremost cutlers of the city said, "It would be counter to nature." G.E. Wolstenholme, one of Firth's directors, downplayed the whole idea by saying, "Rustlessness is not so great a virtue in cutlery, which, of necessity, must be cleaned after each use."

> "Perhaps the idea of producing on a commercial scale a steel which would not corrode sounds ridiculous, at least my directors failed to grasp the significance of it."
> Harry Brearley, Torquay, 1929

Brearley's directors at Firth's couldn't see any future in stainless steel. They refused Brearley's offer to supply heat treated blanks ready for grinding into knife blades, and they refused to apply for a patent for something they deemed useless. In hindsight, the situation was understandable. The cutlers and the steel manufacturers thought that steel that never rusted would adversely affect the demand for their products. This may be so from their perspective as a cutlery supplier (but not from the customer view, nor with demand from dozens of new products that would also be made of the material).

Brearley was left in a quandary, not knowing which way to turn but convinced that the problems of making cutlery from his material were not insurmountable. In June 1914, Brearley happened to be introduced to Ernest Stuart, who was the cutlery manager at the firm of Messrs. R.E. Moseley in Sheffield. Mr. Stuart was skeptical that a rustless steel could possibly exist, but he agreed to work the small sample provided into a few cheese knives.

"A week later Mr. Stuart produced the knives he had made and pronounced them to be both rustless and stainless." Stuart is said to have been responsible for introducing the term *stainless* when, after testing the steel with vinegar, he said, "This steel stains less." Prior to that, Brearley had referred to his invention as "rustless steel." However, af-

ter the first attempt, Stuart also said, in unprintable language, that the steel was very hard and that all his stamping tools were ruined. Brearley said that those first knives were still in use in his home 15 years later and looked as good as new.

Then, Mr. Stuart tried a second time and produced finished knives without damaging the forging and stamping tools. However, the knives were very hard and brittle and were similar to cast iron when fractured. Mr. Stuart had made the steel hot enough so that it would work easily but so hot that it became brittle upon cooling. Brearley himself was invited to attend a third attempt. He admitted that he knew nothing of knifemaking and had not previously witnessed the making of a single table blade. However, he knew the temperature at which this particular steel should be worked and hardened. He assisted in making a dozen blades.

Brearley immediately recognized the practical uses of the new material. In a report dated October 2, 1914, he wrote, "These materials would appear specifically suited for the manufacture of spindles for gas or water meters, pistons and plungers for pumps, ventilators, and valves in gas engines and, perhaps certain forms of cutlery." Thus, the discovery of chromium steel as stainless steel is attributed to Brearley's research. In this same period, others in Germany (Maurer and Strauss at Krupp) and America (Haynes, Armstrong, Becket, and Dantsizen) were also experimenting with alloys of high-chromium steels for possible commercial use.

The steel received quick acceptance by the cutlery industry in the Sheffield area. Mr. Moseley ordered the Firth-produced steel through the Amalgams Company and, within two months, had seven tons on order. He would have liked to have had a monopoly, but by then, other cutlers were lining up to get into the business. "The steel declared dead and nigh worthless was made an absorbing topic of conversation among cutlers and steelmakers." Harry Brearley declared Moseley's to be the first successful producer of what was beginning to be called stainless steel cutlery. In January 1915, a brief announcement of the new metal appeared in the *New York Times*. Firth also promoted the stainless steel in a 1915 advertisement (Fig. 6).

Nonetheless, Brearley had felt wronged by the Firth's directors, who refused to supply blanks and apply for a patent. Because of this situation, Brearley tendered his resignation on December 27, 1915, giving six months' notice, which was accepted. Brearley was 44 years of age. He was not worried about the future, but he was saddened to be separated from the new steel to which he had lost his heart. Above all, he

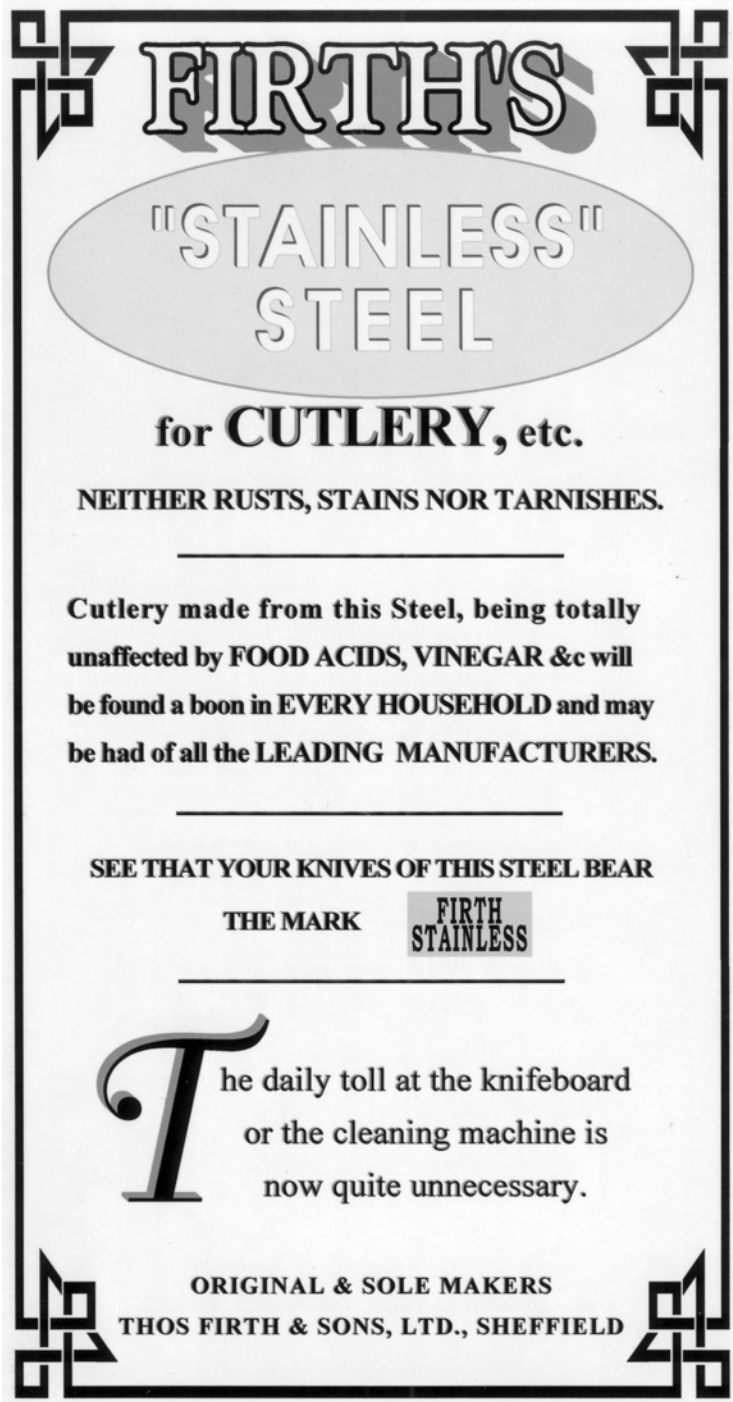

Fig. 6 Early Firth advertisement (1915). Designed by Evelyn D. Roberts, Pittsfield, New Hampshire.

regretted that circumstances forced him to break with a connection that had lasted for seven years. He said, "I need not trouble to describe the attempts made to reach an agreement since none of them was acceptable to me." It was not a happy New Year.

A Stranger Calls. Early in the new year of 1915, from out of the blue, a total stranger appeared one morning on Brearley's doorstep. He was an elderly, white-haired, well-dressed gentleman, 75 years of age. John Maddox was his name, and he had just come up from London. He said that he had connections in the textile business. However, Maddox wanted to know all about stainless steels and was even more enthusiastic than Brearley about the future of them. Maddox said that he knew America well and had considerable experience with patents. He left Brearley with the understanding that he might go to the trouble and expense of getting a patent in Brearley's name. How Maddox had found Brearley is not known.

Brearley was not predisposed to think about patents at that time and dismissed the incident. Maddox, however, turned out to be a man full of energy and became a good friend. When he failed to get a patent, he came back to Sheffield again and again, urging Brearley to apply for an American patent.

Brearley Applies for Patents. Brearley finally set his mind to it and filed for a U.S. patent on March 29, 1915, and for a Canadian patent on April 21. The American application was denied because, with no British patent, the steel was being made by John Brown & Co., Hadfield's, Sanderson, Vicker's, and other Sheffield firms in addition to Firth's and Brown Bayley's. Brearley immediately solicited the help of Sir Robert Hadfield, Dr. Stead, and R.A. Harbord, all of whom provided written statements of their support of Brearley's new application, which was filed on March 6, 1916, and granted on September 5, 1916, excerpts of which are printed in Fig. 7.

Brearley's Canadian patent, which was filed on April 21, 1915, was slightly different from the American patent. Instead of "Cutlery," the title of the patent was "Malleable Steel." The average mechanical properties of the "typical steel," which is actually the composition of the steel of Brearley's discovery in both patents, are for material oil hardened from 900 °C and tempered at 700 °C. The Canadian patent was granted on August 31, 1915.

It is especially interesting to note that Brearley did not try to patent an alloy per se but rather cutlery. This apparently was to overcome the objection of the patent office, which was that patents for chromium steels had already been applied for.

UNITED STATES PATENT OFFICE

HARRY BREARLEY, OF SHEFFIELD, ENGLAND

CUTLERY

1,197,256 Specification of Letters Patent Patented Sept. 5, 1916

Continuation of application filed March 29, 1915. This application filed March 6, 1916

To all to whom it may concern:

Be it known that I, HARRY BREARLEY, residing at Sheffield, Yorkshire, England, have invented a certain new and useful Improvement in Cutlery, of which the following is a full, clear and exact description.

My invention relates to new and useful improvements in cutlery or other hardened and polished articles of manufacture where non-staining properties are desired and has for its object to provide a tempered steel cutlery blade or other hardened article having a polished surface and composed of an alloy which is practically untarnishable when hardened or hardened and tempered. The alloy is malleable and can be forged, rolled, hardened, tempered and polished under ordinary commercial conditions.

A typical composition of the untarnishable steel blades embodying my invention would be as follows: carbon 0.30 percent, manganese 0.30 percent, chromium 13.0 percent, iron 84.6 percent.

What I claim is:

1. A hardened and polished article of manufacture composed of a ferrous alloy containing between nine percent and sixteen percent of chromium, and carbon in quantity less than seven-tenths percent.
2. A hardened and tempered and polished cutlery blade composed of a ferrous alloy containing between nine percent and sixteen percent of chromium, and carbon in quantity less than seven-tenths percent and not containing any microscopically distinguishable free carbides.
3. A hardened and polished cutlery article composed of a ferrous alloy containing between nine percent and sixteen percent chromium and carbon in quantity less than six-tenths percent.
4. A hardened and polished article of manufacture composed of a ferrous alloy containing approximately carbon 0.30 percent, manganese 0.30 percent and chromium 13.0 percent.

Fig. 7 Text excerpts from Brearley's 1916 patent of a stainless steel

When word of this patent reached the directors of Thomas Firth & Sons, they were astonished and immediately foresaw problems in America for their subsidiary, Firth-Sterling Steel Company at McKeesport, Pennsylvania. Brearley's American patent could interfere with the production of stainless steel, which had already been underway at Firth-Sterling for over a year. After considerable debate, Firth's directors agreed that they should offer to purchase a half-share in the American patent. They were only now agreeing to act in accordance with the terms under which Brearley had accepted the position (i.e.,

"Any new facts relative to the Company's manufactures which shall be discovered by Harry Brearley during the period of engagement and any patents based thereon, shall be the property jointly of the Company and Harry Brearley in equal proportion.").

The Firth-Brearley Stainless Steel Syndicate

Brearley agreed to accept the company's offer to purchase a half-share in his patent only if they agreed to his plan to establish a Firth-Brearley Stainless Steel Syndicate, which would be formed "to foster the world-wide production of stainless steel cutlery." This involved Brearley's renewed association with the directors of Firth's, the people he felt had behaved irresponsibly to him, but it seemed quite obvious that Brearley planned to manage the syndicate. The agreement on the syndicate was reached in July 1917, and it stipulated that henceforth "all knife blades made of Brearley's stainless steel alloy shall be stamped with the following logo:"

FIRTH-BREARLEY STAINLESS

In the meantime, Brearley had started his job as Works Manager of Brown Bayley's Steel Works in Sheffield on July 15, 1915. Brearley was then 44 years of age. He threw himself into the work of the new job as if trying to forget the recent unpleasantness. Brearley was kept busy supervising the modification of manufacturing processes. Because of the war, the company was being pressed to undertake the manufacture of special steels, aero-engine crankshafts, and rifle barrels, none of which had been in Brown Bayley's line of work. Brearley also served on several committees associated with the Ministry of Munitions until the end of the war. He worked at Brown Bayley's Steel Works until 1925.

Stainless Steel Becomes Critical for the War Effort. As the Great War progressed and the Kaiser's bombs began dropping on London and other parts of England in 1915, there was a major effort to build fighter planes for the Royal Air Force. Stainless steel was found to be an ideal material for withstanding the high temperatures of aircraft engine exhaust valves when the chromium was increased from 12.5% for the cutlery alloy to 14%.

In 1916, Firth's, the firm that had belittled the value of stainless steel, immediately began marketing Firth's Aeroplane Steel, or FAS. The production of high-chromium steels for other than defense pur-

poses was prohibited by government decree for the duration of hostilities. By that time, most of the steelworks of Sheffield were producing varieties of stainless steel.

The Firth-Brearley Stainless Steel Syndicate Faces an Unexpected Problem in America. An unexpected problem came up in America when Elwood Haynes (Fig. 8) opposed Harry Brearley's patent. Haynes was the president of the Haynes-Stellite Company in Kokomo, Indiana. Haynes had been experimenting with high-chromium, low-carbon steels as early as 1911, primarily to determine if those alloys might make a less expensive cutting tool material than the cobalt-base Stellite alloys of his company. Haynes had filed for a U.S. patent a little earlier than Brearley's first application of March 29, 1915. When Haynes' application was denied, he appealed and requested an interference order, while agreeing that the discoveries were similar and made independently. In the middle of 1917, the Patent Office granted an interference order to Haynes' patent, which he appealed, and finally granted him Patent 1,299,404 on April 1, 1919 (Fig. 9).

Fig. 8 Elwood Haynes, who was a pioneer American automobile maker and an inventor of a series of complex alloys from 1907 to 1913 when searching for durable spark plug alloys. Courtesy of the Elwood Haynes Museum, Kokomo, Indiana.

UNITED STATES PATENT OFFICE

Elwood Haynes, of Kokomo, Indiana, Assignor to the American Stainless Steel Company, of Pittsburgh, Pennsylvania, a Corporation of Pennsylvania

Wrought-Metal Article

1,299,404 **Specification of Letters Patent Apr. 1, 1919**

Application filed March 12, 1915

To all whom it may concern:

Be it known that I, Elwood Haynes, a citizen of the United States, residing at Kokomo, in the County of Howard and State of Indiana, have invented certain new and useful Improvements in Wrought-Metal Articles of which the following is a specification.

This invention relates to wrought metal articles; and it comprises wrought metal articles of manufacture of the nature of cutlery and edged tools, such articles having polished surfaces of the general character which is termed noble, in that such surfaces are incorrodible, lustrous and of permanent nature and such articles being composed of a worked down and hard body of an iron-chromium alloy low in carbon and other metals, such alloy being stiff, strong and elastic, able to take a cutting edge and having other properties of tempered metal; such as, for example, an iron-chromium alloy containing not less than 8 percent chromium and, very advantageously, not less than 10 percent, and not more than 50 to 60 percent, the best proportion being between 15 and 25 percent, and containing not to exceed 1 percent of carbon (the amount of carbon being advantageously between 0.1 and 0.5 percent) with the rest of the alloy consisting mainly of iron, there being no substantial amount, (say, not over 4 to 5 percent) of other metals than iron and chromium in said alloy; all as more fully hereinafter set forth and as claimed.

The present alloy is well adapted for making pen points for fountain pens, chisels, table knives, forks, and other purposes where hard metal of high temper is required.

What I claim is:

1. A wrought metal tool having polished surfaces of noble metal and composed of an alloy of iron and chromium, with carbon in amount between 0.1 percent and 1.0 percent, said alloy being malleable at high temperatures, hard, stiff and strong at ordinary temperatures and capable of taking and retaining an edge.

2. A wrought metal tool having polished surfaces of the incorrodible character of polished surfaces of noble metal and comprising an alloy containing from 8 percent to 60 percent of chromium and 40 percent to 92 percent of iron, with carbon in amount between 0.1 percent and 1.0 percent, said alloy being readily malleable and workable and being substantially free of other metals.

3. A wrought metal tool having polished surfaces of the incorrodible character of polished surfaces of noble metal and comprising an alloy of iron and chromium containing from 15 to 25 percent of chromium, and carbon in amount from 0.1 percent to 1.0 percent, and being malleable, ductile and elastic.

4. A wrought metal article having surfaces of the incorrodible character of surfaces of noble metal, and composed of an alloy of iron and chromium, containing carbon in amount of 0.1 percent to 1.0 percent, said alloy being readily malleable and workable at high temperatures, and hard, stiff and strong at ordinary temperatures.

In testimony whereof, I affix my signature in the presence of two subscribing witnesses.

ELWOOD HAYNES

Witnesses:

H. R. Perry

R. Crawford

Fig. 9 Text excerpts from the 1919 stainless steel patent of Elwood Haynes

The American Stainless Steel Company (1918–1936)

In the meantime, the patent problem was resolved. In 1917, one of the first actions of the syndicate was to make plans to establish a patent-holding company in America to manage the licensing of the Brearley patent. The American Stainless Steel Company was established in Pittsburgh in 1918, just three weeks before Haynes was granted the interference order. The Brearley people went to Haynes after he had successfully contested their patent and, as a compromise, offered him a position on the board and a 30% share in the new company.

The new company, with an office in the Oliver Building in Pittsburgh, was incorporated in the state of Pennsylvania with the following ownership: Firth-Brearley Stainless Steel Syndicate (40%), Elwood Haynes (30%), and the balance shared equally among Firth-Sterling Steel, Bethlehem Steel, Carpenter Steel, Crucible Steel, and Midvale Steel. Each party would receive a royalty, according to their share in the company, on all of the stainless steel manufactured by the various steel companies licensed to make steel under the Brearley and Haynes patents. The two patents together, although quite similar, would make a formidable barrier to any company that planned to make steel without paying what would come to be quite high royalties, on the order of 20%.

The first president of the company was James W. Kinnear of Pittsburgh, who was a prominent corporation attorney. He served until his death in 1922 and was succeeded by James C. Neale, also of Pittsburgh. There were ten directors in all, with Elwood Haynes having two seats, one of which he assigned to his son, March Haynes.

The first manager of the company appears to have been W.H. Marble. He would be involved in licensing agreements, the collection of royalties, the arrangements for meetings of the board, and the promotion of stainless steel. With regard to the latter, it should be noted that, despite its attractive qualities, stainless steel was not easy to sell in the beginning, and it cost four to five times that of carbon steel.

Early in 1920, Marble gave a paper at the Philadelphia convention of the American Society for Steel Treating. His paper was entitled "Stainless Steel—Its Treatment, Properties and Applications" (*Transactions of the American Society for Steel Treating*, Vol 1, Cleveland, Ohio, 1920). The paper was undoubtedly the most comprehensive yet given on cutlery steel. It contained summaries of recent information from five sources, including Dr. W.H. Hatfield, who was Brearley's successor at Brown Firth Research Laboratories, Elwood Haynes, the

New York Testing Laboratories, the National Bureau of Standards, and the Joint Iron and Steel Committee of the Society of Automotive Engineers and the American Society for Testing Materials.

Marble started out on a favorable note by saying, "During the late war period in England all stainless steel supplies were appropriated by the Ministry of Munitions." He reviewed the chemistry specifications, the effects of various elements, manufacturing, forging, rolling, annealing, hardening, and tempering. He also showed an interesting table of temper colors for stainless and tool steels, which revealed that, for a given color, the stainless steel is always a higher temperature than for tool steel, with the difference increasing for higher temperatures. A greenish-blue color, for example, is produced at 1300 °F for stainless steel and at only 625 °F for tool steel.

A chart was also displayed on scaling tests, which showed weight losses for six alloys when tested in air at temperatures from 1300 to 1560 °F when weighed at 24 hour intervals. Stainless steel showed practically no weight loss after 268 hours at 1540 °F and was lower than either 25% nickel steel or tool steel and much lower than for carbon steel and 5% nickel steel.

A table showed the mechanical properties of stainless steel samples that were hardened from 1650 °F. Five samples each were quenched in air, oil, or water and tempered at five temperatures. The elastic limit, tensile strength, percent elongation, and reduction of area were recorded for each specimen. Although not stated, the data are recognized to be from Brearley's test report of October 2, 1913, on an early cast of stainless steel.

Marble ended his paper with the following conclusion:

> "The steel is costly to produce in the form of cutlery by reason of the necessity for better grinding and more careful forging in consequence to its great hardness. For general use, it may be said that it is costly to manufacture by reason of the expensive alloy employed, and the comparatively heavy waste (due to scrap) involved as a result of very careful inspection; but there *is* a very wide field of usefulness before it."

In 1918, licensees of the American Stainless Steel company included Bethlehem Steel, Carpenter Steel, Washington Steel and Ordnance, and Crucible Steel.

American Stainless Steel Company versus Ludlum Steel Company. Ludlum Steel of Watervliet, New York, was not among the licensees,

and when Ludlum Steel began to market its own Neva-Stain and Silchrome stainless steels, there was a possible basis for a lawsuit. These alloys were chromium-silicon steels developed by P.A.E. Armstrong and patented in 1919. The Armstrong alloy was an aircraft valve steel that was sold under the Ludlum Steel trade name Silchrome and later identified in Society of Automotive Engineers' specifications as HNV-3.

In approximately July 1920, F.A. Bigelow, president of Carpenter Steel and one of the directors of the American Stainless Steel Company, sent Elwood Haynes the analysis of the new Ludlum alloy for his comments. Haynes immediately replied, saying it was clearly an infringement of his patent because "the alloy contains more than 8% chromium and was practically stainless." He said his patent was based on "the combination of iron and chromium, and was independent of all other metals, whether added in inappreciable or larger quantities. Neither does it cover the methods of working or heat treating same. Any article made of a combination, therefore, which involves a steel containing more than 8% chromium is an infringement against the patent." The Ludlum alloy was 8% chromium and 3% silicon.

The American Stainless Steel Company board considered the matter and decided to attempt a settlement, but the Ludlum Company stood firm and announced that they would defend any suit based on the use of the unlicensed Neva-Stain cutlery steels. On December 31, 1920, a patent attorney by the name of Christy filed the suit "The American Stainless Steel Company vs. Ludlum Steel Company." The American Stainless Steel Company retained the services of Prof. William Campbell of Columbia College to make some experiments. Harry Brearley also was asked to come to New York, making it clear that just his travel expenses would be paid.

The case came to trial early in1922, with the noted jurist Learned Hand on the bench. Haynes and Brearley testified at different times. Brearley wrote the following in his autobiography about his part in the testimony:

> "When the case opened I was in the witness box for three hours and enjoyed every minute. I had nothing to conceal from the cross-examining and understood the subject and the value of his direct evidence better than he did."

The judge dismissed the case, declaring the patents valid but not infringed by the Armstrong alloys. The Hand decision, which was delivered on April 13, 1922, was reported in *Iron Age*:

> "The issue . . . is whether the addition of silicon, which obviates the additional heating of the plaintiff's composition beyond its critical point, makes the resulting article an infringement. Obviously this could not be . . . Granting that the addition of silicon would not avoid infringement, it does not create."

Haynes felt that the American Stainless Steel Company had proceeded on the wrong basis and listed points he thought should be brought up during an appeal, stressing the idea that neither his nor Brearley's patent covered "any process for either polishing or tempering the alloys." Haynes repeated a point he had presented to his patent attorney: that the primary invention was his "discovery that stainless steel articles can be made from an alloy consisting essentially of 8% or more of chromium and 92% or less of iron." Carbon was not an essential ingredient, but with 0.6% carbon or more, such articles may be tempered or hardened by slightly modifying the manufacturing process. With a chromium content of 10 to 18% and the carbon at 0.6%, "the stainless quality of the article may be enhanced by a suitable heat treatment. The latter feature is covered by Mr. Brearley's patent only, but he gives no specific method for hardening the article."

In October 1922, the Board of Directors decided to appeal Hand's decision and also to dissolve the company if the appeal was lost. On April 16, 1923, the Circuit Court of Appeals handed down a decision that was most welcome to the Board of the American Stainless Steel Company: "Haynes and Brearley both held pioneer patents valid and infringed." In the following statements, Judge Hough gave Haynes credit for first discovering the basic properties of stainless steel:

> "The object of both patents is the same and may be shortly described as a desire to produce what for some years have been increasingly called 'stainless steels.' Although Brearley's patent date is earlier, his date of application is later, and it may be summarily held that Haynes is the generic and Brearley is the specific patent."

Judge Hough gave the reason for reversing the lower court's decision. He reasoned that the defendant has by "omitting silicon . . . produced 'stainless steel;' with the silicon added, he has also produced 'stainless steel;' therefore, in respect of infringement, the silicon is immaterial no matter how beneficial it may be." (Note: A close reading of Judge Hough's reason for reversing the lower court's decision shows that he had come to the erroneous conclusion that all of the alloys

covered by the Brearley and Haynes patents, that is, from 8 to 16% chromium, would be stainless steels. However, any alloys today having less than 10.5% chromium would not be considered to be stainless steels.)

Haynes died on April 13, 1925, at the age of 67. The American Stainless Steel Company continued to have good earnings from 1925 through 1929. However, in the early 1930s, there was a suit with the Rustless Iron Company of Baltimore in which the American Stainless Steel Company failed to have their patents upheld. This may have led to their demise, the date of which is not known. In any event, the company would have been dissolved in 1936 when Harry Brearley's patent expired.

Brearley's Later Years

From 1918 on, after the settlement of the Brearley and Haynes patent dispute, the Firth-Brearley Syndicate continued to play an active role. There was the patent infringement suit of the American Stainless Steel Company against the Ludlum Steel Company, in which the Brearley and Haynes patents were involved. Harry Brearley gave some of the most important testimony, but the court decision, at first, was against the American Stainless Steel company. After an appeal, the decision was reversed.

Because Brearley was in America for the trial, he spent some time on syndicate work. He visited a number of cutlery manufacturers and the Firth-Sterling Steel Company at McKeesport, where he had a good discussion with Gerald Firth, the president. Brearley also reported that he assisted them in making a melt of stainless iron. He concluded his visit in America at the Massachusetts Institute of Technology, where he was invited to give a lecture on stainless steel to the students and some interested men from the area.

Brearley also made an extended trip to South Africa, where he gave lectures on stainless steel at Capetown, Durban, and Pretoria. He delivered six lectures at Johannesburg, which were attended by groups from various scientific societies.

A Fraud-Detection Scheme. After Brearley's retirement, the Firth-Brearley Syndicate stayed in business for a while. The syndicate became involved in one of the most unusual cases in the history of metallurgy when they had reason to believe that A.W. Gamage, a London store, was illegally selling knives with blades stamped "FIRTH STAINLESS," which Firth believed were not made of Firth Steel.

Ordinarily, a case of piracy such as this would be difficult and costly to prove, but not so for Firth's, who had foreseen that such an event might occur and had taken certain precautions.

Firth's had been doping their stainless steel with a small amount of element "X," which was added from an unmarked brown packet to each melt by the melting shop manager toward the end of a melt. The chief chemist and one laboratory assistant were the only ones who knew the identity of element "X," nor was its purpose explained if anyone noticed it. Suspected cases of piracy were proved or disproved by one analyst, working alone after hours, who used a color test to detect element "X." Years later, the Brown Firth laboratories revealed that element "X" was cobalt in an amount equal to approximately 0.03%.

Brearley Receives Metallurgy's Highest Recognition. In 1920, the Council of the Iron and Steel Institute presented Harry Brearley with the Bessemer Gold Medal, which is awarded for outstanding services to the steel industry. He was the fourth recipient of the medal. In his autobiography, Brearley wrote, "This is the only distinction I had ever audibly coveted. I valued this presentation all the more because it was made by Dr. Stead, that dear old man whose simple character and manner and life were as admirable as his metallurgical investigations were excellent."

The following is the last paragraph of his acceptance speech:

> "Dependence on the willing help of others is the part of all who successfully direct a laboratory for industrial research. Most problems relating to iron and steel cannot be definitely stated, and the individual, best qualified by experience to study the problem, and to solve it, might be some workman who is engaged on the job day after day. It is the investigator's greatest achievement to inspire interest in such men to make them confederates to his plan. The lust to work, the desire to find out and to understand things is not confined to those who regularly wear a clean collar and, in thanking the Council and Members of the Iron & Steel Institute for this high honour, I am proud to confess my life-long indebtedness to scores of friends, with hard hands and black faces, who toil at laborious tasks in mills and forges."

After the war, Brearley gave up his job as Works Manager at Brown Bayley's but continued to be responsible for the melting plant, heat treatment, and the laboratory.

Brearley Retires. In 1925, although only 54 years of age, Brearley decided to retire. Since returning from Russia in 1907, he had almost always earned more than enough to supply his wants. He had lived simply and never had a fine house, motor cars, or luxurious food. In addition to savings, he still had income from the American Stainless Steel Company in which he held a 40% interest, and he still had income from the Amalgams Company.

He wanted to live more out of doors, play games, and, in general, do things he had never been able to do in his younger days because of lack of time or money.

Harry Brearley retired from Brown Bayley's on the best of terms, so it seems. His salary stopped, but he still came to work and tended to certain company business. However, as time went on, he became more involved with other matters. He assisted J.H.G. Monypenny, chief of the Research Laboratory at Brown Bayley's, in writing the world's first book in English on stainless steel, *Stainless Iron and Steel*, which was published in 1926. Monypenny acknowledged Brearley "particularly for much help and advice."

Within a year or so, Brearley agreed to do some private metallurgical consulting for half a dozen manufacturers who were not steel producers. Brown Bayley's built him a new 30 square foot office, well lighted, heated, and decorated according to his wishes. He was welcome to entertain his clients there, and he also had use of the laboratory. He was soon busier than ever but relished his work with his new clients. Never had a retiree been treated in such an elegant manner by an employer.

In 1927, approximately ten years after the Firth-Brearley Stainless Steel Syndicate was established with the agreement that all blades made with Firth's stainless steel would be stamped with the logo FIRTH-BREARLEY STAINLESS, Firth's dropped Brearley's name from the logo without consulting him. Brearley was furious, but Firth's was adamant. He never completely got over it. The fact that some degree of cordiality had been restored, however, is evidenced by the later writing of Dr. W.H. Hatfield, his successor at Brown Firth Laboratories, whom he must have met, at least on syndicate business. Hatfield wrote:

> "The city has, of course, been famous for its knives for hundreds of years, but down to a generation ago would rust or stain, and needed much attention in cleaning. Nearly all knives now are

made of stainless thanks to the researches of my friend, Harry Brearley, and those who have assisted in the development. This is a delightful instance where the product of a major industry has been revolutionarily transformed by local effort."

In 1929, while Brearley was recuperating from an operation at Torquay on the coast of Devon, he wrote but did not publish his autobiography. He had the manuscript typewritten and sent it to his only son, Leo, who eventually passed it on to his son, Basil. When planning a celebration to commemorate the 75th anniversary of Brearley's accomplishment, the staff of British Steel Stainless searched for memorabilia and found Basil, who was in Australia, and retrieved the manuscript. British Steel Stainless published the book, which was called *Stainless Steel Pioneer—The Life of Harry Brearley*, along with contemporary photographs, which were furnished by the Kelham Island Industrial Museum.

Brearley set up a fund to reward Sheffield authors of creative papers on metallurgy. The biennial prize was to be awarded by the Sheffield Metallurgical Association. He called it the James Taylor Prize, in honor of his first boss.

Another award of recognition came to Brearley in June 1939 when he was 68 years of age. It was the Freedom of Sheffield Scroll and a Freedom of Sheffield Casket, which was a small, ornate metal box that was adorned with six figures engaged in various metals trades.

In 1941, Brearley wrote another autobiography entitled *Knotted String* and published a record of the old Sheffield steel trade called *Steelmakers*. Brearley continued on as a director on Brown Bayley's Board, a position he held until his death in 1948 at age 76.

75th Anniversary. In 1988, the 75th anniversary of Brearley's discovery of stainless steel was organized by British Steel Stainless to celebrate his achievement. As part of the celebration, a scholarly paper entitled "Sheffield and the Development of Stainless Steel" was presented at the Brearley Centre, British Steel Stainless, on October 25, 1988, by Dr. K.C. Barraclough, who had worked on the development of stainless steel while he was at the Firth Brown Research Laboratories.