INTRODUCTION

By way of introduction I need to do two things. The first is to provide a historical outline of the life of James Watt, a general overview that will assist in situating my specific, and rather specialized, argument about the centrality of chemistry to his life and work. The second is to explain the structure and the strategy of my study, as well as some of the basic assumptions that underlie it.

The 'Great Steamer' – A Life Outlined

James Watt, who the geologist Roderick Murchison referred to in 1839, with a peculiar mixture of deference, affection and condescension, as 'the Great Steamer',[1] had been born just over a hundred years earlier, in 1736, to a moderately prosperous merchant family in Greenock, a small town on the lower reaches of the River Clyde, near Glasgow in Scotland. Watt's paternal grandfather was a 'professor' of mathematics, teaching that subject and navigation in a community dominated increasingly in the mid-eighteenth century by maritime trade. Watt's father was a ships' chandler and general merchant. While Watt's elder brother John entered the family business – he was lost at sea on a merchant venture – the family was prosperous enough to invest in an informal apprenticeship for Watt to the London-based instrument maker John Morgan. The young Watt's time in London was undoubtedly difficult. He worked exceedingly hard and suffered problems with his health. But the experience opened up for him a world of instruments, skills and trade that profoundly shaped his later career.[2]

The next step in that career was Watt's establishment as an instrument-maker at the University of Glasgow, within the confines of the College. Though Watt certainly did make and repair instruments for the professorate of the College he also engaged in a more general trade in musical instruments and fancy toys. In the early days he was also an agent for his father's business and plied the general hardware trade.[3] By all accounts, as a child Watt had been studious and thoughtful, though his education at the local grammar school had been badly interrupted by health problems. Whatever the case with his early education, after his apprenticeship he became an ardent and effective autodidact. He took full advantage during the later 1750s and early 1760s of the associations with the

Glasgow College professorate, and students, that his position at the College gave him. These were the years of his 'discipleship' with the newly appointed Professor of Chemistry, Joseph Black, from whom, in an informal fashion, Watt imbibed much of his early knowledge of chemistry, and of the chemistry of heat in particular. These were the years of Watt's first experiments with steam and with a model steam engine, famously given to him to repair by the Professor of Natural Philosophy, John Anderson in 1763. During this time too Watt befriended a number of students at the university, young men close to his own age. Among these was John Robison, his lifelong friend, and in his later years a key witness, both legal and literary, to Watt's work on the steam engine.[4]

On Glasgow Green today, in the shadow of the massive obelisk commemorating Lord Nelson, is a modest, inscribed boulder supposedly marking the spot where, in 1765, having contemplated the problems of the model Newcomen engine, Watt had the sudden inspiration of the separate condenser. His idea of condensing the steam in a separate vessel rather than in the main cylinder into which it had originally been injected led to a transformation in the efficiency of steam engines. The boulder celebrating this supposed 'Eureka!' moment was placed there only as recently as 1969, the year of the bicentenary of Watt's first steam-engine patent claiming the separate condenser as his invention. The story of the inspiration on Glasgow Green, however, goes back to the early nineteenth century. There is no direct evidence of its veracity in the Watt archives and it is one of many examples of the difficulties of separating fact and fiction in Watt's life.[5]

By the time that he took out his patent, Watt was already in a partnership with Dr John Roebuck of Kinneil, with a view to constructing a steam engine on Watt's new principles. Progress was slow and, faced with the exigencies of supporting a new family – Watt had married a cousin, Margaret Miller, in 1764, and their first child Margaret had been born in 1767, with James Jr following two years later – he abandoned the instrument and hardware business to pursue his fortune for the next few years as a journeyman civil engineer and surveyor. Watt worked on a score of projects, mainly canal and harbour surveys but also bridge and waterwheel constructions in the early 1770s.[6] It was whilst away from home, having just begun the Caledonian Canal survey, in September 1773, that Watt learned that his wife had died in the aftermath of childbirth. This brought his life to a state of personal and professional crisis. The work he was pursuing was incompatible with his obligation to his motherless children, and left him little time to pursue his true engineering enthusiasms. To cap it all, his partner in the steam-engine venture was in financial difficulties and it was increasingly obvious that the project was not going to prosper under his auspices.

In these circumstances, in 1774, Watt left Scotland to settle in Birmingham in the English Midlands and to pursue a new partnership with Matthew Boulton, the entrepreneurial 'hardware man' of that town.[7] Watt had met Boulton and

members of the circle known as the 'Lunar Society'[8] some years before. In fact, one of that circle, Dr William Small, had given Watt important advice on drawing up the specification for his 1769 patent. Boulton, who had his own reasons for being interested in steam power, negotiated an agreement with Roebuck for the 'transfer' of Watt and his scheme to Soho, Birmingham. The incipient engine was removed from Kinneil and installed at the Soho manufactory. Watt's 1769 patent had already run a significant part of its course and the new partners' capacity to exploit it was only just reaching fruition, and so, as part of the new partnership arrangements, Boulton and Watt agreed to seek an extension of the patent by Act of Parliament. Here Boulton's well-known and well-honed lobbying skills came into their own and the partnership was granted an extension of the 1769 patent (redrawn in 1775 so as to constitute a new one) to the year 1800.[9]

In Birmingham, Watt certainly profited from and enjoyed the natural philosophical intercourse with his fellow 'Lunatics', as the members of the Lunar Society designated themselves. His natural philosophical knowledge and acumen increased considerably during this period. But the late 1770s and early 1780s were also a difficult time for Watt. The primary market for the first Boulton & Watt engines at this period lay in the mining districts of Cornwall where Newcomen engines had been used for many years in pumping the mines. Although in retrospect we can say that the Boulton & Watt engines offered decisive advantages in efficiency (notably in the saving of fuel, which was expensive in Cornwall) that ought to have made penetration of the market easy, at the time much resistance was encountered. The early engines were not problem-free, and canny Cornish mine venturers sought to drive hard bargains. The business of erecting engines and adapting them to local circumstances was vexed.[10] Watt had to spend much time 'on the road' in Cornwall attending to these matters, a task to which he was temperamentally unsuited. Contentious, face-to-face (or even toe-to-toe) negotiation, bargaining and industrial 'arm wrestling' of the sort that Boulton thrived upon, distressed Watt. Headaches, hypochondria and fits of depression plagued him – as he had previously put it, he would 'rather face a loaded cannon than settle an account or make a bargain'. Boulton's sometimes reckless business practices also worried Watt, who as a much more cautious businessman, was on occasion a valuable counterpoise to his partner's excesses of fiscal irresponsibility and blind enthusiasm.[11]

Gradually, a degree of business stability, together with staffing arrangements that removed Watt from the 'front line' of the Boulton & Watt venture, gave him more time and opportunity to pursue further steam experiments, other philosophical interests and inventive activities. The arrival of the Reverend Joseph Priestley in Birmingham in 1780 gave renewed impetus to Watt's chemical investigations and interests. Priestley was already renowned for his discoveries of new 'airs'.[12] He and Watt shared many chemical interests, but it was Priest-

ley's experiments on the explosion of inflammable air with common air and with dephlogisticated air that led Watt into one of his few, high profile public appearances in the annals of late eighteenth-century natural philosophy. In 1784 Watt published papers in the *Philosophical Transactions* of the Royal Society of London, the most famous of them forming the basis of his claim to have been the discoverer of the compound nature of water.[13] This claim was far from uncontested either at the time or subsequently. In the *Philosophical Transactions* of the same year the eccentric, aristocratic natural philosopher Henry Cavendish published the paper that would be the basis for his own claim, and Lavoisier's later, but consummately theorized and prosecuted, experiments added him to the list of claimants.[14] What became known as the 'water controversy' did not create an enormous stir in the 1780s. Watt and his associates, for a time, vented their anger and frustration at what they saw as at best a careless appropriation of his ideas and at worst their outright theft. But there were good business reasons, if no other, for not creating too sustained a ruckus over the affair. It was not until the mid-nineteenth century that the water controversy was fought out in earnest. The protagonists then had their own agendas.[15] A crucial outcome of their struggle was to be a devaluation and mischaracterization of Watt's chemical work.

Even as he pursued these questions of high chemistry and philosophy Watt was also engaged in steam experiments that led him to the idea of 'expansive working' of the steam engine. This idea, and further key mechanical improvements, including the adaptation of the engine to rotatory motion, were the subject of Watt's second major patent of 1782. With rotatory motion now readily achievable through Watt's sun and planet gear system, the market for driving machinery was opened up to Boulton & Watt engines. The Albion Mill on the banks of the Thames housed one of the early rotative engines for grinding corn. Though not financially successful, and destroyed by fire in 1791, the Albion Mill was a valuable demonstration project, which helped the partnership to move into other rotative applications, especially in textiles, where the bulk of their engine business was to be.[16]

Another interest that Watt began to pursue at this time was in the bleaching of textiles. As part of a growing internationalization of their ventures Boulton and Watt visited Paris in 1786 in response to a government invitation to advise on the pumping machinery supplying water to the Palace of Versailles. They were also hoping, vainly as it turned out, to secure a privilege (the French equivalent of a patent) for their engines in France. Whilst in Paris, Watt, who had been elected a Fellow of the Royal Society of London in 1785, met many of France's leading natural philosophers. They were curious to meet a man whose steam engine improvements were already widely praised and whose papers in the *Philosophical Transactions* had created such a stir. These meetings were to greatly expand Watt's subsequent participation in the republic of letters and, specifically, in the

chemical debates of the late eighteenth century. One of these meetings was with Claude-Louis Berthollet who revealed to Watt his work on the bleaching powers of dephlogisticated muriatic acid. On his return Watt conducted his own experiments and a long correspondence with Berthollet. He advised his father-in-law, who was in the bleaching business, about the new processes and, more generally, played a significant role in the introduction of those techniques into Britain.[17]

Mention of Watt's father-in-law reminds us that, after the loss of his first wife, Watt had married again, to Anne McGrigor. By all accounts a strong personality and a good organizer of Watt's household, Anne bore Watt two more children, Gregory (b. 1777) and Janet (known as Jessy, b. 1779). Meanwhile Watt's son from his first marriage, James Jr, underwent a modern education that included a period of study and travel on the Continent, partially supervised and guided by Watt's friend and chemical collaborator Jean André De Luc. Watt Jr was an independent-minded young man whose relations with his stepmother and his father were often stormy. He was apprenticed to the firm of Taylor and Maxwell in Manchester in 1788, where he participated both in the burgeoning scientific life of the town through the Literary and Philosophical Society (f. 1781) and in the radical politics of some of his associates. During a visit to Paris with Thomas Cooper in late 1791 and 1792 Watt Jr expressed solidarity with the early revolutionaries, a move which, when reported in the British press as the action of 'James Watt', caused his father much embarrassment and distress. For a while Watt Jr was in great danger in the increasingly violent factional maelstrom of the mature revolution. Eventually, in 1794, he managed to return to England and, after a period lying low to ensure that he would not be arrested by British authorities, Watt Jr returned to his family and to the business. From that point onwards Watt Jr was to assume an increasingly prominent role in the business affairs of the newly constituted Boulton, Watt & Co. as the business was gradually passed on to the next generation. Watt Jr, perhaps in an effort to assuage his guilt about early waywardness, became an assiduous, almost maniacal promoter and defender of his father's reputation, especially his claims as an inventor and discoverer.[18]

An early forum for Watt Jr's efforts in that direction was the patent trials of the 1790s. In the face of what they regarded as repeated infringements of their patents by engine 'pirates', Boulton & Watt had considered legal action from the early 1780s. But it was not until the early 1790s, when defaults on financial agreements by Cornish engine users became increasingly widespread, that they began to prosecute. A long, complex, expensive and vexed series of legal cases challenged Watt's ingenuity and stoked the fires of his hypochondria for most of that decade. The eventually successful outcome enabled Boulton & Watt to recoup a very large sum of money in arrears.[19] By this time, in 1800, the original patents had run their course and Watt retired from business.

Other domestic troubles stalked Watt in the early 1790s in the shape of the poor health of his younger children. Jessy succumbed to tuberculosis at the age of fifteen in 1794, after a harrowing illness. His parents invested great hopes in young Gregory. Bright and personable, he showed considerable promise as a philosopher, especially as a geologist, and studied at Glasgow College. But he too battled the dread disease and eventually died from it in 1804. The other child of Watt's first marriage to reach maturity, besides Watt Jr, his eldest child Margaret, had married James Miller, but she died in 1799, leaving four children. The Watts were no strangers to family tragedy.

The prospect of finding an effective treatment for Jessy was one of the major reasons why Watt entered into another of his key collaborations, this time with Dr Thomas Beddoes, on the production and use of 'airs' for medicinal purposes. Watt designed, and Boulton & Watt manufactured and sold, an apparatus for producing therapeutic airs and for delivering them effectively to patients.[20] But Watt's involvement went beyond this into both the chemistry of air production and of therapeutic effects. The steps leading to the establishment of Beddoes's short-lived Pneumatic Institution in Bristol are very revealing of Watt's ongoing defence of the chemistry of phlogiston. Along with his old friend Priestley, by now driven into exile in Pennsylvania by the Church and King riots in Birmingham in the early 1790s, Watt remained one of the last defenders of a phlogistic chemistry against the new chemistry most associated with the work of Lavoisier.

In his later years and in retirement Watt remained actively inventive, though now much of the hands-on work was done by his son or by assistants. With John Southern, Watt further developed the steam indicator, a device whose early forms he had devised in the late 1780s and early 1790s, and which became, in the nineteenth century, perhaps the most important of his lesser-known inventions because of its great utility in measuring the performance of steam engines.[21] Watt also enjoyed spending time in the attic workshop of his home, Heathfield Hall, where he developed machinery for copying statuary. He and his wife travelled, and also purchased land in Wales, establishing the estate that became known as Doldowlod where Watt and his surviving son pursued the habits of country gentlemen.[22]

Released from the cares of business, Watt enjoyed better health than he ever had during his most active years. He gained a reputation as a rather genial, avuncular sage, an ardent and entertaining conversationalist with a, perhaps surprising, taste for light fiction.[23] However, Watt, assisted and encouraged by Watt Jr and others of his circle, also assiduously attended to defending and cultivating his own public image and reputation. He monitored public accounts of his life and works and, where necessary, sought to correct or counter them. For example, when Olinthus Gregory, a professor of mathematics at the Royal Military Academy, Woolwich, with an eye for support of the underdog versus the 'establishment', included material favourable to the Watt steam engine rivals the Hornblowers

in his treatise on mechanics, the Watts arranged for a damning review by John Playfair in the *Edinburgh Review* of just that part of the book.[24] Watt was under pressure from various quarters to give an account of the history of his inventions, and he agreed to do this in a roundabout way by correcting and annotating the articles 'Steam' and Steam-engine' that his friend John Robison had contributed to the third edition of the *Encyclopaedia Britannica* in 1797. Watt reviewed some of his earlier experiments on steam with the assistance of John Southern, and incorporated the results into his annotations. There too Watt published the last of a long line of accounts of his invention of the separate condenser.[25]

Watt received numerous honours, including Foreign membership of the French Institute in 1816 (one of only eight positions), and an honorary Doctorate of Laws from the University of Glasgow in 1806. He reportedly turned down a baronetcy when sounded out on the question by the government through Sir Joseph Banks. Had this been accepted, or publicly known, it would have threatened the 'outsider' status that the Watt camp often sought to cultivate, partly through complaints about the *failure* of government to honour the great man with an appropriate title! Watt also made a few benefactions, including a gift of books in 1816 to his native town of Greenock. Eventually his son was to fund a library building in which to house those books, which became the Watt Monument Library, and a focus of local commemorations of the town's most famous son.[26]

Watt died, after a short illness, aged 83, on 25 August 1819 at Heathfield Hall. He was buried in Handsworth Parish Church in Birmingham where his business partner Matthew Boulton had preceded him. A statue in marble by Francis Chantrey soon dominated a side chapel in which Watt was buried. The obituaries flowed, the most famous and oft-quoted being that in *The Scotsman* newspaper by Francis Jeffrey, the founder of the *Edinburgh Review*. Though Watt was technically the improver of the steam engine, Jeffrey said, 'he should rather be described as its *inventor*'. As such he had conferred inestimable benefit upon his country and upon humanity. He had 'armed the feeble hand of man ... with a power to which no limits can be assigned ... and laid a sure foundation for all those future miracles of mechanical power which are to aid and reward the labours of after generations'.[27]

The making of the legend was already well under way when the 'Great Steamer' departed, but there was a lot more to come.

The Structure and Strategy of this Study

This book has both a general and a specific intent. The specific purpose is to partially recast our understanding of James Watt's improvements of the steam engine and the natural philosophical basis for them. The origins of the steam age, I will argue, lay in an intellectual universe that is profoundly alien to our own. I

do not claim to have fully recovered that intellectual universe, but will be happy if I have pointed in the right general direction. So the comprehensive history of Watt's chemical connections and activities through what we can loosely call the 'Chemical Revolution' remains to be written. This is not it. Indeed part of my specific purpose is to execute a necessary move preliminary to such a comprehensive chemical reconstruction – to suggest that a history of Watt's chemistry, if it were to be written apart from what are conventionally seen as his 'steam engineering' activities, would reinforce an artificial divide between the two which hinders the understanding of both. The broader purpose of the book is to exemplify the ways in which historical sources can be profoundly misleading for such attempts at reconstruction. In doing this I am pursuing old cautions about the perils of Whig history, and clearing away historiographical undergrowth by showing the contingent purposes of documents that have often been taken as transparent historical sources.

The book is divided into two main sections – 'Representations' and 'Realities'. Of course, I am aware that the realities that I offer in the second part of the book are simply my representations of the realities as I see and reconstruct them. My hope is that others will find them a persuasive, or at least a suggestive, account, not that they will be treated as the end of history so far as my subject is concerned.

In 'Representations' I pursue some of the sculptural, pictorial and textual representations of James Watt between his own time and the present, with emphasis on the nineteenth century. It was during the nineteenth century that Watt became a powerful and protean symbol. I am conscious, in presenting these representations, of the splendid work done recently on representations of Watt by Christine MacLeod. Professor MacLeod's work has been an important inspiration and substantive source for what follows.[28] However, we intersect rather than coincide. MacLeod's focus is that of an economic and cultural historian. She looks from representations of Watt outwards into the British economy and society in the nineteenth century and is concerned primarily with how images of Watt are constructed in the service of broader social and economic purposes. I look, primarily, from images of Watt 'inwards' into the knowledge economy, or, perhaps better, knowledge 'ecology'. As an important contributor to the development of arguably the most important technology of industrialization Watt became a symbol that many groups in the knowledge business were anxious to claim. Whether he could, or should, be characterized as a 'natural philosopher', an 'engineer', a 'philosopher engineer', a 'craftsman', or a chemist, as a discoverer or as an inventor, was an issue much contested. A particular strength of Professor MacLeod's research on Watt's reputation is the picture she draws of its construction by the ranks of practical mechanics and other workers. This is an aspect that I am conscious of neglecting in the following pages, partly because my focus is

upon those learned and professional classes in whose hands the construction of Watt's learned character primarily lay.

In analyzing these varied representations I draw a distinction between the 'mechanical' and the 'chemical' Watt. My reason for doing so is that my claim in 'Realities' is that Watt was in a crucially important sense a chemist. This is an unusual, and far from obviously justified, claim – at least in the form that I advance it. Thus, in dealing with representations, I need to examine how and why the mechanical Watt obscured the chemical. Accordingly, Chapter 1 explores representations of Watt in marble, stone and brass, the famous story of Watt and the kettle, and the much less famous story of Watt and the steam indicator, by way of illustrating the dominance of the mechanical Watt in public representations of him. In Chapter 2 I offer some suggestions as to why the chemical Watt disappeared in the course of the nineteenth century. One reason was that the man himself, and his close associates, chose to recast the nature of his achievement in a way that 'proofed' it against rapidly shifting understandings of the nature of heat. Another was that the chemical claim to fame that was allowed to survive this process of self-fashioning, namely Watt as candidate discoverer of the compound nature of water, became the subject of a substantial controversy in which, for different reasons, both the supporters and opponents of Watt's chemical pretensions helped to obscure his chemical understandings. In Chapter 3 I explore the creation of Watt the engineer during the same period. Some advocates of the development of 'engineering science', in particular, adopted Watt as a symbol of what they held dear. In so doing there was an understandable tendency to modernize the man and his ideas. Overall then, characterizations of the great man are related to his self-fashioning, to the commemorations pushed by family and friends, and to the concerns and ambitions of groups seeking, or indeed declining, to adopt Watt as a symbol. The outcome of this 'orgy' of contending representations was a very useful, but profoundly misleading, 'mechanical' Watt.

In Part 2, 'Realities', I turn to the reconstruction of the chemical Watt. Chapter 4 seeks to portray his chemical world and how it came to be that way. Watt was not 'trained' as a chemist in any meaningful sense. But through a series of informal associations, with Joseph Black, J. A. De Luc and Joseph Priestley in particular, and by a great deal of self-education, Watt did become a figure to be reckoned with in the chemical world of the late eighteenth century. I argue that his chemical ideas were the product of the interaction of theory and practice and in so doing bring together episodes in his life and work that are usually considered to be unrelated to each other. The fact that those episodes can be brought together in this way is further evidence, I contend, for the importance of the chemical thread in his work. Having depicted Watt's development as a chemist, I then turn in Chapter 5 to advance and argue the claim that the steam-engine improvements were a product of Watt's chemical philosophy and that in that,

and other, senses the steam engine of the late eighteenth century ought to be seen as a chemical device. The final chapter offers a concluding case study of Watt and the steam indicator. Watt's development of the early versions of this device has encouraged some to regard him as prescient about the science of energy, even as what we might call a 'proto-thermodynamicist', who anticipated some of the most central and important physical insights of the nineteenth century. In showing how elisions have been made between Watt's use of this device, and the use made of it in the theory of thermodynamics, I suggest that his understanding of the indicator was essentially chemical in nature and fundamentally at odds with, rather than being an anticipation of, nineteenth-century thermodynamics.

In ten years time we will mark the 200th anniversary of Watt's death. The 100th Anniversary in 1919 recognized only the mechanical Watt. Perhaps the next commemoration will do more justice to the complexity of the remarkable achievements of a man who was, I suggest, a stranger to our usual ways of understanding him.