The metallurgist as entrepreneur: The career of Sir Robert Hadfield

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Introduction

Sir Robert Hadfield is now largely forgotten as a major industrial figure. True, in his native Sheffield some individuals would still recognise the company name "Hadfields" (if only for the controversial events surrounding the 1980 steel strike), but even they would probably be unable to identify its most illustrious member or recall any details about his life. The relics of Hadfield's life in the city are rapidly being effaced: the firm's famous East Hecla Works has been obliterated by Meadowhall shopping mall (without even a commemorative plaque); the Vestry Hall in Attercliffe, his birthplace, is now derelict; and so too is his country residence, Parkhead House. Hadfield's life seems nothing more than a mordant comment on vanity and the ephemeral fame of "great men", particularly industrialists.

Hadfield's work does survive in the written record. A standard source, *Chamber's Biographical Dictionary*, Edinburgh, W. & R. Chambers, 1990, presents the basic information: born in Sheffield in 1858, the son of a Sheffield steelmaker; took over the family firm on the death of his father; at 24 discovered manganese steel and then silicon steel; and also worked on armour-piercing and heat-resisting steels. This source is typical. It emphasises Hadfield's great discoveries in metallurgy, but only mentions in passing his work as an industrialist.[1] This is unfortunate. After all, what makes Hadfield's career unique is that he was both a renowned metallurgist *and* chairman of one of the world's biggest steel firms. With the possible exception of Sir Henry Bessemer (who actually was not a metallurgist), none of the great names in steel have so successfully straddled the commercial and technical spheres.

This article illuminates Hadfield's business career: how did he become head of a steelmaking firm? how did his metallurgical discoveries relate to the company's business? and what qualities made Hadfield so successful as an entrepreneur? It also addresses some larger themes, such as the part personality plays in industrial development and Hadfield's long-term business legacy. It draws particularly on the Hadfield papers in Sheffield City Library. These are by no means complete (and one can only lament the company's destruction of so much of Hadfield's personal and commercial documentation), but much interesting material has survived.[2]

***Fig 1:** Sir Robert Hadfield at about the turn of the century (possibly in 1905). The stiff, stand up white collar was a trade mark. (Courtesy Sheffield City Library)*

The Years of Success

Hadfield was fortunate to have been born during a transitional period in the steel industry. Two years before his birth, Bessemer had announced his revolutionary pneumatic process; Siemens' open-hearth furnace was soon to be perfected; and by 1868 Robert Mushet had discovered self-hardening tool steel, which hinted at some of the future possibilities in adding elements to steel.[3] In retrospect, we can appreciate that with many of the technical problems in steel production already solved, the field lay wide open for an investigator intent on changing the structure of steel itself.

Sheffield was then the steel capital of the world and Hadfield himself was Sheffield born and bred (Sir John Brown was a close relative and Hadfield was born

within yards of the tomb of Benjamin Huntsman, the inventor of crucible steel). This aside, Hadfield owed his rapid rise to the simple fact that his father, also named Robert, owned a steelworks. The achievements of Robert Hadfield Snr (1832–88) were to be overshadowed by those of his son, but nevertheless they were substantial. The setting was Attercliffe, once a small village in the Don Valley, which was to be inundated after the 1840s by the great Sheffield steel firms: Brown's, Firth's, Vickers, Cammell's, Jessop's and Sanderson Bros.[4] Hadfield's Steel Foundry – based at the Hecla Works in Newhall Road, Attercliffe – joined their ranks in 1872 when there was still room in the industry for companies capable of exploiting new opportunities. Hadfield Snr and his foundry manager, John Mallaband (1831–97), began pioneering two important lines of business. The first was steel castings, which were to be increasingly in demand after the 1870s by the engineering trades, but could only be launched after steelmakers had overcome some formidable production problems.[5] The second was armour-piercing projectiles, another area fraught with immense technical difficulty, in which Continental manufacturers had taken the lead.

When Hadfield joined his father's business shortly after leaving school, it was already an established name in Sheffield steel. His father, by all accounts a thoroughly decent, hard-working and generous man, was a respected pillar of the local community.[6] Hadfield therefore already had social position and wealth (apparently, his father had given him £10,000 on his coming-of-age in 1879!) and his options were wide open. Ignoring the attractions of Oxford and Cambridge or a life of leisure, Hadfield chose steel. At about this time he kept a diary, much as any other adolescent has done, but his interests were far from typical. "Went to business"; "melted steel", were characteristic entries, and the diaries also record experiments with a crucible in his parents' house.[7]

The stage was set for Hadfield's remarkable discovery of 12.5 per cent manganese steel in 1882, the revolutionary nature of which has long been recognised. The unique properties of this alloy (the first commercial austenitic steel) in the water-quenched condition were exceptional toughness and ductility, the capacity to harden rapidly by cold-working to a hardness of about 550 Brinell at the point of stress, and its non-magnetic character, which persisted even in the strain-hardened condition.[8] Hadfield has described the scientific details in his own writings.[9] Less well known is the commercial development of manganese steel, which provides a fascinating business case-study in its own right. The breakthrough did not occur in isolation. A business trip to the Paris Universal Exhibition in 1878 had preceded it, which had introduced Hadfield to the work of French metallurgists, such as Alexander Pourcel of the Terre-Noire Co, in producing high-grade ferro-manganese — a crucial stepping-stone to Hadfield's experiments.[10] Another important inspiration was provided by Hadfield's visit to America in 1882 — an industrial Grand Tour — which, as his extant diaries show, galvanised him into action and released all his latent energies. The vision of a rapidly industrialising America and its huge potential was one Hadfield did not easily forget and it influenced his business strategies for several decades.[11]

Hadfield's genius was not only manifest in the discovery of the alloy, which proved to be the easiest part, but also in his realisation that it was more than simply a metallurgical curiosity. In contrast to other researchers in alloy steel, such as Michael Faraday and Robert Mushet (with whom he has sometimes shared the title of "father" of alloy steels), Hadfield had the entrepreneurial ability to launch the steel commercially. This was important, since it was apparent from the immediate reception of manganese steel that there was little demand from engineers for such an alloy.

Hadfield's thoughts turned to America and in particular to the market for steel railway wheels. His father wrote to J. D. Weeks, their American agent, in 1884: "Now there is nothing that this steel is so well adapted for as Railway and Tram Car wheels, and there is such a vast trade to be done in these that we are most anxious you should induce car wheel manufacturers to adopt our Patents . . . once adopted these steel wheels will annihilate all other wheels owing to their cheapness, lightness and great strength".[12] But Hadfield ran into a problem that has often beset pioneers: the properties of the steel were so novel that a good deal of conservatism had to be overcome; and no one, including Hadfield, was quite sure what manganese steel's best uses would be. As he told Weeks: "in a new material like this and giving such entirely opposite results to ordinary steel, you may be sure that we have to feel our way very slowly, to learn its peculiarities step by step, but I feel confident from the results . . . obtained, that there is a grand future before it".[13] Costly and time-consuming research followed. By 1884 Hadfield was able to report: "We know and are sure it can be regularly and successfully made and what is necessary is to get the material into marketable forms and tried in actual work".[14] Ironically, manganese steel proved unsuitable for railway wheels (because of differential wear), but ideal in trackwork, crushing machinery, excavator teeth and numerous other industrial applications where its work-hardening potential could be realised.

Fortunately, the Hadfield-Weeks' correspondence — some hundreds of transatlantic letters — has survived, impressive for its bulk and the energy with which Hadfield pursued his goal.[15] It shows Hadfield increasingly taking control of the business as his father's health declined from a serious liver complaint (he died in 1888). It was soon apparent that a new and irresistible force had arrived on the scene. Hadfield Snr, who believed that his own ill-health was due to overwork, was disturbed by his son's relentless

dedication and wrote:

> Your grave fault is you *exhaust* your *vital* energy *faster* that it is *possible* for it *humanly* to be replaced. *No medicine* can restore this *equilibrium*. *Change*, *rest may* aid. *Unfortunately* your highly strung *mental organisation* and *over-anxiety combined unfits* you *bearing* this continued *intense high-pressure* and *you will* not *profit* from my *sad* experience. What is *money without health* and happiness?[16]

These poignant warnings had no effect. A young man in a hurry, Hadfield persuaded his father on his death bed to incorporate the business under the Companies Act, thus gaining for the firm the benefits of limited liability and a broader capital base, while maintaining its private character. As Hadfield explained to John Mallaband, who was given a seat on the board: "I am therefore investing much more of my own money than intended, principally for the purpose of being able to have matters so that you and I with my father's interests can control affairs and not be interfered with by anyone".[17] In 1888 Hadfield became both chairman and managing-director and was to exercise absolute control over the company until his death.

Hadfield's dominance stemmed from a large personal shareholding and his voting powers at board level, which meant that he could never be removed or outvoted.[18] It also emanated from his autocratic personality and his phenomenal energy. He regularly worked a sixteen-hour day and was described as the "hardest working man under the sun. He worked in his home, in his office, at the works, in the train, in the drawing room, at the club, in his car".[19] He had a staff of at least six male secretaries, one of whom was constantly at hand (even at night). When travelling between Sheffield and London, he "always brought two or three of his secretaries down with him, travelling in his Rolls Royce, which would have to be driven at a speed at which he could dictate".[20] In addition, he wrote reams of shorthand, a skill he had taught himself. He scolded and nagged his staff continually and had a well-deserved reputation as a martinet. For Hadfield "the ordinary divisions of the day counted for little, [so] that encroachment on their leisure hours was often the lot of members of his staff".[21] When at the works, none of the managers or directors were expected to leave before he did. Naturally, Hadfield was invariably present at important or prestigious occasions. Only once did he miss an annual company meeting: that was in 1909 when the pressures of this intense work-load resulted in such a serious nervous breakdown that it took a world cruise to restore his health.

It would be wrong to suggest that Hadfield did everything. He quickly built up a loyal board and a cadre of able technical and business managers. On the technical side, besides Mallaband, he was assisted in the laboratories by a string of metallurgists, such as I. B. Milne, Gifford Elliot, W. J. Dawson and R. J. Sarjant. Above these was Alexander Jack (1851–1927), who became managing director when Hadfield relinquished that position in 1905; Major Augustus Clerke (1871–1949), who had joined the board in 1913 from the Royal Arsenal; and (Sir) Peter Brown (1866–1948), one of the longest serving members of the firm, who eventually succeeded Hadfield as chairman in 1940. In addition, there were a number of board members chosen for their influence with Government and military departments. In 1888 the young politician George Curzon was given a directorship on the board worth £250 a year when his crony St John Brodrick was at the War Office.[22] But the major decisions were Hadfield's alone and it was he who dictated company strategy. Hadfields' business records, which survive in some profusion for the 1920s, give an insight into the running of the company. Even then, when Hadfield was spending much of his time in London and had effectively handed over power at the works to Brown and Clerke, it was the chairman who still pulled the strings, peppering his directors with streams of memoranda (characteristically red-lined and marked RAH), telegrams and telephone calls. Clearly in awe of him, only rarely did they question his decisions. Hadfield, with his steady stream of scientific discoveries, publications, and honours set the tone of the company. His early experimental successes had taught him a lesson (which seems commonplace now, but was less so then) he never forgot: research and development paid. From the outset funding was ploughed into research and the company's laboratory was soon as advanced as any in the world.[23] Whatever Hadfields' vicissitudes in the commercial world, the prestige of its chairman and the technical excellence of its research and products were never in doubt.

Besides manganese steel there was another area of business where Hadfield decided on a major commitment — armaments — especially armour-piercing projectiles. Despite its importance, this is a subject that has been neglected by historians of metallurgy, perhaps because they have been reluctant to stress the destructive uses of steel, or because the technology itself is so inscrutable. This was an area even more secret than most, that generated few books and papers; and even information on the commercial background is scanty.[24] In a sense, Hadfield merely continued the line charted by his father, but he brought to projectile manufacture his characteristic energy.

The company's interest in armaments began in 1880, when the Government needed shells to breach the new steel-faced armour plate (made by the likes of Brown and Vickers) against which chilled iron Palliser shot was proving ineffective. French firms, such as Holtzer, were then the leaders in armour-piercing shell manufacture. Robert Hadfield Snr accepted the challenge and by 1885 had patented a cast steel "compound armour piercing shell", which had a combination of hardened steel point and resilient body. But not until 1888 was sufficient expertise acquired by

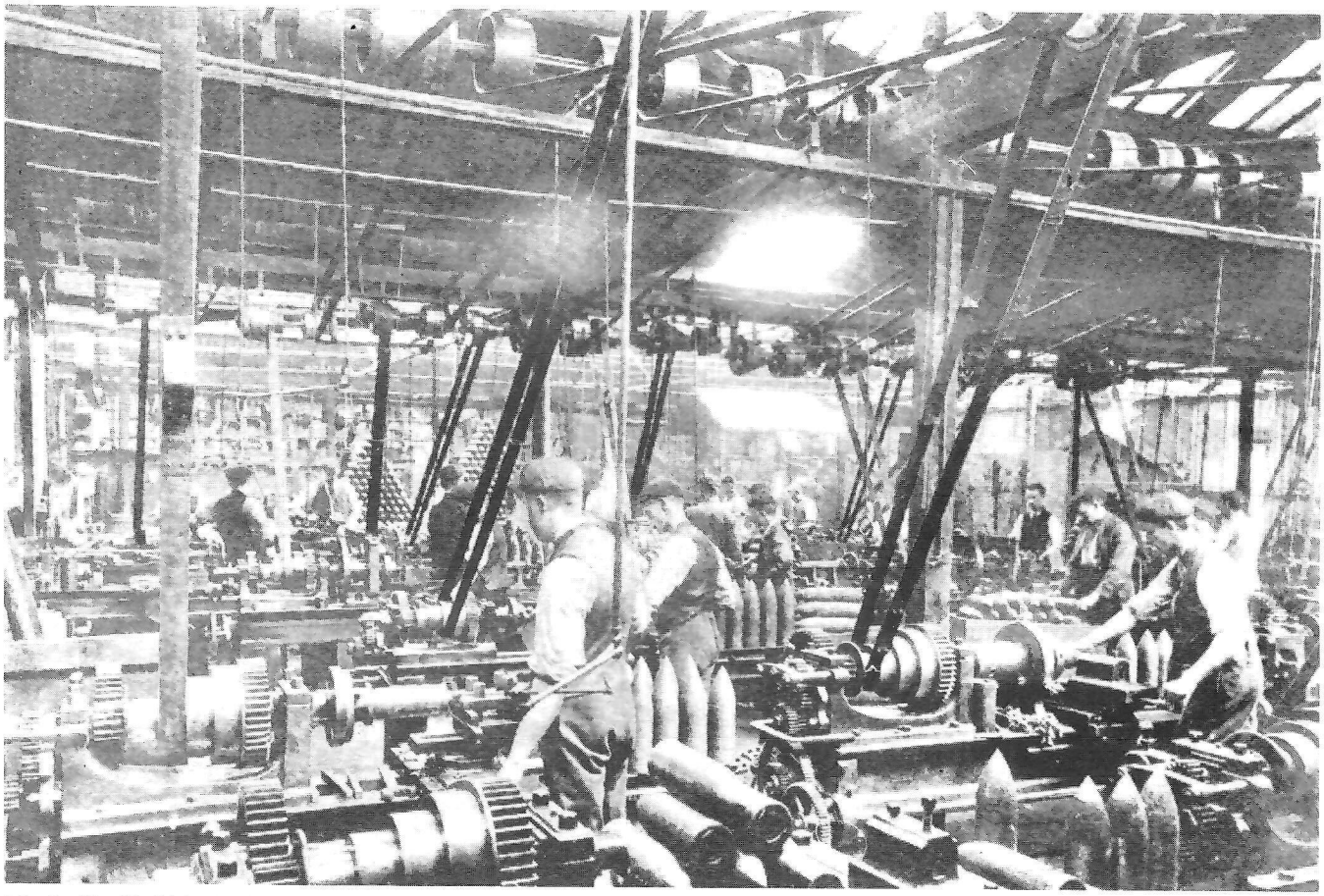

Fig 2: Hadfields' shell shop from a 1905 trade catalogue. The firm became a leader in the manufacture of armour-piercing projectiles. (Courtesy Sheffield City Library)

the firm to execute a Government order for 1,200 6-inch armour-piercing shells.[25] A hint of the problems involved occurs in Mallaband's fatherly letters to Hadfield at this time, when both appear to have been close to a breakdown:

> December 1888: "My Dear Old Boy when will the time come when you will have less to do. I almost despair sometimes and wonder if it will ever come now. Do please try to have a little rest and try to forget *even the shell*".
>
> May 1889: "I am certain this affair of shells has half killed you but thank God I hope you will feel easier . . . I hope if we get through all right you will be able to take it easier and I never shall be satisfied until it is so".[26]

Hadfield's eventual success in this field was said to have been "the result of chemical research into the action of often minute differences in proportions of alloys of iron and of the subsequent special heat-treatment the material receives".[27] This offered a unique challenge to Hadfield's talents and it was said that he "never tired of applying his metallurgical brain to the problems involved in the struggle for supremacy between projectiles and armour plate".[28] In the decade before the First World War it was a battle in which the projectile had the upper hand. A major innovation at the turn of the century was the soft-cap, which cushioned and lubricated the projectile as it hit hardened all-steel arour. Much attention was devoted to capping shells both by Hadfields and by their major competitor in Sheffield, Firth's. Briefly the latter appeared to hold a lead, particularly after the introduction of its "Rendable" explosive shell.[29] In 1898, however, Hadfield made an important breakthrough himself: a modification of the shell head with an "air deflector" (a hollow cap or false nose), which improved the flight velocity and penetrating power.[30] Later he tackled the problem of shells hitting plate at oblique angles, an increasing occurrence as artillery became more sophisticated and firing ranges increased. A design patented in 1912 included V-shaped recesses in the shell head, which prevented it skidding off the plate on impact and allowed it to function reliably at angles of attack up to 15 degrees.[31] The Admiralty could see no benefit in the idea and refused to adopt a design which could have given the Navy a considerable advantage at the Battle of Jutland.[32] Nevertheless, by 1914 Hadfield had made the firm probably the world leader in the highly specialised art of armour-piercing shell manufacture.

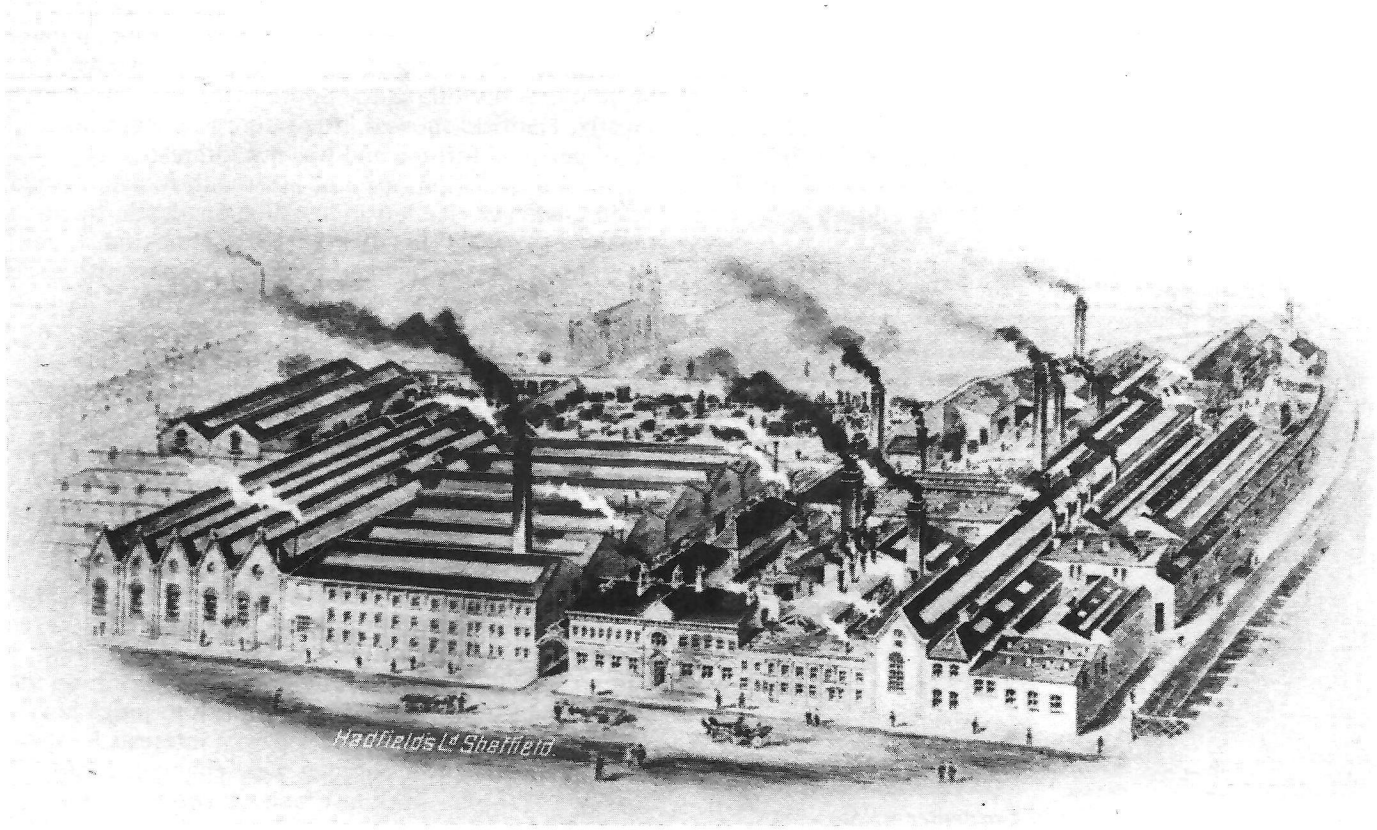

Fig 3: Hadfields' Hecla Works, founded in Sheffield in 1872. The main office building in the centre frontage, still stands in Newhall Road.

Nor did Hadfield neglect other opportunities to utilise his alloys for war. In 1904 Hadfields introduced "Era" steel armour for gun shields. Incorporating manganese and other elements, "Era" could be cast in a mould, contrary to the widespread belief that it was necessary to work metal mechanically to assure qualities of toughness and hardness. On the basis of "Era", which was adopted by the Admiralty, Hadfield suggested an exchange of shares with Armstrong Whitworth, which could have given Hadfield a seat on the board of one of the biggest arms makers in the country. This audacious offer was rejected, but it gives an idea of Hadfield's ambitions and how rapid the firm's progress had been in arms manufacture.[33]

Between 1900 and 1914, Hadfield's dedication, his many patents, his heavy expenditure on research, and his assiduous cultivation of both commercial and military business began reaping rich dividends. Manganese steel took off after the late 1890s and became a major engineering material. A Hadfields' trade catalogue of 1905 shows the wide range of manganese steel products and the enormous business this brought to the firm.[34] Not only did the company produce steel, but it incorporated its alloys in products of its own design. These included various types of rock crushers and stone elevators, which were themselves impressive pieces of engineering. Hadfield's other major alloy, silicon steel, was also entering service in electrical transformers. Meanwhile, Hadfields was supplying the Government with half its requirement for armour-piercing projectiles, with military orders now accounting for about 18 percent of Hadfields' turnover. Abroad the performance was no less impressive: manganese steel trackwork was sold as far afield as Australia; projectile orders were received from Japan; mining equipment was in heavy demand in South Africa; and Hadfield's patents were worked extensively on the Continent. Hadfield himself had maintained a close interest in the USA, visiting it eleven times between 1892 and 1914. He personally introduced manganese steel there through his licencees, the Taylor-Wharton Iron & Steel Co in New Jersey, and also won Hadfields important shell contracts from the US Army and Navy.

Hadfields' profits also took off after the late 1890s (see Figure 5). Between 1894 and 1914 the firm's capital grew from £135,750 to £700,000 and the workforce from 530 to 5,690. The Hecla Works was now inadequate and in 1897 commercial work was transferred to a major new factory, the East Hecla Works, built on a green-field site at nearby Tinsley.[35] From almost nowhere, Hadfields by 1914 had become the fourth largest Sheffield steelmaker (in terms of employment) behind the big three of Vickers, Brown's and Cammell's. This was a remarkable achievement: Hadfield's competitors had an earlier start, were all vertically integrated concerns, and derived strength from alliances and large management teams.

Personality and Motivation

Not only was his company highly successful commercially, but the period before the First World War was a time of great personal triumph for Hadfield: elected president of the Iron & Steel Institute in 1905, the year its members visited Sheffield, he was knighted in 1908 and elected Fellow of the Royal Society in 1909.

Fig 4: Left to right: Sir Henry Carpenter FRS; metallurgist; Bessemer Medallist (1931); W. H. Lysaght; Sir Robert Abbott Hadfield, BT, FRS; metallurgist; Bessemer Medalist 1904; Kenneth Headlam-Morley, Secretary ISI 1933–67. Picture taken in 1934

Hadfield's personal style was well-suited to the ceremonial and formal occasion. Of medium height and slim build, contemporaries found him "good looking in a severe sort of way, [but] rather stiff and unfriendly".[36] Photographs confirm this impression, showing an austere figure, invariably dressed formally in a high, stand-up white collar. He was punctilious with his staff about the wearing of dinner jackets for the evening meetings of the professional societies and was once shocked when a prominent member of the Iron & Steel Institute appeared at such a function wearing his ordinary clothes. He had a similar aversion to profanity, even on the shop-floor. One scientific colleague's "deliberate and ostentatious cult of the vernacular at meetings jarred very much [with] Hadfield's sensibilities as definitely among the things that are not done".[37] A great supporter of trades and technical societies, Hadfield had little interest in social functions that were not in some sense formal, or connected with business or science. Only his powers of oratory were unsuited to the big occasion: as even his friends admitted, his voice was far from impressive. A regular attender and contributor at Iron & Steel Institute meetings, it was recalled that "his rather hard and stiff manner did not make him an attractive speaker".[38]

What of his deeper business motivations? Financially, Hadfield certainly became very wealthy and enjoyed the customary trappings: a Rolls Roycs (which he never drove himself), Parkhead House, a London base in fashionable Carlton House Terrace, and winter vacations at his villa in the South of France.[39] But mostly, Hadfield showed little interest in acquiring a great personal fortune and was not interested in financial speculation, most of his wealth remaining tied up in Hadfields. He left £420,690 at his death, by no means a large sum for such a leading industrialist, and aside from investments and property his personal assets were few (only a few books and paintings).

Temperate in his habits, expensive food and wine meant little to him. He had a passing interest in music, art and books (particularly rare metallurgical texts), but was contemptuous of mere "entertainment", such as radio. Religion evidently did not play as big a part in his life as it did for his father; and although he was a freemason and founded lodges at Sheffield University and the Engineers' Club, London, the brotherhood does not appear to have been a major interest. In 1894 he had married a beautiful and well-connected American, Frances Belt, nee Wickersham, but they had no family. Hadfield's wife hardly emerges from the surviving documents, making it difficult to judge her, but both appear to have had separate interests by the inter-war period. Her energies were channeled into charitable hospital work in France in two world wars, work that was indulgently and generously supported by her husband.[40]

The quest for personal recognition, influence and power was undoubtedly a far more important motivation. Here we come to one of Hadfield's characteristics, which anyone familiar with his career will find difficult to ignore — his transparent vanity. This was apparent in his love of honours, his fascination with the ceremonies of the scientific societies, and his constant outpourings of papers and books.

Something of Hadfield's personality surfaces in his publications, which, notwithstanding their considerable merits, are mostly written in a stiff, verbose and humourless style characteristic of the man. Over 200 publications bear Hadfield's name, ranging from major monographs and scientific articles, to annual reports and letters to *The Times*.[41] In virtually all of these it is impossible to proceed very far before finding Hadfield crowing about his achievements, especially manganese steel. Not for Hadfield the role of quiet, self-effacing scholar. Even when the title might suggest otherwise, the publication is usually about Hadfield and his place in science's great hall of fame.[42] The onward march of metallurgy and its culmination in his own work was his favourite topic and he endlessly recycled the saga throughout his career. Hadfield's lectures, which he laboriously prepared with specimens and slides, spared no details and were evidently something of an endurance test for his listeners.[43] So too were the annual shareholders' meetings, which the chairman milked for maximum effect: in contrast to the annual meetings of Vickers, which were sometimes over in less

than ten minutes, those at Hadfields became "legendary for their long-windedness".[44]

Nor did Hadfield's publications always represent his own work: he was quite happy to utilise his secretaries and research assistants to 'ghost' papers and books. Many of Hadfield's scientific papers were joint publications and it is not always apparent who was responsible for the major effort. This may have been unavoidable in a career as hectic as Hadfield's, but in at least one case, concerning his joint-research with Sir William Barrett on silicon steel, a collaborator felt unhappy with his eventual recompense and credit.[45]

One of Hadfield's closest assistants (and co-author) for nearly forty years was Dr Sidney Main. His unpublished biography of Hadfield gives the best (albeit reverential) portrait.[46] According to Main, two things in life gave Hadfield particular pleasure: one was the weekly privileged gatherings of the dining club of the Royal Society. The other was the production of shells:

> Excepting possibly under the thrill of the great occasion in which he was a central figure, nothing in greater years caused him greater excitement [than projectiles hitting armour]. He was the first from a shelter after a round had been fired to inspect what had happened to the armour plate. On those occasions when he could not be present the telephones were kept incessantly busy and those around him had no peace until the full result could be known.[47]

A test-firing was the usual treat for visitors, who were sometimes given a large-calibre shell as a present. George V accepted one in 1915 as a souvenir and sent it to Buckingham Palace. By 1919 circumstances had changed and Lloyd George, not surprisingly, declined to witness a trial shot and instead asked to be shown works of peace. Recalled Main:

> it was something of a disappointment for Sir Robert. Not to be denied, the round arranged for was fired after the departure of the distinguished visitor: not only that one but several more in succession. Hands were laid on specimen projectiles of antique vintage and instructions given to fire them regardless of any question of the utility or otherwise of so doing. In fact, a regular orgy [took place], and the only time [I] knew [my] chief to let himself go in such a fashion.[48]

It was a revealing episode. Not surprisingly, Hadfield's writings display few regrets at the enormous human suffering inflicted by the output of Sheffield steelworks. After all, the losers had been the Germans, whom Hadfield detested. In a typical outburst, he blamed "Huns of all classes" for the war and attacked German scientists for the alleged civilian atrocities caused by poison gas, flame-throwers, long-range guns, submarines, airships and aeroplanes. In the future, he believed: "the enemy's men of science, when they look back will certainly find everything to be ashamed of and nothing of which they can be proud. On the other hand, the scientific and technical man on the Allies' side has not only clean hands, but a clean mind."[49]

But Hadfield was far from being a monster. He only shared the common patriotic assumptions and prejudices of his day. He was also more complex than has so far been suggested. Hadfield may have been an exasperating employer, but where his own workforce was concerned he was extremely loyal and compassionate. He was the first in the steel industry (and perhaps the first in the country) to reduce working hours. Hadfield later wrote: "Until I introduced my scheme at our Works, the workpeople had to start at 6 a.m. and without breakfast. We first tried 52 hours and then in 1894 . . . went straight to the 48 hours a week, the men coming in after having had their breakfasts at home. This too without any reduction in wages for the shorter time worked".[50] (This can be compared to the seven-day, 84-hour week in American works at that time.[51]) In fact, Hadfield refused to reduce wages, because he did "not believe the underdog should be cut down or asked to consider this unless in dire necessity". He was therefore at the forefront of initiatives to improve industrial relations. Though a great admirer of American industrial methods, he was not attracted by systems such as Taylorism, which he considered promoted efficiency at the expense of the workers. Labour relations were therefore excellent at Hadfields at all levels. The board, too, though worked off their feet, obviously felt there were many compensations: they may have been long-suffering, but they were also nearly all long-serving.

Hadfield also inherited the liberal ideals of his father. He gave steadily to a number of causes both political and scientific. These included the Liberal Party, various organisations involved with furthering Commonwealth and Empire trade, and a number of educational and technical establishments.[52] Keenly aware of the importance of research and development (perhaps *the leitmotif* running through his writings), he not only spent heavily within the company but also supported Sheffield University in funding extensions to its metallurgical laboratories.[53] Interestingly, he gave a fortune (some £100,000, or about half his total lifetime's donations) to his wife for her charitable hospital work. (One wonders whether Hadfield was aware of the irony of subsidising such work from profits partly derived from armaments.) Hadfield was also a faithful servant and supporter of many of the professional institutions, such as the Iron & Steel Institute. Finally, one should say that Hadfield's voracious appetite for self-publicity was not entirely motivated by a craven need for admiration: he was also aware that it publicised the firm, its products and his beloved Sheffield. In short, Hadfield's despotism was benevolent.

Zenith and Decline

The First World War was the turning point in

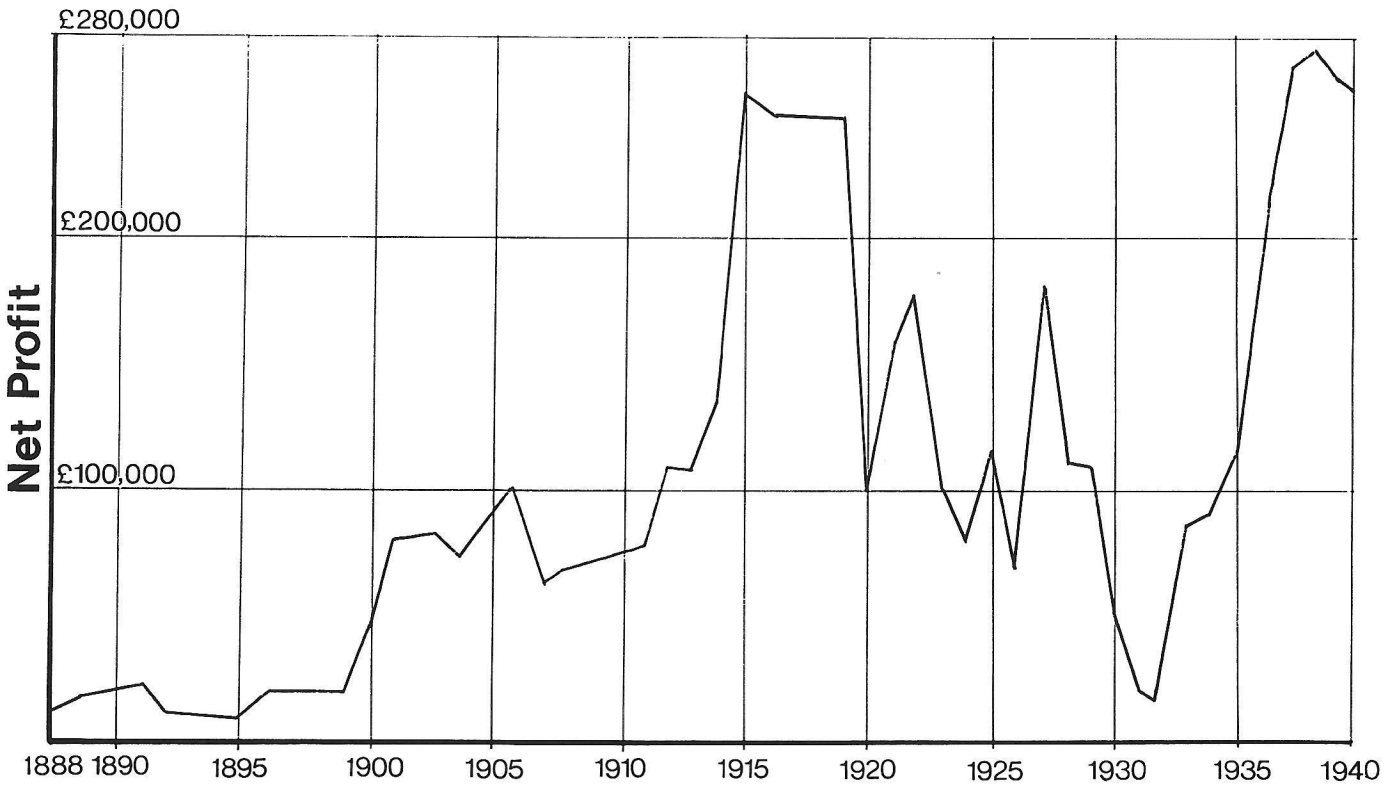

Fig 5: Hadfields Limited: Net profit 1888–1940. (Source Shareholders' minute books)

Hadfield's career, as it was for the Sheffield steel industry. The war effort saw Hadfields at full tide and stretched almost to breaking point. The firm's workforce more than doubled from 6,510 in 1915 to over 14,000 in 1917, while the value of its output soared from £4 million to over £9 million. It was now one of the biggest steel firms in the country. Hadfield was unable to resist the temptation to expand output drastically when the Government demanded more armaments capacity. Hadfields organised a National Projectile Factory within the works; greatly increased its electric steelmaking capacity; began the production of new lines such as howitzers and trench mortars; while Hadfield himself became a member of nearly a hundred councils, committees and sub-committees. His directors were also "working day and night seven days a week [which] imposed upon them a physical and mental strain almost beyond endurance."[54]

The War was immensely profitable to Hadfields, but there was a price to be paid. In the 1920s Hadfield faced a number of problems, both business and personal, which would break the firm's upward momentum. Armaments orders virtually vanished after 1918, leaving the firm's production profile seriously distorted; Hadfields' (and Sheffield's) technical lead weakened once the chairman's alloy steel patents had expired and fresh discoveries became harder to find; and the demand for castings began to stagnate, as growth in the industry switched to rolled products and the newer heat-resisting and stainless steels for the automobile and aircraft industries. National labour problems in the 1920s also ended the stable labour relations at Hadfields and for the first time the company was plagued by disputes.[55] Major strategy decisions were obviously needed. But Hadfield himself was growing old. He had turned 60 in 1918 and three years later underwent a major surgical operation for a fistula. Henceforth, Hadfield was a sick man, who needed the regular ministrations of a male nurse.[56]

But he remained indefatigable. He declined to ally the firm with any of its rivals (as Firth's and Brown's had done), and instead made his own plans. After the war the Hadfield-Penfield Co was formed in Ohio as a realisation of a long-standing dream to begin production in the USA and break into the American market for armour-piercing projectiles (a feat already accomplished by Firth's subsidiary in Pittsburgh) and manganese steel. By 1926 the Bean car company in the West Midlands had also been acquired to give Hadfields a foothold in this expanding industry. New alloys for marine turbines were intensively researched and marketed. In a further effort to find novel technologies, a plant for making the suction rolls and papermaking machinery of the American inventor

William Millspaugh was installed at the East Hecla Works in 1933.

The results were disappointing. Hadfield-Penfield and Bean Cars went bankrupt, both firms failing to find a market for their products and suffering from incompetent management.[57] Hadfield's attempts to find a winning commercial formula with its new corrosion and heat-resisting alloys — the so-called "ATV" steels — also brought poor returns, since the product was expensive to develop and the market a relatively limited one.[58] Exasperated with the lack of success in this area, Hadfield castigated his fellow directors for their lack of effort and highlighted Firth's success with its new "Staybrite" (18/8) stainless steels. He appears to have blamed everyone but himself. On one of those rare occasions when his views were contested, Peter B. Brown replied:

> Firths since the war, as you know, linked up with [Krupps] and got all the advantage of their experience which, of course, gave them a good start. We started much later, and, mainly due to the attitude you personally took up, confined our attention over a very long period to practically ATV steel. We now have a department for pushing these steels, but this takes time. We are all anxious to do the best we can in this direction, but it does not help us much simply to draw attention to what Firths are doing . . . Of course, we could make a splash if you would like to give instructions to that effect, and spend £50,000 or £100,000, but that would not end the expenditure. I believe in walking before we start running.[59]

These blunders proved costly, profits fell, and during the early 1930s the unthinkable happened — Hadfields passed the share divident for four consecutive years and then wrote down its capital. For the first time shareholders, usually kept completely in the dark about the fine points of the Hadfield balance sheet, began asking awkward questions at the annual meetings — answers to which Hadfield, with his stiff manner and carefully-rehearsed speeches, was ill-equipped to provide.

The main problem was the difficult trading conditions of the inter-war period. But Hadfield himself must also carry some of the responsibility, as must his fellow directors. They attempted to transfer a nineteenth-century tyle of management into the twentieth, with little attempt at modernisation. Hadfield's plan to direct operations from London, leaving the daily running of the works in his co-directors' hands, did not always function smoothly. Consequently, the task of running Hadfields' disparate subsidiaries proved beyond them. The firm became particularly stretched during the early 1920s, when it was attempting to run both the Bean car business (an industry about which it knew little) and the Hadfield-Penfield Co. Remarked Hadfield: "This rushing over of our reps. [to the USA] won't do at such a critical time. They leave and no one remains . . . It's a pretty kettle of fish".[60] The management problem appears to have been recognised, but it was impossible to contemplate an overhaul while Hadfield was chairman. He had no intention of retiring. Like many powerful businessman — the tool steelmaker Arthur Balfour (Lord Riverdale) is another example[61] — Hadfield continued working far too long and completely neglected making any arrangements for a successor.

Hadfields needed new blood in the 1930s (interestingly, both Brown and Clerke died in the same decade as their chairman, whilst another director, W. E. Parker, died in the same year); instead it lived on past glories. Hadfield became an increasingly irritable old man, obsessed by fame and honours. Those who knew him well at this time found that "his chief interest appeared to be his abiding fame (already assured by his achievements)".[62] In particular he coveted a peerage, though his papers reveal that he refused the chance to buy one from Lloyd George. Hadfield's vanity, snobbery, his obsession with his past honours (and perhaps also his insecurity) are revealed in a self-congratulatory letter on his "long roll call of work" sent to an unnamed friend in 1928:

> *There are not many men who can show the list of Gold Medals, over a dozen now, and other awards conferred on me. I received my FRS some eighteen years ago, the PM only got his last year and Lord Melchett this year. Then I am very proud to think that I am a "membre correspondante" of the French Academy of Science, this year of the American Academy of Science, and of the Swedish Academy of Science since 1912, receiving too my DSc of Oxford last year . . . All these came to me like a bolt out of the blue for merit only — neither more nor less, no wire pulling or influence and as you can see much of it international. I have done all this scientific work and yet have been able at the same time to run a large industrial establishment . . . helping to make modern Sheffield and keep her abreast in scientific and technical progress and keep her abreast of the times. A large number of other firms have benefited from my work in Sheffield and elsewhere in our country. I am seventy years of age next month . . . but I don't suppose my country will remember all I have done.*[63]

Fortunately, the country's rearmament programme after 1935 rescued Hadfields from the doldrums and the firm began rapidly recovering lost ground. The chairman, however, did not live to appreciate this. In late 1937 Hadfield had a complete mental and physical breakdown and "the interests which had hitherto held him became burdensome. It was with repugnance that any matter requiring mental effort . . . was brought to his attention, and there was a particular aversion against putting pen to paper . . . the spirit that had sustained him after his serious illness in 1921 was no longer there. The upright military figure had become stooped".[64] Hadfield died on 30 September 1940, aged 81, virtually alone at his private home in Surrey.

Legacy

Sir Robert Hadfield's legacy proved a mixed one. At his death Hadfields was still one of the biggest steel foundries in the world. The company minute book records the following tribute in 1940:

> At the time he succeeded his father . . . the Company employed 400 workpeople, its annual turnover amounted to £73,000 and its works covered 4 acres . . . Under his chairmanship it has grown in strength and prosperity until today it employs 9,200 workpeople, its turnover has risen to nearly £5 million and the works cover over 200 acres.[65]

Much of this success was due to the chairman and shows that personality does matter in business. But he also saddled the firm with some intractable weaknesses that were to come home to roost after 1945.

These weaknesses were of two types: one related to Hadfields' product-line, the other to its management. As Figure 5 shows strikingly, the company was at its most profitable when it was functioning as a war machine, a role Hadfield himself found particularly congenial. The company had been launched in 1888 on the back of a large Government projectile order, and when Hadfield died the bulk of the business was again concerned with armaments. Between the wars, he had been reluctant to wind down Hadfields' capability in this area and continued to chase orders and research armour-piercing projectiles.[66] This policy obviously paid dividends during the Second World War, but it was at the expense of commercial business. Not surprisingly, when the war ended and ordnance contracts ceased, the company's order book collapsed. In 1945 the board felt "disquietude for the future prospects of the Company", in the face of overmanning, poor deliveries and the inefficient utilisation of plant. "What we really require is 'mass produced' lines", stated the directors, "[though] the steps we may be called upon to take may be revolutionary, so far as this company is concerned".[67]

But a radical overhaul was hindered by poor management. Hadfield's old team under Brown had steered the company through the war, but when Brown retired in 1945 no successors presented themselves. Hadfield had groomed no heirs apparent. The company admitted that "we have not at present the quality of chief executives necessary for the prosperity of the Company and that outsiders must gradually be brought in to strengthen the personnel".[68] Brown's replacement, Lord Dudley Gordon, did introduce a measure of *gravitas*, but he was a pale reflection of Hadfield with little direct experience of the industry.

In the 1950s when the demand for trackwork, coal mining equipment and ordnance began to dwindle the firm became dangerously exposed. A reorganisation, begun in 1948, did succeed partly in introducing new lines such as precision castings, boron alloys for nuclear reactors and hardened steel rolls. But even in the 1950s the company found it difficult to escape from Hadfield's inheritance. The Korean War provided yet another opportunity to become over-involved in armaments. Millspaugh became a wholly-owned subsidiary in 1945, but after nationalisation (when Hadfields temporarily divested themselves of it) the subsidiary absorbed large amounts of working capital and eventually became a millstone around the firm's neck.

By 1962 control of Hadfields passed to Sir Peter Roberts, the chairman of a consortium known as the Steel Trust, which recognised the need for further reorganisation in the Sheffield steel industry. Norman Hanlon, an engineer from Dorman Long, was recruited as managing director to rebuild and rationalise Hadfields.[69] However, overcapacity was now becoming a serious problem in the steel castings industry, leading in 1967 to the merging of Hadfields' foundry with that of its local rival, Osborn's. This proved a disaster and in the aftermath Hadfields (in a move which must have made its former chairman revolve in his grave) fell to a reverse takeover by Dunford & Elliott, a relatively obscure (though reputable) Sheffield re-rolling firm. Against the backdrop of a declining Sheffield steel industry, the course was now steadily downhill. In a painfully slow demise, Hadfields was bought first by Lonrho and then by the British Steel Corporation and GKN, who closed Hadfields in 1982 after over a hundred years of trading.

Nothing remains of the house that Hadfield built and his fear that he would be forgotten now appears to have been realised. However, to look for his commemoration in buildings, plaques and statuary is perhaps to misconstrue the nature of the technological revolution he fostered. His alloys are still in use and diffused around the world. In fact, Hadfield's formula for manganese steel has remained virtually unchanged since the 1880s. Moreover, the metallurgical tradition that he did so much to promote, based upon an acceptance of the crucial importance of research and development, has now become commonplace.

Whatever Hadfield's failings, it is difficult to withhold our admiration for his enormous energy, tenacity and willpower. Sheffield has seen other remarkable business leaders who have had these qualities — Tom Vickers, Mark Firth, Arthur Balfour — but none carried such a burden of scientific and business responsibility alone for so long. Above all, Hadfield grasped a fundamental truth about business life. As one obituary stated: "What if he did push his wares at all reasonable seasons; they were good wares worth pushing, and if he had been less persistent in his efforts the benefits which he was in a position to confer would have been less widely distributed".[70] The underlying theme of Hadfield's career stands revealed in this statement and remains relevant today: wealth needs to be created.

Acknowledgements

I am grateful to Donald Hodgkinson for my first sight of Sir Robert Hadfield's papers at the East Hecla Works in 1981. Richard Childs and his staff provided continued access to this material at Sheffield City Library Archives (SCLA). Marjorie Sheard, Norman Hanlon and Denis Ward furnished useful recollections and information. Finally, the Leverhulme Trust provided financial support for the writing of this paper, which was initially presented as the K. C. Barraclough Memorial Lecture to the Sheffield Trades Historical Society and Sheffield Metallurgical & Engineering Association, 25 February 1992.

References

1. The standard biographies are all by scientists. See C. H. Desch, *Obituary Notices of Fellows of the Royal Society* 3 (1939–40) 647–64; *idem*, *Dictionary of National Biography 1931–40* (London 1949), 384–6; S. A. Main, 'The Hadfields of Sheffield', *Bulletin of the Institution of Metallurgists* 8 (December 1950), 21–6; idem, 'The Contributions of Sir Robert Hadfield to Metallurgical Science and Technology', in C. S. Smith (ed.), *The Sorby Centennial Symposium on the History of Metallurgy* (New York 1965), 145–62.
2. See G. Tweedale, 'The Records of Hadfields Ltd, Sheffield', *Business Archives*, No 54 (1987), 31–9. One more source has now been located: Hadfield's correspondence with the American astronomer G. E. Hale, 1916–36, at the California Institute of Technology, Pasadena. The vast Hadfield company records were burned by the management in the 1960s, leaving extant the relatively small collection now in SCLA (unless otherwise stated, all manuscripts are from this source). The bulk of Hadfield's own papers must be presumed destroyed.
3. A bound volume in the Hadfield papers in SCLA contains an exchange of letters between Hadfield and Mushet in 1884. The latter haughtily dismissed the claim of manganese steel's inventor to have discovered a new alloy.
4. J. Holland, *The Tour of the Don*, (London 1837), 324–35; G. R. Vine, *The Story of Old Attercliffe* (Sheffield 1932–6); A. D. Walker, Attercliffe ca. 1841–1881: A Study of Its Iron and Steel Workers and Their Families in the Workplace and the Community (Sheffield University MA thesis, 1989).
5. The Hadfields' early problems with steel casting are described in a letter from J. Mallaband to R. A. Hadfield, 6 May 1895.
6. See the lengthy obituaries in the *Sheffield Daily Telegraph* and *Sheffield Independent*, 22 March 1888.
7. See Hadfield's "Scribbling Diaries, 1876–78".
8. *Manganese Steel*, Edinburgh: Published for Hadfields by Oliver & Boyd, 1956, with a foreword by E. W. Colbeck.
9. See also G. Tweedale, 'Sir Robert Hadfield FRS (1858–1940) and the Discovery of Manganese Steel', *Notes and Records of the Royal Society*, 40 (November 1985), 63–73.
10. The Terre-Noire Company's catalogue of its exhibits at the Exhibition was translated by the young Hadfield and then given to his father. The holograph translation is extant in the Hadfield papers. See also H. Lebasteur, *The Metals at the Paris International Exhibition of 1878: Their Resisting Properties and Their Uses in Railway Plant* (London, Paris 1880).
11. Hadfield's American diary does not appear to have survived, but fortunately it is reproduced as an appendix in S. A. Main, The Hadfield's of Sheffield: Pioneers in Steel (unpublished typescript, ca. 1950). However, Hadfield's notebooks of his American trips, in which he describes US steelworks, are extant and give ample evidence of his energy and powers of observation.
12. Hadfield Snr to Weeks, 29 May 1884.
13. R. A. Hadfield to Weeks, 17 April 1884.
14. R. A. Hadfield to Weeks, 4 July 1884.
15. The correspondence is in three leather-bound copy-press letter-books and covers the period, 1882–90.
16. Hadfield Snr to R.A.H., 16 February 1888.
17. Hadfield to Mallaband, 7 April 1888. Hadfield added: "I often wondered how [father] got sufficient capital, but I find he had done very well in certain land speculations, getting out in time, and an old uncle left him a considerable sum".
18. The directors' minute books reveal that in 1888 when the foundry became a limited company, Hadfield took up all 3,300 £10 fully paid ordinary shares; and 4,100 of the 7,700 £7 10s ordinary shares. No one else had more than 200 of the latter. By 1931 Hadfield held 240,000 of 1,844,784 £1 ordinary shares, with no other director holding more than 30,000. While he held 30,000 shares or more Hadfield was automatically managing director and chairman and could neither be rotated nor retired. He also had the right to utilise his patents for his own benefit.
19. *Engineer*, 170 (11 October 1940), 235.
20. Information from Marjorie Sheard, private secretary to Hadfield director E.H.M. Nicholson in the 1920s.
21. *Journal of the Iron & Steel Institute*, 142, No 2 (1940), 288.
22. The way in which Curzon tried to use his influence with Brodrick to further Hadfield's interests (to no great effect) is revealed in the Earl of Midleton papers, British Library, Add. 50073. See also R.P.T. Davenport-Hines, The British Marketing of Armaments 1885–1935, in Davenport-Hines (ed.), *Markets and Bagmen: Studies in the History of Marketing and British Industrial Performance, 1830–1939* (Aldershot 1986), 146–91.
23. For a description of Hadfield's laboratories, see *Journal of the Iron & Steel Institute*, No 2 (1905), 468–71. Such was Hadfield's prestige that the vaunted US Steel corporation hired him as a consultant at this time to draft a blueprint for their research facility and provide general technical help. See Paul A. Tiffany, Corporate Culture and Corporate Change: The Origins of Industrial Research at the United States Steel Corporation, 1901–1929, unpublished paper presented to 29th Annual Meeting of the Society for the History of Technology, 25 October 1986, pp. 4–5.
24. A useful survey is D. Vickers and T. Dawson, 'Armour and Ordnance', in *British Association Handbook and Guide to Sheffield* (Sheffield 1910), 285–329, though it refuses to divulge technical details. Extensive material relating to Hadfield's dealings with the Admiralty and Ministry of Munitions has also been lost: the Public Record Office has weeded most of it as of no interest to historians. Fortunately, the papers of the largest arms manufacturers can sometimes fill the gaps. See C. Trebilcock, *The Vickers Brothers: Armaments and Enterprise, 1864–1914* (1977); K. Warren, *Armstrongs of Elswick: Growth in Engineering and Armaments to the Merger with Vickers* (1989).
25. In 1884 Hadfield admitted to Weeks that the firm was supplying only rough shell castings to Woolwich, since "we have no experience in these matters". Letter to Weeks, 3 January 1884.
26. Quoted in Main (n. 11), chapter 4, pp. 4–5. The original letters appear to have been lost.
27. *The Times*, 21 April 1904.
28. Main (n. 11), chapter 9, p. 1.
29. *Modern Projectile Factories of Thomas Firth & Sons Ltd* (London 1912). See also, *John Brown & Company Ltd: Atlas Works, Sheffield; Shipyard and Engineering Works, Clydebank* (London 1903) 61–8.
30. Patent No. 16,901. 4 August 1898.
31. Patent No. 21,903. 26 September 1912. See also file of legal papers re. armament matters, Hadfields and Firth's, January 1913.
32. See C. N. Robinson, 'Ordnance and Armour', *Brassey's Naval and Shipping Annual* (London 1921–22), 163–95; I. Hogg and J. Batchelor, *Naval Gun* (Poole 1978), 103–5, 116–17. Also useful on the development of armour and projectiles is A. D. Stacey, An Historical Survey of the Manufacture of Naval Armour by Vickers Son & Co, and Their Successors, 1888–1956, English Steel Corporation typescript report (1956) in SCL Local Studies Department.
33. When Hadfield proposed exchanging shares with Armstrong Whitworth, Stuart Rendel wrote to Sir Andrew Noble on 20 November 1907: "What an extraordinary proposal! It puts me flat on my back and is a bolt from the blue! . . . Hadfield is to

become our largest share-holder, to have a seat on our board at a big salary, to draw £5,000 a year for twenty years, and we are to value his shares one-and-a-half times the value of his own . . . all this for a licence in England for a patent that may be worthless tomorrow! What a gamble!". The correspondence, kindly supplied to me by Dr Kenneth Warren, is in the Armstrong Whitworth Papers at the Tyne and Wear Record Office.

34. *Hadfield's Steel Foundry Co Ltd* (Sheffield 1905). See also the internal company document, "The Hadfield System: Its Application and Advantages" (ca 1897).
35. The Hecla Works continued to produce war material and Hadfield still used it as his main office and headquarters.
36. Letter from Lord Riverdale to the author, 18 February 1986.
37. Main (n. 11), chapter 8, p. 8.
38. H. Moore, 'The Iron and Steel Institute: Early Years', *Journal of the Iron & Steel Institute*, 207 (April 1969) 437.
39. Hadfield's London office and residence, 22 Carlton House Terrace, had become his main base by 1914. It allowed him to maintain close contact with Government departments and the scientific societies and henceforth — apart from his winter visits to France — most of his time was spent there. He still visited Sheffield whenever the occasion demanded, staying at Parkhead House, which he had bought in 1898.
40. Amongst the Hadfield papers are the notes (27 March 1939) of J. B. Thomas, Hadfield's executor, concerning an interview with Lady Hadfield. She deeply resented the fact that Hadfield had made provision in his will for others than herself. According to Thomas: "She expressed astonishment [at the value of the estate] and said RAH should have been worth at least half a million pounds. She said he had been badly advised and should have received expert advice so that he could have increased his assets by speculation in shares. I told her that RAH would never have consented". On Lady Hadfield's war work during the period 1914–18, see H. R. Macdonald, *The Story of the Hadfield Hospital* (privately published, n.d.). In the Second World War, she was involved in joint philanthropic work with Lady Spears (Mary Borden) in running the Hadfield-Spears ambulances. See Jacques Duprey, *L'Ambulance Hadfield-Spears* (Paris 1953), and M. Borden, *Journey Down a Blind Alley* (London 1946).
41. SCL Local Studies Department and Archives hold printed bibliographies of Hadfield's writings.
42. See for example, *The Work and Position of the Metallurgical Chemist; also References to Sheffield and Its Place in Metallurgy* (London 1921), which contains several chapters on Hadfield's work. In the chapter entitled "The Lecturer's Research Work", Hadfield reproduces at length Floris Osmond's fulsome praise of the discovery of manganese steel as "equal in importance only to the [discovery of the] effect of quenching". Hadfield immodestly describes this statement as "most important and quite true". Hadfield's most substantial works are *Metallurgy and Its Influence on Modern Progress* (London 1925); and *Faraday and His Metallurgical Researches* (London 1931).
43. Hadfield's presidential address to the Iron & Steel Institute is, characteristically, one of the longest. See *Journal of the Iron & Steel Institute*, no 1 (1905), 27–106.
44. L. Daniells, Metropolis of Steel: Patterns of Sheffield's Industrial History, unpublished typescript in SCL Local Studies Department, 1981, chapter 4, p. 11.
45. An intriguing file in the Hadfield papers documents Hadfield's meetings in 1924 with Barrett, whose complaints about his treatment were eventually stilled by a cheque for £500. One of Barrett's letters, 4 July 1924, refers to Sir James Dewar on his deathbead making a violent attack on Hadfield as "one of those . . . plutocrats who rob other people's brains". In this light, a subtle criticism might be detected in Harold Moore's assertion (n. 38) that Hadfield was an "expert in securing the help of others in his searches".
46. Sidney Main, a physicist, was a self-professed admirer of Hadfield. According to M. Sheard (n. 20), Hadfield had helped Main early in his career in some important personal matters, which was amply repaid by Main's homage. Although weak on Hadfield's industrial career, Main's biography gives the best glimpse of Hadfield's personality and the deferential style itself is revealing. The Iron & Steel Institute declined to publish it, perhaps because of these failings.
47. Main (n. 11), chapter 9, p. 4c.
48. Main (n. 11), chapter 9, p. 8.
49. Presidential address to Faraday Society, 12 November 1918, pp. 4–5. Reprint in SCL Local Studies Department.
50. Hadfield to a "friend", 25 October 1928. Hadfield co-authored with H. de B. Gibbins, *A Shorter Working Day* (London 1892).
51. For a fascinating account of the labour experience in the American steel industry during Hadfield's time, see M. Reutter, *Sparrows Point: Making Steel — The Rise and Ruin of American Industrial Might* (New York 1988).
52. A confidential memo lists Hadfield's gifts between 1889 and 1933: war (including hospital charities) £86,000; political £28,600; universities £10,970; societies £12,750. Total (including various other donations) £185,850.
53. 'Opening of Sir Robert Hadfield Metallurgical Laboratories at Sheffield', *British Steelmaker*, 4 (October 1938), 346–7.
54. Hadfield to Ministry of Munitions, 25 October 1918.
55. Hadfield wrote in an article, 'An Industrial Truce: Strikes, Losses and Perils. An Urgent Appeal', *The Times*, 26 September 1924: "Between 1869 . . . and 1919 . . . we never had a real strike or lock-out which caused the shutting down of the works. It was not until the fatal year of 1921 that the serious trouble began . . . [even though] there was no dispute of any kind between us and our men. The total wages lost to our employees between 1911 and September, 1924, amounted to £847,000 of which no less than £730,000 fell within the years 1919 to 1924. The stoppages which caused these losses were of no earthly advantage to our workers . . . [and] . . . they hit the firm which tried to serve them faithfully".
56. Information from Marjorie Sheard.
57. See G. Tweedale, *Sheffield Steel and America: A Century of Commercial and Technological Interdependence, 1830–1930* (Cambridge 1987); idem, 'Business and Investment Strategies in the Inter-War British Steel Industry: A Case Study of Hadfields Ltd and Bean Cars', *Business History*, 29 (January 1987) 47–72.
58. A modification of 18/8 (18 percent chromium, 8 percent nickel) stainless steel, "ATV" alloys had 20–40 percent nickel, which improved resistance to corrosion attack at high temperatures. Hadfields collaborated on these alloys with the French firm Commentry-Fourchambault et Decazeville, of Imphy.
59. P. B. Brown to Hadfield, 6 December 1927.
60. Hadfield memo, 30 April 1923.
61. According to his son, Arthur Balfour's tragedy was that "like so many Sheffield steelmasters, he carried on working too long . . . until he had a really serious breakdown". See 'Lord Riverdale Remembers', *Quality* (September/October 1984), 33.
62. I. Headlam-Morley (Secretary of the Iron & Steel Institute), *British Steelmaker*, 6 (November 1940), 12.
63. The letter, 25 October 1928, appears to have been intended to further Hadfield's quest for a peerage. Arthur Balfour (Lord Riverdale), equally hardworking but more socially adept, became Sheffield's only steelmaking peer in 1935.
64. Main (n. 11), chapter 13, p. 2.
65. Directors' Minute Book 3, 1 October 1940.
66. Even in the early 1930s, nearly 20 percent of Hadfields' turnover was in munitions, employing over 10 percent of the 4,000 workforce. See Clerke's comments to *Royal Commission on the Private Manufacture and Trading of Arms: Minutes of Evidence*, London, HMSO, Cmd. 5292 (1935–6) 41–85.
67. Reports for 1945 in Directors' Minute Book.
68. Lord Dudley Gordon, "Planning for Future — Personnel", in Directors' Minute Book.
69. Norman Hanlon found that Hadfield's heritage was still alive in the firm in the 1960s, especially with those with direct memories of him, such as the managing director Richard Lamb. Hanlon found the management at Hadfields "well disciplined — to the point of servility". Interview with the author, 12 July 1991.
70. *Engineer* (n. 19).