Percy Armstrong (1883–1949): A transatlantic pioneer of alloy steels

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Introduction

Modern commercial alloy steels are little more than a hundred years old. Before that date, it was assumed, even by the most knowledgeable metallurgists and engineers, that steel was a fairly uniform item—a mixture of iron and carbon—whose qualities, although extremely useful, were essentially limited. Steel, as was well known in the nineteenth century, could be heat-treated to improve its hardness, but that was all. The idea of adding elements to enhance the qualities of steel—say its hardness, or corrosion-resisting properties—was almost unknown. But today alloy steels have become so ubiquitous that we take them for granted. Each day we come into contact with hundreds of alloy steel items, or are transported or accommodated in structures that are made of alloy steels or depend on them in their construction. Some of us will even have our lives saved (or perhaps ended) by alloy steels.

Historians of metallurgy, perhaps more aware than most of the crucial importance of alloy steels, have recently begun unravelling their complicated developoment. The Historical Metallurgy Society made a major contribution to our understanding of this field by hosting a conference in September 1984 on the subject of alloy steels. It brought together much unrecorded development work and many personal memoirs.[1] It shed light on those alloy steel pioneers, now mostly forgotten, who in their day stood at the leading edge of an industry that was transforming the world. Such a man was Percy Armstrong.

Armstrong died a relatively wealthy and well-known American industrialist. In its obituary, the *New York Times* referred to him as: "A leader in the development of complex stainless steel alloys, nationally recognised for his work in metallurgy".[2] A major shareholder in a leading steel company, he had scores of patents to his name, and had lived in considerable style, with homes on the East and West coasts. But his origins were much more modest; in fact, he was not a native American at all.

Early life and career

Percy Albert Ernest Armstrong was born on 29 May 1883 in Camberwell, south-east London, the son of William Percy Armstrong, a wallpaper salesman, and Jessie Lydia Mary, née Hill. His paternal grandfather had been born at Gosforth, Cumbria, in 1826, and had moved to London in unknown circumstances in 1850, marrying there three years later. The family's ancestors hailed from the Anglo-Scottish border country in the seventeenth century.[3]

Percy Armstrong
(courtesy Bernard Armstrong)

Armstrong's early education was at a local board school in Islington, in north-east London. After he left, he took up an engineering apprenticeship at Busby & Co, Pentonville, a north London toolmaking and constructional engineering foundry. He also studied (presumably at evening classes) mechanical engineering at the Northampton Institute, north London (now the City University).

His engineering career was interrupted by a brief interlude, when as a youth he joined the King's Rifle Corps and managed to get to the Boer War under age (probably about 1900). However, once he was back in London he resumed his career with various minor London engineering firms. He was engaged as a departmental foreman at the London Stamping Co and then as assistant foreman and tool designer at the

General Postal Factory. The nature of Armstrong's work at these businesses is unknown, but doubtless they gave him some of the knowledge and experience in treating and manipulating tools and metals which was to prove so useful later.

Like many metallurgists at this time, he had little formal training. But this was not such a great disadvantage in the days when there was a large element of "rule of thumb" in steel technology. He was already showing talent as an inventor. In October 1904, when he was only twenty-one, he registered his first patent—for a speed indicator.[4] Between then and 1915, he registered another six patents—for screw cutting lathes, liquid level indicators, a telephone switch, tyres and the casting of ink rollers. However, none of these were a commercial success and Armstrong was soon on the move. By 1909 he had a wife—a London girl, Carrie Jane, née Whitaker, whom he had married in 1907—and a handicapped son, Walter Percy.

Sometime between 1909 and 1914 he became a "practical expert" for Bohler Brothers, of Sheffield.[5] This was a significant move. Bohler Brothers was a renowned tool steel manufacturer, based in Kapfenburg, Austria. The firm had opened a depot and small forge in Sheffield in the 1890s. importing its steel from Austria. Sheffield at this time was the world's leading tool steel manufacturing centre, a position it had occupied since the late eighteenth century when Benjamin Huntsman had invented his revolutionary crucible steelmaking process.

In fact, Armstrong could not have chosen to work for a Sheffield firm at a better time. England at that time was still the most technologically advanced special steelmaking country in the world and its world-famous steelmaking district of Sheffield still led the way with its innovations in special steels. In the city there had been discovered most of the major alloy steels, containing manganese, silicon and tungsten. It was also the leading UK centre for the manufacture of steel goods, such as cutlery, edge tools, saws, files and many other engineering products. In the early 1900s the field was wide open for an aspiring metallurgist such as Armstrong: metallurgy was still in its infancy, poised uneasily between the age of science and the rule of thumb; the industry stood on the verge of further advances in alloys, particularly tool steels; and production techniques were also being transformed with the advent of the electric furnace.

When Armstrong arrived in Sheffield, there was great interest in the composition and manufacture of tool steel, especially so-called high-speed steels. These high-performance machine-tool steels could cut at red heat and had resulted from the researches at the Bethlehem Steel Company in America of Frederick W. Taylor and Maunsel White. Their improved composition and heat-treatment of alloy tool steels, which were made known after 1901, marked a major advance on the older carbon steel cutting tools. Intense research was soon under way further to improve the Taylor-White steels, with Sheffield manufacturers edging ahead of the Americans in the commercial exploitation of high-speed steel between 1900 and 1914. In fact, Bohler Brothers had evidently opened its Sheffield agency to sell high-speed steel, which the firm was also marketing with some success in the USA at this time.

Apparently, Armstrong was based in Leeds, where his wife and son had soon joined him (though they had returned to London by Christmas 1913). As a practical expert, Armstrong would probably have travelled the workshops in the north of England and elsewhere, explaining to engineers how to handle the complicated heat-treatment for these new "Bohler Rapid" high-speed steels. Clearly by now Armstrong must have had considerable experience with steel manipulation. He also visited Berlin on Bohler Brothers' business before the First World War, which would have given him the chance to have observed Germany's own considerable advances in special steel manufacture.

More interestingly for Armstrong's subsequent career, at about this time he is known to have met Harry Brearley, the Sheffield metallurgist, who was a director of the city's leading steelworks research facility—the Brown-Firth Research laboratory. In 1912 Brearley began a research programme into chromium additions to low-carbon steel, which resulted in the discovery of stainless steel—an innovation that Brearley and local manufacturers immediately applied to the production of cutlery. Nothing is known of the circumstances under which the two men met, but as personalities they were not entirely dissimilar: both were largely self-taught and came from humble backgrounds (Brearley had been born in tenements near the steel works). Perhaps it was more than coincidence that Armstrong, too, began experimenting with chromium additions to steel in about 1914.

Destination America

Meanwhile, Armstrong's professional and personal life underwent a crisis. In 1912 he had established his own firm, the Armstrong Patent File Co, in Mincing Lane, London. It was to manufacture special file-cutting machines to produce files with hyperbola-shaped teeth. But it was not a success. When the First World War broke out, he refused to volunteer again to fight the Germans (whom he had grown to respect during his visit to Berlin) and decided to seek his fortune elsewhere. Leaving his wife and two children (another son, Bernard, had been born in September 1914), he left for America with an older, wealthy divorcee, "Dolly" Grimshaw, née Horton (whose family made liquid soap). Armstrong never saw his wife or children again.[6]

In emigrating to America, Percy Armstrong was following a path well-trodden by English steelmakers and metallurgists. The USA had been Britain's best market for special and alloy steels in the nineteenth century and many Sheffield firms had made fortunes there. Once America launched its own steel industry after the 1860s, it was inevitable that English workers were in demand to supply the required expertise. They helped establish the Pittsburgh crucible steel industry and they were also able to supply much-needed skills in cutlery, saw and file manufacture. Many Sheffield special steelmakers—Sanderson Brothers, Firth's, Jessop's and Edgar Allen's, for example—had also opened their own factories in America before 1914 in the drive to exploit English innovations in alloy steels.[7] As an ambitious high-flyer Armstrong would have been in good company.

When he reached the USA in about 1915, Percy Armstrong soon made his mark. He is understood to have advised the New York Tramway Co on the use of manganese steel for their rail junction points. Manganese steel had been patented in 1883 by the famous Sheffield metallurgist, Sir Robert Hadfield. The first major alloy steel, it had the unique property (due to its 12.5 per cent addition of manganese) of becoming intensely hard under abrasive stresses—which naturally made it ideal for railway trackwork. Armstrong's suggestion to use manganese steel led to a considerable saving on maintenance for the New York tramways. Living in America seems to have released Armstrong's latent energies and he began steadily filing inventions at the US Patent Office. He lodged some 75 American patents between 1917 and 1941 (his obituaries mention over a hundred patents to his name, though this was probably an exaggeration), and others in the UK, Germany and Japan. Besides his work with manganese steel, he patented methods of producing hollow drill steel, by using various cores.

Silcrome

By 1919 "PAE", as he was known, had moved to become a vice-president (sales and research) of the Ludlum Steel Co, in Watervliet, Albany, in New York State. In the same year he registered what was to be his most influential and internationally successful patent for what he described as a "Stable Surface Alloy Steel".[8] This was a ternary steel, containing essentially chromium, silicon and iron, which was found to have a stable surface even when exposed to the searing heat of high temperature gases. The silicon was the novel addition, since this element was usually regarded as an undesirable ingredient, which made an alloy steel brittle. Fortunately, we have an almost contemporary account of this discovery:

> In the course of researches made as long ago as 1914, Mr Armstrong met with difficulties due to rusting and scaling away under heat, and began to experiment to produce weld products which were non-corrosive and non-scaling. He used an electric arc and a copper crucible to make an alloy which contained chromium. But his use of silicon came about by accident. It got into the melt by reduction of the asbestos envelope of his electrode. He subjected these melts to tests for acid effect, corrosion by rusting in atmosphere and to scaling under heat, and recent analyses of the melts of those days indicated that what he made was substantially a stable surface silicon-chromium alloy steel within the range of his first patent. But his researches . . . were interrupted by the war, and it was not until after the Armistice that he resumed his labors, when he made no less than 2,500 melts in order to test the properties of his [alloy].[9]

Armstrong names his new alloys "silcrome", from its main constituent parts: carbon 0.4 per cent, silicon 4 per cent, chromium 8 per cent, with the balance iron. The main patent was registered in the USA in 1919, and other patents followed in the UK in 1921, Germany in 1925 and Japan. With its unique resistance to high temperatures, "silcrome" was soon destined for a glittering career as an engineering steel, especially in engine valves. But Armstrong and Ludlum soon found, as has virtually every patentee of a major discovery, that the originality of his breakthrough would be contested.

To understand why, we must take another look at the history of stainless steel. Brearley's original stainless steel in 1913 contained about 12 per cent chromium (which formed the protective oxide film on the steel's surface, rendering it "stainless"). Sheffield steelmakers and cutlers immediately recognised the usefulness of this, especially for cutlery, and production began during the First World War.[10] Since news of stainless steel had spread so rapidly in Sheffield, Brearley and his employers, Thomas Firth & Sons, did not think it worthwhile to patent the composition in the UK. However, largely on Brearley's initiative, a patent on stainless steel was applied for and granted in the USA in 1915. Almost immediately, an American metallurgist Elwood Haynes stepped forward and successfully contested Brearley's claim. He was able to prove that he had anticipated Brearley's discovery by nearly two years! Rather than waste time and money in litigation the two men (and Firth's, which had a Pittsburgh steelworks) amicably merged their interests into the American Stainless Steel Co. This was a syndicate, composed of American and British steelmakers and metallurgists (such as Haynes, Brearley and Firth's), which licenced stainless steel production in the USA and charged royalties for every ton sold.

The Haynes-Brearley patents were a formidable barrier to infringement: they covered any alloy with 8–60 percent chromium, while Brearley had also specified certain heat-treatment processes. "Silcrome" certainly fell within this range; though on the other hand, the silicon content was not pre-empted and, as we shall see, Armstrong's alloy was not really a stainless steel at all. The American Stainless Steel Co was also charging extremely high royalties—another reason why Ludlum may not have felt obliged to compromise. Whatever the merits of the respective arguments, Ludlum—no doubt partly or wholly on Armstrong's advice—decided to disregard the American Stainless Steel Co.

In 1919, while other manufacturers applied for stainless licences, Ludlum went ahead and began to manufacture and market its own range of stainless steel alloys, under the tradenames "Silcrome" and "Neva-Stain".

The response was predictable. An analysis of "silcrome" found its way to Haynes and he argued that it was clearly an infringement. The American Stainless Steel Co firstly tried to negotiate a settlement with Ludlum, but when that failed they applied to the courts. The suit, "American Stainless Steel Company *versus* Ludlum Steel Company", was filed on 31 December 1920. Within the industry, it became a famous stainless steel test case, much in the same way that the Bethlehem Steel/Niles Bement Pond case in 1907 had settled matters regarding Anglo-American priorities over high-speed steel. Stainless steel manufacturers watched which way the verdict would go with some interest: obviously a defeat for American Stainless would save them years of expensive royalties.

The case came to trial in early 1922, with the distinguished jurist, Learned Hand, on the bench. Brearley arrived from Sheffield to add his weight to his syndicate's case. In his autobiography he recalled his testimony in the witness stand, his instant celebrity, and the court's appreciation of his expert skills. What he did not mention, however, was that Judge Learned Hand at first dismissed the case, apparently because of the silicon content of the Ludlum steels.[11] The patents were judged valid, but not infringed by the Armstrong alloys.

Unfortunately for Ludlum, this decision was almost immediately overturned on appeal. The American Stainless patents were judged valid after all. But even this did not end the matter, since many questions as to damages, future infringements and the scope of the ruling still had to be decided. The verdict was clear enough as regards polished items, such as cutlery, but what about Ludlum's unhardened and unpolished articles, such as automobile valves made from "silcrome"? As it transpired, Ludlum and Armstrong considered their valve steel unaffected by the rulings and continued its manufacture. The courts accepted this, which led Haynes to complain of "the studied attempt on the part of [the court] to aid Armstrong in his effort to evade both the Brearley and Haynes patents".[12] This verdict limited the extent of the settlement made by Ludlum, the exact terms of which are not known, and of course did not affect the validity of American Stainless's basic patents.

Having resisted the challenge of the American Stainless Steel Co, in 1928 Armstrong was able to defend "silcrome" in the courts and to receive credit for it as his own invention.[13] Thus Ludlum was able to go its own way in manufacturing "silcrome". It was soon recognised as a very important industrial alloy. Before Armstrong's discovery, automobile valves had been made either of cast iron (welded to a carbon steel stem), or occasionally tungsten steel. But the latter was expensive and cast iron eventually proved unsuitable as the heat, corrosion and stresses that these valves had to withstand grew. "Silcrome" replaced these materials. Sales increased from 10,000 lb in 1920 to nearly $4\frac{1}{2}$ million lb in 1926 and by the 1930s it was almost universally in use for exhaust valves in the automotive field. As one writer noted: "Silicon-chromium steels have proved very successful in that they are resistant to heat and corrosion effects and have sufficient strength and impact under the general operation of automobile engines".[14] The alloy was to hold its position for motor car valves for the next twenty to thirty years world-wide. A textbook stated: "It is probably true that more exhaust valves have been made in this steel than in all the alternative steels; and its employment is likely to continue, especially for the valves of cool running engines which are not exposed to any unduly corrosive, chemical attack".[15]

Later career

Armstrong undertook considerable research into his silicon-chromium alloy. About 30 of his patents were related to "silcrome" between 1919 and 1941. Some of them were registered jointly, with the vice-president and director of research at Ludlum, Ralph P. DeVries. They collaborated in 1924 on "Tough Stable-Surface Alloy Steel", in 1925 on "Alloy Steel of High Surface Stability", in 1930 on "Alloy of High Surface Stability comprising Nickel & Silicon", and in 1931 on "Alloy Steel containing Nickel, Silicon and Copper". A young assistant of those days recalled: "When I came to Ludlum Steel Company in 1920 [Armstrong] was Vice-President in charge of sales. He also, in a small company such as Ludlum, had a general charge of research, working through Ralph DeVries, who is head of that department".[16] Armstrong's position was unusual: few men in the industry can have directed both sales and research in a company, though it was an indication of his varied background.

"PAE" stayed with Ludlum until about the mid-1920s, when his relationship with the firm dissolved amid patent litigation and recriminations. No details are available, except that the dispute involved contracts and patent royalties.[17] Perhaps, like Brearley, Armstrong was too much of an individualist to remain a "company" man for so long. So Armstrong was not with Ludlum in 1938, when it merged with another pioneer stainless producer, the Allegheny Steel Co of Brackenridge, Pennsylvania.

Armstrong began a career as a metallurgical consultant, moving to Los Angeles between 1933 and 1936. The Latrobe Electric Steel Company and the Jessop Steel Company, both in Pennsylvania, were amongst the firms who made use of his expertise. His involvement with the latter is especially interesting, since it had been founded in Pittsburgh in 1901 by the Sheffield company of the same name. Armstrong became a major shareholder in Jessop's, which by the early 1920s had been taken over by American interests.

His influence at the company must have been considerable, for by the time of his death the managing director at Jessop's was Leonard Grimshaw, his stepson.

In 1936 Armstrong left Beverly Hills (his house was later occupied by Isaac Stern, the renowned violinist) and moved to Westport, Connecticut. His remarkable productivity was beginning to wane. For over fifteen years he had been one of the most prolific of America's alloy steel inventors. From 1917 to 1936 he registered over 50 patents, his most productive years being 1923 (7 patents), 1924 (8 patents) and 1925 (7 patents). The only year in which he registered none was 1918. His patents ranged widely, covering roller bearings, immersion water heaters, electrical furnaces, alloys for cutting steels, and stainless steel tubes. He was also involved in the metallurgical process which enabled automatic cigar lighters in cars to be made and claimed to have made more money from this than from all his other inventions![18] He also developed an important process which aimed at producing composite bodies having facings of a corrosion-resistant material (such as chromium steel) with iron or steel backings. This was the so-called "Armstrong process", patented in 1936, which was to be pushed commercially by the Jessop and Latrobe steel companies.[19]

But after 1936 Armstrong only took out seven patents (the last two in 1941) and appears to have entered a period of semi-retirement. A wealthy man—a demi-dollar millionaire, in the days when the term really meant something—he became a well-known figure in the Engineers Club of New York, the Westchester Country Club and the Fairfield Hunt Club. Surprisingly, "PAE" did not become an American national until 1943, two years after he had married Dolly Grimshaw at Las Vegas.

The last word on his life was in the obituary columns of the newspapers, when they announced his death on 7 August 1949 at the age of 66 at his home in Coleytown Road, Westport, Connecticut, after a long illness. His second wife had predeceased him in 1948 and they had no American family. His English family never learned anything about his career in the USA and only upon genealogical research did they discover (and share) his considerable wealth.[20]

Armstrong had lived to see himself recognised as a leading figure in the development of stainless steel. In the year before his death, the leading trades journal, *Iron Age*, in a survey article on the alloy's history had paid tribute to him as "a pioneer in the development of complex stainless alloys".[21]

References

1 The conference proceedings were published in a special issue of *Historical Metallurgy* 19, No 1 (1985).

2 *New York Times*, 8 August 1949

3 **Bernard Armstrong,** *Anglo-Scottish Relations and The Border* (privately printed, Clan Armstrong Trust Ltd, 1991)

4 British Patent No 22,309, 17 October 1904

5 Information supplied to Bernard Armstrong by the Institution of Mechanical Engineers, letter, 10 September 1957. Percy Armstrong was a member of both the IME and the Iron and Steel Institute

6 The news of Armstrong's departure to New York was later communicated to his wife through her brother, Percy Whitaker. He paid a regular modest maintenance and also partly subsidised the education of his son, Bernard. The latter had no personal recollection of his father

7 **G. Tweedale,** *Sheffield Steel and America: A Century of Commercial and Technological Interdependence, 1830–1930* (Cambridge: Cambridge University Press, 1987)

8 US Patent No 1, 322,511, 25 November 1919. Armstrong's alloy was considered at the time as a type of stainless steel. However, as he pointed out, the term "stainless" was something of a misnomer, since discoloration and staining could occur with most alloys of this type (even Brearley's cutlery stainless steel)—though this did not affect the corrosion-resisting properties or usefulness of the alloy. Armstrong therefore preferred the term "stable surface" or "Rust-less" to describe a surface "that does not suffer from progressive corrosion, but does not mean, in any sense, a surface that will not become darkened, stained, or discolored in some way". See Armstrong, 'Stainless Steel or Rustless Iron Correctly Described as 'Stable Surface Iron', *Transactions of the American Society for Steel Treating* 8 (1925), pp. 163–89, 166; and idem, 'Corrosion Resistant Alloys—Past, Present and Future—with Suggestions as to Future Trend', in 'Symposium on Corrosion Resistance Alloys, *American Society for Testing Materials* 24, Pt. II, (June 1924), pp. 193–207. Discussion, pp. 435–6; letter, pp. 443–449

9 'Silcrome Steel', *Engineering* 126 (1928), p. 368. Quoted in Ernest E. Thum (ed), *The Book of Stainless Steels* (Cleveland, Ohio, 2nd edn, 1935), p. 6, which also has a portrait photo of Armstrong

10 For the best account of the history of stainless steel, see John Trueman, 'The Initiation and Growth of High Alloy (Stainless) Steel Production', *Historical Metallurgy* 19, No 1 (1985), pp. 116–25

11 See H. Brearley, *Knotted String: The Autobiography of a Steel-Maker* (London: Longmans, Green & Co, 1941), pp. 139–42. Brearley makes no mention of Haynes or Armstrong

12 Quoted in Ralph D. Gray, *Alloys and Automobiles: The Life of Elwood Haynes* (Indianapolis: Indiana Historical Society, 1979), p. 164

13 *Engineering* (n. 8). Report of Ludlum Steel Co *versus* Daniel F. Terry

14 Thum, *Stainless Steels*, p. 485

15 See Leslie Aitchison and William I. Pumphrey, *Engineering Steels* (London: Macdonald & Evans, 1953), p. 425. See also F.R. Banks, 'Valve and Valve Seat Technique for Automobile and Aero Engines', *Proceedings of the Institution of Automobile Engineers* 33 (1938–9), pp. 334–94

16 Information from C.B. Templeton, Allegheny Ludlum Steel Corp, April 21, 19 November 1958

17 Ibid

18 Bernard Armstrong interview with G.O. Carlson, Thorndale, Pennsylvania, May 1957

19 Patent 446,439, "Improvements In and Relating to the Manufacture of Composite Metal Bodies"

20 His English family's claim to share equitably with the other legatees in the USA was not contested at law and was very welcome to them

21 **C.A. Zapffe,** 'Who Discovered Stainless Steel?', *Iron Age* 191 (14 October 1948), p. 128.

Authors

Bernard Armstrong (BSc Econ) was formerly Principal of the Technical College in Dunstable, Bedfordshire. In 1957, as Head of Management Studies at Portsmouth Technical College, he was part of a

European team sent to the USA to study American business methods. While there, he took the opportunity to begin researching his father's career, which until then (despite an annual exchange of letters) he had believed had mostly been as a self-professed "salesman of metal products". Since his retirement in 1975 he has been engaged in further genealogical research into the Armstrong family.

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