THE WEST YORKSHIRE TEXTILE ENGINEERING INDUSTRY, 1780-1850

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ABSTRACT

The dissertation examines the origins of textile engineering in Yorkshire, particularly in the context of its relationship with the textile industry and with a wider industrializing community. Because machine-making occupied a unique and crucial role in industrialization, an appreciation of how the industry developed offers a means of better understanding the dynamics of industrialization, and particularly the part played by technological change in the process. Whether the industry worked competitively, or preferred a form of productive association, provides a central theme.

The study considers the technical and social origins of mechanical engineering, examining the change from machine-making as an non-specialist pursuit to its emergence as a specialist industry in its own right. Through case studies concentrating upon Keighley and Leeds, the two major centres of textile engineering in Yorkshire, attention is directed at questions of entrepreneurial origins, the level of skill required as the industry evolved, how the process of technological innovation and diffusion operated, and changes in the organization of machine-making and expansion of markets over the period.

CONTENTS

LIST OF TABLES

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AUTHOR'S DECLARATION

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration.

Map showing the textile districts of Yorkshire, with adjoining areas of Lancashire. The county boundary of Yorkshire is that of the former West Riding; ground above 244m. is shaded.

INTRODUCTION

> The marvellous body of machinery ... is one of the most surprising and interesting spectacles that the eye of man can survey, and presents a forcible example of the subjugation of brute matter to the mind and dominion of man, as effected by science and mechanism.[1]

By the middle of the nineteenth century, the scale and diversity of the British textile industry had become a source of wonder to contemporary commentators.[2] The numbers of factories and of employees, the quantity of raw materials consumed, the size of the export market, and above all the range of mechanical innovations, all excited the admiration of such writers. Yet there is little in these accounts to explain the origins of this machinery which had made possible a revolution in textile production. Beyond the customary references to inventors of certain machines, nothing was said about the means by which machinery was improved, produced and brought into service.

Although textile engineering in Yorkshire had grown from virtually nothing in the closing decades of the eighteenth century to become a major industry in its own right by 1850, its main claim to interest lies beyond its own rapid expansion. To study only the progress of a local industry, however vigorous its growth might have been, still amounts to micro-history, and that can make only a limited contribution to a more general historical understanding.[3] Rather the interest of the burgeoning machine-making industry lies in its relationship with textiles and the wider industrializing community. The machine-making industry supplied the means by which textiles, whose central role in industrialization is indisputable, was able to achieve its astonishing expansion. To understand the origins and the nature of the industry which occupied this special role is therefore a way to better appreciate the dynamics of industrialization, and particularly the role of technological change in that process. That above all is the justification for this work.

Previous histories of the engineering industry have been more concerned with the period of consolidation after 1850 than with its foundations. The emphasis upon this later period, and generally upon large and successful firms, has accentuated an impression of an industry highly organized, concentrated and competitive. For example Kirk follows the fortunes of five of the seven largest firms in the Lancashire machine-making industry between 1870 and 1939.[4] Saul, while identifying certain important features of factory-floor organization in the industry, considers only the period after 1860 in a chapter which covers the whole of mechanical engineering.[5] Floud, though strenuously attempting to account for the entire machine-tool industry, deals with that sector's growth after 1850 and inevitably focuses upon the largest firms.[6]

In contrast with Kirk, Saul and Floud, whose work was not intended to examine earlier engineering, Musson and Robinson's _Science and Technology in the Industrial Revolution_ promises much, with chapters entitled 'Science before the Industrial Revolution', 'The diffusion of technology during the Industrial Revolution', and 'The origins of engineering in Lancashire'.[7] Musson and Robinson assembled an impressive range of evidence, and because early engineering has been so little studied, their work has been influential and is widely quoted.[8] It has also been strongly criticized for failing to meet its extravagant claim to offer 'a major re-interpretation of the Industrial Revolution'.[9] The book has other faults, for despite its title it does not grasp the relationship between science and technology, and fails to explain adequately the technical background of the mechanical engineering industry, specifically the strand of artisan craft from which engineering grew. Although Musson and Robinson make a promising start to their chapter on the origins of Lancashire engineering - 'It is extraordinary how little is known about the engineers who produced the water-wheels, steam engines, textile and other machinery of the early Industrial Revolution.' - the chapter ends lamely 'no doubt the roots of this technical development lie deeper in history ...'. Their broad brush approach, by neglecting subtle distinctions between various groups engaged in early machine-making, both fails to pinpoint links between machine-making and science, and also, despite the cast of thousands, misses any real sense of the industry's dynamism.[10]

It is natural that a history of engineering will be raked over to provide ammunition for those who favour a technological explanation of industrialization. Although engineering, being atypical of the general run of industries, has limited potential as an industrial case study, it can inform a wider debate on the nature of industrialization. On the other hand, any misreading of the character of early engineering can produce a distorted view of technological development. Landes, for example, by accepting Musson and Robinson's impression of the Lancashire industry, overstates the theoretical knowledge of early machine-makers and overlooks changes over decades and distinctions between trades. As a result his conclusions about why the 'harvest of inventions' and their rapid diffusion should have occurred in Britain rather than elsewhere are not fully convincing.[11]

Landes defined the 'heart of the industrial revolution' in terms of technological change.[12] It is possible to see that Landes's stress upon the role of technology in the process is extreme, as many have, yet agree with Rosenberg that 'a responsive machinery-producing industry has been the key to successful industrialization'.[13] Whether Landes or Rosenberg has the emphasis right, the history of machine-making is relevant to the debate about the causes and speed of industrialization. That, then, stands as the main purpose of this work, to provide a clearer view of the origins and development of a trade which played a central role in industrialization. By considering textile engineering in the context of local communities and in the light of its relationship with the textile industry, it is also intended to offer some explanation of both the process of technological change and the nature of competition. A supplementary issue is that of continuity or discontinuity, whether gradual change rooted in long-established tradition could be a distinguishing feature of a new and 'high-tech' industry. There is also a question to be considered of how far the industry's development was planned and directed, or whether it evolved through intuitive responses to a series of problems.

II

Berg has criticized the teleological approach to industrial history, a concentration upon large and successful firms encouraged by the uneven survival of business records and other sources, an approach which produces an 'historical chasm between the known - the factory system and large-scale production - and the unknown - the artisan and the small- and medium-scale producer'.[14] Specifically on the subject of the engineering industry, Floud emphasises that the 'aggregated business history' of large firms can hardly add up to a complete account of an industry when a 'submerged section' of small workshops was responsible for so much of the production.[15]

Previous efforts to identify Floud's 'submerged section' of engineering have not amounted to a great deal, other than in Floud's own work sifting through late-nineteenth century directories. 'It has also to be remembered', says Floud, 'that securing the necessary information becomes progressively more difficult as the enquiry is pushed back into the nineteenth century'.[16] But the eighteenth and early nineteenth centuries are not the Dark Ages, and both Berg and Hudson[17] have shown how a community-wide approach can illuminate aspects of industry when business records alone are inadequate. Even where relevant company records do survive, information from a wider community may offer supporting evidence, and also place industry in its proper context. This makes possible a more accurate assessment of, for example, some of the more exaggerated accounts of success or failure advanced by Victorian commentators. As far as the early engineering industry in Yorkshire is concerned, an emphasis upon community evidence may be the only possible approach, for Floud's 'submerged section' describes more or less the whole industry. Even those who prefer to investigate the large and successful would have to dip underwater in search of the humble origins of what would later become famous firms. But in order that the development of an industry is properly appreciated, it is just as important to uncover failure, to identify those who moved into other trades through choice or necessity, and to know about those modest successes whose businesses did not survive in the long term, yet who managed at least for a time to make an adequate living.

Using sources which fall outside the standard definition of business records has the advantage of showing up small or temporary industrial formations, and perhaps identifying the origins or subsequent careers of lesser participants in a trade. There is another positive benefit in focussing upon a wider community, for where work and social life overlap as they did in early engineering communities, then industrial history should not confine itself to the workplace but ought to take into account social issues. A community-orientated approach to industrial history may be more likely to stress continuities, though that does not mean such a viewpoint is flawed. By setting discontinuities in a context of those things which did not alter, there may be a better means of evaluating the significance of change.

It is, though, a business archive, the records of Richard Hattersley of Keighley and his successors,[18] which has been the mainstay of this research. The Hattersley archive provides a considerable and continuous, though not fully complete, record of the firm's activities from 1793 into the twentieth century. It is fortuitous that it was Hattersley's records which were the ones to survive in such quantity and quality, as his firm occupied a dominant and central position in the Keighley engineering industry during the whole period, and through Hattersley can be traced links with Leeds, the other major engineering centre of West Yorkshire.

Information from Hattersley's records has been amplified or confirmed by using other local evidence so that the Hattersley family, their workers, subcontractors and customers can be drawn into a community context. These other sources are mainly standard ones such as parish registers and census returns, though Keighley records include a muster roll of 1803 which lists almost the whole male population,[19] and also a remarkable secondary work, John Hodgson's much quoted Textile Manufacture and Other Industries in Keighley.[20] Hodgson's information, though not always the dates he quotes, has proved exceptionally accurate where it can be verified. He had lived in Keighley from the age of eight in 1815, and as first a textile manufacturer, and later a rate and tax collector, possessed detailed personal knowledge of the early industries and industrialists of the town.[21]

The main body of information for this study has been drawn from the two main engineering centres, Leeds and Keighley, though incorporating any available evidence of other engineers in the region (which will be referred to conveniently, though anachronistically, as West Yorkshire). Keighley, being a well-defined, self-contained and reasonably static community blessed with good source material, has been able to provide a very full account of early machine-making. The study of Leeds engineering, while not in total quite so satisfactory, is comprehensive in its coverage of the more important engineers.

III

The method adopted in this dissertation is to consider in turn some of the component elements of the new machine-making industry, and attempt to relate each of these topics to wider historical debates, for example on the origins of entrepreneurs, or about the nature of skill. Engineering is set in its community context and defined in relation to its customer industry, textiles. The main themes which recur include the dynamics of technological change and the role of competition, issues of continuity and discontinuity, and whether the industry's development was the result of any conscious planning.

To understand the character and standing of textile engineering, it is necessary to know its precedents, whether, for example, it grew as a sideline of longer established trades, whether it resulted from the self-help efforts of machine-users who had no other means of acquiring machinery, or whether it had connections with the middle-class profession of engineering. The opening chapter considers evidence of the ancestry of machine-making, and also defines phases in the development of the industry between 1780 and 1850.

Crucial to the success of any new industry is the quality of business leadership. In this case the backgrounds of early entrepreneurs, their trade and hence their social origin, can define the character of the early industry. By linking information about entrepreneurial origins with what is known of the fortunes of their firms, it may be possible to conclude that particular skills, or capital, or connection, were especially important in order to succeed. The question of skill is explored further in the second chapter, which examines how a skilled workforce was recruited and trained to make machinery. The skill and knowledge required, though its actual level may have changed over time, could also have been influenced by social conventions. In other words, the trade may have become progressively de-skilled, though still claiming to be skilled in order to protect the vested interests of existing participants. Such a process may also have affected opportunities for mobility, either into entrepreneurship or through advancement as a journeyman.

Relationships within the industry, between entrepreneurs and with the wider workforce, are central to an explanation of the dynamics of technological change. If innovation were taking place on the engineering shop-floor, is it possible to identify what informed it, how it was stimulated, and by what means the resulting technology spread? If innovation were the product of social processes within an innovating community, could it also have been considered the property of that whole community? If that were the case, then previously held beliefs about secrecy and protection of technology require reappraisal. The way in which technology, which was after all the raison d'etre of machine-making, was developed and regarded may provide the best clue to understanding the new industry.

Relationships are explored further in the chapter on the industry's organization, which considers in particular whether textile engineering could really have functioned as a community of producers. Besides describing how work was arranged, this sets out to demonstrate any connections between individual machine-makers and assess the extent of any network of engineers.

Finally there is an examination of the market, looking not merely at its extent, value and location but considering whether it might have played a more inter-active role, influencing the growth, concentration, organization, and the technical development, of the industry.

NOTES:

1. James 1857, p.333.
2. See for example Baines in Ponting (ed.) 1970, and James 1857, chapters IX and X.
3. O'Brien 1993, p.16.
4. Kirk 1983.
5. Saul (ed.) 1970, chapter 5.
6. Floud 1976.
7. Musson and Robinson 1969, chapters I, II, XIII.
8. For example by Landes 1969, p.63; Cantrell 1985 p.6; Mokyr 1990, p.168; Kirk 1983, chapter 1.
9. Coleman 1970, p.575.
10. Musson and Robinson 1969, chapter XIII.
11. Landes 1969, pp.61-4.
12. Landes 1969, p.1.
13. Rosenberg 1976, p.112.
14. Berg 1993, p.18.
15. Floud 1976, p.6.
16. Floud 1976, p.7.
17. Pat Hudson 'Industrializing townships in West Yorkshire 1680-1820', seminar presented at the University of Leeds, May 1994.
18. West Yorkshire Archive Service - hereafter WYAS - Bradford, 32D83.
19. North Yorkshire County Record Office - hereafter NYCRO.
20. Hodgson 1879.
21. Keighley News, 10 April 1880, p.4.

CHAPTER ONE
PRECEDENTS AND PHASES

> It is the Age of Machinery, in every outward and inward sense of that word; the age which, with its whole undivided might, forwards, teaches and practises the great art of adapting means to ends.
> Thomas Carlyle, Signs of the Times (1829)

The origins of mechanical engineering are commonly misunderstood. It has often been assumed, wrongly, that textile machine-making grew as an offshoot from established trades such as that of the millwright. Another misapprehension is to see the industry as static, though growing, rather in the way that pre-Renaissance artists drew children as miniature adults, ignoring those changes which come with development. In this view, textile engineering grew much bigger but essentially it stayed the same. Within such a frozen framework the dynamism which was a distinctive feature of machine-making can easily be understated. The industry thrived because of an ability to respond to its customers' rapidly changing needs, and changed markedly itself as a result. Textile engineering in its infant period, before 1800, was not the same as, nor did it much resemble, the maturing industry of the mid-nineteenth century. Generalized accounts which ignore those distinctive changes during the industry's formative period have failed to properly understand the industry.[1]

This opening chapter has two purposes. First, it will examine possibilities regarding the origins of textile engineering, to determine whether this really was a new industry of the late eighteenth century which developed separately from textiles. Alternative explanations are that it grew out of domestic machine-making, that it was established by millwrights, or that it remained largely a sideline of textile manufacture, splintering off to form a separate industry only much later. Secondly, the chapter aims to distinguish phases in the early textile engineering industry, with some definition of parts, processes and location.

MAKING TRADITIONAL MACHINES

When textiles were produced in domestic workshops, during the first stages of the industrial revolution and earlier, a variety of machinery was already in use. Much of this equipment was of simple, even crude, construction, and it was made mainly from wood. The heaviest machinery used in textile manufacture at that time, the stocks, water wheels and transmission gear in fulling mills, had long been the preserve of the millwright.[2] Less has been recorded about the production of handlooms, spinning wheels and other items for domestic use.

Drawing together evidence from textile districts in southern England and the Midlands during the early modern period, Kerridge shows that looms had been

> fashioned from oak, beech or ash ... fitted with elm or iron screws, nuts and bolts, cane sleys and metal plates and gears. Shuttles and spools were carved out of solid wood. The turner's lathe and the graver's knife were much in evidence.[3]

Specialist tradesmen involved in making this early machinery included turners and wheelwrights (for spinning wheels), carpenters, joiners and locksmiths, and framesmiths (who may sometimes have styled themselves blacksmiths). Kerridge found references to a sixteenth century 'turnour or maker of loomes' in London, and to Canterbury weavers using a 'turner for framyng of ther lomes'. The making of knitting frames was sufficiently organized to have generated a small but significant export market during the seventeenth century.[4] Kerridge locates the specialist machine-making industry of the early modern period in Exeter, Colchester, Canterbury, London and Norwich for looms, and Wymondham, Great Bardfield, Tewkesbury, Norwich and Leicester for spinning wheels and spindles.[5] Similarly handloom weavers on the Scottish borders bought many of their looms from specialist producers in Glasgow or sometimes Edinburgh.[6]

Sometimes machinery was produced, in whole or in part, by machine-users themselves. In Canterbury, Flemish drapers had their own turners' shops, with lathes for making spindles and bobbin blanks.[7] In Norfolk, weavers made loom-frames which they fitted with parts bought ready made from specialists, a practice also adopted by expatriate framework knitters in Avignon in 1658, who fitted metal parts made to order by local clockmakers and locksmiths into frames which they had built themselves.[8] Though no evidence has been found of such a specialist machine-making industry in the north of England, a similar system could have operated, with machine-users building frames and buying parts - spindles, metalwork or wheels - from local smiths or joiners. But as even domestic machine-making demanded a certain level of skill, it is more likely that wood- and metal-workers in textile districts accepted the construction of looms and spinning wheels as an occasional part of their work.

According to directories of 1772-3 and later, some Manchester woodworkers were then making looms in a more systematic and professional fashion.[9] These carpenters grasped an opportunity presented by the huge increase in demand for handlooms after the mechanization of cotton spinning.[10] Early directories for Yorkshire are less helpful in identifying loom-makers, but the domestic machine industry east of the Pennines probably followed a similar path to that in Lancashire. In 1781 a foreigner evidently on a spying mission was able to 'procure a machine to be made' and 'bespoke another lately invented machine' in Leeds. The first of these was 'a compleat spinning jenny', the second a scribbling mill. Who was responsible for their manufacture is not made clear, though the business was still the province of traditional makers, probably woodworkers. The report refers to 'the Makers of these kinds of machines' as though a recognised trade then existed.[11]

The Leeds millwright John Jubb, who had been producing improved machines for scribbling and carding wool and 'Engines &c both for cotton and fleece wool' for several years before 1784, sold four handlooms to John Marshall in 1788, presumably for experiments in weaving linen.[12] It was unusual for such domestic machines to be supplied by a millwright. Benjamin Gott bought handlooms for Bean Ing Mill from small makers in neighbouring villages. Gott's notes of mill practice (c.1810-6) record the purchase of five handlooms at £9 each from Nathan Carlton of Armley, four at £8 from Bentley of Birstall and two at seven guineas from Thomas Taylor of Armley.[13] A directory identified similar small local businesses in 1822, when loom- and shuttle-makers were listed in Barnsley, Dewsbury and Batley,[14] though more were concealed in the listings of general machine-makers. That there remained an industry separate from mainstream textile engineering to cater for the needs of domestic textile-making is shown by an 1838 directory which marked out several joiners as 'Jenny and Loom makers' in Pudsey though not in neighbouring places where they certainly existed.[15] As these domestic machine manufacturers served a purely local market, directories did not usually bother to specify this aspect of their work.

If it is true that handloom weavers experienced a golden age, then handloom-makers must also have found increased business after spinning was mechanized. It was estimated that there were a quarter of a million handlooms at work in the U.K. cotton industry in 1836 [16] and thousands more working in the woollen and worsted branches.[17] But the boom was short-lived, for although handlooms were still in widespread use in the woollen industry as late as 1850, in some cases persisting into the twentieth century, orders for new handlooms would have become increasingly infrequent. Some of those specializing in pre-industrial machinery continued to refine their products. John Antis (or Antes) of Fulneck won a prize from the Society of Arts in 1793 for his improved mechanism for the Saxony wheel.[18] More exotically, John Planta, active in the same trade at Fulneck between 1798 and 1824, developed cabinet-making skills to produce spinning wheels of superlative quality, inlaid with woods and ivory, to be sold as drawing room pieces and lamp-holders.[19] But hand-powered machinery, however improved, was becoming obsolete, most makers did not have the option of a luxury market, and their natural route was back into wood-working trades.

Handlooms have persisted in some sectors of the textile industry. As recently as 1993 a new broadloom was launched to transform the cottage industry in Harris tweed, but by changing the product to suit modern markets rather than trying to alter technology which, though old-fashioned, ideally suits local needs.[20] In Yorkshire, handlooms continued to be widely used for samples and speciality weaves in the Huddersfield industry into the twentieth century.[21] An old handloom, now in the Colne Valley Museum, was rebuilt by J.Stansfield and Son of Almondbury for Josiah France of Honley, perhaps as late as the 1930s. Stansfield was a joiner[22], and the superiority of his work over that of the original loom-maker is clear. Early domestic machines were of simple design and relatively easy for a wood-worker to produce. Colne Valley Museum's replica jenny was made by someone possessing basic handicraft skills, adapting second-hand parts from other types of textile machine.[23]

Those wood-workers who converted to the new machine-making industry, where they continue to be employed on the fringes, acquired a higher degree of skill than had been necessary in domestic machine production. For example, great precision was required of carding machine builders during the opening years of the nineteenth century in the United States, where wood, being more plentiful than iron, was the preferred material.[24] A Gomersal textile engineer interviewed in 1992 still employed a full-time joiner/ coach-builder whose work included making wooden covers for carding machines, and timber carriages for mules.[25] Those carpenters who took up manufacture of the new textile machinery after about 1800 had moved into a different industry, leaving behind them that which made domestic machines. The domestic machinery industry was not a forerunner of modern machine-making and continued to function quite separately from it, for as long as hand machines were required.

MAKING MACHINERY: BEFORE THE MACHINE-MAKERS

Before 1800 a number of machine-makers set up in business in the textile towns of Yorkshire, building new kinds of textile machinery in response to the local demand. They were not established in time to satisfy the earliest needs for such machines, for when the first factories appeared in Yorkshire, from 1780, a local textile engineering industry hardly existed. During this period of transition factory owners adopted various expedients to acquire machinery. Such measures may have been purely short-term and pragmatic, though it is possible that a more enduring machine-making industry grew from these beginnings.

Master millwrights are often credited with a pivotal role in erecting and equipping early factories, planning and organizing the building itself, and recruiting members of various trades, including journeymen millwrights, joiners, clockmakers and smiths, to build the machinery _in situ_.[26] Individual millwrights in Yorkshire have left few traces of their activities at this time, with little known even of major figures like John Jubb of Leeds and John Sutcliffe of

Halifax. The number of millwrights in West Yorkshire was low, and they served a range of industries in addition to textiles. It is not likely that, in general, they would want or need to accept commissions to make textile machines. Millwrights mainly continued their traditional work, building and installing power sources, transmission systems and heavier machines like fulling stocks, and sometimes acting as consultants.[27] Many textile manufacturers were able to organize factory building and oversee machine-making themselves, buying in certain specialist advice. Neither master nor journeymen millwrights were an obvious choice to employ as machine-makers, as their knowledge of textile machines was not necessarily any better than that possessed by other trades, like smiths, who were available at lower rates of pay.

The central role of owners in building and equipping factories is clear from a number of local examples. One of the better documented is the worsted manufacturer Robert Heaton, who built a cotton mill at Ponden, or Roydhouse, six miles from Keighley. He was competent to supervise machinery construction, although it was in a branch of textiles with which he was unfamiliar.[28] Heaton's journal, running from about 1789 until the mill's completion in 1791, shows that he took advice from wherever he could find it when planning his venture. He used a series of agents and advisers, but did not consult a millwright until the project was well under way. Nor did he directly employ an engineer until the mill was complete.

John Weatherhead of Keighley, a joiner who made spinning frames, advised Heaton on sources of metal components in Bradford and in Lancashire, and though he did not supply parts, labour or machines, was paid expenses for a visit to Haworth in 1791, presumably to comment on work at Ponden.[29] Technical advice, as well as machinery, was offered to Heaton by a Lancashire machine-maker:

> Richard Sagar, Burnley, and his brother at Blackburn, makes mules and jennys. He says a room six yards square will hold two mules of about 144 or 150 spindles. A room five yards square will hold two jenneys, a jenny with 100 spindles will cost 7£ and will spin 1lb an Hour from 24 to 30 hanks in a lb.[30]

Although Heaton collected names of several other machine-makers in Bolton and Manchester [31], in the event the machinery for Ponden Mill was built on site, with parts brought in by tradesmen or agents. Heaton covered several pages of his journal with detailed specifications for wood to construct two cotton frames, each nine feet long, three pairs of cards, binders for two spinning frames, and a roving frame.[32] His suppliers included James Greenwood, for brass work, 'two pairs of cards Iron Wheels' and oak planks.[33] Joshua Smith built at least four spinning frames, Peter Milner dealt with the Bradford ironfounder John Sturges on behalf of Heaton, and John Brigg was employed to cut brass for a roving frame.[34] Brigg was subsequently engaged by Heaton and his partner, John Murgatroyd, for one year from September 1791 for forty pounds plus his meat, drink and lodging:

> to come and work for them at Roydhouse, Brass, Iron and Wood Turning and to Act as Engineer for the cotton mill erected there ... [35]

Although Heaton showed an interest in books on mechanics and mathematics, [36] detailed blueprints for machinery could not be gleaned from any written source at this time. Machine specifications which he noted must have come from a personal contact, whose identity is not known. It was possibly the millwright Joseph Tempest, who was first consulted by Heaton in October 1790. Tempest had been under contract as millwright at Walk Mill, Keighley, in 1783, with a secrecy clause regarding the details of machinery there, though he may not himself have made machinery then.[37] By 1793 he was buying rollers from Richard Hattersley and was presumably then producing spinning frames. But at Ponden he is known only to have advised on the design of a waterwheel, and perhaps oversaw the installation of a transmission system.

> Mr Joseph Tempest's Plan for a Mill to spin cotton at Roydhouse - Suppose the Water Wheel be 30 feet in Diameter, The Pitt Wheel must be 23 feet 9 inches and contain 324 teeth in 18 segments, 18 teeth each. The Crown Wheel must be 3 feet 1 inch in Diameter and Contain 41 teeth ...[38]

Heaton also noted that Tempest had placed orders for transmission parts at Sowerby Bridge.[39] There is no mention of him as a machine-maker. After being appointed engineer at Ponden, John Brigg took over the purchase of components, buying bobbins, brass wheels, an 'engine' and other parts in Keighley, and travelling to Halifax and Leeds for tools and engineering equipment.[40] Before Brigg was hired, Heaton had himself superintended the construction of mill and machinery despite his lack of mechanical experience.

Recognizing the advantages of mechanical expertise in such a situation, the partners at Greengate Mill, Keighley, in 1784 employed an engineer called James Greenwood with 'a genius well adapted for constructing the machines and other works'. Despite his lack of capital, Greenwood was intended to become a partner. Though this never came to pass, he stayed long enough to oversee the construction of mill and machinery, following the pattern which was soon widespread of buying metal parts from local suppliers.[41]

Even when ready-made machinery became available, the quality was questionable and quantities limited. One of Benjamin Gott's suppliers in 1794 was Samuel Fortune of Halifax, whose letter suggests a certain lack of sophistication:

> ... we shall send billey and plucker and the willy on Thursday and cume with them to set them up. As we do not

cast for ourself we shall put wood bends to carrey the roulers ...[42]

Gott bought one or two machines from different engineers in Yorkshire, Lancashire and the West Country. Although the net was spread wide, there is an impression that much on offer was less than satisfactory.

John Marshall, the Leeds flax-spinner, was establishing his factory at the same time as Gott, though Marshall's approach was in certain ways exceptional. He, like other entrepreneurs, was centrally involved in developing machinery, but more unusually kept systematic records of technical information and experiments conducted.[43] His notes almost certainly date from the early 1790s, when new factories in Holbeck were planned - Mill A and several other buildings were completed by 1792, and Mill B in 1794.[44] Marshall differed from others in that he was not an established textile manufacturer, and he had chosen a much more risky venture than cotton-spinning. Success with flax hinged upon his ability to overcome technical difficulties, and consequently Marshall's methods differed from those of other factory builders. He already employed the smith Matthew Murray, an exceptionally talented mechanic, whom he had sought out and recruited with particular aims in view. He did not need a millwright or other agent, though potentially useful pieces of information, from books or picked up in conversation with millwrights, engineers and other manufacturers, were noted. Although Marshall produced a list entitled 'Names of Mechanicks &c' [45] only four of those recorded were machine-makers, none of whom were in West Yorkshire, the remaining ten being roller and/or spindle makers or other component suppliers. Marshall, like specialist machine-makers of later years, planned to buy precision parts for machinery of his own, or more accurately, Murray's, construction. Marshall's flax-spinning experiments were more closely related to cotton than to the woollen branches, and the few machine-makers who then existed in Leeds could not satisfy his needs. The Leeds machine-making industry was small and probably less advanced than that in Keighley, where there was considerable experimentation with roller-spinning machinery during the 1790s. After Marshall had achieved success in mechanizing flax-spinning, he continued to keep more than usual control over the development and construction of machinery, maintaining close links with a succession of machine-makers - Murray and Wood, Taylor and Wordsworth, and Peter Fairbairn - whom he had helped to become independently established. But even Marshall, with his keen technical understanding, did not attempt to continue making his own machinery after Murray and Wood left him in 1795. Indeed, it was probably a condition of the agreement between Murray and Marshall that the flax-spinner would obtain his machinery from his former employee.

As late as 1800-4, when machinery was much more readily available from specialist suppliers, Ard Walker, who was not a textile manufacturer but a spirit merchant, personally supervised the construction of his cotton mill in Hunslet.[46] He bought a 30 h.p. steam engine from Fenton, Murray and Wood, while other unspecified payments to them may have been for machinery. Ten spinning frames and other items were bought from Halifax in December 1800, and it has been suggested that these were used as models to be copied by Leeds engineers.[47] Walker's accounts do not make clear exactly how the machine-making was organized. A range of Leeds engineers and other tradesmen were employed on the project. Walker kept separate lists of expenditure on buildings and machinery, the latter including transmission equipment. The machinery account shows payments to Richard Pullan for a boiler, with castings and other metal parts from local founders, including Joseph Shaw, Martin Cawood, and Salt and Gothard, rollers and spindles from William Farmery and others, and deal, oak and beech planks in large quantities. John Nicholls, a millwright, was paid weekly, in cash and in copious quantities of ale for his men, during separate and lengthy periods of the mill's construction, on both the building and 'machinery' accounts. The 'machinery' work could have been confined to traditional millwrights' jobs and excluded textile machine-making. William Milner, a whitesmith, was also retained for many weeks, probably to construct machines. In 1803/4 'Samuel Lawson, clockmaker', actually a machine-maker newly out of his apprenticeship at Murray's, was paid £4 4s 0d for four week's work. Walker also brought in joiners, plumbers and painters to work on machinery. Overall supervision, along with tight financial control, was carried out by Ard Walker himself. The master millwright was only one of a number of contractors used, and his work was probably limited to structural metalwork and power transmission. Significantly one of Walker's last recorded payments was to a wood-worker, and not to the millwright:

> Iveson, joiner, at sundry times for inspecting the make of all the new machinery £7 7s 0d

Tann says that 'for the entrepreneur who lacked practical expertise the millwright was a vital consultant' [48], but Iveson is an example of a new kind of adviser on technical aspects of textile machines. Smiths were also coming to the fore in this respect. These consultants assumed even greater importance where speculative factory builders had no knowledge of the textile industry. One such was William Robinson of Pudsey, who wrote to Walter Stanhope of Horsforth Hall in 1784:

> Thomas Marsden tells me that you intend building a Scribbling Mill at Horsforth and that he had recommended to you to employ me as being a proper Person to superintend the Works ... [49]

Robinson was able to estimate the costs of constructing three scribbling machines, broken down into wood, forged ironwork, cast ironwork, cards and workmanship, besides suggesting probable running costs and projecting annual profits.

But even those with little or no experience in textiles or in mechanics sometimes managed without a consultant. Richard Smith, lord of the manor of Addingham, built High Mill there in 1788/9 apparently without direct assistance from any specialist millwright or machine-maker. He jotted specifications for the building in the back of an account book, did various calculations on the comparative costs and profits of spinning cotton or worsted, and bought parts from Leeds and Skipton - spindles from Skipton, and cast iron wheels from Salt and Gothard in Hunslet.[50] A local blacksmith turned spindles and carried out other unspecified work. Edward Brumfit, who had supplied iron wheels for the machines, drew a rough sketch on a scrap of paper showing Smith how to set up machinery for roller-spinning.[51] Brumfit appears to have been a haulier and may have acted only as a conduit for parts and information to Smith.

Castle Hill Mill, Gomersal, which was started in about 1794 but not completed until 1800, was also an isolated speculative venture by a landowner not experienced in textile manufacture.[52] Although it is not clear who was in day-to-day charge of the project, accounts for 1799-1800 draw a clear distinction between the work of the millwright, David Popplewell, that of a machine-maker called Samuel Holdsworth, and that of Benjamin Ross, a local blacksmith.[53] Wood and castings were brought in separately and the machinery erected at the mill. When work was complete, an inventory and valuation was taken, and while the Leeds millwright and machine-maker John Jubb (I) was one of the valuers of scribbling, carding and spinning machinery and transmission gear, a specialist engine maker, Edward Smalley, was employed to list and value parts of the steam engine.[54] Demarcation lines were emerging between the branches of mechanical engineering.

Such evidence of how early factories, both urban and rural, were built and equipped shows that it was usual for entrepreneurs to supervise the building and commissioning of their own factory. Whether the entrepreneur was a specialist or a speculator, millwrights played a much less central part than has often been claimed, being generally confined to advising on plans, carrying out structural work, or installing gearing and power transmission systems. Using rollers, spindles and flyers bought in from local specialist makers, machines were assembled by smiths or other metal-workers, usually under the supervision of the factory-owner. This role may have been forced upon textile manufacturers, as suitably qualified contractors were few, though there were also advantages in such close involvement as costs could be closely controlled and valuable technical lessons learned.

There is no evidence that such practices continued after about 1805, when the throstle was coming into widespread use in the worsted industry. It was then no longer practical for machine-users to make their own machinery, as most did not have the technical competence which had become necessary. A local textile engineering industry, recognisable and distinct, had taken machine-making into a new and specialist phase. This new industry had precedents quite unconnected with those factory owners who had built their own machines.

MAKING MACHINERY: USERS AS MAKERS

If it is true that machine-users made machinery only as a temporary expedient during a period of transition, c.1780 to c.1805, and that specialist textile engineering had quite a separate ancestry, then certain evidence suggesting that machine-making by users continued after 1805 requires explanation. A clear impression was given by some witnesses to two Select Committees investigating the machinery trade [55] that machine-users produced their own machinery throughout the first half of the nineteenth century. Some were well qualified for this, particularly those who had changed from machine-making to become textile manufacturers, such as M'Connell and Kennedy in Manchester and Berry Smith in Keighley.[56] Many textile manufacturers, though, had neither the ability nor the desire to make machines, preferring if possible to buy from specialist suppliers. That a contrary impression emerged from the parliamentary evidence can be explained, for the sample interviewed was far from representative. The Select Committees concentrated upon cotton manufacture in Lancashire, where machines were indeed produced by some of the larger textile firms. In the Yorkshire woollen and worsted industries, between the opening years of the century and Samuel Lister's emergence as a machine-maker in the 1840s, it was much more unusual for users to make their own machinery.

Indeed, the claims that many Lancashire users made textile machines require cautious examination. In 1824 Thomas Cheek Hewes, a Manchester-based millwright, suggested that a great many did.[57] Thomas Ashton of Hyde, described as a spinner and powerloom manufacturer who had introduced the powerloom into his neighbourhood, was one such:

> It is the general rule with us now, to make our own machinery ... solely for my own use; I do not make any for sale.[58]

This may have been a means of dealing with periodic shortages, when demand for machinery far outstripped supply. Hewes and Ashton were giving evidence at a time when powerlooms were being introduced into the cotton branch, and specialist engineers were unable to satisfy demand. Henry Holdsworth had experienced similar problems when he moved to

Glasgow from Manchester in 1799 and found it impossible to buy the machines he needed.[59] Reluctantly he tried to make his own, but failing to find good workmen, and deterred by the high price of tools, instead managed to commission a young mechanic to do the work. By 1803 the arrangement had broken down as his machine-maker was busy using Holdsworth's specifications to reproduce the same items for others, even though, in Holdsworth's view, these machines were already out of date. So Holdsworth bought improved parts from Manchester and managed to recruit a few workmen who could fabricate machinery using heavy components made in Glasgow. Continuing supply problems with cotton spinning machinery had forced him to continue this practice as late as 1824.

But Holdsworth had long experience of machine-making, dating back to his days in Manchester. For non-specialists to attempt machine-making was not usually cost effective. In the 1790s M'Connell and Kennedy were willing to supply metal components for mules, but warned customers contemplating building their own frames that 'making machinery is generally very expensive to those who are not in the habit of it'.[60] To the 1841 Select Committee, Grenville Withers, an engineer conversant with the machine-making industries of Belgium and England, suggested that it was uneconomic for textile manufacturers to make machinery. For a Belgian machine-user to produce his own 'it must necessarily cost very dear made in that way' and would have been cheaper from either an English or a Belgian specialist.[61] In that case it is unlikely that users would have built their own machinery through choice. Thomas Ashton claimed in 1841 that 'a very great increase [in machine making] took place in consequence of the demand ... many manufacturers now make their own machinery', implying that this had been a new phenomenon since 1824 in the cotton industry.[62] But for the flax industry, James G.Marshall of Leeds was unequivocal in stating that English spinners ordered machines 'almost entirely from parties who are machine-makers ... I understand it to be the same on the continent'.[63]

Marshall's comments may well have applied to the whole of the Yorkshire textile industry, for no other evidence has been found that users made their own machines between about 1800 and the 1840s, except where the textile manufacturer was, or had formerly been, primarily a machine-maker. In Lancashire it appears that a few large manufacturers embarked upon machine-making when demand for machinery was so high that specialists could not quickly satisfy it, though this course would have had its own difficulties, notably in finding suitable mechanics at a time of shortage. But once equipped with a machine shop, these users may have chosen to continue making their own machines.

It is possible to show that the production of machinery by textile manufacturers was exceptional, even in Lancashire. A high proportion of mechanics in factories was employed on the repair and maintenance of machinery throughout the period. 'I suppose there are as many employed in repairing, as there are in making [machinery]', said Ashton.[64] And Peter Ewart, a machine-maker turned cotton spinner: 'In cotton mills in general, there are as many persons employed in keeping the machinery in order, as there are employed in the making of it'.[65] In 1841, William Jenkinson of Salford, representing the machine-makers' committee, referred to 'immense numbers of mechanics employed in mills, not only in the making of machinery, but in the repairing of it; almost every mill has its mechanics, more or less'.[66] The Leeds flax-spinner Marshall, who bought in all his machinery, employed 1200 people in 1833, 70 or 80 of whom were mechanics [67] and who must therefore have been engaged solely upon repair and maintenance. In 151 firms in Lancashire in 1833 which employed in total 31,444 on preparing and spinning cotton, and 16,040 on weaving, the numbers of 'engineers, mechanics, firemen, roller coverers etc.' came to only 1,161, or fewer than 8 on average per firm.[68] Considering that these firms each averaged over 300 employees, and that every factory needed a number of mechanics to attend to steam engines and boilers as well as routine maintenance and repair, Ure's figures show that there were not enough engineers and mechanics to provide a viable machine-making department in more than a handful of the 151 Lancashire factories. It is plain that the great majority of textile manufacturers there relied upon specialist machine-makers. In Yorkshire, there is little indication of machinery being made for personal use during the early nineteenth century. A change may have come as a result of the powerloom shortage in the 1840s. Black Dyke Mills at Queensbury, which despite its remoteness had not even acquired a repair shop until 1838, began to make its own looms in 1844, and having started continued, so that by 1887 Foster's own machines accounted for 459 looms out of a total of 785 in use.[69] But Foster's never made spinning machinery, and produced only a few combs, which suggests that machine-making by such firms was embarked upon only as a last resort, with buying from specialist engineers the preferred option.

MAKING MACHINERY: THE GENESIS OF A SPECIALIST INDUSTRY

During the last two decades of the eighteenth century there emerged in West Yorkshire a nascent machine-making industry which attempted to cater for the needs of local textile entrepreneurs. Although a range of trades was involved in these early efforts, in general the new machine-makers stood apart from domestic machine-making and from textile manufacture itself. The early phase peaked in about 1800, and by 1805 almost all those woodworkers and miscellaneous craftsmen who had been involved in textile machinery had disappeared from the trade. Only the most technically competent survived, notably smiths and others with metal-working skills. At this point a recognisable, specialist textile engineering industry began to exist.

The end of the first phase of modern machine-making coincided with a change from wood to cast iron as the main material for machine frames.[70] Perhaps more significantly, the years around 1800 saw an increasing sophistication in spinning machines. Roller spinning spread and the throstle was introduced, developments demanding new levels of precision from engineers.[71] In specialization and precision the industry still had some way to go, but by the 1820s the skill of a common smith was no longer adequate for machine-making. With the introduction of improved machine tools, skill requirements were altered, though generally undiminished [72], and at the same time larger concerns were integrating production, acquiring foundries and bringing under one roof processes which had previously been carried out by subcontractors.[73] During this third phase, dating from perhaps 1830, some firms which had previously concentrated upon components made a transition into machine production, particularly in response to demand for powerlooms in the worsted and woollen branches. A fourth phase, around the mid-century, saw a consolidation of the industry, confirming the market leaders, and a new emphasis upon overseas markets after the lifting of the export ban in 1843. There emerged a professionalism in the sales effort, and a protective attitude towards technology, which had not previously existed.

By the 1840s, mechanical engineering was seen as having three clear divisions.

> I should make three classes of the mechanical arts: the manufacture of steam-engines, mill-gearing, hydraulic presses and such other heavy machinery, I should call one class; the next, and a separate branch, I should say, was tool-making; and the third I should call machine-making,

with its various branches of spindle and fly-making, and roller-making.[74]

These components, rollers, spindles and flyers, far from being spare parts, had from the start been central to any attempt to build operational machinery. It was because Richard Hattersley developed an expertise in making such components that many of the non-specialists in the first phase of the industry in Keighley were able to function at all as machine-makers, as Hattersley supplied every would-be textile engineer in the area with rollers, spindles and flyers before 1805.[75] The dependence of the industry upon the likes of Hattersley was recognised by contemporaries:

The parts of machines are made to fit the rollers and spindles, and not the rollers and spindles to fit the parts; for it is chiefly in the rollers and spindles that nicety and accuracy are required.[76]

Rollers and spindles were 'those parts which a stranger would be most desirous of getting' [77] and in Manchester further specialization produced 'two or three classes of spindle makers, separate and distinct trades, masters and men'.[78] Likewise roller-making employed 'a distinct set [of mechanics]; it has been a business in itself'.[79] In 1841, the manufacture of spindles was still largely unmechanized, and highly skilled. It required accurate forging, precise grinding, then setting 'and I should say that there is not one man in a thousand that could set a spindle, unless he had given his time to that particular part of the art'.[80] Though specialization brought increased efficiency along with improved quality, prices of rollers and spindles continued to rise, by as much as thirty per cent over a few months in 1824.[81] Roller and spindle manufacturers were overwhelmed by orders - 'the persons of whom I have rollers and spindles are anxious to keep out of our sight, for they have promised more than they can perform'[82] - and even when the machinery market was flat continued a brisk business in repairs and replacements.[83] Inevitably mechanization put an end to this profitable trade, in the shape of a forging machine invented by William Ryder in 1840.[84]

Richard Hattersley's career illustrates precisely the changing role of component manufacturers. In the 1790s Hattersley supplied mainly machine-makers and cotton spinners in Keighley and nearby. From 1805 he developed a network of specialist subcontractors in Keighley and important customers among the worsted and flax machine-makers of Leeds - Taylor and Wordsworth, Samuel Lawson, Peter Fairbairn and others - and had more orders than he could promptly meet. His correspondence files contain a stream of complaints about delays in supplying these parts during the 1820s, and about poor quality and high prices.[85] Until Richard Hattersley's death in 1829, the firm's main products were rollers, spindles and flyers. Perhaps anticipating the demise of roller and spindle-making as such a profitable activity, George Hattersley began to make looms in the 1830s, and was primarily a powerloom manufacturer by the mid-1840s.

Even as large firms integrated their processes within factories, a small-scale sector remained significant, and within it subcontracting continued to be widespread. This served partly to provide flexibility for the larger concerns. Additionally smaller firms mopped up repair and renewal work in a pattern which has continued. For instance in the 1980s the machine-shop at Joshua Ellis's of Dewsbury bought all patterns and tools necessary to make spares for Dobcross looms when the Dobcross works closed, and continue to supply these parts to other users; William Hardill of Cleckheaton, formerly subcontractors to P. and C.Garnett, still produces parts for Garnett's machines even though the larger firm has closed. There is an established practice of making spares for other people's machinery, and it is by such adaptability, diversification, and dis-integration (for example shedding foundries and again using subcontractors), features upon which the early industry was built, that a rump of the textile engineering industry has managed to survive.

THE SCALE AND LOCATION OF TEXTILE ENGINEERING

In 1907 textile engineering was the largest single branch of engineering, and had become 'an overwhelmingly dominant force in world trade' exporting 45 per cent of its output. On the eve of the Great War the industry employed 40,000 men, and even in the United States, the only place in the world not dependent upon Britain for the majority of its machines, Keighley firms monopolized the market for worsted machinery.[86] An inkling of the industry's size at the mid-century comes from census figures in 1851, when engineering in Leeds employed 7.400 people (almost all of them men), nine per cent of the occupied population.[87] Of these the majority were making textile machines, and many were already concentrated in establishments employing hundreds of workers.[88] In Keighley, where only two firms had a workforce whose numbers reached three figures, a polarization of large and small concerns was nonetheless evident.

Keighley and Leeds emerged as major centres of textile engineering. Keighley, which had started with cotton machinery, quickly switched to worsted and the main firms in the town, William Smith and George Hattersley, by the mid-century specialized, respectively, in worsted spinning frames and looms. A large part of the Leeds industry was devoted to flax machines, though some of the same firms were also involved in worsted and silk machinery. Bradford and Bingley were considered worthy of inclusion in a list of machine-making centres in 1841, though textile engineering in Bradford was never of a size to match the worsted industry there.[89] The Spen Valley produced woollen machinery as well as card clothing, and Huddersfield had a sizable machine-making industry. Many firms continued to make a variety of products, perhaps for more than one branch of textiles. Even in Lancashire, where specialization had advanced further, there remained a certain flexibility. For example Thomas Marsden, a machine-maker of some repute, was serving the woollen and flax industries as well as cotton from his premises in Salford in 1836.[90] He may not have been typical. The trend in both Yorkshire and Lancashire was strongly towards specialization, particularly for larger firms, as the mid-century approached.

CONCLUSION

The industry which from the late eighteenth century produced new kinds of textile machines had not grown out of traditional machine-making. Nor did it descend directly from the efforts of factory owners producing their own machinery before 1805, though the Marshall/Murray partnership, in several ways exceptional, also provides an exception to this generalization. The idea that machine-users continued to engage in machine-making after 1805 is disproved both by anecdotal evidence and by the overall figures of mechanics employed in textiles. Distinct phases can be identified in the development of textile engineering, coinciding with changes in products and processes. The phases are distinguished by changing skill requirements for tradesmen, and by a growing scale and specialization among the leaders of the industry.

NOTES:

1. See for example Musson and Robinson 1969, chapter XIII.
2. Tann 1974, pp.80-1.
3. Kerridge 1985, p.174.
4. Kerridge 1985, p.174.
5. Kerridge 1985, p.175.
6. Gulvin, *pers. comm.*
7. Kerridge 1985, p.175.
8. Kerridge 1985, p.175.
9. Musson and Robinson 1969, pp.431-2.
10. Musson and Robinson 1969, p.432.
11. *Leeds Intelligencer*, 6 February 1781.
12. *Leeds Mercury*, 23 November 1784; Turner 1966, p.1.10.
13. Crump (ed.) 1931, p.293.
14. Baines 1822, pp.138, 165, 456.
15. White 1838, pp.455-6.
16. Compared with 100,000 powerlooms: Ure 1836, p.xxix.
17. Sigsworth 1958, p.35.
18. Griffiths *et al.* 1992, p.888.
19. Information at Fulneck Museum.
20. *The Guardian*, 22 July 1993.
21. Jenkins and Ponting 1982, pp.116-7.
22. Kelly's Directory 1912.
23. Sykes 1992.
24. Gross 1987, pp.808-9.
25. Briggs *pers. comm.*
26. Tann 1970, p.100.
27. For a fuller discussion of the role of millwrights in machine-making see chapter 2.
28. WYAS Bradford, DB2/6/3 - hereafter Heaton.
29. Heaton, pp.36-7, 106.
30. Heaton, p.27.
31. Heaton, p.10.
32. Heaton, pp.114-8.
33. Heaton, pp.104-5, 107, 118.
34. Heaton, p.107.
35. Heaton, p.121.
36. Heaton, pp.110-1.
37. Hodgson 1879, p.36.
38. Heaton, p.100.
39. Heaton, p.116.
40. Heaton, pp.123, 127.
41. Ingle 1974, pp.9-11.
42. Crump (ed.) 1931, p.215.
43. Brotherton Library, Marshall MS200/57.
44. Rimmer 1960, pp.34-6, 45.
45. Brotherton Library, Marshall MS200/57, p.6.
46. WYAS Leeds, DB23.
47. Connell 1975, pp.162-3.
48. Tann 1974, p.85.
49. WYAS Bradford, Sp.St./14/39.
50. YAS, DD61 Account book of Richard Smith of Addingham, 1777. For this reference and other information on Smith and High Mill I am grateful to Mrs Kate Mason.

51. The sketch is reproduced in Mason 1989, p.21.
52. Cookson and Cookson 1992, pp.117-8.
53. Bretton Hall, BEA/C3/B16/6.
54. Bretton Hall, BEA/C3/B16/6.
55. PP (HC) 1824 (51) V; PP (HC) 1841 (201) VII.
56. Lee 1972; Hodgson 1879, pp.252-6.
57. PP (HC) 1824 (51) V, p.347.
58. PP (HC) 1824 (51) V, p.304.
59. PP (HC) 1824 (51) V, pp.378-9.
60. Catling 1970, p.46.
61. PP (HC) 1841 (201) VII, p.46.
62. PP (HC) 1841 (201) VII, p.22.
63. PP (HC) 1841 (201) VII, p.194.
64. PP (HC) 1824 (51) V, p.303.
65. PP (HC) 1824 (51) V, p.256.
66. PP (HC) 1841 (201) VII, p.107.
67. Morris 1990, p.89.
68. Ure 1836, p.342.
69. Sigsworth 1958, pp.184-5.
70. PP (HC) 1824 (51) V, pp.381, 383.
71. For fuller information on technological innovation and diffusion in the various branches of textiles see Giles and Goodall 1992, chapter 1; Crump and Ghorbal 1935; Jenkins and Ponting 1982, chapters 2 and 5; on worsted, Sigsworth 1958, James 1857, chapters IX and X; on cotton, Jenkins 1979, Hills 1968; on flax, Rimmer 1960; also Derry and Williams 1960.
72. See chapter 3.
73. For information about the development of machine tools see Steeds 1969; Rolt 1965; Klemm 1959, parts 5 and 6.
74. PP (HC) 1841 (201) VII, p.95, evidence of William Jenkinson.
75. WYAS Bradford, 32D83/5/1.
76. PP (HC) 1824 (51) V, p.381; for information on this point I am grateful to Dr J.A.Iredale.
77. PP (HC) 1824 (51) V, p.344.
78. PP (HC) 1824 (51) V, p.253, evidence of Peter Ewart.
79. PP (HC) 1824 (51) V, p.301.
80. PP (HC) 1841 (201) VII, p.99, evidence of William Jenkinson.
81. PP (HC) 1824 (51) V, pp.299, 301-2, 341.
82. PP (HC) 1824 (51) V, p.343, evidence of Thomas Cheek Hewes.
83. PP (HC) 1824 (51) V, p.301.
84 _Proceedings of the Institution of Mechanical Engineers_ 1868, p.17, for which reference I am grateful to Dr D.A.Farnie.
85. WYAS Bradford, 32D83/32/1 and /2.
86. Saul 1970, pp.142-4.
87. Rimmer 1967, pp.158-78.
88. See chapter 5.
89. PP (HC) 1841 (201) VII, p.393; Banks 1925-6, p.16.
90. _Leeds Mercury_, 4 June 1836; PP (HC) 1841 (201) VII, p.83 etc.

CHAPTER TWO

THE TECHNICAL AND SOCIAL ORIGINS OF ENTREPRENEURS

> We have a number of men who have risen from being common mechanics to being men of great eminence.
> (PP (HC) 1841 (201) VII, p.106, evidence of William Jenkinson)

Contemporary, or near contemporary, sources suggest that Yorkshire machine-makers were generally men of modest beginnings. According to James Watt junior in 1802, Leeds engineers were 'men without character and without means', none of them 'eligible connections' for Boulton and Watt.[1] Later machine-makers who achieved great financial and technical success received the full attention of Victorian hagiographers with pointed emphasis on their humble origins. From such nineteenth century biographies grew an enduring notion that entrepreneurs in many industries emerged from diverse backgrounds, an idea which has only recently been systematically challenged.[2] Honeyman has stressed the need to recognise as exceptional any great success achieved by those from the lower rungs of society.[3]

But are Honeyman's conclusions applicable to a new and highly technical industry with a rapidly expanding market? Machine-making did not require a large or sustained investment in fixed capital, though it was increasingly essential that engineering entrepreneurs should possess a high degree of technical expertise. In these respects textile engineering differed from the cases which Honeyman studied. In some industries, where large numbers of ambitious small men were attracted by low entry costs, the resulting overcapacity led to the failure of the smallest firms.[4] If, in general, entrepreneurs who lacked resources were less likely to survive and succeed, what of the men of small capital in a new industry whose market was growing fast? If their failure or withdrawal cannot be attributed to a declining market, what were the reasons? It is more likely that the explanation lies in technical inadequacy than in lowly social and financial status. If humble men had wider opportunities during periods of change, as Alfred Marshall believed, then textile engineering, as a new industry without direct precedents, and consequently without established vested interests, offered great possibilities. Erickson suggests that small men were more likely to succeed in small-scale highly competitive industries like hosiery, than in the likes of steel-making.[5] Level of skill could have been the decisive feature, allowing a small but technically competent entrepreneur to become established while the market was booming, accumulating assets to cushion against a downturn.

Koditschek, in identifying a new bourgeoisie emerging in Bradford during the second quarter of the nineteenth century, places engineering entrepreneurs among 'the new generation of nascent bourgeois elites'.[6] But entrepreneurship does not have to be synonymous with bourgeoisie. It could be practised by manufacturer or artisan, and was 'a quality possessed by a whole host of petty producers'.[7] Smail, whose study was based on Halifax textile manufacturers in the early eighteenth century, believes that 'the initial stages of industrialization ... were accomplished within the terms of an artisanal culture' and that 'even some aspects of [the manufacturers'] economic practice were artisanal'.[8] Smail's conclusions provide a useful hypothesis which may be applicable to machine-making: that artisanal culture and economic practices characterized the early stages of the industry, and that only later in its formation did entrepreneurs develop into 'a distinct cultural type', acquiring different aspirations and behaviour in the process.[9]

The technical ancestry of machine-making has to be explained if this point is to be proved. There is an enduring belief that machine-making descended from a miscellaneous collection of millwrights, clockmakers, woodworkers and others. That is incompatible with an 'artisanal' view, that the industry grew from entrepreneurs of modest backgrounds, sustained by a common and growing expertise, specialization, knowledge and skill. The first objective of this chapter is to explain the role of millwrights, in particular, and also that of clockmakers and engineers, all of whom were of a rather higher social standing than artisans in general. Having in the opening chapter dismissed pre-industrial machine-makers and textile manufacturers as founders of the textile engineering industry, and if it is possible to consign to a marginal role millwrights, clockmakers and middle class engineers, then there remains a group of artisans, perhaps already established as small entrepreneurs when machine-making was developing as an industry, who made a key contribution to textile engineering. The social standing and technical competence of this latter group, and the factors leading to entrepreneurial success, are the subject of the later part of this chapter.

In such an analysis it is important that those who were not conspicuously successful are included. The 'submerged' sector, whose later importance in engineering Floud has emphasised,[10] includes downright failures as well as modest successes and those who left the industry through choice. Even in the industry's earliest days, such firms had their significance, if only as negative evidence of the qualities necessary for success. So although early engineering in Yorkshire cannot provide the large population of entrepreneurs which Crouzet believes necessary for conclusive study,[11] it is certain that the whole 'submerged' sector which was operating in Keighley, and a substantial proportion of the group in Leeds before 1850, has been traced. This approach has the advantage of highlighting the importance of the training and trading networks which existed in engineering, and will perhaps provide an explanation of why certain firms survived.

MILLWRIGHTS

There is a deep-rooted conviction that millwrights were 'the forerunners of present day mechanical engineers'.[12] Despite a paucity of evidence, this belief has been confidently and uncritically repeated, and amplified, until there seems no room for doubt. 'We know that millwrights contributed heavily to the mechanical developments of the Industrial Revolution'.[13] 'Millwrights, who had formerly been itinerant craftsmen, established shops for building machinery'.[14] Morris has the 'shadowy figures' of millwrights and machine builders in Leeds working together on a vast range of products from power sources, including steam engines, and gearing, to both heavy and fine machinery.[15] Commonly millwrights and machine-makers are considered as a single occupation.[16]

This is very misleading, for there was a social as well as a technical distinction between millwrights on the one hand, and artisans such as smiths and carpenters on the other. Tann has hinted at the superior education and training, and the wide horizons, of many late eighteenth century millwrights.[17] That Yorkshire millwrights enjoyed relatively high status is suggested by the form of address, the title 'Mr', used in many instances, and the description 'yeoman', applied for example to John Jubb.[18] They were also engaged upon a kind of work quite distinct from textile machine-making, their involvement in the latter industry being peripheral. It is true that some millwrights experimented with machine-making, and that a few actually converted to become machine-makers, but their numerical and technical importance was no more than that of woodworkers or founders.

By the time that machine-making was entering its technical phase, in the first decade of the nineteenth century, it was an exceptional millwright who remained involved in machine-making, in Yorkshire at least. Jubb is the only such example known in the county, managing to combine his millwright's work with machine-making, for Peter Fairbairn had never worked in Leeds as a millwright.

What is the origin of the idea that millwrights founded textile engineering? The belief that millwrights and clockmakers were the first machine-makers probably stems from standard phrases used in late eighteenth and early nineteenth century insurance policies[19] where the contents of textile factories, apart from steam engines and boilers, were subdivided into 'millwrights work' and 'clockmakers work'. The former generally included heavy transmission and 'going gear', the latter the machinery itself. Though clockmakers have even less connection than millwrights with machine-making, these two trades have retained a near monopoly on the foundations of mechanical engineering, in popular imagination at least. The idea that millwrights were of paramount importance was further reinforced by the overblown claims of William Fairbairn about the development of the trade, and in particular his own contribution to it. His ideas were influential. An obituary in The Engineer in 1874 suggested that Fairbairn had 'abolished the millwright, and introduced the mechanical engineer'.[20] The latter part of this statement is wildly exaggerated, the former clearly untrue. The millwright continued, and continues, to function as a distinct trade in his own right.

Millwrights possessed a wide range of skills in many aspects of engineering though their main expertise lay in making and mending prime movers and transmission equipment. They were able to adapt to new circumstances, for example becoming involved in designing and building early factories in various industries.[21] The trade of millwright was long-established, dating at least from the middle ages.[22] A definition written in 1747 suggests that a level of education was required which would have been beyond many artisans at that time:

> The Trade is a Branch of Carpentry (with some assistance fromthe Smith) but rather heavier work, yet very ingenious, to understand and perform which well a person ought to have a good Turn of Mind for Mechanics, at least to have some knowledge in Arithmetic, in which a lad ought to be instructed before he goes to learn this Art; for there is a great variety in Mills, as well as in the Structure and Workmanship of them, some being worked by Horses, some by Wind, others by Water shooting over and others by its running under. And why not in Time by Fire too, as well as Engines?[23]

The sum of £100 to £150 which would set up a millwright in business was larger than the capital required for most artisan trades. Furthermore, apprentice millwrights were charged a premium of £5 or £10.[24] Millwrighting was therefore open only to those with some means - modest, perhaps, yet beyond many common working men. Even allowing for some poetic licence, Sir William Fairbairn's much-quoted account essentially makes the same point, describing millwrights as a profession rather than a trade:

> ... the millwright of the [eighteenth] century was an itinerant engineer and mechanic of high reputation. In the practice of his profession he had mainly to depend on his own resources ... [he] was a kind of jack-of-all-trades, who could with equal facility work at the lathe, the anvil or the carpenter's bench ... he could handle the axe, the hammer and the plane with equal skill and precision; he could turn, bore or forge ...[25]

The common view of the millwright, said Fairbairn, was of one of 'superior attainments and intellectual power'.[26]

> Generally he was a fair arithmetician, knew something of geometry, levelling and mensuration and in some cases possessed a very competent knowledge of practical mechanics. He could calculate the velocities, strength and

power of machines; could draw in plan and in section ... and could construct buildings, conduits or watercourses ...[27]

Such paragons of versatility do not represent the whole story of millwrighting, for there was also a 'pre-industrial' type much more akin to a carpenter, who concentrated upon repairs and simple work.[28] Such men, lacking the lauded adaptability of Fairbairn's super-millwright, are even less likely to have involved themselves in a new and demanding trade like textile engineering.

Millwrights worked in any industry which used a power system, notably corn milling and fulling.[29] As the first power-driven textile machines, slubbing billies and scribbling and carding engines, were housed in fulling mills, millwrights were involved in installing them and in connecting them to the power source, though not, generally, in building such machinery. Millwrights concentrated upon what they were best qualified to do, as their traditional skills were in great demand in the closing decades of the eighteenth century,[30] especially connected with the expansion in new factories. There was a vast amount of new work in building factories and equipping them with power sources and transmission equipment, and their subsequent repair and maintenance. As a result millwrights were in demand in their own trade, and consequently had no need to be involved in textile machine-making. The millwrights' society regulated their rate of pay, which was substantially higher than that of a smith or equivalent artisan. There were therefore strong economic incentives to employ smiths rather than millwrights to build machinery, other things being equal. Millwrights were also conscious of possessing a superior status and were reluctant to let go of their traditional work and privileges. This sense of superiority caused them to maintain a distance from textile engineering, though later concessions had to be made to the newer industry.

> We make our machines so much better, and so much cheaper, that [the millwrights'] trade, that used to scoff and spurn at the name of an engineer, are obliged to take up the name of an engineer, and conduct their business by the engineer's economy, and that change in the short progress of fifteen or twenty years.[31]

After the first phase of textile engineering, when a few millwrights experimented with the new machines, millwrights' involvement in machine-making was generally confined to the heavy equipment associated with finishing processes, like fulling stocks, washing machines, and later tentering machinery. Tann's examples from the Somerset and Wiltshire woollen district fit into the same categories, either an early experiment, or the manufacture of heavy finishing machinery.[32] Leeds provides similar instances, such as William Kilburn of Holbeck, whose products included stocks and accessories, washing machines and teazling machines.[33] The trade of millwright which still exists, no longer identified with the construction of factories or transmission systems, is understood in the textile trade as a manufacturer of milling or finishing machinery.[34]

Demarcation lines between the work of machine-makers and millwrights were in place at an early phase. This is clear even where entrepreneurs engaged in both types of work. Thomas Cheek Hewes was 'extensively employed in erecting mills, and filling them with machinery' in Manchester.[35] Of his 140 to 150 employees, Hewes counted about 40 who were engaged on heavy mill work, in which he included:

> water wheels and shafting, and mill wheels of different descriptions, and the framing, and all the appendages till it comes to machinery, which is detached from the heavy mill work generally by a belt or rope; that distinguishes the millwright work from the machinery.[36]

It is said that Hewes had quite distinct views of the two parts of his company, with machine-making the 'bread and butter' activity which allowed him to pursue his interest in power supply, until eventually machine-making was allowed to decline and the firm concentrated upon building water-wheels and fireproof mills.[37]

Published works of the time reflect the distinction between millwrights' work and that of machine builders, and furthermore show technical dynamism within the millwrights' trade. A debate on optimum methods and efficiency was continuing from John Banks' work of the 1790s, to Nicholson's Operative Mechanic in 1825. In most cases the machines referred to were waterwheels, windmills or plant for processing agricultural products.[38] Sutcliffe did discuss some aspects of cotton machinery, though related to setting up and gearing rather than manufacturing machines, and the emphasis of his work was upon civil engineering, factory building and power.[39]

Although a type of pre-industrial millwright appears to have survived into the nineteenth century, overall the trade took a progressive view in overcoming practical problems posed by new industrial processes, and consequently retained a high reputation and standing. But the millwright's sphere, though wide enough to include factory construction, power sources and transmission, and building heavy machinery for textile finishing and for other industries, did not encompass the manufacture of textile machinery.

CLOCKMAKERS

On the surface there appears a strong case that clockmakers were involved in early textile engineering. Unlike 'millwrights work', the 'clockmakers work' mentioned in insurance valuations undoubtedly refers to textile machinery. If 'clockmakers work' were actually carried out by clockmakers, then clockmakers were indeed textile machine-makers.

The alleged movement of artisans from clockmaking into textile and machine tool engineering has been explained by a decline in their original trade. It is said that crisis in the clock- and watch-making industry, linked to division of labour and de-skilling, was exacerbated by Pitt's tax on timepieces in 1797, and the loss of foreign markets to Swiss competition after 1815.[40] Landes suggests that Coventry journeymen once noted for their skill moved into rough manual jobs,[41] though clockmakers elsewhere are assumed to have turned skills they possessed to more appropriate uses. For instance from 1823, when a patent on lace-making machinery expired, Birmingham clockmakers found that they could almost double their incomes making the 'insides' for bobbin net machines in Nottingham, and master clockmakers in Birmingham produced the same parts on subcontract.[42] Felkin noted the attractions of frame-making:

> All were very highly paid and the profits of the masters were great in proportion. During several years the demand was so great that it could not be supplied: the news of such wonderful wages, independence and jollity spread like wildfire so that speedily machine smiths, locksmiths and blacksmiths, together with every watchmaker ... within 50 or 80 miles, came together in the garret workshops ... of Nottingham.[43]

It is therefore a possibility that a sustained depression in their trade motivated clock- and watch-makers in Yorkshire and elsewhere to seek opportunities in trades like mechanical engineering. A number of well-known instances are often cited as evidence of a connection between textile machines and clockmakers in the eighteenth century. However, the possibility must be recognised that these were not clockmakers in the conventional sense, but that the term was being applied to mean machine-maker. Arkwright and Strutt of Cromford advertised in 1771 for 'two journeymen Clock-Makers or others that understands Tooth and Pinion well ...'[44] In Manchester in 1782 there was advertised 'Employment for Clock-Makers ... Would be more agreeable if they have been before employed in Cotton Works' and in 1789 a machine maker wanted 'Clockmakers and Turners'.[45] A missing employee, 'by trade a Clock smith' but lately a 'Filer and Turner' was sought by cotton mill owners in 1785.[46] John Kennedy, a prominent machine maker and cotton spinner in Manchester, told the Manchester Literary and Philosophical Society in 1815:

> By degrees, a higher class of mechanics such as watch and clock-makers, white-smiths, and mathematical instrument makers, began to be wanted; and in a short time a wide field was opened for the application of their more accurate and scientific mechanism. Those workmen were first chiefly employed in constructing the valuable machines invented by Mr Arkwright ...[47]

Another claim on behalf of clockmakers is that they developed machine tools for use in industries other than their own. If this were true, it could only have been in the Prescot area of Lancashire where the watch and clock tool-making industry was exclusively concentrated.[48] John Wyke of Prescot and Liverpool (d.1787), for example, is said to have made a wheel-cutting engine and other tools for machine making.[49] It is also suggested that lathes, drills and wheel-cutting engines used by instrument-, clock- and watch-makers were developed into heavy power-driven machine tools from the late eighteenth century onwards.[50] Such claims are largely or wholly speculative, although the publication of a detailed catalogue by John Wyke in the early or mid 1760s, aimed at a range of trades besides clock- and watch-makers, could have been a means of disseminating tool design.[51] But the notion that clockmakers' tools, and indeed clockmakers, were significant in textile machine-making is unconvincing, because the precision which they supposedly brought to mechanical engineering did not start to be a reality until after 1820.[52] Clockmakers may have designed improved lathes and developed a rudimentary slide rest,[53] but the essential innovations in machine-making tools, notably to the lathe and the planer, were the work of engineers such as Wilkinson, Bramah, Maudslay, Clements, Roberts, Whitworth, Fox, Nasmyth and Murray, none of whom was connected with clockmaking.[54]

If clockmakers' tools were not of use in textile engineering, what of clockmakers themselves? If the trade had been thoroughly de-skilled, as has been alleged, then its value to machine-making was diminished, for precision and adaptability were the skills needed in making new types of machinery. Contemporary definitions of clockmaking make no reference to connections with other engineering trades, suggesting on the contrary that the trade had become increasingly narrow:

> If we were to define the word clockmaker agreeably to the derivation of the term, we should simply say that it means a man who makes clocks, and this definition, at one period of the art, would have been sufficient for our purpose; but since clocks have become so common ... the art of making them has not been confined, as at first, to one department of mechanics, but has gradually ramified into various branches so distinct from one another, that the maker of one part is frequently unacquainted with the operations requisite for the manipulations of another, equally essential ...[55]

Rees listed seventeen operations involved in clockmaking, explaining the subdivision of labour as a result of increased use of machinery which had brought 'expedition, and consequently ... cheapness'.[56] The trade in Lancashire at that time was highly departmentalized,[57] though separation of processes had started much earlier:

> Of late years the watchmaker ... scarce makes anything belonging to a watch, he only employes the different tradesmen ... and puts the several pieces of the movement together, and adjusts and finishes it.[58]

The term 'clockmaker', quite apart from any application to machine-making, had many meanings. Some clockmakers were goldsmiths or jewellers, others carpenters or cabinet makers who produced clock cases. Yet others calling themselves clockmakers never made clocks, but were retailers or perhaps blacksmiths or locksmiths who repaired church and other clocks.[59] Watchmaking was concentrated in certain centres, whereas clock parts, which were larger and similar to blacksmiths' work, were produced over a much wider area.[60] Diversity within the watchmaking/ clockmaking trade is significant, as watchmakers and jewellers had no affinity with machine-making, while those who made and repaired metal parts of large clocks were working on a scale which resembled that of early textile machines.[61] In Glasgow, where there were many public clocks, it is known that their repair was carried out by smiths.[62]

So on the face of it some sections of the clockmaking industry could have possessed the means and the motivation to enter textile engineering. There is, however, much contrary evidence. Some contemporary testimony actually suggests that clockmakers were not suitable as textile machine-makers. Peter Ewart, who had trained as an engineer under both Rennie and Boulton and Watt, told the Select Committee in 1824:

> ... the clock and watch tool and movement makers in Lancashire ... are considered the best workmen ... their workmanship is excellent; they use the same sort of tools that the cotton machine makers use, but they are brought up to no employment but making those clock and watch tools and movements; and when those men come to be employed in making cotton machines, we find that they have almost as much to learn as if they had never learnt any working in metal at all ... We have found them quite insufficient to do any ordinary filing and turning, when they have been taken from the work at which they have been exclusively employed.[63]

Ewart was speaking at a time when textile machine-making had entered a specialized technical phase, but the same point had been made by James Lawson, Boulton and Watt's northern agent in the 1790s, who thought the Lancashire watch movement makers, who 'had only been used to small work', unsuitable for heavier engineering.[64]

But the most convincing evidence to counter claims that clockmakers were significant in textile engineering, can be found by looking closely at those clockmakers who were supposedly early machine-makers. Certainly there were a few Yorkshire clock- and instrument-makers who transferred to other branches of engineering. Benjamin Huntsman (1704-1776), the steel maker, was originally a clockmaker, as was William Flather of Halifax (1810-1879) who became a piano pin-maker. The engineer John Smeaton (1724-1792) trained as a mathematical instrument maker.[65] But there are few known links even between those clockmakers who appear on Loomes's exhaustive list, and the textile industry in general. Thomas Lister (II) of Halifax (1745-1814), who was a famous and successful clockmaker, owned a half interest in a cotton spinning mill, but this was merely a kind of local investment which any wealthy man might have made.[66] Loomes knows his clockmakers by the clocks they made, listing hundreds active in the county from the seventeenth to the early nineteenth century. With the exception of one or two whose position is ambiguous (see below), none of those listed made textile machinery. Yorkshire appears not to have been unique in this lack of connection between genuine clockmakers and engineering, as, for example, a comprehensive list of Wigan clockmakers from 1650 to 1850 mentions no links with machine-making.[67] Furthermore, in Switzerland, where British expertise was imported to help build early machines, there is no suggestion that native clockmaking skills were recruited to use in engineering.[68]

In Keighley, of eighteen entrepreneurs who made textile machinery before 1830, only two were ever referred to as clockmakers. William Lawson, whose clocks are described by Loomes, came from a line of watch- and clockmakers working in the town from 1740 or earlier.[69] Lawson was already a customer of Richard Hattersley in 1793, buying parts such as 'clock irons' and 'ironwork for ongin' which may have been intended for either clocks or machines.[70] During the machine-making boom of 1800-1, Lawson was making throstles, for he bought large numbers of rollers and flyers from Hattersley. But the purchases fell sharply in 1802,[71] and a directory of 1822 shows that Lawson had reverted to clock- and watch-making. His contribution to machine-making seems to have been negligible.

The case of the other Keighley clockmaker/ textile engineer was quite different. From a humble start in 1795 William Smith created a business of world renown making spinning frames.[72] Although by then well-established as a machine-maker, Smith was described as a clockmaker in the list of West Riding voters for 1807, and the same appendage was used in Hattersley's sales ledger and subsequently repeated by Hodgson.[73] It is certain, though, that William Smith never made clocks. Loomes was unable to cite any.[74] Smith was in fact one of the first men in Keighley, perhaps the very first, to be trained as a textile engineer, receiving his grounding in 'the art and mystery of machine making' on Arkwright's water frames as an apprentice at Low Mill, the first cotton factory in Yorkshire, from 1780.[75] The career of William Smith shows not a clockmaker turned machine-maker, but rather application of the term clockmaker to someone closely identified with Arkwright's machinery.

In Leeds there was one significant machine-maker connected with clockmaking. Samuel Lawson started his business in 1812, so was actually part of a second wave of machine-making entrepreneurs, and he was not himself a clockmaker. It was Lawson's father Thomas (b.1754) who had made the transition from clockmaking to textile engineering.[76] Thomas and his father Samuel (b.1728) were clockmakers of repute in Keighley. Thomas could have been a brother of William Lawson (above), as they were both recorded as working in Keighley in 1793 [77] but he left the town shortly afterwards to act as agent in establishing a factory in Burley-in-Wharfedale. Thomas Lawson was said to have had 'considerable skill as a mechanical engineer' and was 'in request among those who established textile manufactories'.[78] He left Burley in 1803 to join J. and J. Holroyd of Sheepscar in a new cotton mill in Mabgate. Samuel Lawson (1782-1866) served an apprenticeship with Fenton, Murray and Wood, according to notes made by a descendant, though this would have meant that he went to Leeds some time before his father's move there. He would also have been one of Murray's first apprentices. Samuel described himself in 1812, when he started in business, as a blacksmith and maker of flax-spinning machinery. One reference has been found to Samuel Lawson as a clockmaker, in the accounts of Ard Walker's mill in 1803/4 when he had recently completed his apprenticeship and may still have been employed by Murray. Samuel Lawson was certainly renowned for intricate work, such as the planetarium shown at an exhibition in Leeds in 1839 and subsequently exhibited at his Mabgate engineering works, but he never made clocks professionally.[79]

The inevitable conclusion is that 'clockmakers work' in Yorkshire factories was not carried out by clockmakers, and therefore clockmakers, in the generally understood meaning of that trade, were not textile machine-makers. Evidence which suggests the contrary can be explained. The Babbage and Felkin evidence, though quite specific, relates only to the Midlands frame-making industry, where machines were much more delicate and had an inner mechanism providing apparently suitable work for clockmakers. The finer parts of northern textile machinery, rollers, spindles and flyers, although requiring precision, were on a different scale and remained the province of the smith. There was no separate inner mechanism. Secondly the 'advertisement' evidence, from Arkwright and others, comes from a very early period of textile engineering, the 1770s and 1780s. At this time some clockmakers did try out machine-making in the way that many other metal- and wood-workers experimented in it. In Yorkshire, the only clockmakers discovered to have been working in textile engineering came from one family, the Lawsons of Keighley, and only one of them successfully sustained a transition into machine-making. There is another explanation of the advertisement evidence, which is that the word 'clockmaker' was used interchangeably with 'machine-maker', especially when referring to Arkwright's machinery. William Smith and Samuel Lawson were not clockmakers, but were described as such because a terminology within the new industry had not become generally established, and for a time 'clockmaker' was understood to refer to machine-maker, as 'clockwork' could mean any mechanical device.[80] 'Clockwork' was used in the eighteenth century to describe any kind of mechanism. Models 'moved by clockwork', in the way that the word now means:

> the automatic and mechanical nature of the action, or its unvarying regularity; hence such phrases as 'like clockwork', 'regular as clockwork'[81]

In Lancashire, M'Connell and Kennedy served apprenticeships during the 1780s, undoubtedly as machine-makers, but they too have been described as clockmakers.[82] There is no evidence that they made clocks, nor any reason for them to have done so. The description was applied because that term was still synonymous with machine-maker. Arkwright, who had employed a Warrington clockmaker, John Kay, to help develop his first spinning frame, later applied the description to himself and may have been the originator of this application of the word.[83] Perhaps he intended to summon an association with an old and respected trade. The image persisted into the next century - '... as to spinning frames, they are now made with all the nicety of clockwork ...' [84] - though the term had ceased to be used in place of machine-maker.

In Yorkshire, and probably also in Lancashire, most clockmakers made clocks but never machines. A very few who had trained as clockmakers experimented in textile machine-making with limited long-term success, while some who were described as clockmakers worked entirely in textile machine-making and had never made a clock. The contribution of clockmakers, as a trade, to the new industry was rather less even than that of millwrights.

DEFINITIONS AND DISTINCTIONS

The problems of terminology which obstruct an understanding of clockmakers' work also apply to other trades related to machine-making. There is a particular difficulty with the term 'engineer', which suggested a man of professional standing, but was ambiguous, including within its scope military and civil as well as mechanical pursuits.[85] As Rees defined it, 'engineer'

> ... in its general sense, applies to a contriver or maker of any kind of useful engines or machines. In its more proper sense, it denotes an officer in an army or fortified place ... [86]

It is said that until the mid-nineteenth century there was no clear differentiation between 'civil' and 'mechanical' engineering.[87] In the 'mechanical' sense there had sometimes been a presumption that the description related to those connected with steam engines, and that such an engineer required capital and connections:

The Engineer makes Engines for raising Water by Fire, either for supplying Reservoirs or draining Mines ... The Engineer requires a very mechanically turned head ... He employs Smiths of various sorts, Founders for his Brass work, Plumbers for his Leadwork, and a Class of Shoemakers for making his Leather Pipes. He requires a large stock (at least £500) to set up with, and a considerable Acquaintance among the Gentry.[88]

But Watt, who thought of himself as a natural philosopher, tried to distance himself when he claimed in 1771 to have no experience of 'engineering in the vulgar manner'.[89] The definition of engineer was already broadening.

'Engineer' was certainly adopted in some cases by early textile machine-makers, but was only one of a range of descriptions applied to them. The term 'machine-maker' was in existence in the 1780s, though it had not found universal application. 'Mechanic' was used but carried a connotation of belonging to the lower orders, perhaps as a journeyman carrying out maintenance work in a textile factory. 'Millwright' carried weight but was not a relevant description for most machine-makers. So until suitable terminology was settled, many of those engaged in textile engineering continued to describe themselves, at least in official documents such as parish registers and the muster roll, by their original trade. When they began to rise in the world, difficulties were encountered in finding suitable labels. Matthew Murray called himself 'whitesmith', the trade in which he had been apprenticed, on his first patent in 1790.[90] Later he was sometimes said to be an ironfounder, for a foundry formed part of his business. The term 'ironfounder' could be used as a catch-all, a blanket word for someone who founded and forged iron into various products, carrying the suggestion of higher status as ironfounding was an established trade associated, like coal-mining, with land ownership and higher levels of capital investment. In 1807 Murray was the only man in Holbeck's list of voters to be styled 'engineer',[91] a term which indicates more about his growing social standing than it tells of his actual trade. The problem of terminology followed both Murray and Wood to their graves. Murray's cast iron obelisk of 1826 in Holbeck churchyard refers to him as a 'civil engineer',[92] distinguishing him from the military and with the advantage of brevity, but hardly adequate to describe the work for which he is famed. To his partner David Wood, originally a blacksmith, was applied the curious appendage 'mechanician' on his tombstone in 1820.[93] Some thought had gone into this. Wood was much more than a humble mechanic, but unlike his son, referred to at the time as a gentleman, had not the education or background to claim membership of a higher class.[94] Similarly Richard Hattersley, despite his substantial achievements as a textile engineer, continued up to his death in 1829 to call himself whitesmith, and occasionally machine-maker, though he had made few actual machines.[95] These examples suggest that suitable terminology had not been found for the new industry by the 1820s, with 'engineer' so widely used that it was misleading. For instance, Murray's sons-in-law were described as 'engineer' when they married, though one had been apprenticed to Murray as founder, another as machine-maker, and the third has left no evidence of any superior antecedents.[96]

The term 'engineer' should therefore be treated with caution, and should not be allowed to infer middle class origins. No evidence has been uncovered to show that any middle class engineer was engaged in textile machine-making in Yorkshire. More usually artisanal descriptions continued to be employed, providing further indication that the roots of textile engineering lay with that class of worker.

ORIGINS OF THE FIRST MACHINE-MAKING ENTREPRENEURS

If millwrights, clockmakers and middle-class engineers were of only marginal importance, then who founded textile engineering? If, as Smail suggests,[97] entrepreneurship was a feature possessed by many small artisans, then it is quite possible that such a group laid the foundations of this new industry, and that those who eventually achieved success moulded themselves only later into something more recognizable to the modern observer as a businessman.

Accepting that technical ability was the key to success as a machine-maker, as entry costs were low it is feasible that men of humble beginnings dominated the early industry. Artisans like blacksmiths lacked the social status, and perhaps even the modest capital, of millwrights and clockmakers, but had a distinct technical advantage in machine-making. Social or financial disadvantage need not rule out success if a degree of mutual support, in the artisan tradition, were available.

The continuance of traditional patterns of organization, characterized by a lack of any kind of business record, explains in large part why the real origins of engineering have been so misunderstood by historians. But this 'submerged' sector is capable of illumination. Through detailed study of early centres of engineering, in this case Keighley and Leeds, it is possible to identify a population of machine-makers which is complete, or almost so. The key indicator of origins, both technical and social, is trade, and such information is readily available as many machine-makers continued to describe themselves by their apprenticed trade, even long after they had given it up. Another advantage of this 'complete population' approach is that some assessment can be made of success and failure, and the reasons for particular outcomes in particular cases. It is rarely possible to be absolutely certain why a particular enterprise thrived, or failed to survive, or continued with apparent success yet did not expand. But with a whole group of machine-makers, some common qualities of entrepreneurship, technical ability, or support from an artisan network, may be discernible among those whose careers followed similar paths.

Keighley, being clearly defined and well documented, has provided comprehensive evidence of an early machine-making industry. Richard Hattersley's sales records, which run from 1793, were central to this exercise, for by cross-checking with information from Hodgson's account of the first textile engineers, from the Craven Muster Roll of 1803, and from parish registers, along with directories and other miscellaneous sources, it can be established that Hattersley supplied every would-be machine-maker in the town with rollers, spindles, and other parts.[98] For the Leeds industry, which was in any case less clearly defined, such thoroughness is not possible as sources comparable to those in Keighley do not exist. Yet although its peripheral parts are less well known, Leeds can provide better evidence of the growth of very large engineering firms before 1850, so that views of the industry in Leeds and Keighley in many ways complement each other.

Eighteen textile engineers worked in Keighley in the late eighteenth century or into the first decades of the nineteenth (Table 2.1). All the firms were very small, employing at most a handful of journeymen and one or two apprentices. Some of the eighteen listed may never have been more than a one-man business, and some may have made only one or two machines. Because they are few in number and each career was highly individual, the origins of entrepreneurs are difficult to categorise into a form which can be expressed statistically. It may not be possible to go further in summary than to say that there are as many woodworkers as metalworkers among the group as a whole, though the later entrants to entrepreneurship were metalworkers. The outline of the Leeds industry (Table 2.3) is less satisfactory during this early phase, relying mainly upon directory evidence and what is known of major firms. Because the Leeds evidence is slanted away from the smallest and least successful firms, those from a metal-working background gain more prominence than woodworkers (Table 2.4). But as in Keighley this was a new industry with no standard career path, and it was possible for Joshua Wordsworth, a carpenter by trade, to become one of the most successful machine-making entrepreneurs in Leeds with a career spanning the first half of the nineteenth century - though possibly he was carried, technically at least, by his partner Joseph Taylor.

The majority of early firms were of short duration, failing to survive through the industry's watershed of c.1805. The lifespan of a company is not, though, a certain measure of its success. In many cases the reasons for a firm's failure to survive or grow can only be guessed. Sometimes the business folded when its head died and had no partner or son to carry on. There are also cases where entrepreneurs made a commercial decision to move into another industry without apparently having failed as a machine-maker. But much of this is speculative, as comparative standards of product are not known, nor is detailed information available about companies' finances. Nor is it possible to say exactly what contribution was made respectively by successful or failed firms to the emerging textile engineering industry.

Twelve of the eighteen early Keighley machine-making entrepreneurs had left the industry by 1805. Most had reverted to their original trade, though three, Brigg, Greenwood, and Tempest, disappeared from Keighley records and could have continued engineering careers elsewhere. But there is no definite evidence of that, and of the twelve leavers nothing substantial has survived, neither businesses descending from them, nor their former trainees carrying on the machine-making trade. There is a suggestion that two of the leavers, Nicholson and Weatherhead, collaborated on the invention of a hand throstle,[99] but no confirmation has been found. Possibly the two men introduced some minor improvement to the spinning operation. That apart, there is nothing to suggest that the leavers made any contribution to technological progress in the industry.

If the dozen leavers had a negligible impact on the local machine industry, that is not to say that their careers always ended in outright failure. Some, like Thomas Corlass, whose machine-making was ancillary to his cotton-spinning business, were clearly unsuccessful commercially.[100] But others were able to make the most of changing opportunities, showing versatility as entrepreneurs rather than as technicians. Lodge Calvert, for example, was a joiner who made throstles for a few years, perhaps only for his own use, until about 1805 when he gave up machine-making to concentrate first upon cotton-spinning, and later worsted-spinning, both with great success.[101] Such detailed information is not available about those who dropped out of the Leeds engineering industry during its formative phase. But if there is a generalization to be made, it is that woodworkers did not survive as entrepreneurs in the industry unless they had made a thorough transition, effectively re-training as Titus Longbottom seems to have done, or unless they could partner someone with superior technical abilities, like Wordsworth with Taylor, and Fenton, who took care of the book-keeping while leaving the engineering business to Murray and Wood.[102] Mechanical skills, particularly those of smiths, were all important for entrepreneurs at this stage.

To have survived past the first decade of the nineteenth century may have been an achievement, but continuing success was by no means assured. Six Keighley firms lasted through that watershed, but by the mid-century only two of them were still in existence, though neither of those survived unscathed the death of their founder. This experience emphasises that the demands placed upon entrepreneurs during a period of rapid technological change were heavy, for it was generally when an entrepreneur was unable to continue, and inadequate arrangements had been made for the succession, that the business folded. This generalization applies to those Keighley firms which passed the watershed of c.1805 but failed to reach the mid-century: William Carr, whose business declined after his retirement in 1817 as his sons were not of equivalent stature; Michael Merrall, killed in 1819 when his sons were too young to take over; and Titus Longbottom, who left no heir and whose firm died with him in 1831. Berry Smith had lost interest in machine-making by about 1830 and switched to the textile industry, which may have seemed more profitable and less demanding to an ageing man who lacked a son to share the burdens of business. In Leeds, similar examples prove how imperative was the role of the business leader in a dynamic new industry. John Jubb (II), whose father had started a transition from millwrighting to machine-making in the 1780s, outlived the older man by only eight years, and because his own sons were not even into their apprenticeships when he died in 1816, the firm was soon forced out of business.[103] Fenton, Murray and Wood lost its impetus after Murray's death in 1826 and eventually faded away after several years under the guidance of the lacklustre Richard Jackson,[104] though the technical legacy from its early period was outstanding (see below). Zebulon Stirk, who had been among the leading makers of textile machines and steam engines in Leeds during the 1820s, saw his firm decline to employ only half a dozen in his old age.[105] He too seems to have lacked male heirs.

Those whose businesses survived long-term in Keighley, Richard Hattersley and William Smith, had numerous sons but that in itself presented a problem, for firm and competent direction was needed to maintain viability as machine-makers. Both companies had to reorganize after the death of the founder, in order to exclude sons who did not fit in personally or technically. This strategy was self-evidently successful.[106]

The first generation of textile engineers emerged from a group of wood- and metal-working trades, small-scale craftsmen working on their own account, or for another as a journeyman. As sons commonly followed into their father's trade, information about fathers' occupations further reinforces a perception of their social status. The early machine-makers ran businesses much as they would have carried on a more traditional craft, on a modest scale usually as sole traders, though there were exceptions. Hattersley had a partner, Thomas Binns, from 1793 to 1810, who has been omitted from Table 2.1 as his interest seems to have been purely financial. In Leeds there were a few more partnerships. The only known sleeping partner there was Lister, of Fenton, Murray and Wood. Otherwise partners either made a wholehearted commitment to engineering, like Wordsworth, or had another part to play, like Fenton and his book-keeping, or Mark Walker whose textile background enabled him to make a significant contribution to technical developments with Samuel Lawson.[107] But without metal-working skill invested in their principal, firms did not survive the first decade of the nineteenth century. In the main it was blacksmiths and whitesmiths who lasted through that period, and those trained by smiths who came to call themselves machine-makers.

In many ways the vast majority of machine-makers operating before 1805 are irrelevant to understanding the mid-nineteenth century industry as such a great discontinuity had taken place, most of the early group leaving no discernible legacy. The important question is how the early experience of machine-making transmitted itself through to a new and more technical generation.

	Original trade	Dates recorded in business	Later career
John Brigg	Turner ?	1791-1794	n/k
Lodge Calvert	Joiner	1799-c1805	Textiles
William Carr	Engineer ?	c1790-c1817 (retired)	Sons continued, to c.1840
Thomas Corlass	Joiner	1799-c1804	Insolvent
James Greenwood	Engineer/mechanic	c1791	Moved to Leeds
Richard Hattersley	Whitesmith	from 1789	Continued
Joseph Hindle	Joiner	1799-c1804	Probably reverted to joinery
John Inman, snr.& jnr.	Joiners	1793-c1805	Joinery
William Lawson	Clockmaker	?1793-c1805	Clockmaker
Titus Longbottom	Joiner/machinist	1809-1831	Died; no successor
Michael Merrall	Blacksmith	?1808-1819	Died; no successor
John Nicholson	Printer ?	1793-1802	Bookseller
George Richardson	Founder	c1800-c1802	Founder
Berry Smith	Machine-maker	1800-c1830-35	Textiles
Thomas Smith	n/k	?1793-?1804	n/k
William Smith	Mechanic	from 1795	Continued
Joseph Tempest	Millwright	?1793-?1795	n/k
John Weatherhead	Joiner	?1789-?1798	n/k

MAIN SOURCES: NYCRO, Craven Muster Roll 1803; WYAS Bradford, 32D83/2/1 and 5/1; Hodgson 1879; Keighley Parish Register.

TABLE 2.1: Careers of early textile engineers in Keighley

	Employees in 1851:	Origins of firm:
Richard Sharp Bailey	n/k	n/k; short-lived
George Bland	12	Founded c.1835; Bland was a blacksmith from Addingham.
Briggs and Banks	31	Three young partners, all Keighley-born, spindle-makers and mechanics.
George Hattersley	168 (including c.70 in worsted spinning)	Descended from Richard Hattersley; George was a roller and spindle-maker.
John Midgley	n/k	Ex-apprentice of Titus Longbottom
Thomas Mills	22	Mainly a founder. Not successful as a machine-maker.
Jesse Ross	n/k	Possibly working alone. Short-lived
Charles & Allan Smith	6	Sons of Thomas, ex-apprentice of Berry Smith. Firm founded c.1815
John & Samuel Smith	80	Trained by Hattersley. Founded c.1818. 1866: 400-500 employees
William Smith & Sons	n/k; large	Est. 1795 by ex-apprentice at Low Mill. Employed c.750 in 1878, c.1500 in 1890s.

MAIN SOURCES: White's Directory 1853; 1851 census for Keighley.

TABLE 2.2: Keighley textile engineers: origins of those in business in 1853

	Earliest reference	Latest reference
Peter Fairbairn (1799-1861)	1826	firm continued
FENTON, MURRAY AND WOOD:		
James Fenton (1754-1834)	1799	firm continued
Matthew Murray (1765-1826)	c.1794	firm continued
David Wood (1761-1820)	c.1794	firm continued
MACLEA AND MARCH:		
Charles Gascoigne Maclea (1793-1864)	1825	retired 1843; firm continued
Joseph Ogdin March (1799-1888)	1825	retired c.1880;firm continued
John Jubb (I) (d.1808)	c.1780	firm continued
LAWSON AND WALKER:		
Samuel Lawson (1782-1866)	1812	firm continued
Mark Walker	1817	left Lawson c.1830
Zebulon Stirk (1782-alive 1851)	1813	still working in 1851
TAYLOR AND WORDSWORTH:		
Joseph Taylor (1777-1848)	probably 1806	firm continued
Joshua Wordsworth (1780-1848)	probably 1806	firm continued

TABLE 2.3: Leeds textile engineers: entrepreneurs 1780-1830
(continued overleaf)

	Earliest reference	Latest reference
OTHERS:		
Joseph Drabble	1798	1809-11
Richard Cluderay	1815	1837
William Farmery	c.1800	c.1809
James Proctor/ John Proctor	1798	1826
Thomas Bedford	1807	1809
Charles Crosland	1816	1822
Thomas Marriott	1798	c.1809
Joseph Matthews	1816	1853
John Rose	1816	1826
Joseph Sugden	1817	1837
Thomas Taylor (1790-1840)	1817	1826
William Varley	1816	1837
John Wade	1807	1809
William Whitworth	1816	1826
Robert Wood	1822	1853

MAIN SOURCES: Leeds and Yorkshire directories 1798-1853

TABLE 2.3: Leeds textile engineers: entrepreneurs 1780-1830

	Original trade	Father's occupation
Peter Fairbairn	millwright	farmer/farm manager
FENTON, MURRAY AND WOOD:		
James Fenton	linen merchant	linen merchant
Matthew Murray	whitesmith	Not known
David Wood	blacksmith	blacksmith
MACLEA AND MARCH:		
Charles Gascoigne Maclea	engineer	(grandfather: minister)
Joseph Ogdin March	smith/machine-maker	woollen manufacturer
John Jubb (I)	millwright	Not known
LAWSON AND WALKER:		
Samuel Lawson	smith/machine-maker	clockmaker turned machine-maker
Mark Walker	textile manufacturer	Not known
Zebulon Stirk	whitesmith	Not known
TAYLOR AND WORDSWORTH:		
Joseph Taylor	mechanic	Not known
Joshua Wordsworth	carpenter	Not known

TABLE 2.4: Leeds textile engineers: occupational backgrounds
(continued overleaf)

	Original trade	Father's occupation
OTHERS:		
Joseph Drabble	n/k	n/k
Richard Cluderay	whitesmith	n/k
William Farmery	coachmaker	n/k
James Proctor/ John Proctor	smiths	n/k
Thomas Bedford	machine-maker?	n/k
Charles Crosland	machine-maker?	n/k
Thomas Marriott	joiner?	n/k
Joseph Matthews	whitesmith?	n/k
John Rose	whitesmith?	n/k
Joseph Sugden	n/k	n/k
Thomas Taylor	machine-maker	n/k
William Varley	wiredrawer and cardmaker: family business established in Hunslet in 1740	
John Wade	n/k	n/k
William Whitworth	n/k	n/k
Robert Wood	millwright	millwright?

MAIN SOURCES: Various parish registers and directories

TABLE 2.4: Leeds textile engineers: occupational backgrounds

	Place of birth	Denomination
Peter Fairbairn	Kelso (trained in Newcastle)	Church of England
FENTON, MURRAY AND WOOD:		
James Fenton	Hunslet	Unitarian
Matthew Murray	Newcastle or Stockton	Church of England
David Wood	Ulleskelf, near Tadcaster	Wesleyan Methodist
MACLEA AND MARCH:		
Charles Gascoigne Maclea	Edinburgh	Church of England
Joseph Ogdin March	Holbeck	Church of England
John Jubb (I)	Doncaster ??	Not known
LAWSON AND WALKER:		
Samuel Lawson	Keighley	Not known
Mark Walker	Not known	Not known
Zebulon Stirk	Otley	Not known
TAYLOR AND WORDSWORTH:		
Joseph Taylor	probably Keighley	Congregationalist
Joshua Wordsworth	Thurgoland, near Barnsley	Not known

MAIN SOURCES: Various parish registers.

TABLE 2.5: Leeds textile engineers: geographical origins and religious affiliations

TRAINING NETWORKS

The second generation of machine-making entrepreneurs, those who went into business after about 1805, were technically far ahead of most of their predecessors. In Yorkshire's two leading centres of machine-making there had been little overlap with the first phase of textile engineering. The hiatus of c.1805 was bridged by only six firms in Keighley, already referred to above, and by two or perhaps three firms in Leeds - Jubb's, which soon failed, Fenton, Murray and Wood, and possibly Taylor and Wordsworth which may have been a continuation of the older firm of Drabble. The discontinuity in the industry is striking. It seems particularly puzzling that such a reduction in the existing firms coincided with a period when machinery was apparently in great demand, and expertise was at a premium. The explanation is that many of the earliest makers had not possessed high degrees of proficiency. Consequently, when iron replaced wood as the main material in the early years of the nineteenth century, and greater precision was demanded of machinery, at the same time as a severe downturn in trade following the boom of 1800-1,[108] less competent machine-makers were forced out of business. This is illustrated in Richard Hattersley's sales, for while the newly established business of Berry Smith thrived and grew exponentially during years of supposed depression, many other machine-makers were giving up altogether.[109] Berry Smith was a newly-trained specialist machine-maker who had learned his trade from William Carr, whereas the drop-outs were relative amateurs who failed for want of technical ability, apparent from their lack of any enduring legacy in the form of technology, techniques or trained labour.

Hence the building of an industry which was already highly specialized in the 1820s, and employed thousands of skilled employees by 1850, was the achievement of a very small group of entrepreneurs. To show how the process worked, how expertise was transmitted to a new generation of business leaders, it is possible to trace the ancestry of the largest firms working at the mid-century. For the Keighley industry, Table 2.2 confirms that George Hattersley and William Smith were the sole direct descendants of the pre-1810 generation. However, almost every firm of substance in the half century to 1850 can be seen to have come down from three textile engineers who had started in business in the town between 1789 and 1795 (see Table 2.6). All these three were by trade metal-workers, Richard Hattersley a whitesmith from Ecclesfield, William Carr an engineer from Preston, and William Smith, trained as a mechanic at the Arkwright system mill in Keighley during the early 1780s.

The three leading engineers passed on their expertise direct to apprentices or by re-training skilled metal workers from allied trades. Some of these went on to become entrepreneurs themselves. Michael Merrall, after finishing an apprenticeship as a blacksmith in Keighley, gained specialist knowledge of rollers, spindles and flyers while working for Richard Hattersley from 1796 or earlier, until about 1808. He was still close to Hattersley after setting up in business on his own, as the two supplied each other with parts and materials, although Merrall also made boilers and repaired steam engines. Merrall's business did not survive his sudden death in 1819 in an accident with his own steam engine.[110] More enduring was the firm of Hattersley's former apprentices John and Samuel Smith, which was established in about 1818, employed 80 hands in 1851 and between 400 and 500 by 1866.[111] Titus Longbottom was another who had converted to the trade. After completing his apprenticeship as a joiner/ machinist with his father, Longbottom gained experience as a machine-maker for two years with Berry Smith, himself an ex-apprentice of William

Carr, before setting up alone in 1809.[112] Although Longbottom's firm did not survive him, it was a significant one and he too had trained a future entrepreneur, John Midgley.

The technical ancestry of six of Keighley's ten mid-century machine-makers can be traced to those three textile engineers who bridged the gap between the industry's first and second phases (Tables 2.2 and 2.6). Of the rest, Bailey and Ross, both woolcombing machinery makers, seem to have been one-man operations which were as short-lived as they were small. Any training links which may have existed between George Bland or Briggs and Banks and the rest of the Keighley industry remain unconfirmed. Bland was a blacksmith from Addingham who was working in Keighley as early as 1822, becoming a noted powerloom maker in his own right in about 1835.[113] It is almost certain that Bland, and probably his sometime partner Fox, worked for one of the large Keighley engineers before 1835. Briggs and Banks was a young firm in 1851, already employing 31, with partners aged 29 to 35, all Keighley born.[114] They made powerlooms, rollers, spindles and flyers, the products for which Hattersley was noted, and it is possible that they too were Hattersley-trained.

The picture of a training network in Leeds is even more stark, reflecting the pervasive influence of Matthew Murray. Murray and Wood survived almost alone through the hiatus of c.1805, as John Jubb's firm had folded before 1820 and no links between Jubb and the continuing industry have been proved. Of the four major Leeds firms in existence at the mid-century, probably three had been founded by ex-employees of Murray - Maclea and March, Samuel Lawson, and perhaps Taylor and Wordsworth (Table 2.7). The exception was Peter Fairbairn, a late arrival to the industry whose skill had been imported to Yorkshire. So though Murray's title of

'Father of Leeds Engineering' was supposed to relate to his pioneering works in introducing various branches of mechanical engineering to the town,[115] he was in a different sense the father of textile engineering in Leeds for he had trained many of the significant entrepreneurs of the nineteenth century.

Proving the training links within Leeds and Keighley indicates how skills and knowledge, both technical and entrepreneurial, were disseminated to a new generation. It also undermines the idea that self-sufficiency was possible, for success in the maturing industry depended upon a thorough grounding in the trade from one of those few who had carried machine-making through to the nineteenth century. Furthermore, a trading network was as important as these training links in enabling men of few means to embark upon entrepreneurship. The trading connections enabled some pooling of technical resources, a sharing of work by means of the subcontract system to help new firms over lean periods, and financial help via extended credit. For established firms to assist up-and-coming entrepreneurs was not altruism, as Hattersley found, for although some of the newcomers would fail and perhaps remain indebted, it took only one or two like Berry Smith for the favour to reap a handsome dividend. That is not to say that such patronage was a mere cold calculation, for in the continuing artisan tradition there was a propensity to assist others, especially ex-apprentices branching out alone. The second generation of entrepreneurs was still imbued with the spirit of the class of artisans from which they had sprung.

WILLIAM CARR
(in business 1790-c1817)

(sons) Edward Carr
John Carr
Thomas Carr of Bingley

(partner 1793) Richardson
who later took Thomas
Mills as partner c.1814
(Mills in business in
Keighley in 1853)

(apprentice) Berry Smith (c.1790)

(employee) Titus Longbottom
(1807-9)

(apprentice) John Midgley
(in business as power loom
maker c.1837-1850s)

(apprentice) Thomas Smith
(left by 1815)

(sons) Charles and Allan
Smith
(in business in 1853)

RICHARD HATTERSLEY
(in business 1789-1829)

(sons)
George Hattersley of Keighley
Samuel Hattersley of Bradford
Jonathan Hattersley of Leeds
(all in business in 1853;
George and Samuel direct
successors of Richard)

(employee
c.1796-1808)
Michael
Merrall
(d.1819)

(apprentices)
John and Samuel Smith
(in business c1818- both dead by
1850 but firm continued)

TABLE 2.6:
Keighley textile engineers:
training and entrepreneurial links

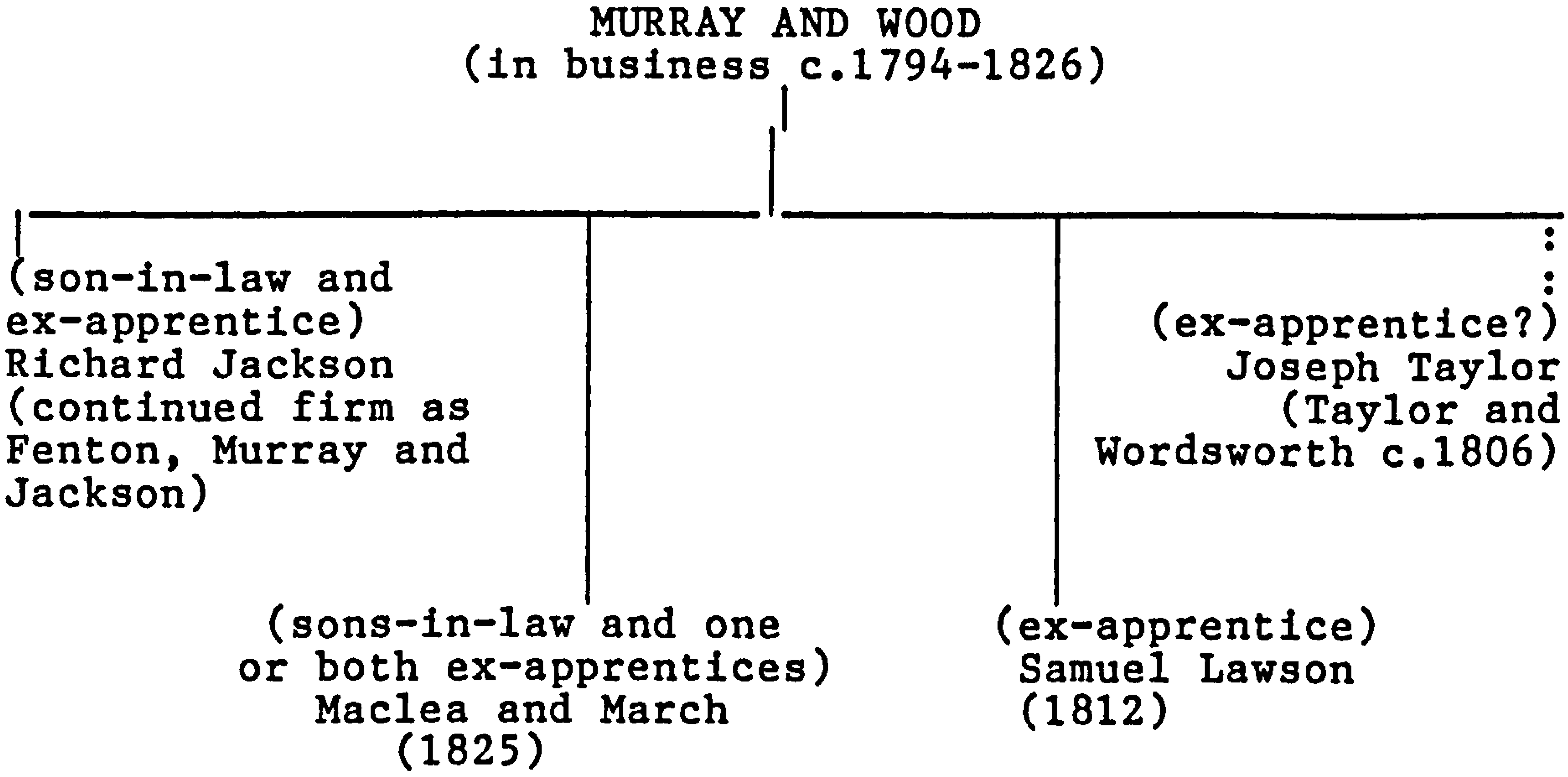

TABLE 2.7:
Leeds textile engineers:
training and entrepreneurial links

CONNECTIONS AND COMMUNITIES

So it was usual for engineering entrepreneurs to maintain close commercial and technical links with others in the local trade, based upon trading and training connections, and positively to assist young journeymen setting up as small masters. As the first group of successful machine-makers had in common a background in skilled crafts, this may have been a manifestation of an artisan tradition. It is also possible that there were other features of their origins which had created a bond between machine-makers, perhaps that they had come from the same villages or shared religious affiliations, and that such common features affected their commercial behaviour to each other.

As far as geographical origins, of the three influential early engineers in Keighley, two were in-migrants, Hattersley from Sheffield in 1789, Carr from Preston the following year. William Smith was Keighley-born. All the significant entrepreneurs of the period up to 1850 were either born and apprenticed in Keighley, or born in nearby villages and trained in machine-making in Keighley. After the first small influx of metal-working skill in 1790, expertise in textile engineering was almost entirely generated from within Keighley.

Leeds seems to present a much more cosmopolitan picture in the geographical origins of its entrepreneurs (Table 2.5). Of the major entrepreneurial figures, only March was born in or near Leeds. Others came from the Sheffield area, from Scotland or the north-east, or from Keighley. But though they may have brought with them metal-working skills, apart from Peter Fairbairn, a late-comer exceptional in many ways, the group of entrepreneurs acquired their knowledge of textile machines in Leeds. Murray and Wood, both smiths, learned from their experiences with John Marshall, and most of the rest learned as apprentices or journeymen with Murray and Wood. The success of the machine-making industry both in Keighley and in Leeds resulted from developments within the community of textile engineers, rather than by an importation of skills and knowledge from elsewhere. The places of origin of these men are too scattered for any sense of communal identity to have existed between them before they moved to Leeds, though it is possible that some of the textile engineers had already known each other and that this may have influenced their business dealings.

As far as religious groupings are concerned, the Leeds machine-makers belonged to a spread of established and non-conformist churches (Table 2.5). In Keighley, although Hattersley and Berry Smith shared allegiance for a time to the Swedenborgian church, which had an appeal to scientists and engineers, there is little common religious ground between the machine-makers as a whole.

Other than in their growing skill and their artisan background, there is little to connect these entrepreneurs. Social cohesion was something which developed among the group as their industry assumed its own identity. The resulting social and personal connections will be further explored in chapter 5.

CONCLUSION

Early machine-making entrepreneurs were almost all from the class of skilled artisan, from backgrounds which were humble though not the very lowest. To succeed in the first phase of the industry required skill in metal-working, though a few wood-workers were able to adapt. In the second phase, it was essential to have directly relevant training in machine-making, a grounding which could come only from the few engineers who had managed to survive an hiatus in the industry around 1805. Entrepreneurs in the maturing industry were consequently 'home-grown', qualifying for a place in the community of engineers by virtue of skills acquired from within that group rather than through external factors such as capital or other connections. In fact capital and connections could not deliver success if the necessary skills were lacking. On the other hand, with expertise and drive it was possible to succeed despite modest origins. The overcapacity which drove out small firms in the industries which Honeyman studied did not occur in textile engineering, because skill was crucial and remained relatively scarce. Small firms which failed in machine-making generally did so because their principal lacked such expertise.

Despite the 'high tech' products of textile engineering, relationships within the new industry continued to be influenced by an artisan tradition of mutual support. This state of affairs did not begin to change until process methods modernized and some businesses grew much larger, from about 1830. Koditschek's 'nascent bourgeois elite' was a minority within machine-making, with many small-scale entrepreneurs continuing to organise their affairs in a way which may better fit Smail's definition of 'artisanal'.

The enterprise and versatility displayed by the earliest group of machine-makers confirms Smail's idea that entrepreneurship was then a widespread quality. That so many failed has been shown to be due to a lack of technical rather than entrepreneurial abilities. But the technical hurdles, in stopping so many, actually provided a means by which men of lowly origin could achieve great success, by preventing overcapacity in the industry. Hence textile engineering can show genuine cases of rags to riches, though there was no such thing as an entirely self-made man when machine-making relied upon close connections in an artisan tradition.

NOTES:

1. Scott (ed.) 1928, p.42.
2. Honeyman 1982, p.160.
3. Honeyman 1982, p.170.
4. Honeyman 1982, p.168.
5. Erickson 1959, p.79.
6. Koditschek 1990, pp.97, 179.
7. Smail 1991-2, p.792.
8. Smail 1991-2, p.808.
9. Smail 1991-2, p.808.
10. Floud 1976, p.6.
11. Crouzet 1985, pp.52-3.
12 Scott (ed.) 1928, p.20.
13. Rae 1975, p.411, citing Musson and Robinson 1969, p.429.
14. Crouzet 1985, p.90.
15. Morris 1990, p.33.
16. For example Foster 1974, p.225.
17. Tann 1974, p.85.
18. YAS, MS1415, 24 November 1791.
19. See for example Jenkins 1975, p.110.
20. Pole (ed.) 1970, p.436.
21. Tann 1970, chapter 6; and chapter 1, above.
22. Jefferys 1970, p.9; for an account of millwrights in south Yorkshire in the early modern period, see Ball 1993.
23. Tann 1970, p.99.
24. Tann 1970, p.99.
25. Pole (ed.) 1970 [1861], p.27; Jefferys 1970, p.9.
26. Pole (ed.) 1970, p.ix.
27. Pole (ed.) 1970, p.ix.
28. Ball 1993.
29. Tann 1974, pp.80-1.
30. Tann 1974, p.81.
31. Evidence of Alexander Galloway, PP (HC) 1824 (51) V, p.28; see also pp.39-41. The point has also been made by More 1980, p.196.
32. Tann 1974, p.82.
33. Scott 1931-2, pp.39-42.
34. John Briggs, pers. comm.
35. PP (HC) 1824 (51) V, p.340.
36. PP (HC) 1824 (51) V, p.341.
37. Smith 1969, p.35.
38. See for example Banks 1795 and 1803; Gray 1804; Sutcliffe 1816; Nicholson 1825 and 1830.
39. Sutcliffe 1816, p.1 et seq.
40. Landes 1983, pp.274-5.
41. Landes 1983, p.280.
42. Babbage 1835, pp.349-52.
43. Honeyman 1982, p.117.
44. Tann 1970, p.100.
45. Musson and Robinson 1969, p.456.
46. Musson and Robinson 1969, p.456.
47. Musson and Robinson 1969, p.435.

48. Dane 1973, p.51.
49. Musson and Robinson 1969, p.437.
50. Musson 1980, p.90.
51. Smith 1977, p.16 etc.
52. Checkland 1969, p.81.
53. Usher 1982, pp.364-5.
54. Jefferys 1970, p.13; Pole (ed.) 1970, p.421, pp.266-7; Musson 1980, p.88; Usher 1982, p.367; Checkland 1969, pp.77-8; Turner 1966, p.1.3; Musson and Robinson 1969, p.65.
55. Rees 1819.
56. Rees 1819.
57. Tupling 1949, p.22.
58. Loomes 1972, pp.8-9, quoting the London Tradesman 1747.
59. Loomes 1972, pp.8-9.
60. Dane 1973, p.51.
61. Ron Fitzgerald has pointed out the similarity between the mechanism of a factory clock at Armley Mills Museum, and parts of an early machine.
62. Gordon Jackson pers. comm.
63. PP (HC) 1824 (51) V, p.251.
64. Musson and Robinson 1969, p.439.
65. Loomes 1972, pp.32, 179.
66. Loomes 1972.
67. Hawkes 1950.
68. Henderson 1965, p.203 et seq.
69. Loomes 1972.
70. WYAS Bradford, 32D83/5/1.
71. WYAS Bradford, 32D83/2/1.
72. Hodgson 1879, p.245.
73. Anon. 1807, p.367; WYAS Bradford, 32D83/2/1; Hodgson 1879, p.245.
74. Loomes 1972.
75. Hodgson 1879, pp.212-3. The suggestion that Arkwright himself supervised the building of machinery there is unconfirmed, though the owners of Low Mill were certainly in communication with Jedediah Strutt in 1786 over payment of royalties for using Arkwright's patent machinery: Fitton and Wadsworth 1958, p.93.
76. WYAS Leeds, Acc 2371/80/2.
77. Universal British Directory 1793.
78. WYAS Leeds, Acc 2371/80/2.
79. WYAS Leeds, Acc 2371/76.
80. Though contemporary definitions are not specific on this point. See Marchant's dictionary of 1760, where 'clock' is 'a large machine or instrument for telling the hour ...'. Crabb's Universal Technological Dictionary of 1823 has 'clock-work' as 'that part of the movement which strikes the hours &c on a bell, in distinction from that part called the Watch-work, which is designed to exhibit the time on a dial plate'.
81. Oxford English Dictionary 1961 II, p.511.
82. Lee 1972, p.17.

83. Usher 1982, pp.298-9; Musson and Robinson 1969, p.438.
84. James 1857, p.535, quoting Nasmyth.
85. Rae 1975, p.411.
86. Rees 1819 XIII.
87. Musson 1980, p.87.
88. The London Tradesman, 1747, quoted by Tames (ed.) 1971, pp.79-80.
89. Robinson and Musson 1969, p.5.
90. Turner 1966, p.1.3.
91. Scott (ed.) 1928, p.80.
92. Scott 1931-32, p.164.
93. YAS, Inscriptions, Balm Lane Wesleyan Methodists, Holbeck.
94. Borthwick Institute, Exch. Dec. 1820.
95. For example WYAS HQ, Deeds vol. GO, 13 Feb. 1817 and vol. HN, 24 June 1821.
96. WYAS HQ, P68/4/12; Turner 1966, p.7.2; see Taylor's Biographia Leodiensis, pp.517-8.
97. Smail 1991-2, pp.792, 808.
98. WYAS Bradford, 32D83/2/1 and 5/1, etc.; Hodgson 1879; NYCRO, Craven Muster Roll.
99. Keighley 1879 [1858], p.110, repeated by Hodgson 1879, p.240.
100. Hodgson 1879, pp.227-8; Keighley Library, Apprenticeship indenture 1802.
101. Hodgson 1879, p.20.
102. Scott (ed.) 1928, pp.36, 40-1.
103. Borthwick Institute, Exch. October 1816.
104. Turner 1966, chapter 9, p.11.7.
105. Leeds census 1851, 2321/329.
106. For further discussion of planning the succession, see chapter 5, below.
107. WYAS Leeds, Acc. 2371/ Box 76.
108. Jenkins and Ponting 1982, pp.60-70.
109. WYAS Bradford, 32D83/5/1.
110. Hodgson 1879, p.262; Keighley Parish Register, Burial 1 Nov. 1819.
111. Hodgson 1879, pp.256-9; Keighley News 1 Dec. 1866; Keighley Library, Rate Book; Keighley census 1851.
112. Hodgson 1879, pp.259-60. The date is confirmed in Hattersley's records: WYAS Bradford, 32D83/6/1. Longbottom's father had also made machinery, producing throstles and carding engines during the 1790s: WYAS Bradford, 32D83/5/1 and 2/1. See also Longbottom 1986.
113. Hodgson 1879, pp.269-71; Addingham Parish Register, 30 June 1822, for which reference I am grateful to Mrs Kate Mason.
114. Keighley census, 1851.
115. Scott (ed.) 1928, p.80.

CHAPTER THREE

THE DEVELOPMENT OF A SKILLED LABOUR FORCE

By the middle of the nineteenth century a workforce of many thousands had been trained in machine-making. These workers belonged to the class which came to be called an aristocracy of labour, relatively well paid and widely acknowledged as skilled. The vast majority, though, were actually in situations of dependency, employed by others, and apparently carrying out a more narrowly defined range of duties, in much larger establishments, than their immediate predecessors had done. Whether it is true that machine-makers at the mid-century were becoming de-skilled and losing touch with the artisanal traditions which had supposedly sustained an earlier generation, are issues which this chapter will explore.

It might be expected that the earliest workers in textile engineering would have come from backgrounds similar to those of the first entrepreneurs, and would in that case have had sufficient know-how and opportunity to move into entrepreneurship. But the number of artisans who turned to entrepreneurship was small, and falling as a proportion through the period. The engineering workforce at the mid-century had progressed a long way from supposedly artisanal roots to become, in the large shops at least, a regimented industrial proletariat. These thousands of skilled workers had chosen, or been forced into, a path away from the relative independence of self-employment to which earlier generations of their class might have aspired. This may have been a result of heavier capital requirements to set up in the later industry, though the small-scale sector in engineering continued to be very significant. But another possible explanation is that these workers, though presumed skilled, were not really so, and that their position owed more to trade protectionism than it did to intrinsic worth, with their lack of competence covered up by a division of labour and a range of modern machine-tools which were possible only in the largest factories.

So alongside questions about the origins of this labour force in a new trade, and how they had acquired the necessary skills and knowledge to make machinery, there is another set of issues about the level of new skills which were needed, the ways in which a labour force was recruited and used, and whether specialization had developed to such a degree that opportunities for textile engineering journeymen to be mobile, either geographically or upwards into entrepreneurship, had become extremely limited because the trade in general was losing its broad-based competence.

SKILL AND SPECIALIZATION

Pre-industrial machinery was produced by local tradesmen such as smiths and joiners who also pursued other activities, or, in the case of fulling machinery, by millwrights who worked full-time in engineering, though not exclusively in textile engineering, and were constantly moving to where their skills were required. This workforce could therefore be described as part-time, as its members were partly occupied elsewhere, either in other industries or in other districts. The labour force was skilled, but it was not highly specialized.

Changes in machine-making - a growth in demand for the products, the increasing complexity of those products, and new production techniques - meant that the workforce had to adjust, in its size, location and degree of specialization. New and more technological products initially demanded a higher degree of skill from the workforce, though once changes had been absorbed, processes mechanized and machine-making re-organized by further division of labour, then it is entirely feasible that the result could have been a de-skilling of the machine-maker's trade. Like other craft trades, machine-making around the turn of the nineteenth century was frequently referred to as an 'Art and Mystery' though at some stage its emphasis shifted to become technical/ scientific. Cardwell has argued that the development of textile machinery in the eighteenth century happened totally independently of science, but that once the process of innovation was established, a host of new problems arose that stimulated scientific enquiry and gave rise to new forms of industry.[1] This proposition, which may explain a changing ethos in the engineering industry, will be further examined in the following chapter.

There is also a dimension to the development of a new labour force which goes beyond an acquisition of manual skills and technical knowledge. As one nineteenth century engineer explained 'The life and education of the workshop ... is twofold - technical and social'.[2] The social context is what Wright called the 'inner life of workshops'.[3] This aspect of skilled work was portrayed by Wright as partly a protective device to ensure that the boundaries of the trade, who was 'in' and who was 'out', were carefully defined and preserved. The phenomenon had many positive elements, including a duty among tradesmen to help those of their members fallen on hard times, and a pooling of information about jobs and employers in other towns.[4] The generalizations in Wright's account regarding social aspects of initiation into a trade are echoed by George Sturt, writing about the wheelwrights' trade in the late nineteenth century. Sturt refers to 'the waggon builder's lore' being 'a tangled network of country prejudices ... for the most part the details were but dimly understood', though 'necessity gave the law at every detail, and in scores of ways insisted on conformity'.[5] It was essential that the waggon builder had grasped manual skills and technical details, though not in any scientific way - 'reasoned science for us did not exist' said Sturt[6] - but the trade was more than that, encompassing local custom as well as an empirically-founded technical skill, all acquired through apprenticeship.

In a new trade such as machine-making, one would expect the 'lore' to be less firmly entrenched. This could be a positive advantage, enabling greater flexibility in entry to the trade, mobility and entrepreneurial activity. It is possible, though, that 'custom' could be quickly created to protect the position of those already in a new trade, with restrictions upon the passing of information so that a body of knowledge was contained and an air of mystery introduced. More positively, in other ways the new trade would need to develop its own networks and modus operandi. Relationships had to be forged between buyer and seller, engineer and subcontractor, along with an understanding of what was required in each of these roles, and information must be available about who was 'in' the trade and what kind of work they could perform.

Skills essential to the development of machine-making grew from more traditional occupations. Geographically, a few of the Leeds and Keighley machine-making entrepreneurs have been traced back to south Yorkshire (see Table 2.5), and in particular can be linked to the nail-making trade. It might be expected that employees in the machine-making industry, if they were in-migrants to West Yorkshire, could have originated in those same trades and villages near Sheffield. There is evidence that an 'old order' in the South Yorkshire metal trades was breaking up before 1780 when, for example, iron production had undergone substantial change.[7] Nail-making was an industry in transition, and its demise as a part of a dual economy in the area centred on Ecclesfield, the 'metropolis of the nail trade',[8] appears to have displaced a number of skilled metal-workers.

Nail-making has long been recognized as significant in the process of industrialization. W.H.B.Court said that it was impossible to understand the industrial revolution of the West Midlands without assigning to 'this apparently trivial and uninteresting occupation a high place as one of the factors making for change', and Hey believes the same to have been true for South Yorkshire,[9] attributing a key role to 'the humble nailing trade' in the development of the South Yorkshire iron industry after 1750.[10] Although the Ecclesfield nail-makers attempted to limit entry to their trade by an agreement insisting upon seven-year apprenticeship,[11] the reality was that it was 'the least skilled of the iron trades'.[12] In the West Midlands it was carried on by women and children with little training.[13] The Ecclesfield nailing trade was finally killed by mechanization in the early nineteenth century,[14] but had long been in terminal decline thanks to over-manning and the loss of agricultural holdings which had traditionally been a mainstay of the nailer's income.[15] Not all the nail-makers fled the area, for many of the backyard smithies were converted to file shops[16] and file-making flourished for years after that. Richard Hattersley continued to obtain files for his Keighley machine shop from his old home village.

It might be expected that some of these displaced smiths would have moved to West Yorkshire, where a new metal-working industry was in process of foundation. The distances were small, the metal-working background appears relevant, and some of the smiths may have also had a knowledge of textiles, as the domestic linen industry was widespread around the area west of Barnsley.[17] There are a few examples of such migration into textile engineering in Keighley or Leeds, though these come mainly in the group which became successful entrepreneurs, rather than employees, in machine-making. Hattersley came from an extensive nail-making family in Ecclesfield, where two Hattersleys had been listed among the masters of 39 nail-shops there in 1707, and five of that name were signatories to the Ecclesfield Nailers' Agreement of 1733.[18] Richard Hattersley had settled briefly in Sheffield in the 1780s before his final move to entrepreneurship in Keighley in 1789.[19] The cutlery trade in Sheffield was closely controlled by guild[20] and therefore not open to displaced nailers. That such artisans would consequently move into a neighbouring new industry where no such restrictions applied, is a tempting conclusion which is unfortunately not supported by any firm evidence. This class of worker left little trace of their movements. Though it is known that Richard Hattersley recruited a number of kinsmen, presumably from Ecclesfield, for long and short periods in the 1790s (see below), on the whole he relied upon local, Keighley, labour. This conforms to a pattern identified by Rowlands in the West Midlands, where both capital and manpower for the transition to new trades in the eighteenth century were, she believes, 'drawn from the community itself' with 'no evidence to suggest that there was any marked recruitment of men from outside the region'.[21]

THE THEORY AND REALITY OF SKILL

Skill can be defined in a number of ways. For example More has distinguished between the economist's view that skill is something essential to a job which is acquired by training, and a sociologist's perception of skill as a social construct which is strictly unnecessary to the efficient functioning of industry.[22] More's area of interest, however, starts in the late Victorian period, when much greater formal knowledge was required of skilled engineering workers[23] and the trade had acquired an institutionalized framework, as well as an acknowledged group of lesser trained semi-skilled workers. That is not to say that the 'social' aspect of skill had not existed in the earlier engineering industry. For example, it had been used to limit entry to nail-making in the Ecclesfield district in the eighteenth century, for although two years was quite long enough to learn the trade[24] a seven-year apprenticeship was insisted upon to prevent young men from prematurely setting up as masters. However it would have been difficult and generally undesirable to apply such restrictions to a new and dynamic trade like machine-making, and no evidence has been found of any such attempts to control entry. Supporting the 'economist's' view, it does seem that a degree of training, to inculcate both manual skills and technical knowledge, was a necessary precondition for the efficient manufacture of machinery. Semi-skilled and unskilled workers could be used to carry out certain tasks in the textile engineering workshop and factory, but a core of skilled labour remained essential.

Because the products of textile engineering were new, and the processes employed were improvised from other industries, for a time there could be no fixed body of knowledge in the new trade which could be used to define a path of training. Expertise in the new skills had to be acquired by a variety of means. When the first textile engineers started in business, apprentice-trained machine-makers could not have existed. How much skill was then required is debatable. Clearly not just anyone could successfully survive as a machine-maker, even in the 1780s and 1790s, though a broad range of wood- and metal-working tradesmen did try. An early advertisement by John Jubb, the noted millwright and machine maker, suggests the vagueness of qualifications for such work:

> MECHANICKS WANTED - three or four good workmen who understand the making and fitting up of cotton or worsted machinery...[25]

It was only later, after about 1805, that a genuine barrier to entry emerged, in the form of a higher degree of metal-working skill and the possession of a body of technical knowledge. A general definition of skill is adequate to understand the requirements for early machine-makers: a skilled worker might be 'one possessing a special ability acquired through a learning process either of formal apprenticeship or, increasingly, in an informal manner, and that from this skill derives clear notions of an artisan status ...'[26]

Using this general definition, what was the level of skill of those workers who came into the new industry, and how much knowledge of textile machines did they possess? Even a humble nail-smith was a relatively skilled worker, showing a great facility with the hammer. The work was endlessly repetitious yet it involved a high degree of precision:

> [I remember] as a boy, watching the making of hand-made nails ... The rod of iron was cut into the required lengths across a 'cold-sate' let into an anvil, with the cutting edge upwards, and was then deftly picked up and dropped into a hole in the anvil. A sharp blow with the hammer not only completed the head at one operation, but jumped the nail out of the hole, leaving it ready for the next nail.[27]

Such skill could be adapted to use in other metal-working industries. As Mathias has pointed out, before precision machine tools came into being, everything was a 'one-off', so that much rested upon the individual skills of an artisan. Mathias emphasises the scarcity of specialized skills, and how few centres existed where precision metal-work could be carried out.[28]

This makes it all the more surprising if skilled metal-workers were not being drawn from South Yorkshire. But movements of migrating journeymen are difficult to track, and it may be that the problem is one of evidence, that migration was occurring but cannot easily be proved. In Leeds, for example, with its growing and shifting population, large numbers were moving in, out and around the town, presenting major problems in tracing the origins of workers even in such a relatively small and specialised industry. Keighley may provide a partial solution to this problem, for although existing evidence is inadequate to show precise movements of skilled workers, there is the possibility of analysing the town's entire labour force at the end of the eighteenth century. If it can be demonstrated that this workforce was numerically and technically adequate to adapt to the requirements of textile engineering, then perhaps in-migrants were not required, for the South Yorkshire nail-smiths' skills were actually no more directly relevant to textile engineering than were those of a local smith. Any tentative conclusions about Keighley, though, would not necessarily apply to Leeds, for the larger town was less self-contained and is much nearer to South Yorkshire, so may have been a greater magnet than Keighley for displaced smiths.

The Craven Muster Roll of 1803 [29] listed local men who were available for military service. As in many official records, respondents often cited their original occupation, the one in which an apprenticeship had been served, rather than the trade in which they were working in 1803. The list is therefore informative about occupational structure in Keighley before the emergence of a fully-fledged machine-making industry, and shows the bed-rock upon which textile engineering was built. It provides the names of 1118 men, supposedly the entire male population of Keighley parish who were aged between 17 and 55 at the time. With the exception of apprentices, whose trade was unspecified in the roll and some of whom were too young to have been included, it can be assumed that all men forming part of a potential pool of labour for the machine-making industry would appear on the roll. Most of the 'engineers' listed in Keighley parish lived in the town itself, though those based on the rural

Brass filer	2
Blacksmith	9
Whitesmith	8
Smith	4
Machine Maker	1
Engine Man	1
Founder	2
Brass founder/ brazier	3
Tinworker	2
Clockmaker	2
Shuttlemaker	1
Woodturner	3
Turner	2
Joiner	20
Carpenter	7
Apprentices known to have been engineers	2
Nailmaker	4
Combmaker	7

Total number of men listed in the parish 1118

SOURCE: North Yorkshire County Record Office, Craven Muster Roll 1803

TABLE 3.1: Tradesmen in engineering and broadly related industries in Keighley Parish, 1803

outskirts of the parish may never have come into contact with textile engineering. The purpose here, though, is to show a pool of labour potentially capable of forming a skilled labour force of machine-makers.

Totals for each 'engineering' trade are reproduced in Table 3.1. The definition of 'engineering' used here is a loose one, taking in all kinds of wood- and metal-workers, although by this time wood-workers were of decreasing significance in textile engineering. The roll lists 34 metal-workers, 33 wood-workers, and two apprentices known to have been textile engineers, though the actual number would have been higher. The parish did not have a single millwright listed. There were four nail-makers and seven comb-makers, trades which do not seem to have had any direct input into machine-making in the Keighley area. Nail-making remained an important industry in the nearby village of Silsden from about 1760 until the end of the nineteenth century, with up to 250 forges there[30] and over 30 nail-makers recorded in the 1803 muster roll, but no connections have been found between these neighbouring industries.

ORIGINS OF THE EARLY LABOUR FORCE

The Craven Muster Roll shows that small yet significant numbers of specialists, in the form of brass filers, tinworkers and engineers, then existed. The size of the workforce in textile engineering was very small at this time, for firms were operating upon similar principles to artisan workshops.[31] Some of those on the Muster Roll were already entrepreneurs in machine-making, though not necessarily describing themselves as such. As for the remainder, is it possible to tell who was working as an employee in textile engineering, what exactly they were doing, and how competently they were doing it? Information is more difficult to find than for the entrepreneurial group, as many of those involved were less fully committed to the trade, for example combining machine-making with other work for other employers. But at some stage, when a combination of skill and knowledge come to amount to specialization, machine-making became a trade in its own right.

The first apprentice-trained machine-makers entered the trade as trainees during the 1780s, like William Smith, who nevertheless described himself as a brass filer in 1803, or in the 1790s, such as Berry Smith who was the first in Keighley to adopt the name of machine-maker. There were others who did not call themselves machine-makers because they did not make machines, but who were training with firms which were beginning to specialize in aspects of textile engineering, like Samuel and George Hattersley who were apprenticed to their father. These individuals are known about because they belong to that well-documented group which provided an entrepreneurial lead in the early nineteenth century. Their early specialization gave them an edge in the industry, which is why they were able to build successful entrepreneurial careers. It is therefore unlikely that they are typical of a wider labour force, and one has to look beyond them to establish the nature of employees in the early industry.

Two early series of wages records for Richard Hattersley's employees, covering the periods January 1796 to December 1798 and October 1808 to June 1809,[32] provide information from which Tables 3.2 and 3.3 have been drawn up. In some cases the type of work done by these workers was indicated, though information in Hattersley's books is generally sparse. Details of individuals from the Craven Muster Roll of 1803 have been used to supplement the Hattersley data, though there are sometimes uncertainties about whether the correct individual has been identified on the muster roll.

For the period 1796-1798 (Table 3.2), Hattersley employed a total of 19 people. These can be divided into three categories. First there was a core of three skilled workers: Hattersley himself, usually described as a whitesmith, Thomas Eamet or Emmet, a whitesmith or smith, and Michael Merrall, referred to as a blacksmith or whitesmith in various records and later to become an entrepreneur himself.[33] These three men were kept in constant employment. The second category was family members who were taken into the firm as apprentices: Samuel Hattersley at the age of about 10, George Hattersley at about nine, and Solomon Hattersley, who was not Richard's son though presumably a relative. Solomon was employed from 1796 (and perhaps earlier), was still described as an apprentice in 1803, and continued to work for Richard for many years, being his highest paid regular employee in 1808-9. The third, and by far the largest, category of employee was casual staff, who numbered 13 in all. Some of these did very little work for Hattersley during the period, while others seem to have been used on a regular basis during busy times. Two of them, John and N.Hattersley, may have been relatives who visited Keighley to help out for a few weeks, for they were not sons of Richard or residents of the town. A characteristic which many of the casuals seemed to share was that they were not skilled in engineering, either in metal- or wood-working. A number were described as weavers or labourers in 1803. They were mainly young people, perhaps children, and the listing within the Craven Muster Roll suggests that they lived in very close proximity to Hattersley and his workshop. (The roll appears to have been drawn up in a topographical way, so that people living in the same hamlet were grouped together.) Hattersley was therefore employing mostly very local, young, untrained labour rather than engaging men from related trades such as joiners who certainly existed in some numbers in Keighley at the time.[34] Presumably it suited Hattersley to have a flexible pool of cheap labour on his doorstep, rather than having to ensure constant employment for skilled, and hence more expensive, employees. None of the 13 casuals used during 1796/8 appears on his list of employees in 1808/9. If their skills were of a relatively low order they could easily have been replaced, and Hattersley need not have made great efforts to retain any of them. This is evidence that different levels of skill were recognized and employed within the early industry, indicating that a separation of tasks, or division of labour, already applied. If not, how could precision parts have been produced by unskilled people without machine tools?

But perhaps there is another explanation for the absorption of unskilled or semi-skilled workers. What exactly was the work they were engaged upon? From examining any eighteenth century textile machine a modern observer would conclude that no exceptional degree of skill was required in its manufacture.[35] The theory behind its operation was simple, and the construction techniques not difficult for anyone with a training in wood- or metal-working. The fact that even Richard Hattersley, working at the skilled end of the trade, was able to function with a proportion of relatively unskilled labour, could be seen as supporting the view that only a low grade of expertise was demanded. There are several arguments in contradiction of this, in particular relating to the skill shortages which continued to afflict engineering and which will be further considered below. But on the specific point of the complexity of the work, Landes has suggested that early textile machines, 'modest, rudimentary, wooden contrivances', were nonetheless 'complicated ... to contemporaries'.[36] Intricacy is in the eye of the beholder.

It can be demonstrated that Richard Hattersley's work required a high measure of skill. By 1796 his firm made and repaired rollers, spindles and flyers, and continued to produce nails and screws as well as carrying out general jobbing work.[37] All three branches of Hattersley's work demanded a skilled input. The precision of rollers, spindles and flyers was central to the success of mechanized spinning,[38] and Hattersley's command of the local market in these products rested upon his technical superiority. Secondly, as discussed above, nail and screw making was still a hand craft requiring dexterity and specialized skill. Third, general jobbing work and repairs were reckoned to be no less skilled than other aspects of a trade, being considered 'the true test of aptitude' of a craftsman.[39] Peter Fairbairn in 1841 concurred that this work was most demanding, suggesting that repairs were the only type of work still requiring an all-round skill.[40] The equipment used by Hattersley in the 1790s was simple: his workshop had bellows and hearth, benches with vice, a 'cutting ingen', but otherwise only handtools such as brace and bit, files and hammers.[41] So customers were paying not for sophisticated machinery, but for skills and knowledge which they did not themselves possess, otherwise they could have made or repaired the items themselves. For Hattersley to carry out so much precision work, division of labour must have been used to enable uniform items to be made without machine tools, and without even a high concentration of skilled men. Presumably this was possible only if certain workers specialized in certain tasks. Boulton and Watt had used a similar idea, though on a much grander scale, to achieve the maximum precision possible without machine tools at Soho in the 1780s and 1790s.[42]

If customers were putting the parts together, then fitting was a skill which Hattersley's men did not need. But his practice of supplying precision parts for others to assemble conforms to a general pattern within the machine-making industry. For example, before 1800 Boulton and Watt were consulting engineers rather than engine manufacturers, supplying customers with plans and drawings, and precision parts which came from subcontractors such as John Wilkinson. The customer usually ordered boilers and pistons from their own local supplier, and arranged for local engineers to fit the engine, perhaps under the supervision of a Boulton and Watt erector temporarily taken into their employment.[43] M'Connel and Kennedy, Manchester machine-makers in the 1790s, bought in components from small manufacturers: rollers from Matlock, Mayfield (Derbyshire) and Mosley, cards from Halifax and spindles from Stalybridge.[44] The increasing size of machines, along with a change from wooden to iron frames evident before 1800, meant that it was often convenient to supply machines in pre-fabricated form. M'Connel wrote to a Belfast customer in 1797:

> Would it not be cheaper and more convenient for you to have all the iron and brass work made here and sent over ready to be put together, and to have a confidential and experienced journeyman machine maker or two to go from here and make the woodwork and fit up the mules with you, and to have one or two complete mules made here and sent over for a pattern, that you might see that those fitted up with you were the same.[45]

Specialization among the workforce was a continuing trend which is apparent from Hattersley's next series of wages records, covering a nine month period in 1808-9 (Table 3.3). While the emphasis in Hattersley's products remained upon rollers, spindles and flyers and other parts for textile machines, the nature of the customers had changed. In the 1790s, Hattersley was supplying many of his products direct to textile manufacturers. By 1808, even though Hattersley retained a large number of such clients, there had been a shift towards a few machine-makers, who between them accounted for a large proportion of the value of his output. Machinery had become the province of metal-workers as iron, rather than wood, became the dominant material used. Although Hattersley had still not taken on fitting, the volume of work he was processing and increased standards of precision expected by his customers meant that his labour force had been upgraded to cope with the growing specialization. There is an impression of greater stability and growing professionalism, and it is perhaps at this point that a trade of textile engineering had begun to exist in its own right.

Apart from members of his family, the individuals employed by Hattersley were entirely different from the group of workers recorded ten years earlier. The core of skilled workers still consisted of only about four men: Richard Hattersley, who had doubled his own wage to two guineas a week, Richard Fowler, a whitesmith by trade who seems to have specialized in turning and fluting rollers, Robert

Scafe or Skaife, a smith, and Nimrod Holmes, formerly a weaver who had perhaps been re-trained as an engineer as he was paid the same wage as Scafe. John Driver, also a former textile worker, received a slightly lower wage and worked for most of the period. There were several ways in which flexibility was introduced into the workforce. Firstly, casual labour was used, though of a different type from the young and unskilled workers brought in during the 1790s. Some of these occasional workers were used for specific skilled tasks such as fly forging or screw cutting. One at least of the casuals was paid the wage of a fully skilled man. A second method of achieving flexibility is demonstrated by Hattersley's use of day rates, piece rates and laying off labour. In many cases it was Hattersley's sons, George, still an apprentice, and Samuel, now out of his time, and the kinsman Solomon, who were temporarily put out of work so that 'core' workers, who were probably men with families, could maintain a wage. At other times there were opportunities to work on piece rates in order to boost weekly earnings and presumably help Hattersley cope with a sudden rush of work. But almost every worker was laid off at some time during these nine months.

The two series of records of Hattersley's employees point to the use of similar means of organizing work in each period. A small core of skilled workers was supplemented by a flexible and varying number of casual and subcontract labour. In the second period the group of casual workers was more specialized than their equivalents had been in the 1790s. It seems that some of Hattersley's work could be broken down into simple tasks, capable of being carried out by unskilled or semi-skilled labour. The role of the skilled 'core' would be to carry out any tasks which were more difficult and also to supervise the work of the less skilled. When work was short, the whole of the tasks were reserved for the 'core'. Thus Hattersley would be paying

NAME:	PERIOD OF EMPLOYMENT	WEEKLY WAGE	OCCUPATION
Edm. Bradley	Oct.97 to c.Aug.98	casual	?Labourer 1803
Jos. Cook	Dec.97 to Aug.98	casual	
Jos. Crossley	Apr.96 to Oct.97 and other occasional times	c.9 shillings	Weaver 1803
Thomas Eamet (Emmet)	every week	c.9s 10d	Whitesmith 1803 Smith 1817
George Hattersley (b.1789)	from mid 1798	apprentice rates	Richard's son
John Hattersley	Dec 1796 only	casual	not RH's son
N.Hattersley	Four weeks in 1796	c.13s 8d	not RH's son
Richard Hattersley	Every week	£1 1s 0d	Whitesmith 1803
Samuel Hattersley (b.1785)	from mid 1796	apprentice rates	RH's son Apprentice 1803
Solomon Hattersley	every week	apprentice rates	Not RH's son Apprentice 1803
Michael Merrall	every week	c.12 shillings	See Note 3
Robert and Wm.Morrill	Dec.96 to Oct.97	casual	Wm. Merrall: Apprentice 1803
Robert Smith	6 or 8 weeks in 1796	casual	?Weaver 1803
Reuben Stell	Feb.96 to June 96 and other occasional times	casual	Weaver 1803
Jos.Sugden	Feb.96 to Apr.96	c.4 shillings	Weaver 1803
Thomas and Roger Teal	Occasional weeks in 1796		Thomas Teal: ? cottoner/infirm 1803
D.Wildman	Feb.96 to Apr.96	c.4 shillings	Thomas Wildman: Weaver 1803

SOURCE: WYAS Bradford, 32D83/6/1 Richard Hattersley's cash book 1795 -1820.

TABLE 3.2:
Labour employed by Richard Hattersley during the period January 1796 to December 1798

NOTES TO TABLE 3.2:

1. It is not clear from the cash book whether casual labourers were paid by the hour or by the piece.
2. 1803 occupations are taken from the Craven Muster Roll (NYCRO). Other occupational information was extracted from the Keighley Parish Register.
3. Merrall (born c.1774) was apprenticed to William Parker, a blacksmith. He joined Hattersley in about 1795. Described as blacksmith in 1803, and whitesmith in parish registers for 1813 etc.

NAME	STATUS	WAGE (SIX DAYS)	OCCUPATION (1803 occupation)
John Driver	Mainly f/t; left Apr.09	14s 0d	(?Weaver or ?Cotton spinner)
Richard Fowler	f/t, then all p/w	18s 0d	Turning and fluting rollers. (Whitesmith aged 17-30)
George Hattersley	f/t, some p/w, or laid off	14s 0d	Still apprenticed
Richard Hattersley	f/t	£2 2s 0d	
Samuel Hattersley	f/t or p/w or laid off	18s 0d	
Solomon Hattersley	f/t or p/w (flyers) or laid off	£1 1s 0d	
Nimrod Holmes	f/t	15s 0d	(Weaver aged 17-30)
Joseph Midgley	f/t	8s 0d	Apprentice ? see note 1
Robert Scafe/Skaife	f/t	15s 0d	(Smith aged over 30)
William Smith	p/w (flyers)	£1 1s 0d	See note 2
Other occasional labour:			
James Bowskill		18s 0d	
Samuel Haggas	p/w		Fly forger
James Holmes	p/w		Screw cutter
James Spencer		14s 0d	
George Stell		14s 0d or 15s 0d	

SOURCE: WYAS Bradford, 32D83/10/1. 1803 descriptions are derived from the Craven Muster Roll (NYCRO). F/t means full-time, p/t part-time, p/w is piecework.

NOTES: 1. This is probably the same Midgley who contracted to serve Hattersley as spindle forger for six years from 1822, and as manager of the whole of the spindle forging from 1825 (WYAS Bradford, 32D83/12/1).
2. William Smith was an early machine maker who had his own business from 1795 - see Chapter 2. He was directly employed by Hattersley for a total of nine days during this period, in addition to the piece work on flyers. In 1803 Smith was described as a brass filer.

TABLE 3.3: Labour employed by Richard Hattersley October 1808 to June 1809

more to have unskilled work carried out at such times, but was looking to safeguard his supply of skilled men for periods when more work became available.

GROWING SKILLS AND LABOUR SHORTAGES

Among Hattersley's workforce, the trade of central significance in the 1790s and 1800s was that of the smith, whether whitesmith or blacksmith. The term 'smith' can be used very broadly to denote a craftsman working in wood or other materials, as well as the more usual metal-working definition. The Oxford English Dictionary of 1919 defined whitesmith as:

> a. a worker in 'white iron'; a tinsmith. b. one who polishes or finishes metal goods, as distinguished from one who forges them ...

A whitesmith may then have been what in 1747 was described as a 'Vice-man':

> In all Smith's Shops they are divided into three classes; the Fire-Man, or he who forges the work; the Vice-Man, or he who files and finishes it; and the Hammer-Man ... the Vice-Man requires the nicest hand and the most mechanic Head, especially if concerned in Movements.[46]

Because some of the Keighley men were described sometimes as whitesmith, and at other times as blacksmith, this suggests that the demarcation line between the branches may not have been at all rigid. Smiths could be versatile enough to move into fine and specialised work, as Rowlands has shown in the West Midlands industries during the eighteenth century, where even such crafts as jewellery and toy-making can be traced from the trade of the smith.[47] Hattersley's efforts to cushion his skilled workers against unemployment or under-employment suggest that these men, although still describing themselves as smiths, had become more specialist and were in possession of skills which made them of particular value to a textile engineer. After all, there were apparently plenty of general smiths available to Hattersley, had he wanted them, in Keighley parish, or from the south Yorkshire nail-making districts. Thomas Cheek Hewes, the Manchester machine-maker, confirmed the increased specialization of smiths in 1824, when his own workmen '[would] not allow a common blacksmith, that only has to forge iron into any kind of shape, to work at our trade, because he has not worked in the cotton trade'.[48] Peter Fairbairn's workforce included 'a corps of blacksmiths' in 1841, their work highly mechanized and presumably of a repetitive nature.[49]

Advertisements for engineering workers showed a growing need for technical knowledge as well as craft skills. As early as 1789, George Lyster of Revolution Mill, Retford, who wanted a number of joiners, whitesmiths and turners, was asking for a 'Blacksmith who has been used to work a Steam Engine, or wishes to be instructed and employed in working one of the Patent Engines ...'[50] In 1792 Wright and White, opening a textile machine workshop in Leeds, were specific enough to ask for a 'Billy-maker', or one who could construct slubbing billies, as well as requiring general joiners.[51] John Jubb's advertisement in the Leeds Intelligencer of 1794 demanded technical knowledge from would-be machine-makers:

> John Jubb, Mill Wright and Machinery Maker, Leeds, is in want of 3 journeymen Mill-wrights and the same number of joiners who have been accustomed to work at Scribbling and Carding Machines, also a whitesmith who understands the above Businesses. An apprentice is also wanted.[52]

The skill of joiner or smith alone was becoming inadequate.

Although the wording of Jubb's advertisement is ambiguous, the millwrights he needed were almost certainly destined for work other than machine-making. As millwrights played only a limited role in entrepreneurship in this new industry,[53] so their journeymen equivalents seem not to have been involved in the machine-making labour force. As already noted, Keighley, which was to become a leading centre of textile machine-making, did not have a millwright listed among its inhabitants in 1803. Nor have millwrights been identified in the employment of any Keighley machine-maker. The relationship between millwrights and mechanical engineers on an entrepreneurial level has been investigated in some detail above (chapter 2), but the same issue arises in a context of the engineering workforce as a whole. For example, it has been claimed that the skills of the millwright were vital to the development of specialized engineering, that 'millwrights' many skills were gradually parcelled out among distinct classes of workmen' until eventually the millwright was displaced by 'semi-skilled' engineers such as fitters, turners and drillers.[54] The notion of the millwright as founder of modern mechanical engineering is roundly contradicted by the Keighley evidence, which supports the idea that millwrights should be relegated to a minor role in the origins of engineering. More has attacked the 'pervasive myth' that millwrights were the ancestors of nineteenth century engineers, emphasising instead the importance of smiths, in particular the 'vice-man' who filed and finished the work of the smith or turner and can be considered forerunner of the fitter.[55]

The same considerations which would have deterred entrepreneur millwrights from engaging in textile engineering apply equally to journeymen millwrights. The new industry was risky, whereas their own trade offered plenty of work, independence and mobility, and was strictly controlled by their society, ensuring that, before 1814 and the ending of wage regulation, millwrights could command a weekly wage of about 42 shillings.[56] From the point of view of Hattersley and others like him, there was no advantage in paying such high wages for skills which were no more relevant to textile machine-making than those of a smith who could be employed at less than half the cost. Millwrights maintained a clear identity as a separate trade, organized in societies quite apart from the first engineering trades unions, which admitted a miscellaneous selection of skilled and semi-skilled men.[57] Once de-regulated, though, the wages of millwrights did not sustain their previously high levels. Journeymen millwrights in Leeds were paid about 26 shillings a week in 1839. Although still among the highest paid and fullest employed in the Leeds workforce, this represented a drop in status from 1814.[58] The rigid practices of millwrights had undermined their position in the longer term, though they managed to hold on to their traditional pay and conditions in some places. Alexander Galloway told the Select Committee in 1824:

> ... in engineer shops, new men's wages are generally fixed after working a fortnight on trial: we give as much as we can afford to the most expert men, and then bring down the reward upon that standard; but in the business of a millwright, all the men have two guineas a week, and a man of that class formerly was employed to turn a grindstone, while one at 18s. a week would have done as well ... The consequence has been, that engineers have become millwrights, and ... [millwrights] are obliged to take up the name of an engineer, and conduct their business by the engineer's economy, and that change in the short progress of fifteen or twenty years.[59]

Elsewhere is evidence that 'millwrights men would not work with an engineer' and that having a carding machine repaired by London millwrights had 'cost double the money that a new engine would have cost in Manchester'.[60] These separate testimonies confirm that the trade of millwright still stood apart from other branches of engineering in 1824, even if some journeymen millwrights had by then been obliged to accept a reduction in wages or go to work for machine-makers. A reported shortage of work for millwrights compared with an abundance of employment available in machine manufacture may account for this.[61] But the idea that millwrights in general had fallen upon hard times during a period of high activity in factory building is unconvincing. Perhaps too many had been trained, and at an inadequate level.

The labour shortages are further confirmation that skills needed for mechanical engineering at this time were real enough. Boulton and Watt had experienced numerous problems in finding and retaining suitable labour, especially fitters and founders. Watt wrote to John Smeaton in 1778:

> We wish we could join you in saying that we can easily find operative engineers who can put engines together according to plan, as clockmakers do clocks; we have yet found exceedingly few of them.[62]

In the same year, Boulton wrote to his partner about difficulties with some of the engine erectors, who were smiths trained by Watt and who worked directly for the customer:

> Sam Evans and young Perrins at Bedworth are two drunken, idle, stupid, careless, conceited rascals and have used the engine and their masters so ill that they wish to change them, but these two fellows say, and their masters seem to believe, that it requires the learning and knowledge of a University man to keep an engine in order.[63]

Boulton seemed to suggest that the level of skill was not as high as the customer might believe. Is it possible, though, that workers as unsatisfactory as these would have been retained if there were any prospect of replacing them? Tann has suggested that a select few engineers of high reputation were able to attract a disproportionately large number of skilled workers [64] in which case the problems of smaller firms in attracting skilled workers would be further intensified. There was also a general shortage of trained workers in the iron and steel industries as a whole after 1770,[65] specific local instances including Matthew Murray's difficulties in keeping a full complement of skilled men at the Round Foundry in Leeds.[66] The only real solution to these general skill shortages would have been a concerted effort to train new labour.

GRADES OF SKILL

Because engineering workshops differed so much in the way that they organized their production, there was wide variation in the degree of specialization expected of workers. So although textile engineering acquired an identity separate from other industries in the early 1800s, a training in the trade of machine-maker could imply different kinds of skill according to the type of establishment involved. Furthermore, while the shortages of labour and other evidence show skills to have been real enough in the period before machine tools were introduced, it is feasible that the trade could later have become de-skilled, in parts at least, from the 1820s following process mechanization.

As early as the 1790s, some engineering factories had developed a high degree of division of labour. This was a particular feature of steam engine manufacturers and foundries, where obvious benefits followed from a highly organized through-flow of work. Heavy capital investment, in large machine tools, some of which had to be permanently bedded-in if they were to be of any use,[67] and in other items such as overhead lifting equipment, was a feature in this type of establishment. Such an arrangement was economic only for those involved in producing relatively large quantities of heavy items, but neither desirable nor possible for many textile machine-makers. The shops of Boulton and Watt and of Matthew Murray were in 1800 as atypical of engineering as the early factories of Benjamin Gott and John Marshall had been in the textile industry. As late as the 1830s and 1840s, when a few large factories were beginning to dominate textile engineering, and improved machine tools were readily available, small workshops still played an important role. Nowhere is this contrast between the small and the large, between old and new methods, better illustrated than in the autobiography of Thomas Wood of Bingley (1822-1880). Wood served his apprenticeship with a powerloom maker in his home town, leaving there in 1845 for Hibbert and Platt of Oldham. Platt's employed nearly 2000 men and used tools mainly of Whitworth's make.

> I, who had never worked in a shop with more than 8 or 10 men and with country-made tools, the very best of which Platts would have thrown away as utterly useless ... had cause to fear that I should not succeed and be found as efficient as other men in a place where no favour was shown ...[68]

But Wood found that he was able to 'drop into place' at Platt's, although the demands were so different from those in a small shop, particularly in the narrowness of the tasks set:

> Men in large shops are not troubled with a variety of work, but had one class of work and special tools. The men soon became expert and turned out a large quantity of work with the requisite exactness without a little of the thought required of those who work in small shops where fresh work continually turns up, but always the same old tools. I learned quickness and accuracy, also that hard work and application were indispensable.[69]

The implication is not that work was more or less skilled in the larger establishment, but that techniques were entirely different. The quantity of work processed enabled a fine sub-division of labour, much greater repetition and consequently a higher degree of accuracy. When Wood was laid off by Platt's a year later, he found work in 'a small engine shop with no proper order or economical way of working' in Darlington.[70] His account suggests that as standards were generally improving, skill was no less required:

> At my work I was gaining confidence, of which I was sadly deficient. Of course the class of work was something new to me, but I often saw men pose as good hands, 'clever', who I was persuaded owed their all to bounce and brag ... The improved method of working and supervision has been the death of ... these windbags.[71]

The other possible means of achieving specialization in textile engineering, and hence improved standards of accuracy with or without machine tools, was for an individual firm itself to specialize by concentrating upon particular types of component or machine. Richard Hattersley's specialist niche in rollers, spindles and flyers is an example. There are indications that these specialist trades had themselves become further sub-divided by the 1820s:

> ... there are two or three classes of spindle makers, separate and distinct trades, masters and men. Before the demand was so great as it is, one master spindle maker would make several kinds of spindles; now since the demand has increased so much, he confines his work to one kind of spindles only; each man confines his work to a smaller variety of spindles, and by that means produces them better adapted to the purpose, and cheaper than others could do before.[72]

Roller-making had also developed as a separate trade:

> Are not a distinct set of mechanics employed in making rollers? - A distinct set, it has been a business in itself.
> It is one of the subdivisions of labour? - Yes.[73]

Employment contracts which Hattersley issued at this time show how he further divided work within his firm.[74] Many of these agreements relate to subcontract work, where Hattersley offered enhanced piece rates in return for a commitment to serve him for a number of years. For example, in 1818 William Sharpe of Keighley, worsted spindle maker, accepted an offer of 36 shillings per gross for spindles, 6 shillings more than he had previously been paid, in exchange for binding himself to Hattersley for six years and 'taking the whole management of the spindle department'. Samuel Haggas and William Denton were contracted for five years from 1820 to forge flyers at 13 shillings per gross, with Hattersley undertaking to reserve all such work for them. Joseph Midgley was taken on in 1822 for six years, with a sliding scale of rates according to the size of spindle forged, and was also given the job of repairing tools. In 1825 Midgley's contract was altered to accommodate the management of the spindle forging department. Other contracts in the 1820s refer to flyer forging, flyer finishing, roller turning and flyer repair, each as distinct specializations.

The separate classification of these activities as trades in their own right, when taken with Hattersley's strenuous efforts to bind these workers to him, does not support the idea that textile engineering was becoming de-skilled. Not long after this, though, when machine tools had become much more widespread, William Jenkinson told the Select Committee on Machinery that 'by the production of tools, machinery is made by almost labourers'.[75] Jenkinson though was trying to argue that the export of machinery should be allowed so that Britain could maintain an advantage, over foreigners with machine tools who could potentially produce equally good machines with unskilled labour. Elsewhere in his evidence Jenkinson drew distinctions between those employees he considered inferior, and his much less dispensable 'best men'.[76] He also spoke of how a machine-maker would make 'one kind of machine his principal study ... by that means each is able to make cheaper and better than they otherwise could'.[77] If de-skilling had progressed to the extent that Jenkinson's earlier evidence had suggested, such specialization within firms would have been unnecessary.

At about the same time, and also in Lancashire, James Nasmyth was claiming that a machine tool revolution in his factory had broken the hold of the skilled worker upon engineering. Nasmyth, like his former master Maudsley, frequently introduced new tools in an effort to reduce reliance on 'mere manual strength or dexterity'.[78] Even his semi-skilled employees, it is said, were threatened by 'totally unskilled labourers, including young boys, who were competent to act as machine minders'.[79] After a strike in 1836 Nasmyth went to Scotland where 64 'wheelwrights and carpenters, smiths and stonemasons' were recruited, later sending for their relatives so that Scots made up a majority of Nasmyth's new workforce. However these men were later unable to gain employment with other Lancashire engineers.[80] Nasmyth said that this was because they were considered 'Nobs' or blacklegs, but the proposition must be considered that they did not have the necessary skill to hold a job in a less automated workshop.

That skill continued to be necessary in all sections of the industry throughout the period is borne out by the failure of machine-makers to use the labour of women and children. As textile engineering before 1850 was a young and dynamic industry which had not developed or inherited restrictive employment practices, in theory there was nothing to prevent the use of cheap female and child labour, had such labour been of use at any stage in the industry's growth. Although women are said to have been excluded from new industries in the nineteenth century,[81] sections of the engineering trade retained features such as small workshops and a widespread use of subcontract, which had more in common with evolving industries than with those distinctly new ones like railways, gas and electricity. But women and children under 14 were conspicuously absent from machine-making. It is hardly feasible that social constraints alone would have stopped women's employment in engineering, in an age when females were readily allowed into mines or into newly automated occupations like weaving, which had traditionally been reserved for men. It is likely then that this pool of cheap labour was not employed in textile engineering because it did not have the necessary skills, possession of which could come about only through a specific training which had not been offered to women. Berg has suggested that the labour of women and children was not only cheap, but a bargain, and though called unskilled could offer a degree of manual dexterity capable of being turned to good use in a factory.[82] Women and children were cheap, available, dexterous, not apparently debarred by any legal or institutional constraints, but still were not employed in textile engineering. They had no access to the body of technical knowledge in the trade, but that did not matter, for as semi-skilled workers they would have had jobs broken down and allocated to them by people with greater expertise. What debarred them from any part in the machine-making trade was their lack of familiarity with tools and techniques in metal-working. Women had never been smiths, perhaps because they were not considered strong enough, or perhaps just because they were not considered. Whatever the reason, their past absence from participation in metal-working placed them at a severe disadvantage in the new trade. The result was that the widows of Michael Merrall and John Jubb were unable to sustain their husbands' businesses as machine-makers until a time when sons were old enough to take over, in the same way that widows managed to carry on family businesses in many other trades. If women could run firms in other industries, the failure of the machine-makers' widows cannot be attributed necessarily to a lack of entrepreneurial ability, or prejudice against their sex. The problem lay in their inability to take close personal control of the technical aspects of business.

Further evidence to support the idea that textile engineering remained highly skilled comes in the lack of opposition made to the introduction of process machinery within the industry. McClaine says of engineering in the period after 1824, that 'while many of the operations previously done by hand could be done by machines, the machines must be operated by skilled men, since an unskilled operator would spoil more work on a machine than he would if engaged in handwork'.[83] If automation did not bring about de-skilling, then there was no point in a skilled labour force opposing the introduction of machinery. A high proportion of skilled labour was still needed among the workforce engaged on batch work in the larger factories, as technical knowledge and intelligence to some extent replaced traditional manual skills. Peter Fairbairn confirmed that the numbers of skilled men needed remained high:

> In the manufactory of machinery, though more machinery has been introduced, which has greatly improved the accuracy and finish of the work, yet I am of opinion the demand for workpeople in this line is at least equal now to what it has been at any former period.[84]

In smaller workshops, where repair work and one-off jobs were carried out, all-round skills were needed. Even where parts were produced in larger numbers, it may have proved economic to retain fully skilled men and occasionally use them for lower grade jobs, rather than have semi-skilled workers whose abilities were too limited to allow them to do other tasks in the workshop.

CONDITIONS OF EMPLOYMENT

The 'characteristic irregularity' of late eighteenth and early nineteenth century working habits [85] was turned to economic advantage by early engineers. Piecework and day rates could be used flexibly to increase output or control costs, according to the state of trade. Some casual employees were available to come into the main workshop when needed, or would receive work at home, and apparently filled other parts of their working lives with casual or subcontract work for other employers or in other industries.[86] This 'semi-domestic' system was not universal, and probably faded away in the early years of the nineteenth century, though the use of subcontractors, both large and small, continued to be a distinctive feature of the industry. In contrast, more formal arrangements existed in establishments like Murray's in Leeds, where articled labour was regularly employed as early as 1802.[87] Richard Hattersley's use of fixed term contracts from about 1818 has been referred to already. By engaging in such agreements employers lost some flexibility, and employees gained security, though at the expense of being free to accept any better offer. The use of contracts indicates a growing importance to employers of a stable and regular workforce possessed of specific skills.

In larger shops, combinations of piece and day rates were intended to maximize high quality production, and to motivate, and consequently retain, those workers who had the most prized skills. Thomas Cheek Hewes, whose millwrights continued to receive pay by the day in the traditional pattern of their trade, had been obliged to shift from two thirds day work to two thirds piece work in his machine-making division to achieve greater productivity. His piece-workers would make perhaps 36s to 40s a week, compared with 30s if paid by the day. Hewes did not wish to convert entirely to piece-rates as he thought that some of his men would be unable to maintain an acceptable quality of product if they worked at higher speed.[88] The standard rate of pay for 'operative machine-makers' was reported to have remained at about the same level, 26s to 30s a week, in 1841, though much depended upon 'the cleverness of the men'. More were employed on regular wages than on piece rates, but 'the piece hands are generally first-class men, and some of them will earn as much as 3l. and 4l. a week'.[89]

Even under the most formal contracts, employers overlooked certain types of irregular behaviour. Watt's early problems with drunken engine erectors have been mentioned.[90] Thomas Wood, while stressing the importance of technical competence and hard work at Platt's in the 1840s, described his fellow workers as 'wicked and reckless' satisfied only by 'a rough and rude plenty' and given to gambling while at work.[91] George Hattersley noted absences of workers and apprentices in the 1830s, going to the length of having them ordered back to work by a magistrate in some cases, but he did not dismiss these recalcitrant employees.[92] That such behaviour was tolerated indicates the value placed upon key skilled workers.

The social aspects of life as a tradesman, along with a sense of who was 'in' and who 'out', emphasised by Wright,[93] suggest that a strong solidarity existed within the trade. But no evidence has been uncovered to show that this craft consciousness translated itself into more tangible form. Although skilled workers may have combined to exert influence within some of the larger engineering establishments, there is nothing to indicate that trade unions or societies were influential in regulating wages, entry or training in the early stages of mechanical engineering in West Yorkshire. The workforce was mainly dispersed, and heterogeneous, consisting of both employees and the self-employed in a variety of occupations and arrangements. Under such circumstances highly-organized and influential unions could not be expected to function. They came later, with the concentration of the industry in factories.

APPRENTICESHIP AND TRAINING

From a tiny nucleus in the early years of the nineteenth century, the engineering workforce grew to number thousands by 1850. As it was essential for a high percentage of this machine-making labour force to be skilled, whatever their degree of specialization, it follows that there had been a concerted effort within the industry to train new workers. The only possible method of training was 'on the job' in establishments which produced textile machines, and the process of inculcating skills and knowledge was a long one:

> We cannot make machine makers so quickly as any other description of persons; they require a long time to learn, though all is done and has been, for a considerable time, to increase the number of mechanics.[94]

The bulk of the training was carried out under a system of apprenticeship which was a continuation of the traditional one for skilled trades.[95] In large establishments the apprentice was bound to a journeyman, though in smaller engineering workshops an artisan-type system continued where the teaching was done by the master himself.

It has been argued that apprenticeship in its true sense had ceased to exist by 1800.[96] There were also contemporary suggestions that apprenticeship was no longer relevant to needs. Some of these claims amount to political rhetoric advanced in support of deregulation of the workplace, while others hinge upon different understanding of what was meant by apprenticeship. Nasmyth's opposition to a traditional type of apprenticeship was bound up with his 'heroic' view of technical progress. He believed that a 'Free Trade in

Ability' had been responsible for the greatest advances in mechanical invention. Brindley, Smeaton and Watt 'owed very little to the seven years' rut in which they were trained' and everything to their 'innate industry, skill and opportunity'.[97] (In fact, neither Brindley nor Smeaton nor Watt had served a conventional seven-year apprenticeship). Apprenticeship, 'the fag end of the feudal system', which encouraged bad work, bad behaviour and bad example, he considered should be abolished.[98] Nasmyth himself dispensed with apprentices, instead employing trainees who were allowed to progress according to ability. As discussed above, his technically advanced factory was not a typical one. Other examples of claims to have abolished apprenticeship, for instance at Platt's of Oldham in the 1860s,[99] were in similarly modern shops. Peter Fairbairn told the Children's Employment Commission in 1834 that he did not indenture anyone, though every one of his employees had, he said, entered the trade at 13 or 14, suggesting that formal apprenticeship was still operating even if it was called something else.[100]

Nasmyth's case in favour of nurturing exceptional talents overlooked the fundamental needs of the engineering industry. Though he relished the notion of having a new James Watt emerge under his tutelage, there was a limit to how many such heroic figures could be accommodated within a firm. The real need in Nasmyth's time was for skilled workers to perform routine shop-floor duties. As Roll has pointed out, 'the great inventive genius' Watt was 'entirely unsuited for a business career'.[101] New engineering factories equipped with modern machine tools demanded closely defined skills, while smaller workshops preferred all-round manual abilities to a less exacting standard, but every machine-making establishment demanded high levels of skill and knowledge which somehow had to be imparted to new entrants to the trade. Whether these new employees were called apprentices or trainees, whether formally indentured or not, whether trained in general skills or in methods specific to a large firm, and however long it took, still they had to go through a programme of education before they could carry out skilled work and qualify for skilled rates of pay.

It could have been advantageous to a large firm to confine training to specific aspects of their own operations, and in this way retain trained workers because the skills were not transferable. This might avoid wasting money on training workers who could then sell their skills elsewhere in the market place. There were few large engineering firms in Yorkshire before the 1830s who were big enough to use such a practice, though the likes of Peter Fairbairn with his 'corps of blacksmiths' may have been approaching it in the 1840s.[102] Fairbairn had always displayed an open mind about formal qualifications, instead concentrating on finding certain abilities and qualities in his workers. In 1830 he advertised:

> Wanted a man who is perfectly competent to engage the grinding and polishing of machinery items. None need apply who are not well acquainted with the business.[103]

A week later Fairbairn was looking for three 'vice men' who could 'bring recommendations as being good and steady workmen'.[104] Even such skilled recruits would have needed a degree of further training to enable them to fit into his highly departmentalized factory.

As in any new trade, a first generation of skilled workers had to be trained by those who had converted from other occupations. The first apprentices were recruited to machine-making in the early 1780s. Prominent examples include James M'Connel, sent from Scotland to an uncle in Lancashire in 1781 when aged about 19, and his later partner

John Kennedy, who was 15 when he joined the same master making carding engines, jennies and water frames in 1784.[105] William Smith, son of a corn miller, was apprenticed in Keighley in the mid 1780s.[106] But for the new trade to have expanded as it did in the first half of the nineteenth century, it had to recruit from beyond the range of 'engineering' occupations [107] with which it had first been associated. Some apprentices were boys whose fathers followed dying trades such as handloom weaving. In 1836, the 14 year-old Thomas Wood, hoping to be relieved of the 'bondage of factory life', wanted to be a weaver like his father, or a woolcomber, and eventually become his own master.

> Father would not hear of it, so I was put to be a mechanic. Perhaps it caused as much remark among our neighbours as it would now if I put a son to be a doctor ... I wonder if anyone thought of the anomaly of sending me to a powerloom-maker for my trade while powerlooms were slowly and surely drying up industrial life. Perhaps my father accepted the inevitable, or, more likely still, I was sent there because there was no other opening. Mechanics, though so plentiful now [1878] were rather scarce then; I am quite sure in saying there were not twenty in Bingley either in shops or factories.[108]

Wood's father's earnings were less than ten shillings a week. Thomas, the eldest of ten children, had been earning 4s 9d in a mill. As an apprentice, he worked a month or two for nothing, then three months at 1s 6d, gradually rising to 8s in his final year, when aged twenty. Wood's parents made a considerable short-term financial sacrifice to enable him to train as a mechanic, implying that the decision had been taken more positively than he suggests. In Armley, formerly a centre of handloom weaving, it was reported that twenty boys had become apprenticed to mechanics in 1840.[109] An impression from the 1851 census in Keighley is of a very young workforce in the engineering industry, many of them sons of men who were not themselves engineers.

By then a seven year training in machine-making was usual. Given that 21 was the age at which skilled status was conferred, boys had to join when 14 or 15. Apprenticeship had become more formal than when the 19 year-old M'Connel started in the trade, or when Matthew Murray offered training to:

> ... a Number of Young Men from Sixteen to Eighteen Years of Age, that would engage for a Term of Years to work in a STEAM ENGINE MANUFACTORY, where they may learn a valuable Business and meet with constant Employment ... [110]

This more casual approach to apprenticeship and training had suited the industry during its formative years when skilled labour was in acutely short supply. Someone like Murray could employ traditional artisans or unskilled labourers, to be trained up in new methods which at that time were still in process of formulation.[111] Formal regulation of apprenticeship and wages was finally abolished in 1813/4 [112] but the system had long been in disarray and in any case new industries such as textile engineering were not bound by Elizabethan statutes. There was therefore an opportunity, and a need, for new systems of training to develop. The way in which Richard Hattersley tailored a skilled workforce, employing traditional craftsmen such as smiths, and also training unskilled people for specific tasks, has been described above. After 1810, when products and methods were better established in textile engineering, the main source of new skilled labour was the seven year apprenticeship. More has shown that apprenticeship, far from being an obstacle to the spread of skills, continued to be necessary in skilled trades through the nineteenth century.[113] Hattersley's had employed apprentices during Richard Hattersley's time, but started to keep formal notes of apprenticeship dates and birthdays only in about 1829. In the years 1832 and 1833, a total of 14 apprentices were employed, most of them 14 or 15 years of age, and contracted for six or seven years. But there remained other, less conventional, arrangements, where older trainees were recruited to serve shorter terms. William Preston, whose age was not specified but who was described as an artificer, was bound in 1833 'to be apprentice for two years to learn the art of making spindles, rollers, etc'. His wage of 15 shillings a week suggests that he was already an adult and could offer some degree of skill, as the rate paid to final year apprentices at that time by Hattersley was only eight shillings.[114] Such a contract as Preston's demonstrates the value of formal arrangements, for to have been taught by Hattersley as a roller and spindle maker conferred a recognisable qualification which had its own value in the labour market. This was one of the great advantages of apprenticeship, that it had common currency, certifying that the holder possessed certain skills. The evidence that such skills were real rather than socially constructed is found in persistent wage differentials, says More.[115]

Whether a full seven year training was always needed is arguable. The fact that Hattersley considered he could train some men in a shorter time suggests that it depended upon the trainee's previous experience, though William Fairbairn thought that even an expert workman in other kinds of machinery would take 'a considerable time' to train as a cotton machine-maker.[116] Training requirements would also depend upon the size of the firm and variety of work which the trainee was required to perform. As for 14 or 15 year-old apprentices, the first months were generally spent in running errands, not a wholly trivial pursuit as the trainee was becoming familiar with tools and materials.[117] Many of the apprentices who joined engineering firms at 14 had been working already for perhaps five years in textile factories where they would have acquired at least a basic knowledge of the workings of machines. Apprenticeship may have been artificially prolonged so that the employer could tie the trainee to the firm for longer and recoup some of his investment in training, paying a fully competent 19 or 20 year-old less than the skilled rate. But on the other hand, men newly out of apprenticeship were not necessarily viewed as fully skilled, being called 'improver' and often moving to different firms in order to broaden their experience.[118]

PROSPECTS OF MOBILITY

A degree of mobility had been a feature of some of the artisan trades associated with early machine-making. Young journeymen, often with the encouragement of employers, moved to different shops, to other districts, and even abroad, intending to broaden their experience. It was equally acceptable to set up in self-employment. As machine-making developed into a trade with its own identity separate from traditional craft skills, and with increasingly specialized sub-divisions, mobility may have become irrelevant or undesirable, or both. It may even have become impossible, for a highly skilled yet narrow training in an automated workshop could have extinguished any prospects of employment elsewhere, just as a broad general training on obsolete machines might have restricted Thomas Wood.

Millwrights had been renowned for their frequent moves from place to place, partly because some of their work was site-based, but they also travelled in order to gain a first rate experience as young journeymen. Thus the 'restless wanderings' of Peter Fairbairn which have been considered a sign of an impatient nature [119] were actually firmly founded in the customs of his trade. Through these travels he gained the skill and confidence to convert entirely to machine-making. Fairbairn served his apprenticeship to a Newcastle engineer and millwright, went to Holdsworth's of Glasgow as foreman and then traveller, worked for his famous brother in Manchester for two periods, was employed by Rennie in London for a time, and spent a year in France where he worked for

British companies in Charenton and Paris. After three years of travel as a journeyman, he returned to Holdsworth's Anderston Foundry as a partner from 1824 until his move to Leeds in about 1826.[120] On his travels, Fairbairn came into contact with the 'leading mechanicians and manufacturers of the day', including Rennie, 'then at the height of his fame', and gained 'a fair knowledge of French industrial pursuits'.[121]. With similar intentions the machine tool manufacturer John Stirk (1838-1917), after completing an apprenticeship with Joseph Ogdin March in Leeds, moved to work for Peter Fairbairn, then Shepherd, Hill and Co., Darling and Sellers of Keighley, and Buck and Watkin and Scott Brothers of Halifax before setting up his own business in the latter town in 1866.[122] Such mobility was encouraged by employers who hoped that the journeyman would eventually return better qualified.[123] Especially when technology was advancing fast and few technical books were available, directed 'restless wanderings' made good sense for a young man with ambition.

Thomas Wood had this idea in 1845. He gave notice to leave the small shop in which he had served his time.

> I thought I was deficient in my trade, though I learned, and long practised, all I could learn there. But I heard about new tools, new machines, and new ways of working. I could never hope to see them in our shop, and if I was to learn, and improve, I would do so now before I either married or thought of it.[124]

Wood was clear about what he wanted, aiming straight for Platt's in Oldham. Experience of working in a large and modern shop maintained an attraction for engineering workers. A grapevine existed in workshops based on 'the travellers' tales of those who have been on tramp' through which information was passed concerning employment possibilities elsewhere.[125] Improving skills by migration could mean enhanced job prospects in an industry where there was much repair work and versatility was prized.[126] On the other hand, the end of apprenticeship meant the end of job security, and a youth who could not prove his worth, or whose master was short of work, would be sacked even though his wage at 21 may have been only seventy per cent of the top rate.[127] Mobility then became a necessity.

Labour mobility was one means of reconciling the supply of skilled workers to demand. Although the industry was expanding overall during the nineteenth century, it did suffer periods of stagnation during which employers could not or would not take a long term view on training a future skilled labour force. When a recovery came, there would be an immediate skills shortage, and the long lead-in time and expense of training were reasons to poach skilled workers from other companies. There is evidence, though not in Yorkshire, of local agreements between employers to refrain from such behaviour.[128] The 'slow process of breeding' skilled workers was the main reason for such enticement,[129] though employers may have been looking also to acquire restricted technical information.[130]

The other avenue of mobility for the journeyman was into entrepreneurship. This too was an accepted route to follow, in the tradition of master/ journeyman relationships. Burnett attributes the closeness of craftsman and employer to their near equality in skill, intelligence and manners, with journeymen able to aspire to the role of entrepreneur because skill and connection were for a long time more important than capital and machinery.[131] Randall describes similar close links between masters and men in the West of England clothing industry, where 'nascent competitors' were not viewed with hostility but were given help and credit.[132]

In textile engineering, the distinction between the employed and the employer was not always clear cut. The putting out of work to subcontractors, the way in which methods of payment switched between day rates and piecework, and the use of casual labour or the laying off of regular workers, all contributed to a blurring of relationships. There is evidence that when Hattersley's employees did make a break into entrepreneurship, close links continued to exist with their former master. An early example is Michael Merrall, who had left Hattersley by 1808, having worked for him for perhaps ten years, but continued to buy from and supply parts to Hattersley until Merrall's death in 1819.[133] Two of Hattersley's key employees in 1808-9 were Richard Fowler and Robert Skaife.[134] The name of Skaife reappears in Hattersley's records in 1829 when spindles, flyers and other parts were supplied to 'Skaife and Co, Banks Mill'.[135] Fowler had gradually moved from pay by the day to piece rates by 1809, and seems later to have broken away into entrepreneurship as various payments were made in the 1820s to 'Richard Fowler, Son and Co', presumably for subcontract work on rollers.[136] Fowler and Skaife, working for themselves in a small way, did not establish firms which were to have a major impact upon the Keighley trade, but they were following the well-trodden path of a journeyman into self-employment.

As the main purpose of mobility had always been to extend a journeyman's range of skills and knowledge, any limitations imposed by narrow specializations in modern factory production, or by old-fashioned tuition in workshops, would not alone have held back an employee intent upon bettering himself. Many of those who moved around probably did through choice, as, in general, plenty of work was available as the industry expanded in Yorkshire. John Stirk had broadened his horizons with a few well-chosen moves around major firms within West Yorkshire. As far as entrepreneurship was concerned, there remained opportunities to go into small-scale self-employment, perhaps in repairs or in manufacture of specialist components. With a rented workshop, and few tools and machines required for a limited range of work, not much capital was needed, and skill and connection remained paramount. But the growth of a large-scale sector in engineering had made a difference to opportunities for journeymen. It was no longer possible for a journeyman to compete as a manufacturer of whole machines, as he would have been unable to raise enough capital to set up as a mass-producer on an economic scale. Secondly, as a producer of components he would probably be very dependant upon a few large customers, lacking the broadly-based business of his equivalent a generation or two earlier. Thirdly, journeymen may have had wider opportunities within the large-scale sector. While it was still possible to move between firms to increase experience, skilled workers could also choose to specialize within a firm, confining their work to a narrow field in the expectation that they could improve their earnings potential through piecework.

CONCLUSION

Skills in textile engineering were very real throughout the period, though they varied in different sectors of the industry and also gradually narrowed and intensified. Persistent wage differentials are not the most convincing evidence for the reality of skill, as labour shortages may explain engineers' relatively high earnings. But as entry to the industry was not limited by institutional constraints, manpower shortages could have been eased by introducing obvious pools of cheap labour, such as local women, or less cheap but possibly more adaptable labour like the displaced South Yorkshire nailmakers. Such substitution did not take place, suggesting that skilled engineers did possess qualities which were not readily reproducible.

The trade of textile engineer, in all its variations, originated in the same crafts which had produced the first successful entrepreneurs, particularly that of the smith. The workforce was mainly locally recruited as communities had numerous potential machine-makers in the pre-existing wood and metal trades, and before 1805 were also using unskilled labour. After 1805 it was mainly metal-workers who made the conversion to the new trade, though sometimes other adults were re-trained. Such flexibility, of working patterns and entry paths, diminished during the first decades of the nineteenth century. The industry's massive expansion from the 1820s was achieved only through the development of a traditional system of apprenticeship, though skill shortages were a recurring feature during the 1820s and 1830s.

After 1820 most entrants joined as apprentices, attracted away from dying trades such as hand-weaving by the employment opportunities and relatively high pay and status of textile engineering. Even the growing regimentation of the industry may have appealed, offering a measure of stability which was attractive to those who had seen the insecurity of other trades. Mobility began to lose its relevance when broad-based skills were no longer a requirement, though workers could still move around if they felt it necessary, if they had ambitions to progress, or in times of unemployment. Apprenticeship in textile engineering brought a recognized qualification which could gain the holder access to larger or smaller engineering establishments. The skills were marketable, not so narrow that they could not be adapted to other engineering firms, yet specialised enough to benefit from exposure to other parts of the industry. At the same time, because of the changing scale of the industry, it had become much harder to move into entrepreneurship.

NOTES:

1. Cardwell 1972, p.100.
2. Wright 1867, p.107.
3. Wright 1867, p.83.
4. Wright 1867, pp.100-1, 104-5.
5. Sturt 1963, pp.73-4.
6. Sturt 1963, p.19.
7. Raistrick and Allen 1939, pp.176-7.
8. Butterworth 1920-4, p.114.
9. Hey 1971-9, p.36.
10. Hey 1991, p.305.
11. Butterworth 1920-24, p.116.
12. Rowlands 1975, p.26.
13. Hey 1968, p.58.
14. Hey 1968, p.59.
15. The enclosure of Ecclesfield took place in the 1780s - see Hey 1968, p.31; Winder (ed.) 1921, p.14.
16. Hey 1968, pp.59-60.
17. Hey 1968, pp.240-1.
18. Winder (ed.) 1921, p.9; Butterworth 1920-4, p.114.
19. Sheffield Cathedral Register, Marriage 11 April 1784; baptisms 25 May 1785, 7 September 1787, 13 April 1789.
20. Hey 1968, p.58.
21. Rowlands 1975, p.147.
22. More 1980, preface.
23. More 1980, p.79.
24. Butterworth 1920-4, p.114.
25. Leeds Mercury, 6 January 1789.
26. Rule (ed.) 1979, p.xii.
27. Winder (ed.) 1921, pp.8-9.
28. Mathias 1979, p.35.
29. NYCRO.
30. Mason 1971, p.6.
31. See chapter 2.
32. WYAS Bradford, 32D83/6/1 and 32D83/10/1.
33. See chapter 2.
34. See Table 3.1.
35. See Crump (ed.) 1931, p.9, and Rees's Cyclopaedia for illustrations which, according to Crump, show out-dated eighteenth century machinery.
36. Landes 1969, pp.64-5.
37. WYAS Bradford, 32D83/2/1. The respective importance of these various parts of Hattersley's business cannot be quantified, because of the way sales records were kept.
38. PP (HC) 1824 (51) V, p.381.
39. Sturt 1963, p.175.
40. Cantrell 1985, p.226.
41. WYAS Bradford, 32D83/5/1.
42. Roll 1968, pp.149-57 etc.; whether the Soho 'experiment' was as innovative as Roll suggests is open to debate, as Boulton and Watt borrowed techniques from Matthew Murray, John Wilkinson and others. For further discussion of the division of labour see chapter 5.
43. Roll 1968, pp.24-5.

44. Lee 1972, pp.17-8.
45. Lee 1972, p.20.
46. R.Campbell 1747, The London Tradesman, quoted by More 1980, p.195.
47. Rowlands 1975, p.133.
48. PP (HC) 1824 (51) V, p.348.
49. Chambers's Edinburgh Journal No 513, 27 Nov. 1841, p.354.
50. Leeds Intelligencer, 22 September 1789.
51. Crump (ed.) 1931, p.327.
52. Crump (ed.) 1931, p.321.
53. See chapter 2.
54. Cantrell 1985, pp.226-7.
55. More 1980, pp.195-6.
56. Burnett (ed.) 1974, p.265.
57. More 1980, pp.146-7.
58. Morris 1990, p.105.
59. PP (HC) 1824 (51) V, p.28.
60. PP (HC) 1824 (51) V, p.39, p.300.
61. PP (HC) 1824 (51) V, p.300.
62. Roll 1968, p.61.
63. Roll 1968, p.62.
64. Tann 1978, p.374.
65. Ashton 1963, p.200.
66. Scott (ed.) 1928, pp.38-41.
67. R.Fitzgerald pers. comm.
68. Burnett (ed.) 1974, p.310.
69. Burnett (ed.) 1974, p.310.
70. Burnett (ed.) 1974, p.311.
71. Burnett (ed.) 1974, p.312.
72. PP (HC) 1824 (51) V, p.253; evidence of Ewart and Kennedy.
73. PP (HC) 1824 (51) V, p.301; evidence of Ashton and Bremner.
74. WYAS Bradford, 32D83/12/1.
75. PP (HC) 1841 (201) VII, p.96.
76. PP (HC) 1841 (201) VII, p.98.
77. PP (HC) 1841 (201) VII, p.98.
78. Checkland 1964, p.134.
79. Cantrell 1985, p.227.
80. Cantrell 1985, pp.241-2.
81. Jordan 1989, pp.274, 294.
82. Berg 1991b, p.177.
83. Quoted by More 1980, p.155.
84. PP (HC) 1834 (167) C1, p.43.
85. Rule 1986, p.130.
86. See for example WYAS Bradford, 32D83/10/1.
87. Scott (ed.) 1928, p.36.
88. PP (HC) 1824 (51) V, p.345.
89. PP (HC) 1841 (201) VII, p.104, evidence of William Jenkinson.
90. Roll 1968, pp.61-2.
91. Burnett (ed.) 1974, p.311.
92. WYAS Bradford, 32D83/12/1.

93. Wright 1867, pp.103-7.
94. Evidence of Thomas Ashton, PP (HC) 1824 (51) V, p.304.
95. More 1980, pp.42-4.
96. For this and a fuller definition of apprenticeship, see More 1980, chapter 3, especially pp.41-5.
97. Cantrell 1985, pp.237-8.
98. Cantrell 1985, p.239.
99. Rule 1986, p.121.
100. PP (HC) 1834 (167) C1, p.43.
101. Roll 1968, p.20.
102. Chambers's Edinburgh Journal No. 513, 27 Nov. 1841, p.354.
103. Leeds Mercury, 8 May 1830.
104. Leeds Mercury, 15 May 1830.
105. Lee 1972, pp.10-1.
106. Hodgson 1879, p.244; Feather 1983.
107. See Table 3.1.
108. Burnett (ed.) 1974, p.307.
109. Morris 1990, p.35, quoting PP (HC) 1840 23, pp.582-3.
110. Crump (ed.) 1931, pp.322-3, quoting Leeds Mercury, 3 August 1799.
111. Pollard 1968, pp.196-7.
112. Burnett (ed.) 1974, p.265.
113. More 1980, chapter 7.
114. WYAS Bradford, 32D83/12/1.
115. More 1980, p.164.
116. PP (HC) 1824 (51) V, p.569.
117. More 1980, p.78.
118. More 1980, pp.71-2; Burnett (ed.) 1974, p.309.
119. Anon. 1946, p.2.
120. Anon. 1861, p.29; Walker 1884, pp.252-4.
121. Walker 1884, p.254.
122. Calderdale Reference Library, P621.
123. More 1980, pp.141-2.
124. Burnett (ed.) 1974, p.309.
125. Wright 1867, p.100.
126. More 1980, pp.71-2.
127. Sturt 1963, p.175; Burnett (ed.) 1974, p.309.
128. Pollard 1968, p.199.
129. Pollard 1968, p.206.
130. See for example Scott (ed.) 1928, pp.38-41; the transfer of technical knowledge by these means will be discussed in chapter 4.
131. Burnett (ed.) 1974, pp.251-2.
132. Randall 1991, p.92.
133. WYAS Bradford, 32D83/2/2.
134. WYAS Bradford, 32D83/10/1.
135. WYAS Bradford, 32D83/15/2.
136. WYAS Bradford, 32D83/10/4.

CHAPTER FOUR

INNOVATION AND THE DIFFUSION OF TECHNOLOGY

> The history of inventions is not only that of inventors but that of collective experience, which gradually solves the problems set by collective needs.[1]

> Invention breeds invention.
> (Ralph Waldo Emerson 1803-1882).

Between 1780 and 1850, mechanization was successfully applied to a range of processes in every branch of textiles. This was a significant achievement, for each major division of the textile industry - cotton, worsted, wool and flax - required a distinct range of machinery tailored to its precise needs at each stage of production. Converting raw wool into finished cloth involved 34 operations, in which, according to Baines in 1858, 16 different machines were used.[2] In the worsted branch, where mechanization of woolcombing in the 1840s marked the end of hand labour altogether,[3] the number of processes was fewer than in woollens, but the wide variety of worsted products, some incorporating other types of fibre, demanded a range of specialized machinery. Taking account of these many and diverse processes within the four main branches, allowing for major adjustments which may have been necessary to convert a machine for a different product even within the same branch, and keeping in mind also that many trials were carried out and inadequate machines improved before satisfactory solutions were achieved, it is beyond doubt that many hundreds of individual innovations were involved in the mechanization of textiles.

To be more precise is difficult, for machinery underwent constant modification. An outline ancestry can be identified for certain machines, in the way that William Fairbairn described stages in the evolution of the cotton powerloom.[4]

Most improvements, though, went unrecorded. Consequently it is impossible to use specific evidence of improvements in machines to prove or disprove the idea that particular economic circumstances might have dictated the pace of technological change, and impossible to be certain when, or indeed whether, technology developed its own momentum independent of external economic forces.[5]

There are in any case wider questions, for example about the influence of science in technological development, or concerning distinctions between invention and innovation, which even complete lists of adaptations and improvements to machines could not answer. Indeed an unsatisfactory aspect of much literature dealing with such issues is that evidence is used in a general way, and conclusions are consequently superficial, failing to explain adequately the dynamics of technological development and diffusion. By focussing upon one industry - and that industry at the heart of debate about industrialization and innovation - it is hoped that some of these issues can be clarified or more satisfactorily defined.

A major question can be summarised as that of strategy *versus* tactics, whether innovation could be planned and directed, or whether it consisted merely of spontaneous responses to immediate problems. Related to this is a question of the value of individualistic invention, and whether that could have made a greater contribution to technical advance than did collective efforts.

The term 'invention' itself presents a difficulty. The word has come to carry a connotation beyond its dictionary definition of 'a contrivance' or 'a thing devised'. While innovation can mean anything new, large or small, significant or not, and so encompasses any improvement made to textile machinery, 'invention' is generally used to suggest something altogether original, perhaps even with a hint of that 'heroic' inventor whose existence has been generally declared untenable. Gilfillan suggests that the word 'invention' is perhaps the hardest in the language to define, but rather than give up on the attempt, interprets it as 'a combination of several ideas, and which ones are involved, and which are more important, is always a question', adding that invention is a thing without boundaries.[6] It is certainly difficult to find an indisputable example of an invention. For example, Leonardo da Vinci's late fifteenth century designs of textile machines would presumably be accepted in the popular definition of 'invention', as they contained a degree of originality.[7] But these 'inventions' were incapable of execution as they defeated contemporary engineering skills. There is doubt about whether some of them would have worked, but as they could not be built, they could not be tried and improved. On the other hand, the work of Arkwright, who is also generally considered an inventor, was far from original, owing much to earlier machines and to the work of collaborators. According to the criteria applied by Samuel Smiles, whose inventor was not a man of vision, but rather one who could practically execute an idea,[8] Leonardo would presumably not have qualified for the title. Neither perhaps would Arkwright, relying as he had upon the work of others. Smiles, whose biographical works concentrated upon the lives of engineers and iron-workers, emphasised hard work and application as the keys to success and did not directly peddle the idea of the heroic genius as inventor. But his approach, in emphasizing the success achieved by individuals, was one of the planks upon which the 'heroic' myth of great inventors was constructed.

Enos tried to distinguish between invention and innovation by measuring the interval between a product first appearing in substantially useful form, that is, invention, and its first commercial application, which he called innovation. He claimed that this process took several years, even in mechanical engineering where ideas were generally developed much faster than in other industries.[9] Rosenberg has criticised Enos's work specifically for overestimating the commercial feasibility of the 'inventions' used to prove his theory.[10] But Rosenberg also makes general criticisms, shifting the debate to potentially more useful ground. He reminds of the need to consider economic as well as technical influences, with commercial success depending on 'a careful discrimination among those aspects of past practices which need to be rejected and those which need to be continued'.[11] He complains of an 'artificial segregation of invention from innovation' and similarly of invention from diffusion.[12] Continuities in innovation, believes Rosenberg, have been overlooked while discontinuities received disproportionate attention, and the early stages of invention have been accorded 'excessive significance' while crucial later stages are ignored.[13] Accompanying this distorted picture of innovation is an exaggerated view of the importance of 'pure' scientific knowledge in comparison to 'lower' forms such as 'mere' technological or engineering knowledge.[14] There is a problem of semantics in distinguishing invention from innovation, or science from technology, or theoretical knowledge from empirical, which means that these terms have to be used cautiously and with qualification, but there is little point in trying to define them rigidly and artificially.

A more useful way of thinking about innovation in textiles is to take Mathias's idea of 'continuum' improvement, those countless, unrecorded modifications which machinery underwent. Collectively, Mathias believes, these 'may yield a cumulative advance in productivity greater than the identifiable discrete innovations'.[15] Gilfillan suggests that 'the very essence of invention ... [is] its evolutionary nature, its being almost wholly an age-old, multitudinous accretion of little details, modifications, perfectings, minute additions ...' [16] If this is so, then the workplace environment was of immense significance in generating ideas, and the 'heroic' inventor can be accorded the diminished role which he deserves, brought down to earth alongside other innovators. Musson points out that 'few, if any, scholars nowadays would subscribe to a naive 'heroic theory' of inventions',[17] and there, it might appear, is an end to the debate, except that several loose ends remain. Musson himself, though forced by the weight of scholarly opinion to dispense with heroes, will not let go of the notion of individuality in the process of innovation. He thinks that, because hard thought and effort and perhaps failure were involved in innovation, then 'inevitability', the idea of socially determined invention, is 'ludicrous'.[18] But he is wrong in claiming that the idea of inevitability 'completely ignores the realities of individual achievement, the imaginative insight, sustained effort, and mixture of motives involved'.[19] By jettisoning the notion of heroic inventors, historians have been able to accord due credit to these qualities which Musson emphasizes, and there is no contradiction with 'inevitability'. 'Inevitability' does not mean that achievements are possible without hard work, bright ideas, and in some cases failure. There is plenty of evidence to show that, faced with a specific problem, it can be possible to 'invent' to order. This need not diminish the achievements of certain talented individuals, as Smiles, whose stories show the possibilities of using determination, hard work and skill to solve a given problem, was still able to laud individual success.[20] For if inventions are not inevitable, then the implication is that 'genius' is the main requirement for invention, and that brings the argument back to heroic inventors, whose day, even Musson would concede, is surely past.[21]

If the notion of individual genius can be dispensed with as the major component of invention, can the 'inventor' be replaced by a community in possession of relevant skills and intense knowledge of its customer industry, and fuelled by economic imperatives? Such an idea would agree with a Marxist view, that social processes are more important than inspired flashes of individual genius, and that institutional and economic environments play a major role in the processes of invention and innovation.[22]

A further legacy of the 'heroic' view which has never been satisfactorily explained is the role in innovation of protection and secrecy. The close guarding of 'inventions' complements the 'great inventors' myth, and has proved to be a more enduring belief than heroic inventors themselves. But tales of secrecy may have been seriously exaggerated. It seems unlikely that secrecy could have been a general rule in the industry, being neither practical in a small community of machine makers, nor perhaps desirable. If much of the secrecy was a myth, and information was actually widely circulated and even shared, this is further indication that a measure of collaboration rather than intense and jealous competition helped develop technology in the textile engineering industry.

SCIENCE AND INVENTION

> It is well known that the most useful discoveries that have been made in every branch of art and manufactures have not been made by speculative philosophers in their closets, but by ingenious mechanics, conversant in the practices in use in their time, and practically acquainted with the subject-matter of their discoveries.[23]

Even in the eighteenth century, commentators slipped easily into a convention of treating technology and science as separate and distinct types of knowledge. By implication 'pure' science, then called natural philosophy, was of a higher order than applied mechanics. James Watt, for example, is said to have considered himself a natural philosopher first, and an engineer second, claiming in 1771 that he had no experience of 'engineering in the vulgar manner'.[24] Rosenberg attributes the persistence of this belief that technological knowledge was inferior to science, to the prejudice of economists.[25] Whether or not Rosenberg is correct in this, the key issue is not whether science was in some way superior to technology, but rather the influence of scientific thought upon technological advance during the industrial revolution. This argument, about the relative importance of the contribution of science and of empiricism to the innovation process, was not settled by Musson and Robinson, and remains unresolved.[26]

It has been argued that little can be gained from an artificial separation of interests in natural science from interests in technique, as the same groups and publications were involved in both.[27] That may be true at the level of an educated and leisured class, but even if links between science and technique can be demonstrated there, the point is still not proven that such largely theoretical work filtered down into the process of mechanical innovation. Furthermore, if science did indeed penetrate the early engineering workshops, we do not know whether it arrived in the form of directly applicable packages of knowledge, or in the guise of the mathematical and mechanical tools of a scientist.[28] There is also a danger of expecting too much of science, in what Mathias has called 'a golden age of amateurs, cranks, quacks and crazy theorizing'.[29] There certainly existed a small international scientific community which engaged, via the medium of learned journals, in a debate which was accessible to the likes of the multilingual Smeaton.[30] Furthermore there was a body of practical workpeople whose skills and knowledge were considered of such value that their emigration was forbidden by law until the 1820s. But how far was the international debate of the first, educated, group, relevant to technical advance in the workshops of the second, artisan, group? Did these artisans come into contact with science at all? Cardwell thinks not, believing that men like Arkwright, Hargreaves and Crompton worked in a way 'totally independent of science' and that a scientific input to engineering came only later, in response to problems arising once processes had been mechanized.[31]

As far as formal education was concerned, mechanics was not considered a science at the universities of Oxford and Cambridge, where, as a branch of mathematics, it was taught by repetitive and non-experimental lectures. The elder Rennie, though keen on theoretical understanding, prevented his son from embarking upon such an education as he thought that it would turn him away from practical engineering,[32] which implies that he saw theory and practice as scarcely compatible. Few English engineers had had any contact with university. In this as in much else, Watt was unusual, though his contact with theoretical science had been in Glasgow rather than at an English university. The Scottish education system, which had a high reputation for mathematics and practical subjects, did make some contribution to early textile engineering in the north of England. The Fairbairn brothers, M'Connel and Kennedy, and Charles Gascoigne Maclea all received at least an elementary education in Scotland. The noted innovator Isaac Holden (1807-1897) described his good fortune at having been born in Scotland:

> I should not have had the education I had otherwise ... Forty years ago the Scotch [sic] were the best educated nation in the world ...[33]

Holden's education had been spasmodic but included attending the school of John Kennedy, 'a man of considerable mathematical and scientific attainments', and Holden himself had worked as a mathematics teacher and later lectured in science.[34] The tone of comments on Holden's education suggests that his thorough training in mathematics and science had been unusual at that time in Yorkshire.

If 'state of the art' mathematics and science in universities can be discounted as major contributors to technical development, was there a lesser form of mathematical and scientific knowledge accessible to innovating shop-floor engineers? Mathias has argued that abstract scientific or formal knowledge was not crucial in the development of artisan technology and skills,[35] and shop-floor mechanics would only with great difficulty have found and used such information. The literature on mechanics, engineering and drawing available in English in the 1790s and up to about 1825, when compared with that in French, was backward and in short supply. Cardwell describes the English textbooks as 'belonging to an earlier century' and suggests that English work on mechanics and mathematics had not progressed significantly since Newton.[36] But it is unlikely that many engineering workers before 1825 saw such books, which were expensive, scarce and probably unintelligible to one of limited education. John Nicholson's Millwright's Guide (1830) contains a two page bibliography of published treatises on millwork, of which the earliest date from the seventeenth century. Even if a reader could follow the science in these works, he would have needed to know German, Dutch, Latin and French as well as English in order to understand them all. Robert Heaton listed some of these books at the time that he was planning the machinery for a new factory at Ponden, near Haworth, in 1791. The books in which Heaton was interested were entirely theoretical, on mathematics, mechanics and natural philosophy,[37] many were over twenty years old, with two of them - Ditton's Laws of Nature and Motion (1705), and Moxon's Mecanic Exercises (1695) published almost a century earlier. The 'nadir of English science' which Cardwell dates to about 1800 did not find its renaissance until Babbage and Herschel after 1820 [38] so these ancient theoretical works may have been the only books of even marginal relevance to Heaton's requirements. But it is not known whether Heaton bought the books he noted in his journal, and if so whether he used them to help in his work. As a merchant, and patently a man of some education, Heaton would have been better able to use such books than Checkland's 'untutored mechanic' for whom mathematical theory was impossible and in any case 'far removed from practice'.[39]

However there had appeared a new kind of handbook, ostensibly aimed at mechanics, which may have bridged the divide between abstract and empirical work. The first of these was John Banks's Treatise on Mills (1795), followed by his book On the Power of Machines (1803). Then came Andrew Gray in 1804 with The Experienced Millwright; or, a treatise on the construction of some of the most useful machines, published in Edinburgh, the American Oliver Evans with his Young Steam Engineer's Guide in 1805, John Sutcliffe's

Treatise on Canals and Reservoirs (1816), Robert Brunton's Compendium of Mechanics, published in Glasgow in 1825 and into its fourth edition by 1828, and John Nicholson with The Operative Mechanic and British Machinist (1825), reissued in part as The Millwright's Guide in 1830. Nicholson's first edition had been sold in thirty weekly parts at one shilling each, making it affordable to a wider audience than scientific works had hitherto reached. All the new handbooks adopted a straightforward style designed to appeal to the non-scientific reader. In fact the connections of these books to science were slender, their contents generally limited to the most basic mathematics and mechanics, practical calculations for the use of millwrights, and specific though simple diagrams of various machines, mainly in the province of millwrights. Brunton, 'a mechanic of Glasgow', ranged from weights and measures to the strength of materials, his work informed by experience rather than by abstraction, and he recognised the divide between his trade and the higher calling of scientist:

> ... that much-wished-for time appears to be at hand, when Mechanics shall not only be acknowledged cunning artificers, but men of Science: when the word Mechanic shall convey the idea of wisdom and understanding, and the profession, highly fraught with good to man, shall be honoured and respected.[40]

Unlike Brunton, Banks was not a practical workman, styling himself 'lecturer in experimental philosophy'. His introduction to A Treatise on Mills suggests that practical mechanics might have benefited from greater attention to theory:

> It is true, that we have in the kingdom many intelligent engineers, and excellent mechanics; and there are others who can execute better than they can design, otherwise there would not have been so much money expended in attempting what men of science know to be impossible.[41]

In On the Power of Machines, Banks conceded that his own work could similarly be improved:

> The problem concerning the lathe is accurate, but not by any means what I could wish. Some person better acquainted with science may perhaps give a much shorter and simpler solution, but it is the best I could give.[42]

Banks's criticisms of some of the claims made for waterwheels and other machinery suggest that a debate was taking place on the efficiency of various machines, though in the realm of technologists rather than in scientific circles.[43] Banks in turn was taken to task by Sutcliffe for mistakes in calculations on waterwheels.[44] There is little in these books which relates to textile machinery, beyond heavy items such as fulling stocks and the design of factories themselves, all of which was the province of millwrights. Sutcliffe had a section on 'the carding, roving, drawing, stretching and spinning of cotton' which was largely concerned with setting up and maintaining machinery. Only Nicholson, a civil engineer, included a lengthy section on textile machines, though this was a general and historical account of processes which included sections lifted from Rees's Cyclopaedia,[45] and significantly the textile sections were omitted from his 1830 edition republished as The Millwright's Guide. The publishers of such books recognized that millwrights' work, relatively wide-ranging and slow to change, provided easier subject matter than did the new branches of mechanical engineering. To textile engineers, books offered neither scientific enlightenment nor useful technological information, as technology evolved too quickly for books to keep pace. This is shown in the list of subscribers to Banks's first book, which stimulated a wide interest in Yorkshire and Lancashire among proprietors of ironworks, cotton- and flax-spinners, merchants, millers, and others. Though the range of industries is wide, the backgrounds of subscribers is narrow, overwhelmingly from the educated middle-class, with more ministers and schoolmasters than mechanical engineers. Ten pages of subscribers contain no identifiable Yorkshire textile engineer, which suggests that such books appealed more to a general, educated readership, than to an uneducated person who, even though engaged upon apparently relevant work, was not accustomed to buying or consulting books. Like Rees's Cyclopaedia, which was itself in an eighteenth century mould, such books were often a matter of record rather than design, at least as they related to the new machine-making industry.[46]

Most entrepreneurs and journeymen making machines before 1850 had had, at best, a very elementary education. Andrew Ure in 1835 recognized the contribution of 'mechanised talent' to the remarkable developments in textile engineering, acknowledging that this elite of skilled labour had had little or no formal education.[47] Samuel Owen, who worked for Matthew Murray before 1804, noted the lack of basic education of the workforce at the Round Foundry. He had left Boulton and Watt after four years to join Fenton, Murray and Wood, whom he considered 'the best manufacturers of steam engines in England', but even so:

> Few knew the simple rules of arithmetic save the clerk in the office. Mr Murray made his calculations with a carpenter sliding rule. I was looked up to as a light and became a companion to my principals, and several workmen took lessons in arithmetic from me.[48]

Thomas Wood of Bingley, who attended a small local school where he learned to read, followed by two years at grammar school from the age of six where he studied Latin grammar and writing, though no mathematics, was probably better educated than the average journeyman engineer in the 1820s.[49] Mechanics' Institutes, which started to appear in the 1820s, played little part in vocational education, though they may have helped improve the basic arithmetical skills of some workers. In Keighley, for example, only about a quarter of the institute's membership belonged to metal-working trades, which was reflected in the general nature of lectures offered.[50] There were occasional classes in writing, arithmetic, geography and drawing, though technical drawing, which proved to be extremely popular, was not taught there until the 1850s.

Had science, or even mathematics and theoretical mechanics, been considered a useful or relevant subject for application to textile engineering, then it could have been introduced to the industry through the education and training of sons of entrepreneurs. By the 1830s and 1840s the more successful machine-makers had the means to bring science into their sons' curriculum. The number of engineers who were wealthy and well-connected enough to send sons to university was limited, but even those few preferred an education which was commercial and mechanical, or even linguistic, rather than scientific. Samuel Lawson's son John (c.1808-c.1884), 'one of the most resourceful mechanics of his day' who was responsible for great extensions in the company after Samuel's death in 1866, served a conventional apprenticeship.[51] John's own sons, also successful industrialists, were Arthur, later Sir Arthur Tredgold Lawson, Bart., (1844-1915) and Frederick (1845-1915). Arthur was educated at St Peter's School, York, then Winchester and Cambridge, before returning for practical training to Mabgate Foundry, while Fred went to Leeds Grammar School, then served an eight-year apprenticeship in the machine works, eventually becoming a partner in 1876.[52] Peter Fairbairn's only son, Andrew (1828-1901), was sent to schools in Leeds, Switzerland and Glasgow before Cambridge and the Inner Temple, where he was called to the Bar in 1852. He ceased legal practice in 1855 to join the family business. Andrew Fairbairn made extended visits to the United States and Hanover, where he studied German and familiarized himself with the workings of flax mills, and later investigated textile industries across Europe.[53] The Keighley industry, where social and financial status of entrepreneurs before 1850 was generally lower than that of Leeds, does not provide comparable examples. There, apprenticeship remained the usual route into the industry for owners and journeymen alike. George Hattersley was bankrupt in 1832, so his eldest son went straight to work as an apprentice while the firm was being rebuilt. In 1844, two younger sons were at a private academy near Ripon, and another was undergoing some kind of commercial training in Bradford.[54] There is no evidence that any of these sons, who were to inherit one of the two largest engineering businesses in Keighley, had any formal scientific or even technical education.

If most significant technological progress was achieved in a workshop rather than in a laboratory, by machine-makers who apparently had little or no exposure to scientific books or any education in science, then Landes is correct in emphasising the importance of mechanical skills in the innovation process, and may be right in claiming for technology a role in the growth of scientific knowledge.[55] Pickstone has suggested that eighteenth century science was a descriptive process, with analytical approaches developing from about 1800 and ideas of control and formal techno-science emerging later.[56] Checkland too puts practical skills before theory, suggesting that 'mechanical improvement on the basis of untheoretical perception' was possible for pragmatic mechanics who did not need to understand mathematics as they could judge stresses and safety limits by eye.[57] There is wisdom, though, in Mathias's caution against excessive generalization, as the relationships between scientific knowledge and technical innovations were diffuse and complex.[58]

It may be, for instance, that the development of a quasi-scientific method in innovation had greater significance for textile engineers than the influence of 'pure' science. On the other hand, innovation was stimulated not by a scientific impetus, but by an encouraging technical and commercial environment. But these are elements of the same phenomenon, which can perhaps be described as a practical approach to problem-solving, informed by a strong commercial sense. Mathias distinguishes between the application of scientific method, also called the experimental tradition, and intrinsic scientific knowledge.[59] Referring to developments in naval medicine at the close of the eighteenth century, he points to a contemporary assumption 'that the secrets of nature would yield to the efforts to understand them and that enhanced control ... would follow'.[60] Such a belief may explain the dogged pursuit of solutions to engineering problems by certain innovators. Their methods of experiment were mechanical, practical and empirical, but could also be systematic.[61] Thus the influence of science can be seen in two forms, in the way that scientific method shaped an approach to innovation, and also in a growth of that positive philosophy born in scientific circles which gave engineers confidence that given problems could be solved. In addition, innovators were helped by advances in associated technology, such as bearings, lubricants, metals, and tools, which owed a direct debt to the work of science. Ultimately, though, quasi-scientific method must not be confused with science, and the empirical achievements of textile engineers should be recognised for what they were. The industry developed methods to suit its needs, which owed little to abstractions. Furthermore, the importance of a commercial environment where improvements to machines could be swiftly evaluated must be recognised.

Matthew Boulton, much more a businessman than James Watt, was trying to concentrate his partner's attention when he wrote:

> ... we are not anxious about the honour of acquiring gold medals nor of making an eclat in philosophical societies.[62]

Engineering may have been vulgar, but scientific distinction was superfluous to those seeking commercial success. Boulton and Watt, who were middle class, educated, and had access to the international scientific community, were not typical engineers of their time. Most machine-makers did not have the option of rejecting membership of philosophical societies, as they did not belong to the middle class. In any case, the work of such societies was at best marginally relevant to mechanical engineers. The small scientific societies in Leeds, dating from Joseph Priestley's residence in the town between 1767 and 1773, were interested in chemistry, medicine and other philosophical topics, but had no connection with the engineering industry which was growing up on their doorstep.[63] Musson and Robinson's account of the supposed flow of scientific information around the industrial community of Leeds fails to pinpoint any real links with machine-making.[64] Their evidence amounts to two prominent textile manufacturers beginning to apply scientific method in dyeing techniques, and a discussion of the constitutions of various amateur scientific groups in Leeds. Far from proving any link with engineering, these lists of members demonstrate the entirely middle-class nature of the groups. Matthew Murray joined one group in his old age, in 1818, when he had also joined the middle class, but notably had had nothing to do with the amateur scientists during his most productive and innovative years. Science remained a pastime for the leisured middle class, and its body of knowledge had little effect upon textile engineering.

THE DIFFUSION OF TECHNOLOGY

The channels through which eighteenth century technology was disseminated have been summarized as 'men, manuals and machines'.[65] Of these, the particular importance of the individual in spreading technical information is emphasised by many historians.[66] Though much of the historical discussion concerns the export of technology to continental Europe or North America, essentially the means of transmission were the same, whether in a local or an international context. But, as Bruland remarks, many historians who express interest in the history of technology, or in technological diffusion itself, have not explained precisely how technological change operates.[67] It may be possible in a case study to be more specific about this process.

It seems that any new machine which proved useful was quickly assimilated within the textile industry. For example, there were said to be 170 scribbling machines working within 17 miles to the south and west of Leeds by 1786.[68] What is not known is to what extent these machines were replicas of each other, or whether they had undergone modification to improve their performance or to apply them to different kinds of work. In communities where skills in textiles, and in basic engineering, were plentiful, it is likely that a process of gradual improvement was taking place, particularly as adjustments were needed simply to make these early machines work at all. Trials and gradual refinements were of great significance cumulatively, though mainly undocumented.

Though there were some attempts to impede the spread of technology (further discussed below), information circulated easily, and internationally. Even when it was illegal to allow machinery or technicians to go abroad, there are numerous instances of technology being exported by such means.[69] The activities of customs officials, the war with France, and prospects of heavy fines and commercial losses could not stop what Mathias has called 'technological Darwinism'.[70] So well established was this trade in technology that it was possible to insure illegal exports at a rate 30 to 40 per cent higher than standard premiums.[71] But the flow of technology was not merely outwards, as new European ideas and techniques were constantly arriving, from the early modern period, to be joined later by imports of American innovations.[72] 'We have derived almost as many good inventions from foreigners, as we have originated among ourselves', said a witness to the 1829 Select Committee on Patent Laws.[73] In 1841 it was claimed that:

> ... the greatest portion of new inventions lately introduced to this country have come from abroad ... not improvements in machines, but rather entirely new inventions ... [74]

Curtis thought that America was the source of many original ideas, the inventiveness of its natives stimulated by labour shortages and 'untrammelled by predilections in favour of a machine already in existence'.[75] But once imported to Britain, such machines were generally improved, he said:

> It is not the case that parties have come here to perfect the machines; they are perfect, as the foreigner imagines, when he brings them to this country; but when they come here they are placed in the hands of mechanics ... [who] from the more extensive knowledge they have of the working of the various machines, are better able to perfect them, the workmen generally paying great attention to the different working parts.[76]

Peter Fairbairn told the Select Committee he had 'had machines from the inventions of Swiss, and the workmanship of those machines was exceedingly good ...' [77] It has been suggested that British textile manufacturers lost out by being insufficiently receptive to foreign ideas, for instance in their failure to adopt American and Belgian condensers until many years after the machines had first appeared.[78] Rosenberg, however, stresses European receptivity to new technologies, reckoning the ability to assimilate ideas perhaps 'as important as inventiveness itself'.[79] This ability to adapt and assimilate technology was the key to successful industrialization,[80] and in accepting this, the role of 'heroic' invention is further marginalized. The throstle, enormously important in worsted spinning during the first half of the nineteenth century, provides an example of this process, its ancestry traceable to Arkwright's cotton frame, which was modified as the technology moved around Leicester, Warwick and other places during the 1780s and 1790s.[81] And Arkwright's frame itself had antecedents in the ideas of Wyatt and Paul and others.

But how, specifically, was information conveyed? What was the relative importance of Inkster's 'men, manuals and machines' as conduits of technology?[82] Machines themselves are an obvious source of information and machine-makers, in selling their product, were inevitably disseminating technology. This has implications for the argument about whether secrecy was feasible (see below). The idea that textile manufacturers would under normal circumstances buy a machine in order to copy it seems far-fetched, as it would usually be cheaper and more practical to buy machines direct from a specialist maker. In an account of the diffusion of textile technology to the United States, Jeremy has shown that machines themselves could be successfully copied, and even improved in the rebuilding, but that there were major delays and difficulties. British technicians were required to supervise American craftsmen who made the machinery, and acquisition of parts and ancillary items such as card clothing posed a problem.[83] Where patentees charged a premium, as did Boulton and Watt for their steam engines and Lister for his combs, then there might have been a point in piracy, which is why Boulton and Watt and Lister so assiduously defended their rights through the courts. The examples of whole machines being used as models from which others could be copied arose where users wished to evade a prohibition, or they come from a time before a specialist machine-making industry could adequately meet demand. The case of the German in Leeds found in 1781 with 'a compleat spinning jenny' in his possession, and a 'scribbling mill' on order from Armley, both which machines were to be packed and exported, fits into both these categories.[84] A suggestion that the Leeds cotton spinner Ard Walker employed a spindle maker specifically to copy frames bought from Halifax in 1800 may be correct, though there is no firm evidence of it in Walker's records.[85] Several witnesses to the two Select Committees on machinery, fearing a widespread export of machines to continental engineers for use as models, confirmed that such emulation was possible and was indeed already occurring.[86] But the point was also made that the first copies would not be good ones, and that 'it would be a very long time before they could make them so cheap, and so well adapted to the purpose as ours'.[87]

Though drawings or reduced size models were easier to smuggle than whole machines, they presented similar, perhaps greater, difficulties to the machine-builder.

> No drawing or model, except it was as large as the machine itself; not a model but a machine can possibly point out the parts where the best work is necessarily to be applied, in order to adapt a machine to its purpose.[88]

From this it can be inferred that technical drawing and model-making were in their infancy. Engineering drawings, other than the most rudimentary of sketches, are rarely encountered in this early phase, and were still 'few and far between' in the industry as late as the 1920s.[89] As detailed drawings were required to accompany patent registration, a lack of drawing skill could have been another factor inhibiting the less educated from applying for patents. True engineering drawings were restricted to larger firms such as Boulton and Watt, who as consulting engineers issued drawings as part of the package they sold. In Yorkshire, Matthew Murray had a reputation as a fine draughtsman, but was exceptional, perhaps unique, in this respect.[90] Almost the first item mentioned in Murray's will of 1825 was 'my Mechanical Drawings and Mechanical Books' which were bequeathed to his favoured son-in-law Richard Jackson.[91] Other early drawings were the work of amateurs, perhaps little more than a rough sketch or an aide memoire. A surgeon, variously described as French or from Gloucestershire though later claiming allegiance to the United States, when arrested in London after escaping from Leeds in 1784 was found to have had 'plans of a scribbling machine, a willy and a scribbling-dick' in his possession, along with models and parts for various textile machines.[92] The same man supposedly appeared in Boston, U.S., 'to introduce the manufactory of woollens ... he has no models, but drawings upon paper of different machines'.[93] The American Zachariah Allen was able to sketch machines and factory lay-outs in Yorkshire in 1825, and may have been able thus to convey useful design information, but though competent and accompanied by explanatory notes his efforts fell far short of detailed technical drawings.[94]

Models were a convenient alternative means of smuggling information abroad [95] or storing it for one's own use, as

Hattersley's 'Pattern Flyer' and 'Fluting Engine Moddles' referred to in 1832 demonstrate.[96] Matthew Murray himself used models, as in 1809 when he submitted a flax hackling machine to the Society of Arts, for which he was awarded a Gold Medal, the model being later exhibited in the Science Museum,[97] and in 1824, when he referred to models of engines.[98] Murray had given 'patterns and specimens of our workmanship' to representatives of Boulton and Watt, which enabled the Birmingham firm to copy parts of his steam engines,[99] for foundry patterns were another means of storing and possibly disseminating technical information.[100] Before about 1830 it was unusual for machine-makers to cast for themselves, and as patterns in regular use would be kept at a local foundry, then part of a machine's specifications would be accessible to others outside the firm, perhaps even to competitors. The importance of these patterns, and a possible confusion in terminology between patterns and models, is clear from an advertisement of 1808:

> Leeds Foundry: Martin Cawood and Son, having purchased the whole of THE MODELS belonging to Leeds Bridge Foundry, late Mr Pryor's, respectfully beg leave to inform the Friends of Mr Pryor, that they may be accommodated with Castings from them as usual.[101]

'Model' was also used sometimes to mean prototype machine[102] and could be taken to mean design, as implied by 'They have all the models of England in France at present'.[103]

The other possible method by which details of designs and techniques could be conveyed was through publications, though there were few of these before regular specialist journals appeared in the middle of the nineteenth century. Jeremy considers the publication of Rees's Cyclopaedia between 1802 and 1820 to have been something of a breakthrough.[104] In fact the specifications provided by Rees were in themselves inadequate as directions for constructing a machine, besides which Rees was not fully up-to-date in the machinery he illustrated. When Rees's work was published, the days of the amateur machine-maker were past, and it is unthinkable that the textile engineering industry relied on such a source for its technical information.

The difficulty with impersonal methods of technology transfer before 1850 was that they did not suit the way that textile engineering worked. In the main, skills in drawing and modelling were not refined enough to convey necessary information, and even if there had been a better developed representational method of passing information, a workforce which lacked skill in literacy and numeracy and which had been trained to function on a more practical level, would have had difficulty dealing with it. But more than that, technology was not inert, could not be captured, frozen and sold on. Technological problems were ones of making and working, and in the solving of them, innovation naturally followed. The engineering environment itself was all important and because innovation was generated in an atmosphere of personal communication where little was written down or otherwise recorded, then inter-personal means long remained the most important means of diffusing technology.

PERSON TO PERSON

Information about technology and technique circulated by word of mouth and by practical demonstration at several levels. The most basic and obvious of these was within the workshop environment as a matter of everyday necessity. As the skills of a trade could be transmitted orally, so could the knowledge component, even as late as the 1920s:

> It was my experience that skilled men passed [technology] on to apprentices by word of mouth and practical example.[105]

Apprentices moved on, working for others or setting up for themselves, in the same town or in a place where they saw an opening. George Hattersley's younger brother Jonathan, displaced when his father's old firm broke up, set out to try his luck in Leeds, Burnley and Bradford before settling in Leeds in apparent direct competition with his brothers.[106] The technical and commercial information which he had picked up within the family firm helped him to establish his own successful company on the doorstep of his father's biggest customers.[107] Information could also pass through workers who were less skilled, but whose day-to-day contact had made them familiar with every detail of a machine. John Greenwood, who set up the second cotton mill in Keighley in 1782 but could not make his spinning frames work, asked a girl who worked at the jealously guarded, Arkwright-system Low Mill to help. Although apparently an unskilled machine-minder, she immediately spotted that he lacked washers under the bobbins, and the fault was quickly rectified.[108] A number of young people were said to have been trained at Cromford to run the machinery at Low Mill, which despite the air of secrecy surrounding the whole enterprise was in itself a means of spreading knowledge of the water frame.[109]

A network of subcontractors and casual employees in textile engineering provided other easy channels for the circulation of information. Richard Hattersley was at the centre of one such formation in Keighley, further explored in chapter 5, and in turn became a subcontractor to others, supplying spindles, flyers and rollers, and later complete machines, to Taylor and Wordsworth, Maclea and March, Lawson and Walker, Murray and Wood and other prominent Leeds machine-makers.[110] Passage of technical information on this network must have been a daily occurrence. Additionally Hattersley had links beyond the local engineering industry. In February and March 1821 his eldest son, Samuel, was sent out in pursuit of orders and unpaid debts, visiting customers in Todmorden, Manchester, Ashton, Stalybridge, Oldham, Halifax and further up the Calder Valley. Later he went to Linton, Grassington, Gisburn, Clitheroe and Whalley. In Preston at 'Sleddon's Place' the foreman showed him round:

> which proved a treat indeed. I saw the completest Machines, for their various uses, that I ever saw ... [111]

And in Burnley he noted that one manufacturer 'intends to make alterations to his spinning machines soon'. Just as much as orders and debts, such information was Hattersley's bread and butter, and the method of collecting it continued with the next generation. The notebooks of George Hattersley's eldest son, Richard L. Hattersley (1820-1900), record his excursions to the continent from 1846 until the closing years of the nineteenth century. Though the main intention was to sell looms, he also constantly sketched and noted technical information.[112]

The network extended beyond engineering and into other trades. The scribbling miller Joseph Rogerson worked in a trade whose technology was well-established by the early years of the nineteenth century, with a partner, Charles Lord, a millwright working independently of Rogerson,[113] taking responsibility for technical matters. But although Rogerson's diaries are of little technical interest, they show that interchange between trades which provided a ready conduit for information. Rogerson's scribbling and fulling mill was a public one to which clothiers brought their own wool and cloth for processing.[114] Besides the many visits by clothiers, almost every week came tradesmen to nail cards, or millwrights to adjust the machinery. Rogerson noted potentially useful information:

> A patent steam engine of 16¼ Inches Cylinder will not carry 3 scribblers 3 Carders puller & Willy & 3 Fallers & a Driver, for so it was told me by a Slubber from Yeadon ...[115]

He was also in communication with the ironworks at Low Moor, visiting there a number of times, and in 1808 'Mr Wetnell from Low Moor Foundry Din'd at our house today'.[116] If Rogerson's contacts were typical of those of small industrialists, and there is no reason to think that they were not, then it is easy to see how quickly any new idea could circulate on such a network of overlapping working and social relationships.

On the other hand some gathering of information was more deliberate and purposeful. John Marshall sent Matthew Murray to Cheshire in 1790 with the express purpose of checking spinning techniques.[117] B.F.Lister made a number of calls on textile factories in 1791 while planning machinery for his own establishment:

> 20 April Went to Addingham to see the Worsted Mill.
> 11 May Went up to Hepton B[ridge] to see the cotton machines.[118]

Lister's journal goes on to record sizes of water wheels, numbers and sizes of machines and running costs, followed by estimates of costs and requirements for his own factory. At about the same time, Robert Heaton of Ponden was preparing to launch into cotton-spinning. His journal records conversations with machine-makers and millwrights, detailing materials needed to build machines, specifications for transmission equipment, and the size of building required to accommodate it all.[119] Joseph Rogerson could be equally methodical when he had a particular purpose, as in 1813 when considering gas lighting for his scribbling mill, he visited two neighbouring factories to inspect their systems before going 'to get what information I could of Mr Glover Whitesmith respecting the erecting Gass Lights'.[120] The personal approach to collecting information continued long after this, for in 1847 George Hattersley was seeking details of looms in use in the linen trade from Edward Hattersley of Barnsley, presumably a relative. Edward offered to show him 'what is doing in Barnsley as I can have access to any of the Power Loom factorys in the Town ...'[121]

The system of introductions, often conducted very casually, was enough to gain many foreigners admission to industrial premises. A few firms, conscious of the ease with which information might be transported away in the head of a knowledgeable stranger, banned visitors altogether. But that was unusual, as contemporary comment on Boulton and Watt shows:

> With respect to the practice of the house of Bolton and Watt, they have always displayed an uncommon degree of mystery; and have always shut their works against any competent judge in England, and therefore foreigners have been no worse treated than every body else; but my opinion is decidedly, that they have nothing to show beyond what is well known in other places; they continue from pride that exclusion which before was dictated by interest.[122]

The experiences of J.C.Fischer and Zachariah Allen show the ease with which foreign visitors could gain access to factories. Fischer, a Swiss steel-maker, carried an introduction to James Watt in 1814, which brought lavish hospitality and immediate admission to the whole of Boulton and Watt's works.[123] On this short acquaintance Watt wrote an introduction to Philips and Lee, cotton-spinners in Salford, who in turn introduced Fischer to Benjamin Gott in Leeds. After seeing Gott's factories, a letter of introduction from Gott took him into John Marshall's flax mill. Though it was said that foreigners were not normally admitted there, Marshall himself conducted Fischer around the works.[124] While staying in Leeds, Fischer was also able to inspect the Middleton railway, and went out to Low Moor ironworks where he was shown round by a partner. On a later visit, in 1825, Fischer met more engineers and iron and steel-makers, in Lancashire and South Yorkshire, some of them through compatriots who were working or training in Manchester.[125] There is nothing in his account to suggest that technical information was concealed from outsiders. Zachariah Allen's journal indicates that he had little difficulty obtaining access to factories, and even where machinery was of the most modern kind, nothing was held back. He records one altercation with a textile manufacturer into whose premises he had been escorted by a machine-maker who wanted to show him a new kind of carding engine, but this was clearly an exceptional response.[126] Allen was seen as a potential customer, and generally treated with hospitality. The same attitude was shown by William Jenkinson in 1841 towards some who might have been viewed as competitors:

> Do you give [foreign machine-makers] free access to your works, or is there any restraint imposed upon their inspection of new machinery and new inventions? - If they come properly introduced we never make any hesitation about it.
> Your object as machine-makers being to sell the articles which you produce? - Yes.[127]

Even where he had been chased from the premises, Allen managed to note the dimensions of the new carding engine. But written record was not essential where there was already intimate knowledge of a machine. Samuel Slater, who first successfully introduced Arkwright-style machinery to the United States, took not a single drawing or note when he migrated from England, and was able to replicate the machines from memory in 1790-1.[128]

Bruland has argued convincingly that the lifting of the export ban in 1843 should be recognised as a watershed which allowed the machine-making industry to take a central role in the international diffusion of technology. Before that, she believes, the agent of international technology transfer was 'the individual craftsman, artisan, engineer or entrepreneur'.[129] Considerable numbers of British mechanics certainly took advantage of foreign demand for their skills and knowledge.[130] At the same time foreign visitors, out of innocent interest or with particular purpose, collected information about mechanical advances in Britain, and British travellers for similar reasons observed continental techniques.[131] The crude result may have been a net outflow of information from Britain, but it could also be argued that wider benefits would flow from an exchange of technology, and that foreigners had a contribution to offer to the process, as science itself had developed on an international circuit.

Zachariah Allen's journal shows that technology transfer was not a simple switch of information from an advanced economy to one which was less developed. The published account of his European trip[132] demonstrates a range of interests going far beyond a narrow focus upon Allen's own trade. Much of what he recorded was well-established, even traditional, and he was as interested in techniques as in engineering novelties. Allen also touched on contrasts between American and British machinery, not always finding favour with the British version.[133] In fact he hints at a certain reluctance to adopt new methods in Britain, for example in Benjamin Gott's opposition to a newly improved method of steam milling.[134] But as Allen was taking note of British methods, the British manufacturers whom he met were doubtless absorbing some of his suggestions, suggesting the possibility of a two way, mutually beneficial technical and commercial interchange. Some of the ideas which passed would be of no use, others could be useful, while many would need substantial adaptation, technologies often being highly specific to particular environments.[135]

As personal channels are confirmed as the essential route for technology to pass, some personal motives should be noted for encouraging diffusion. There is no reason to think that engineers were very different from scientists in taking a pride in sharing discoveries and recognising the value of pooling ideas. This could be seen as a risky strategy, conceding a personal economic interest in technology in favour of potentially enhanced benefits from a communal approach, but in reality most engineers may have had no choice, if secrecy were futile and other methods of protection not available to them.

THE USE OF PATENTS

> A patent is a feeble protection against the rapacity, piracy and theft of too many of the manufacturing class. There is scarcely an instance, I believe, of a patent being granted for any invention of real value, against which attempts have not been made to overthrow or evade it.[136]

Though much has been written about patents,[137] interest has concentrated upon the mechanics of patenting and the diffusion of patented innovations. Unpatented products are often considered only peripherally, and there is a prevalent assumption that such improvements, being unpatented, were consequently of a lower order than ones which had been patented.[138] Such an approach fails to address two basic yet highly significant questions. First, how effective and useful were patents for the community of innovators as a whole, and secondly, how extensively were they employed by textile inventors? To assess the value of patents, which is a matter of opinion, use can be made of concrete evidence available on the second point, the extent to which patents were used.

Many claims have been made for patents, even that they stimulated innovation. Cooper implied this in classing the patent system among 'institutional inducements for invention'.[139] Others have suggested that the system impeded the flow of technology, or that it helped the spread by bringing details of inventions to public notice, or that it failed to help dissemination because technical details were stored in a bureaucratic and inaccessible manner.[140] But historians interested in the effects of the patent system have scarcely noticed that patents were used only for a small minority of textile innovations, even though the textile industry, quite rightly, features heavily in this debate. To put this in perspective, Sullivan has calculated that 1,976 patents were issued for textile inventions in England between 1711 and 1850. These amount to 15 per cent of the total patents issued over the period.[141] But 1,467 of the textile patents were taken out after 1820. For the period 1760 to 1820, when inventive activity was supposedly at its height, textile patents totalled 471, or fewer than eight a year - this for all branches of the textile industry across the whole country. Sullivan has also shown how low was the rate of patenting in textiles relative to the numbers employed in the industry.[142] Jeremy's regional breakdown of inventors suggests that the West Country produced almost two thirds of patents in the woollen industry between 1790 and 1830 - 70 compared with Yorkshire's 41, or about one a year.[143] Furthermore patents in the woollen industry were heavily concentrated in finishing operations, accounting for 16 of the 19 woollen patents between 1790 and 1812, 38 out of 43 between 1813 and 1824, and 31 of the 46 patents issued between 1825 and

1830.[144] These figures provide overwhelming evidence that the propensity to patent was much more marked in the West of England than in Yorkshire, and in the merchant-dominated finishing operations rather than in the preparation, spinning or weaving of wool. In the cotton industry there was a wider spread of patents across different processes but nonetheless numbers of patents were relatively small, a total of 168 patents over the forty years from 1790 to 1830, or just over four a year on average. The figures so obviously lack completeness as a record of innovations that they cannot be used as the sole basis for general conclusions about inventive activity in the textile industry, and serious doubts must be expressed about broad and sweeping conclusions which rely almost entirely on patent records for substance.[145]

It could be argued that, as major inventions in textiles were patented, consequently patents are useful as a record of important original ideas in the industry. The 'heroic' inventors, Arkwright, Cartwright and their like, all used the patent system. But this line of reasoning rests on the discredited 'heroic' view of innovation, assuming that those improvements which were patented were in fact the most important ones. It is certain that some highly significant technical breakthroughs were never patented, such as the throstle, enormously important in worsted spinning before 1850, which developed from the work of Arkwright himself in a series of major adaptations which remained unpatented.[146] The act of patenting could itself give a renown and a fame to an innovation which perhaps its technical merits did not warrant. In any case it is practically impossible to categorise innovations as either a 'Great Invention' or some lesser sort of improvement.[147] For textiles at least there is not, perhaps cannot be, data which would enable a line to be drawn between the two. The exercise harks back to ideas of heroic inventors, missing the point that success was achieved by making things work, which usually involved solving the engineering problems.

If it is accepted that a dynamic innovating community of engineers was mainly responsible for the significant technical breakthroughs in textiles, then there are obvious practical explanations for the failure to use patents. The costs and red tape of patenting must have deterred innovators from using the system, and there were also suspicions that patents were insecure and that the whole exercise of patenting could be counterproductive.[148] In a fast moving technical environment, patenting, with its attendant risk of descent into an unfamiliar quagmire of paperwork and expense, must have held out few attractions. Those like Boulton and Watt who did well out of patents had the financial and social means to use the system.[149] Most Yorkshire textile engineers did not.

How, then, to explain the patenting which did take place in Yorkshire? John Marshall, who had the means, patented his early flax machines, which had required considerable investment of time and money to make work. The patents were taken out in the name of his engineer, Matthew Murray, in 1790 and 1793. So when Murray set up his own business in about 1794 he was already familiar with the process of patenting and he registered three patents for improvements to steam engines between 1799 and 1802.[150] However, when Joseph March went to work at the Round Foundry in 1814, he found there a planing machine, invented by Murray but unpatented:

> ... like many inventions in those days, it was kept as much secret as possible, being locked up in a small room by itself to which the ordinary workmen could not obtain access ...[151]

Murray seems to have been deterred from using patents after suffering an apparent injustice under the system when challenged by Boulton and Watt,[152] patenting only one further invention after the consequent 1803 court case.[153] As for the planing machine, intended only for use in Murray's own works, secrecy may have been more effective than a costly patent which could have further disseminated the technology. For textile machinery, which needed to be in open use, patenting would have been a more practical option than secrecy. However it was hardly considered by engineers with few resources, that is, the majority, perhaps because they had been deterred by the example of those who had tried the patent system and had their fingers burnt.

There are examples in the Select Committee enquiries of patent use in textile engineering between 1800 and the 1840s, but these were Lancashire engineers better off than most of their Yorkshire counterparts, and who had invested heavily in development costs.[154] A change in attitude towards patents is discernible during the 1840s, with the 1852 Patent Law Amendment Act a result rather than a cause of the change.[155] Isaac Holden and Samuel Lister were at the centre of a move towards a more formal path to innovation. When Holden invented the Lucifer match in about 1829, he declined to patent what had been, he said, a fortunate accident. Later his employer, Townend, who objected on principle to patenting, refused to protect Holden's woolcombing improvements. Holden believed in using patents to protect work done over a period, and thought that Townend was losing by failing to patent. This difference of opinion was said to have been the cause of his leaving to form the seven-year partnership with Samuel Lister.[156] Holden and Lister set out to corner the market in France for their own wool, by impeding the spread of competing ideas there.[157] This vigorous use and aggressive defence of patents, initiated by Lister, was something new.[158] Though the introduction of simplified and much cheaper patents in 1852 meant that the system became more accessible, few were able to emulate the Lister technique to the full, as it required enormous wealth. Lister paid £27,000 to Donisthorpe for a share of his woolcomb patent, £33,000 for Heilman's patent, and £20,000 for the 1853 patent on the Noble comb. In the 1850s Lister's nip, an improvement on the Lister-Cartwright square motion comb, employed one worker to do what three had previously done, enjoying a complete monopoly:

> ... and the trade was well satisfied to give me what otherwise would have appeared to be an outrageous price, the sum of TWELVE HUNDRED POUNDS A MACHINE, OR A THOUSAND POUNDS PATENT RIGHT, the machine itself costing about two hundred ... and for years I sold a large number.[159]

It was not only the means at his disposal which made Lister exceptional. The perfection of the woolcomb marked a turning point, for it was the last major textile process to be mechanized. Lister was essentially a textile manufacturer who had taken up machine-making in order to deal with certain mechanical problems. He was able to set about systematically designing the necessary machine, at whatever cost, and patent protection was a essential feature of his method. Few shared his wealth or his commitment to such long term projects, but he may have brought protection into fashion again, especially as profitable innovations were becoming scarcer. If the pace of innovation was slowing, and the general community of engineers was no longer producing many new ideas, perhaps because a more professional approach to development work was needed by 1850 as machines became increasingly complex, then the time was ripe for a new system to be introduced. For innovation to become a deliberate and conscious process requiring considerable investment by an individual firm, then patents had to be used to secure a compensating return.

To summarise on the use, and therefore the usefulness, of patents, it appears that in relation to the amount of innovation taking place in textile engineering, patents were rarely applied after the failure of Arkwright's patent in 1785, until the mid-1840s with Holden and Lister. Some of the claims made for patents, such as that they stimulated or spread new ideas, can therefore hardly be valid for the textile industry during its period of most vigorous innovation. It is equally clear that a lack of patents in an industry must not be equated with a failure to innovate. That patenting was concentrated in certain industries, or certain localities, indicates nothing more than a greater disposition there to use the patent system. In well-established, heavily capitalized industries there existed the means and the incentive to patent, while in the industries where patents were rare though innovation was obviously taking place, much is explained by the class of person responsible for many of the innovations. The reward for those humble innovators came through increased business rather than through monopolization of a discovery. Sokoloff and Khan, studying inventions in the United States between 1790 and 1846, argue that an unprecedented expansion of markets produced new problems which those familiar with basic technology, that is, very many of the population at the time, were able and motivated to resolve.[160] In the United States this manifested itself in a large number of patents.[161] In Britain, where patenting was more difficult and expensive, Sokoloff and Khan's 'democratization of invention' was presumably happening but without the application of patents. The idea that markets were stimulating new technical solutions from a range of relatively uneducated people finds an echo in the description by John James of the worsted industry after 1815, when 'a new era' in preparing and spinning technology resulted from post-war high prices.[162]

It was in the interests of machine-makers constantly to improve and upgrade. In engineering, the atmosphere of inventiveness and dynamism could have extended as far as antipathy to the patent system. MacLeod has attempted to describe this ethos in the engineering industry, where 'reputations were made by the successful solution of novel problems ... not by the monopolization of particular machines'.[163] The involvement of William Fairbairn, and many lowlier mechanics, in the movement for patent reform, may signal that the character of the industry in this respect was changing by the mid-century.[164]

CHECKS ON THE FLOW

> [Mr Watt] was without the smallest wish to appropriate knowledge to himself, and one of his greatest delights was to set others in the same road to knowledge with himself. No man could be more distant from the jealous concealment of a Tradesman ...[165]

In theory at least, the desire to profit from a technical advantage could provide a strong motive to protect innovations. If the use of patents was not a practical option, then 'jealous concealment' may have been an alternative. A belief that secrecy was widely employed has persisted as part of a romanticised view of innovation, even surviving after the generally accepted demise of the 'heroic' inventor.

Attempts to use secrecy in the Yorkshire textile industry occurred only in the earliest period of mechanization and were mainly associated with Arkwright's spinning system and similar cotton factories in Keighley, where indentures and employment contracts with secrecy clauses were tried. James Greenwood, a mechanic involved in setting up West Greengate Mill, Keighley, in 1784, signed one such agreement. It was intended that Greenwood become a partner in the mill but in the event this did not happen, and by 1791 he had moved on to help Robert Heaton equip his new cotton factory at Ponden.[166] Thomas Robinson, a joiner, and Joseph Tempest, a millwright, bound themselves to a firm of cotton-spinners at Walk Mill, Keighley, in 1783, on condition they would 'forfeit £100 if [they] reveal or make known any secret respecting the construction or movements of any of the machines or works'.[167] Although Robinson subsequently turned to shop-keeping,[168] Tempest continued in engineering after leaving Walk Mill. He was a millwright and machine-maker, working for Heaton in 1790 and later a regular customer of Richard Hattersley, from whom he bought parts for spinning frames.[169] It has been suggested that secrecy clauses in contracts may have been designed to foil Arkwright's agents rather than keep details from competitors.[170] If correct, it may explain why such contracts are not found after the collapse of Arkwright's patents in 1785. Or perhaps employers came to realise that secrecy agreements could be at best only temporary impediments to the movement of technology, and that little could be done to prevent a knowledgeable employee moving on to work for a competitor or for himself.

As Baumber suggests, there can be other explanations for secrecy besides the obvious one of containing technology. For example, the security surrounding Benjamin Gott's factory in Leeds meant that its workings remained a mystery to others in the trade.[171] and this has been seen as deliberate secretiveness. But the radical feature of Gott's establishment was in its organization, not in the technology used, with close security part of a system to protect goods in the factory from theft or damage. Smaller textile workshops, whose activities were open to public view, were using technology as modern as anything of Gott's. Crump points out that 'the industry at Bramley and in the neighbouring villages had adopted and assimilated all the current inventions' in the first years of the nineteenth century.[172] Openness was the order of the day, as in the case of Pudsey clothiers in the 1820s who 'have no secret in the manufacturing, are not afraid of others getting their styles and patterns, all is fair and above board, as they are nearly all making similar goods'.[173] Recalling the case of Rogerson and his wide circle of contacts, any attempts to curtail the flow of technology through secrecy in such communities were doomed to fail, were generally viewed as anti-social, and seem to have been abandoned early, if tried at all.

Warnings against spies in the Leeds newspapers refer specifically to sharing information with foreigners, implying that information was allowed to pass more freely within the domestic industry:

> We hope all persons concerned in managing these machines will, for the future, take care how they suffer unknown persons to make observations on them, as the consequences to this country may be very fatal.[174]

But secrecy between countries was as unworkable as that between factories, for even when the export of machinery was banned and France and Britain were at war, technology was passing across the Channel without apparent hindrance. Secrecy may have been appropriate for a one-off specialized machine tool, as with Matthew Murray's planing machine (above), but could not be effective for a textile machine, the value of which lay in multiple and continuous operation in a factory. The 1824 Select Committee was told of a case in 1819 when a flax-dressing machine had deliberately not been patented 'thereby keeping it as secret as it was possible to be'. Within six months identical machines were on sale in France.[175] James G.Marshall in 1841 showed a certain reticence in sharing information with foreigners, though it was only those engaged in the same branch of manufacture whom he attempted to exclude from his Leeds factory, and his intention was rather to prevent the poaching of key workers and avoid general inconvenience, as well as a vague hope of retaining information about techniques as much as details of machinery. He did not object to the same foreigners having access to the machine shops which supplied him. Significantly, his stated view was that 'reciprocity of advantages is, I believe, on the whole, the most advantageous policy', and when asked about French attempts to maintain secrecy, replied that he 'should rather doubt the practicability of that being maintained'.[176]

So practicability may not be the only, or even the main, explanation for why patents and secrecy were so little used. It should rather be asked whether the interests of most textile manufacturers or engineers lay in regulating the spread of technology. In general, a technically competent machine-maker was likely to benefit from the free circulation of any invention which could make existing types of machines obsolete, providing it had not been developed at his expense. Similarly many textile manufacturers would welcome technological advance which increased efficiency and productivity. Those active in developing innovations, whether engineers or textile manufacturers, would probably resist the free spread of any resulting new technology. But those who could afford to engage in major development work also had the means to use the patent system, which was supposed to offer such men a chance to recoup some, or all, or many times, their investment in new products. If the patented machine were offered at too high a price, or with too stringent conditions attached, there arose a strong incentive to pirate the technology by straight copying, or to produce a parallel invention. Remembering the example of Arkwright and others, many innovators may have concluded that legal protection was simply not worth the time and expense involved. They may also have remembered that after Arkwright had failed in his costly attempts to keep secrets and protect patents, he went on to make a vast fortune, by actually using the machines to spin cotton. Profits were made by using the machines for their intended purpose, and not by engaging in futile attempts at concealment and patenting.

THE REALIZATION OF IDEAS

> ... most mechanical inventions are of a very composite character, and are led up to by the labour and the study of a long succession of workers ... But the making of the invention is not the sole difficulty. It is one thing to invent, said Sir Marc Brunel, and another thing to make the invention work.[177]

It may be that a failure to make things work in practice formed the greatest barrier to technological diffusion. If diffusion were delayed, the explanation may be found not in secrecy or patents or social resistance, but rather in the fact that few products can be applied immediately and perfectly in practice.[178] Success depended upon an ability to be receptive and open-minded, and it was essential to adapt before one could adopt.[179] Great 'inventors' like Holden and Lister may be more accurately described as adaptors, their strength coming from an ability to fill a gap in the market, responding to a commercial impetus with a technical solution. The bottleneck which Holden and Lister broke was well-known within the worsted industry long before they became interested in it, but it required considerable engineering flair to achieve a satisfactory solution, along with enough commercial judgement to recognise that the game was worth the candle. In the same way it had been possible for Richard Roberts, who claimed to know nothing about cotton-spinning, to perfect the self-acting mule in response to a direct appeal by cotton-spinners who wanted to undermine striking employees. The idea of a self-actor was not original, but Roberts was the first to 'work it out into a practicable process'.[180] Peter Fairbairn, credited with some of the greatest breakthroughs of the nineteenth century in worsted- and flax- spinning and preparing, and in machine tools, was described in an early biography as 'an inventor and improver of machinery'.[181] Many of his most successful machines built upon the work of others, but he brought to the task considerable engineering skill and commercial knowledge, as well as a background in cotton machine-making in Manchester and Glasgow.

This movement of ideas from one branch of textiles to another, often from cotton into woollens or flax, was significant. In the way that machines, once patented, were rendered unusable by competitors but could stimulate parallel innovation, similarly machines working in one branch of textiles could act as models for parallel applications to other fibres. Widespread use of precedent suggests that adaptation was generally a more satisfactory option than starting from scratch. In the case of engineering in West Yorkshire, there is much evidence that early machines were supplied from the west, from the cotton districts of Lancashire[182]: Manchester machine-makers opening a warehouse and workshop in Leeds in 1792, Benjamin Gott buying machines from Lancashire in the 1790s, the purchase of Manchester machinery by Pildacre Mill, Ossett, in 1792 and 1793, John Marshall collecting names of engineers in the Manchester area at about the same time.[183] Further north, the Keighley machine-makers were drawing upon experience from across the Pennines. William Carr, reputedly the 'cleverest mechanist' in Keighley at the turn of the century, had arrived from Preston in 1790 to establish a business servicing cotton-spinners, later becoming an becoming an influential maker of worsted spinning frames.[184] Robert Heaton's investigations between c.1786 and 1791 led him to machine makers in Bolton, Manchester, Burnley and Blackburn.[185]

Machines from Lancashire were not directly applicable to the Yorkshire industry, for they were themselves far from perfect, and in any case needed adaptation to worsted and woollen fibres. Mathias has emphasised that the commercial and technical context needs to be ripe for paper ideas to be brought to fruition, the classic example being Leonardo's designs which could not be realized in his own time.[186] Engineering problems were still acute three hundred years later, when they severely hampered James Watt's attempts to build an efficient steam engine. However, greater accuracy in manufacturing components was only part of the solution. There were also inevitably operational difficulties to overcome, by those who adapted the machines of others, or who merely set out to make them work: Marshall with the Darlington machinery, Gott with his Bramah press, James Ackroyd of Halifax with a French Jacquard.[187] Wyatt and Paul, credited with the invention of spinning by roller in 1738, were not able to work the system, and it was left to Arkwright to bring it into operation in the cotton industry.[188] The subsequent application of roller spinning to the worsted industry needed much experiment and adjustment to Arkwright's water frame.[189] Cartwright's powerloom, though based on sound theory, was not commercially or technically successful. Cartwright himself started the process of modification immediately after his first patent was granted, engaging the most skilled machine-makers Manchester could offer, who nevertheless 'despaired of ever making it answer the purpose it was intended for'.[190] By the time Strickland wrote her memoir in 1843, the loom had been radically altered:

> The patent ... has doubtless been receiving continual additions from various hands during the last fifty years; and the beautiful machine ... differs considerably in detail, even from the most improved form of Mr Cartwright's invention.[191]

It had taken forty years for Cartwright's idea to be effectively applied to worsted weaving.[192] That was not the end of its evolution, for the worsted powerloom continued to be refined in order to speed and improve its performance, and to adapt it to different products. Richard L.Hattersley and his foreman John Wilkinson produced an impressive list of improvements and new applications for that loom during the third quarter of the nineteenth century.[193]

The persistence of mechanical and operational difficulties was recognised by the use of a package system, where attempts were made to satisfy customers by sending skilled fitters to install machines, and even personnel to work them for a period. Skilled erectors accompanied Matthew Murray's engines.[194] Later exporters to Norway went much further, including technical information, machinery, ancillary equipment, construction expertise and skilled British operative and managerial labour in the package.[195] These arrangements were not a sales gimmick, as it was essential for machine-users to be trained in operating and maintaining the machinery to run at maximum efficiency. Even the most modern textile machines need constant attention if they are to run efficiently, with powerlooms shaken out of adjustment so quickly by vibration that modern weaving shops employ almost as many tuners as weavers.[196]

One who apparently specialized in bringing imperfect machinery into use was a cloth finisher called William Hirst. In 1816:

> Fenton Murray & Co ... told me that if I would use the hydraulic presses, they would let me have them at almost any price, as they wanted to get them into the hands of some party who could bring them into operation, so as to give them a fair chance ...[197]

By Hirst's account (the purpose of which was self promotion), he was praised by Murray for persistence in making the machine work.[198] Hirst was also credited with finding a solution to using gig mills on Yorkshire cloths, which needed a change to the prior process, fulling.[199] There are other instances of the successful mechanization of one textile process requiring a review of preceding or following operations. For powerloom weaving to work well, said William Fairbairn, automatic dressing machines were essential.[200] Cartwright's loom had become easier to operate as machine-spun yarn improved in quality, and after Radcliffe devised a system of dressing the warp before it was placed upon the loom.[201] It has been suggested that all those successful in spinning innovations were 'compelled' to turn their attention to improving preparatory machinery.[202] Whether such pressure to change adjacent processes arose primarily from technical needs or from commercial considerations is not always clear, but it is of the greatest significance that the environment itself stimulated innovation. Useful invention could not take place in a vacuum. The innovators needed an understanding of textile production and a grasp of those mechanical processes already in operation, a kind of specialized knowledge which was widespread in textile communities.

Even self-conscious work directed towards producing a specific new major mechanical breakthrough, which might once have been styled an heroic invention, owed much to the stimulating local environment. Innovators did not start with a blank slate, but built upon what had gone before, informed by an awareness of the needs of local industry. Marshall and Murray made improvements to flax-spinning and weaving, starting from an imperfect spinning machine by Kendrew and Porthouse, and using looms from John Jubb and others based on Cartwright's designs.[203] Lister's woolcomb built upon the work of Cartwright and Donisthorpe and others, while Lister's one-time partner, Isaac Holden, started an illustrious career in textiles by 'exercising his ingenuity' upon some imperfect combing machines which he had persuaded his employer to buy in 1833.[204] The later acrimonious dispute between Lister and Holden, concerning who was the true inventor of the woolcomb, stemmed from the fact that their work derived from that of others. They produced solutions which worked, but they had not started from scratch, and their answers came in response to specific practical difficulties which the industry was experiencing. Evidence that all innovation was incremental, growing out of the work of others, is overwhelming.

By accepting that innovation can in reality be nothing other than a cumulative process, then two further issues can be resolved. The first question is whether innovation was mainly the province of machine-makers or machine-users. MacLeod brought this issue to prominence by floating as hypothesis a polarized model where machine-users were responsible for 'radical inventions' and machine-makers devised lesser, incremental innovations.[205] The evidence for this assertion is thin, coming mainly from patents which, as has been shown above, are inadequate as a record of innovation in this industry. The sterility and simplicity of this model ignore the dynamism which was such a feature of textile engineering. MacLeod's theory, besides over-emphasising heroic-type inventions, also fails to recognise the difficulties in distinguishing between makers and users, particularly as some of the same people were involved in both activities. Many engineers also engaged in textile manufacture, mainly as a sideline but sometimes to the extent that eventually they ceased their engineering activities. Examples of those who switched over completely include M'Connel and Kennedy of Manchester, who had given up engineering in favour of cotton spinning by the early years of the nineteenth century,[206] and Berry Smith, a successful machine-maker in business in Keighley from 1801, who had become solely a commission worsted spinner by about 1830.[207] Machine-makers with interests in textile manufacture are found in all branches of the industry and throughout the period. John Jubb was a partner in Churwell cotton mill during the 1780s.[208] Joshua Wordsworth owned a business in Barnsley, spinning and manufacturing linen and mixed fabrics, in 1846.[209] Samuel Lawson, who had been in partnership with a flax-spinner called Mark Walker from about 1817 until 1832, continued to run a flax-dressing and spinning concern, which employed 66 people in 1834.[210] Richard Hattersley's eldest son, Samuel, was put in charge of their small worsted spinning business in Keighley between about 1817 and 1822, before being sent to manage a new machine-making branch in Bradford in 1824.[211] The next generation of Hattersleys employed a similar arrangement, with George's third son, Edwin, managing their four worsted spinning factories in the Worth Valley between _c_.1850 and _c_.1890 while the more technical Richard Longden Hattersley took over the machine-making business.[212]

There are a number of commercial reasons why machine-makers should have engaged in textile production. Most obviously, being so close to textiles they could identify profitable opportunities. The prospect of steady, rather than spectacular, earnings from commission spinning may have attracted those who wished to have a more evenly spread income than the fluctuating capital goods market offered. M'Connel is said to have taken up cotton spinning when left with two mules which customers had ordered but could not pay for.[213] A sideline in textiles also provided a chance to demonstrate the latest technology in action, persuading or pushing other textile manufacturers to follow suit. Furthermore, family members who did not fit into the main engineering business could be found a managerial role, perhaps suitable for a less technically able son, in the subsidiary firm. This probably partly explains the involvement in textiles of Richard Hattersley and his son George, both of whom had large numbers of sons, not all of them cut out for a career in engineering.

But there were also technological reasons for the vertical expansion into textiles. As practical experimentation was so important to technological development, a textile factory could be a laboratory in which to try and perfect new machinery. Additionally, in working the processes solutions to technical bottlenecks may have suggested themselves. The examples quoted above of textile engineers who were also involved in textile manufacture - Jubb, Wordsworth, Lawson, Hattersley - are all men who were leaders in the industry, at the forefront of technical development in their time. Others, notably Matthew Murray and Peter Fairbairn, retained exceptionally close links with one textile manufacturer and so were able to conduct trials and observations on the factory floor. Relationships between makers and users were altogether more complex and positive than MacLeod's static model suggests. The engineers cannot be denied an early and a central role in technological innovation. Some of their dynamism and motivation to solve problems is conveyed in the evidence of

Peter Ewart, a cotton-spinner and himself a former machine-maker:

> ... it is only within three years there have been any silk mills in Manchester; since those have been introduced, there has been a great deal of excitement among the machine makers to improve the silk machinery. I have been told ... that considerable improvements have been made in silk machinery, even in the short time that it has been introduced in Manchester.[214]

The element of co-operation, or productive association, in the dynamics of technical progress was emphasised by Peter Fairbairn to the 1841 enquiry:

> From your observation what is your opinion as to the persons who suggest improvements in machinery; do the improvements proceed generally from those who are connected with the working of the machines, or from those who make the machines?
> - From both. As a machine-maker, I am very much indebted to the spinners; if they have any improvement to bring into operation they suggest it to me, and I carry out the mechanical department.[215]

This insight into the working of the Yorkshire textile and engineering industries need not necessarily conflict with Henry Holdsworth's view:

> ... the cotton spinners make all the improvements; it would not pay a machine maker to adopt new plans till their merits were established by practice.[216]

For Holdsworth worked in Glasgow, where machine-making, as an off-shoot of Manchester textile engineering, apparently lacked that initiative which was such a feature of the more vigorous Lancashire and Yorkshire industries.

The second issue which is enlightened by an appreciation of the significance of cumulative innovation, is the role of the workforce in technical progress. While Richard L.Hattersley acknowledged the contribution of his foreman over 35 years,[217] many employees who came forward with suggestions for improvements remained as unrecorded as were their ideas. That is not to say that their schemes were insignificant.

> Are not many of the improvements in your machines, actually suggested by the workmen themselves?
> (Mr Taylor) Many, constantly.[218]

They were also encouraged by the prospect of a bonus payment:

> Did you ever know the operative mechanic ... suggest any important improvement? - Yes, very often.
> And the probability would be, that the more practice he had the more improvements he would suggest? - Yes; and the English mechanic is noted for that which you now speak of; because there is an inducement for him to do so; he often gets very liberally rewarded for it.
> How does he produce his improvement; is it upon paper or in the process of hand-labour? - It is very seldom on paper, but by hand, showing you what he can do, and what would be an improvement.[219]

Employees made frequent and valuable contributions to product development and it was recognized that the firm's principal, however talented, could not hold a monopoly on ideas. The best engineering firms were constantly innovating, and introduced formal systems to work out improvements. The son of the chief draughtsman at Wellington Foundry in the mid-nineteenth century, whose father had reported directly to Peter Fairbairn, described how there had been:

> a great many new ideas and improvements in machinery at that time ... it is clear that the Drawing Office had its thinking cap on a good many times.[220]

This was the main function of draughtsmen, who made only general drawings and rough sketches which were then tested out in the works.

Ideas, then, were realized by practical operatives of all classes and in both textile and engineering industries, responding to constant stimuli from the environment in which they worked.

CONCLUSION

The features of technological advance in textile engineering identified in this chapter are consistent with a predominantly small-scale industry run by former artisans. Innovation was a localized, grass-roots phenomenon, in which formal science and written sources played little or no discernible part. Because the main channels for information and skills were interpersonal, it was near impossible to maintain secrecy or protect technology, and the few early efforts to do so were quickly abandoned. Patents were hardly used, being expensive and providing no certainty of protection, but in any case they did not fit the _modus operandi_ of the industry. Success was achieved not through protectionism, nor by any theoretical means, but by making things work. That machines were successfully applied to dozens of separate processes in the different textile branches, and continued to be developed and improved thereafter, shows how dynamic was the new industry. Innovation was a cumulative process, with ideas springing from both textiles and engineering but generally worked out to practicability by engineers. There was little in the way of strategic overview, groups of engineers responding practically to immediate problems.

Collective needs could indeed beget collective solutions. A community of artisans with varying skills was vital to successful machine-making, a point which Mathias illustrates by examining the converse, the difficulty of trying to transplant and 'indigenize' innovations to different cultures.[221] Thus imported machines could have appeared much more radical than local products, but only because they had been developed to suit a different environment. The means by which they were designed would have been the same, gradual adaptation to suit local needs. The 'innovating community', a combination of makers and users, also offered the advantage of being able to readily assess the economic feasibility of new technology. For as Rosenberg has argued, even if a product is technically possible, it is another matter to decide whether it is economically superior. Commercial success rests upon recognizing the value of continuity as well as discontinuity.[222]

If technology were indeed subjected to appraisal by a whole community, it is then only a short step to accepting that new ideas were not considered the property of a single firm, but could be shared. The idea that collaboration can occur in circumstances where one would rather expect intense competition is not original. Saxonhouse, for example, showed that Japanese cotton-spinners engaged in 'firm-to-firm technical assistance' during the nineteenth century.[223] It is possible that a measure of co-operation could co-exist with competition. Engineers and textile manufacturers may have recognized that technological progress could deliver advantages across the whole community, and that sharing ideas would generate new ideas. The fact that most engineering happened within a network of interdependent subcontractors means that an apparently paradoxical state of 'co-operative competition' could exist.[224]

The concept of 'heroic' breakthroughs, in textile engineering at least, is unsustainable. Innovation was a gradual building of knowledge, in which even the most famous participants started from the work of others. Most significant technical progress occurred within the workmanlike atmosphere of the engineering industry. This bears out the idea that innovations could, in a sense, be produced to order. The form of such an order may not have been explicit, the process perhaps required minor flashes of 'genius' by individuals, but nonetheless innovation came in response to needs brought forward by local textile manufacturers or their engineers. The argument that demand could have stimulated technical progress is to be further developed in chapter 6.

With the organizational base of textile engineering shifting in favour of fewer, larger and more specialized firms from about 1830, it appears that views on the protection of technology were hardening as opportunities to produce major innovations lessened. By the mid-century, machine-makers were more likely to protect innovations from competitors, and collaborative ventures had had their day. How far the industry had moved from being 'community' centred to become 'firm' centred will be examined in the following chapter.

NOTES:

1. Mantoux 1961, p.206.
2. Ponting (ed.) 1970, pp.71-3.
3. Ponting (ed.) 1970, p.128.
4. Fairbairn 1867, II, p.lxxii.
5. See Musson (ed.) 1972a, p.41.
6. Gilfillan 1970, pp.23-4, 28, 31.
7. Exactly how much is debatable: Ponting 1979, pp.30-2.
8. Checkland 1964, p.78.
9. Rosenberg 1976, pp.69-70.
10. Rosenberg 1976, pp.69-71.
11. Rosenberg 1976, p.74.
12. Rosenberg 1976, p.75.
13. Rosenberg 1976, p.77.
14. Rosenberg 1976, pp.61-2, 77.
15. Mathias 1979, p.56.
16. Gilfillan 1970, p.3.
17. Musson 1972a, pp.48-9.
18. Musson 1972a, p.49. For an opposing view see Gilfillan 1970, p.10.
19. Musson 1972a, p.49.
20. Smiles 1863.
21. For discussion of the role of the market in stimulating innovation, see the introduction to chapter 6.
22. Rosenberg 1982, p.35. See also Gilfillan 1970, pp.49, 52.
23. Serjeant Adair pleading for Richard Arkwright, R.Arkwright vs. Peter Nightingale 1785, quoted in Mantoux 1961, p.206.
24. Robinson and Musson 1969, p.5.
25. Rosenberg 1976, pp.61-2.
26. See Chapman 1968-70, pp.373-7.
27. Inkster 1990, p.421; see also Musson and Robinson 1969, chapters 1 and 2.
28. Thompson 1973, pp.85-6.
29. Mathias 1979, pp.72-3.
30. R.Fitzgerald _pers. comm._
31. Cardwell 1972, p.100. Gilfillan's model seems to agree: Gilfillan 1970, p.6.
32. Checkland 1964, p.76.
33. _Bradford Daily Telegraph_, 6 May 1897.
34. _Keighley News_, 14 August 1897, p.5.
35. Mathias 1979, p.34.
36. Cardwell 1972, p.124; on the state of mathematics in England at this time, see Enros 1981.
37. WYAS Bradford, DB2/6/3.
38. Cardwell 1972, chapter 5.
39. Checkland 1964, p.74.
40. Brunton 1828, preface to fourth edition.
41. Banks 1795, p.viii.
42. Banks 1803, p.iv.
43. Banks 1803, p.iii.
44. Chapman 1968-70, pp.374-5.
45. Nicholson 1825, pp.378-415.

46. For ideas on this point I am grateful to Dr. Joe Marsh.
47. Cardwell 1972, pp.39-40.
48. Brotherton Library, Mss. 165, Notes of E.K.Scott.
49. Burnett (ed.) 1974, p.305.
50. Lumby 1982.
51. *Yorkshire Evening News*, 24 Feb. 1915.
52. *Yorkshire Post*, 2 June 1915; *Yorkshire Evening News*, 24 Feb. 1915; *Proceedings of the Institution of Mechanical Engineers* 1915, p.481.
53. Walker 1884, p.279; Jeremy (ed.) 1984 Vol. 2, p.311.
54. WYAS Bradford, 32D83/33/4.
55. Landes 1969, p.61.
56. Pickstone 1993.
57. Checkland 1964, pp.73-4.
58. Mathias 1979, p.72.
59. Mathias 1979, p.85.
60. Mathias 1979, p.85.
61. See, for example, Marshall's records of experiments, Gott's notes of mill practice which indicate constant enquiry and small improvement, and Heaton's journal of casual but detailed observations: Brotherton Library, Marshall Mss. MS200/57; Crump (ed.) 1931, pp.287-307; WYAS Bradford, DB2/6/3.
62. Boulton to Watt, 1783, quoted in Tann 1978, p.368.
63. Morris 1990, pp.203-4.
64. Musson and Robinson 1969, pp.153-9.
65. Inkster 1990, p.405.
66. See for example Jeremy 1981; Bruland 1989, pp.5, 22, etc.; MacLeod 1992, p.286.
67. Bruland 1989, pp.14-6.
68. Crump (ed.) 1931, pp.315-6.
69. See Chaloner 1968-9; Goodchild 1983; Harris 1978 and 1988; Heaton 1960; Jeremy 1977, 1981 and 1982; Mathias 1979, chapter 2; Schmitt 1986.
70. Mathias 1979, p.57.
71. Babbage 1835, pp.345-6.
72. Benson 1983, p.7; Harris 1985, p.129; Inkster 1990, pp.423-4, 434; Farnie 1990, pp.154-6; Musson and Robinson 1969, pp.60-4; see also Catling and Richards in J.G.Jenkins (ed.) 1972.
73. Musson and Robinson 1969, p.63.
74. PP (HC) 1841 (201) VII, p.111, evidence of Matthew Curtis.
75. PP (HC) 1841 (201) VII, p.111.
76. PP (HC) 1841 (201) VII, p.113.
77. PP (HC) 1841 (201) VII, p. 212.
78. Lawson 1887, pp.54-5.
79. Rosenberg 1982, quoted by Inkster 1990, p.403.
80. Inkster 1990, p.403.
81. English 1969, pp.152-3, citing W.Felkin 1867.
82. Inkster 1990, p.405.
83. Jeremy 1981, pp.15, 84-6.
84. *Leeds Intelligencer*, 6 Feb. 1781; Crump (ed.) 1931, p.314.

85. Connell 1975, pp.162-3; WYAS Leeds, DB23.
86. PP (HC) 1824 (51) V, pp.303, 342; PP (HC) 1841 (201) VII, pp.44, 99, 110; see also Saul 1970, p.144.
87. PP (HC) 1824 (51) V, p.251.
88. PP (HC) 1824 (51) V, p.251, evidence of Peter Ewart. See also p.303.
89. Sir William Swallow, *pers comm*; who has also suggested that perspective or '*exploded*' drawings similar to those used in modern developing countries may have been used to identify parts and show the order of assembly. Nothing of this kind has been found.
90. Scott (ed.) 1928, pp.18, 32.
91. Borthwick Institute, Exch. June 1826.
92. Crump (ed.) 1931, pp.10, 326.
93. *Leeds Intelligencer*, 25 Nov. 1788.
94. Rhode Island Historical Society, Zachariah Allen Papers, Journal of European Trip 1825, for copies of which I am grateful to Dr. David Jeremy.
95. Rimmer 1960, p.234.
96. WYAS Bradford, 32D83/33/1.
97. Scott (ed.) 1928, p.51.
98. Scott (ed.) 1928, pp.30, 32.
99. Scott (ed.) 1928, p.12.
100. Swallow, *pers. comm.*, confirms that this still applied in the 1920s. Briggs, *pers. comm.*, used a similar system in 1992.
101. *Leeds Intelligencer*, 7 March 1808.
102. See Hodgson 1879, p.251.
103. PP (HC) 1824 (51) V, p.104.
104. Jeremy 1981, p.39.
105. Swallow, *pers. comm.*
106. Keighley Parish Register, 1827 to 1837; White's *Directory* 1837, p.568; ibid. 1857, p.128; WYAS HQ, Deeds Vol LI 529 no 525.
107. Leeds census 1851, 2321/39.
108. Hodgson 1879, p.218.
109. The origin of the Cromford story is to be found in William Keighley's *Keighley Past and Present* (1879), p.116, written in about 1854.
110. WYAS Bradford, 32D83/2/5.
111. WYAS Bradford, 32D83/15/1.
112. WYAS Bradford, 32D83/42.
113. Hargrave and Crump (eds.) 1931, p.63.
114. Hargrave and Crump (eds.) 1931, p.60.
115. Hargrave and Crump (eds.) 1931, p.77.
116. Hargrave and Crump (eds.) 1931, pp.90, 94.
117. Turner 1966, p.1.12.
118. Brotherton Library, Marriner Mss., Box 66.
119. WYAS Bradford, DB2/6/3.
120. Hargrave and Crump (eds.) 1931, p.156.
121. WYAS Bradford, 32D83/33/7.
122. PP (HC) 1824 (51) V, p.20, evidence of Alexander Galloway.
123. Henderson 1966, pp.131-4.

124. Henderson 1966, pp.57-60.
125. Henderson 1966, pp.62-5.
126. Rhode Island Historical Society, Zachariah Allen Papers, Journal of European Trip 1825, p.72.
127. PP (HC) 1841 (201) VII, p.107.
128. White 1967, pp.77-8.
129. Bruland 1989, p.5.
130. See for example Heaton 1960; Brotherton Library, Mss. 165, notes of Samuel Owen 1844.
131. See for example Woolrich 1986, pp. 66-8.
132. Allen 1832.
133. Allen 1832, pp.171, 196-7.
134. Rhode Island Historical Society, Zachariah Allen Papers, Journal of European Trip 1825, pp.55-6.
135. Bruland 1989, p.22.
136. Edmund Cartwright c.1820, quoted by Burnley 1889, p.134.
137. See for example MacLeod 1988, Dutton 1984, Sullivan 1990.
138. For example MacLeod 1992.
139. Cooper 1991, p.838.
140. MacLeod 1991.
141. Sullivan 1990, p.352.
142. Sullivan 1990, pp.353-4.
143. Jeremy 1981, p.57.
144. Jeremy 1981, p.55.
145. For example, MacLeod 1992.
146. English 1969, pp.152-3.
147. Though Khan and Sokoloff, 1993, MacLeod 1992, and others, have attempted to make such a distinction.
148. MacLeod 1991, pp.896-7, 906-7. Problems encountered by those wishing to take out or enforce patents before 1852 are further discussed by MacLeod 1992, pp.288-9 and 1988, pp.89, 102.
149. Robinson 1972, p.139.
150. Scott (ed.) 1928, p.50.
151. Scott (ed.) 1928, p.49.
152. Scott (ed.) 1928, pp.11-2.
153. Scott (ed.) 1928, p.50.
154. PP (HC) 1824 (51) V, p.309; PP (HC) 1841 (201) VII, pp.100-1.
155. Dutton 1984, p.63; MacLeod 1992, pp.288-9.
156. Keighley News, 14 August 1897; though Jennings 1982, p.32, blames the split on a disagreement over status and profits.
157. Honeyman and Goodman 1986, pp.4-5.
158. Honeyman and Goodman 1986, p.25.
159. Lister 1905, p.46.
160. Sokoloff and Khan 1990, p.363.
161. Sokoloff 1988 p.819.
162. James 1857, p.383-4.
163. MacLeod 1988, p.104.
164. Dutton 1984, pp.58-9.
165. Professor John Robison of Glasgow University, on Watt

in Glasgow c.1762, quoted by Robinson and Musson 1969, p.25.
166. Baumber 1983, pp.43-4; WYAS Bradford, DB2/6/3.
167. Hodgson 1879, pp.36-9.
168. Hodgson 1879, pp.140-1.
169. WYAS Bradford, DB2/6/3; 32D83/5/1.
170. Baumber 1983, p.44.
171. Crump (ed.) 1931, p.33.
172. Crump (ed.) 1931, p.6.
173. Lawson 1887, p.23.
174. Leeds Mercury, 6 Feb. 1781; Leeds Intelligencer, 6 Feb. 1781.
175. PP (HC) 1824 (51) V, p.162.
176. PP (HC) 1841 (201) VII, p.195.
177. Smiles 1863, pp.178-9.
178. Paulinyi 1986, p.161.
179. Inkster 1990, p.403.
180. Smiles 1863, pp.267-9.
181. Taylor 1865, pp.491-6.
182. See chapter 1.
183. Crump (ed.) 1931, pp.327, 211-3; Goodchild 1971, pp.340-1; Brotherton Library, Marshall Mss. MS200/57.
184. Hodgson 1879, pp.249-52, 260.
185. WYAS Bradford, DB2/6/3, pp.10, 27.
186. Mathias 1979, p.76; see also Ponting 1979.
187. Rimmer 1960, p.27; Crump (ed.) 1931, pp.49-50; James 1857, p.440.
188. Usher 1982, pp.297-8.
189. Hodgson 1879, pp.240-1.
190. Strickland 1843, p.72.
191. Strickland 1843, p.59.
192. Hodgson 1879, p.267; Jenkins and Ponting 1982, pp.110-1
193. Hodgson 1879, pp.272-3.
194. Scott (ed.) 1928, p.24.
195. Bruland 1989, pp.5-6.
196. D.M.Wood, draft thesis, chapter 2.
197. Hirst 1844, p.8.
198. Hirst 1844, p.8.
199. Crump (ed.) 1931, pp.48-50.
200. Fairbairn 1867, p.clxxii.
201. Strickland 1843, pp.218-9.
202. Hills 1970, p.73.
203. Rimmer 1960, pp.23, 27-33; Turner 1966, p.1.10.
204. Keighley News, 14 August 1897.
205. MacLeod 1992, p.290.
206. Lee 1972, p.23.
207. Hodgson 1879, pp.252-6; PP (HC) 1834 XX (167) C1, pp.220-1.
208. Leeds Mercury, 23 November 1784.
209. Borthwick Institute, Prog. September 1846.
210. PP (HC) 1834 XX (167) C1, p.249; WYAS Leeds, Acc. 2371/ Box 80/ Bundle 2; Ward 1972, pp.422-3.
211. WYAS Bradford, 32D83/9/2.
212. Keighley census 1851; WYAS Bradford, 32D83,

introduction to list.

213. Lee 1972, p.10.
214. PP (HC) 1824 (51) V, p.255.
215. PP (HC) 1841 (201) VII, p.211, evidence of Peter Fairbairn.
216. PP (HC) 1824 (51) V, p.380.
217. Hodgson 1879, p.272.
218. PP (HC) 1824 (51) V, p.38, evidence of Philip Taylor, engineer.
219. PP (HC) 1841 (201) VII, p.106, evidence of William Jenkinson.
220. Anon. 1946, pp.15-7.
221. Mathias 1979, pp.36-7.
222. Rosenberg 1976, pp.72-4.
223. Saxonhouse 1974, pp.161-3.
224. For ideas on this point I am grateful to Dr Steve Caunce.

CHAPTER FIVE
ESTABLISHMENTS AND NETWORKS

The idea of an innovating community in the early engineering industry echoes Sokoloff's 'democracy of invention', and raises the question of whether some form of 'democracy' could also have infiltrated the process of production. The notion of the community as a strategic institution in shaping an emerging industry is not unduly idealistic. Sabel and Zeitlin build upon Proudhon's idea to show that competition and productive association could be complementary rather than mutually exclusive forms of economic behaviour.[1] Smail identifies entrepreneurship as 'a quality possessed by a whole host of petty producers' during early industrialization, stressing that their economic behaviour should be explained in a cultural context.[2] Randall emphasises the importance of 'a community character which ... was both dynamic and conservative' among West Riding woollen workers, concluding that we should 'recognise how deeply the social context of manufacturing production influences its potential for transformation'.[3] Unlike the woollen industry, machine-making was not entrenched in custom, so that change was presumably less painful and more readily accepted, yet Randall's ideas are as applicable to textile engineering as they are to the longer established industry which it served.

The 'social context' of textile engineering is the focus of this chapter. Berg, in recent work on networks in the Birmingham metal trades, points out the limitations of concentrating upon a few large and successful firms in any industrial study, with the concomitant danger of overlooking what was potentially the largest and most dynamic sector.[4] This tendency to dissect only the biggest and most lasting firms she attributes in part to a bias stemming from an overemphasis upon traditional kinds of historical record, such as business and official papers which tend not to shed light upon the unknown small-scale producer, the artisan or the unenduring. But Berg also cautions against an assumption that eighteenth century industry was polarized between large and small producers,[5] while identifying that such a polarization in the Birmingham metal trades had in fact taken place by 1840. To an extent this pattern is consistent with developments in engineering in West Yorkshire.

But although superficially there are similarities between the workshop-based organization of the metal trades in West Yorkshire and Birmingham, and Sheffield, whose industry Berg also discusses, significant differences are apparent. There were many more firms in the Birmingham metal trades, some of them employing hundreds by the mid eighteenth century. Fifty smaller firms in existence in 1780 each employed twenty to forty workers.[6] Such a firm in West Yorkshire at the time would have been considered exceptionally large. Sheffield may have provided a model for the West Yorkshire engineers, as its industry was characterized by small masters and flexible patterns of subcontracting. There were so many of these that cut-price competition seriously threatened their livelihoods,[7] which may explain the migration north into the textile districts of some of those entrepreneurs discussed in chapter 2. The key difference, though, between Birmingham and Sheffield on the one hand, and Keighley, Leeds and other West Yorkshire engineering centres on the other, was that the West Yorkshire industry was not controlled by a network of merchants, but was rather distinguished by the relationship with its customer industry, textiles. As a newly established industry, textile engineering was free of any pre-existing institutional constraints, such as guilds or mercantile structures. Furthermore, because its products were capital goods with a clearly defined market, textile engineering had no need for the kind of separate distribution network which consumer goods manufacturers used, and which would perhaps have allowed merchants a role in the trade. This had implications for the way in which work itself was organized. Before precision machine tools were available, accuracy was achieved by fine division of labour in the Birmingham and Sheffield metal trades. Outworkers who performed these repetitive tasks were dependant upon the merchants who supplied work and bought their produce. Such mass production was not required in West Yorkshire machine-making, in the early period at least, and although some parts were manufactured in quantities, subcontractors maintained a greater independence from the machine-makers they served.

The relationship between firms within the textile engineering industry needs to be further explored. Should the industry be thought of as a dispersed factory, with components supplied by different firms and brought together for assembly? Few integrated engineering factories existed before 1820. Matthew Murray, whose establishment was referred to as a manufactory as early as 1799, was exceptional.[8] Most machine-makers inhabited works, workshops, machine-makers' shops, or foundries. At what stage these developed to become factories is a point at issue. A simple yardstick of this development is evidence that production was becoming integrated, often signalled by the acquisition of a foundry.

Engineering does not neatly fit general models of factory development. Early machine-making, characterized by small batch production, does not match those industries where mass production was a feature. However, recent debate on routes to the factory has emphasised the range of organizational possibilities in different industries and locations over a period of more than half a century.[9] This debate has advanced three main theories for the growth of factories, all of which are worth considering in the context of textile engineering changing to a largely factory-based industry by the mid nineteenth century. Was Landes's 'logic of technology' inescapable?[10] Did engineers see a route to greater efficiency and cost effectiveness in centralizing operations on one site? Or was the main aim, as Marglin would have it, to gain control of the workforce?[11] These last two questions overlap, with a key issue in engineering that of quality control. In fact the explanation of why engineering became a factory industry combines elements of all three ideas.

SCALE AND SPECIALIZATION

While it is obvious that any study which considers only large and successful businesses will produce a distorted view of industry,[12] many of the early machine-making firms were so small and transient that there are considerable difficulties in achieving a comprehensive and detailed survey of their activities. By the standards of other industries even the largest engineering establishments were modest in size, especially during their formative years.

Mostly uninsured and intestate, early textile engineers frustrate attempts at systematic analysis. There is some evidence of size and financial standing, but it is piecemeal and not suited to methodical treatment. The few recorded insurance policies relate only to larger firms, quote figures which are approximations, and in some cases are only for buildings, giving no valuation of stock or equipment (see Table 5.1). Probate records are also unsatisfactory as a measure of general worth in the industry, applying only to the better off, and citing the value only of movable estate while excluding real estate and business property (Table 5.2).[13] Hattersley's abundant and atypical records have supplied a series of valuations which indicate the amount of capital required to service such a business over the period, though these figures are incomplete for tools and equipment

(Table 5.4). Even so, the most illuminating insight may be George Hattersley's aside, in a letter of the 1860s, indicating that it had been possible to go back into business with a modest '500 borowed money' in 1832 after the firm's bankruptcy.[14]

1798: Hargreaves, Cave and Longley, Builders.
Tenants: Murray and Co.
Buildings £700; Steam engine £100; Contents £200
Total £1000

1800: Hargreaves, Cave and Longley, Builders.
Tenants: Fenton, Murray and Wood
Buildings £1400
Owned by Fenton, Murray and Wood: Steam engine £150; Utensils and stock in trade £600

1804: Fenton, Murray and Wood (Hargreaves and Cave mortgagees)
Buildings, steam engine, utensils, stock in trade: Total £6050

1817: James Maud.
Tenant: Wadsworth and Co [Taylor and Wordsworth]
Mechanics workshop and engine house £650; going gear £50; steam engine £100. Total (without contents) £800

1824: Zebulon Stirk and William Horsfield
Buildings £1500; steam engine £400; Stock £1000.
Total: £2900

SOURCE: Guildhall Library, RE 164622; RE 37 172611-2; RE 50 210457; Sun 116/920393; Sun 11937/145 1018179.

TABLE 5.1
Insurance Valuations: Leeds Machine-Makers

1808	John Jubb (I)	£3,000
1816	John Jubb (II)	£5,000
1819	Michael Merrall	£300
1820	David Wood	£14,000
1826	Matthew Murray	£8,000
1846	Joshua Wordsworth	£25,000
1848	Joseph Taylor	£12,000
1851	William Smith	£4,000

SOURCE: Borthwick Institute

TABLE 5.2
Probate Valuations: Leeds and Keighley Machine-Makers

George Hattersley	c. 100
George Bland	12
Briggs and Banks	3 partners, 31 employees
Thomas Mills (also foundry)	22
Charles and Allan Smith	6
John and Samuel Smith	80
Samuel Lawson	400
Jonathan Hattersley (Leeds)	134
Zebulon Stirk	6
Maclea and March	211
Peter Fairbairn	850

SOURCE: Census Return of 1851. Information for Fairbairn is in the entry for his partner Greenwood at 2321/200; for Lawson in the entry of his son John at 2319/670.

TABLE 5.3
Numbers of employees: Leeds and Keighley Machine-Makers, 1851

As a potential yardstick, labour force figures also present problems of interpretation in an industry where work was put out to subcontract or supplied in a semi-finished state, and where firms engaged in a range of activities beyond machine-making. It was common for larger businesses also to make castings, steam engines or even have a textile branch which, though apparently separate, may have included its employees in total labour force figures.[15] On the whole, though, numbers of employees provide a comprehensible statistic giving a ready indication of the scale of an operation. Though information about numbers of employees is patchy in the 1851 census, enough has been recorded to show that some of the Leeds (mainly flax) machine-makers, notably Lawson and Fairbairn, were already of immense size (Table 5.3). Of the 7,415 engineering workers then in Leeds[16] 400 were with Lawson, 850 at Fairbairn's and 211 at Maclea and March, with Taylor and Wordsworth accounting for several hundred more. At the other extreme, hundreds were still employed in small workshops on the traditional pattern, with a master and handful of journeymen. Not all mobility was upward, for

22 April 1793: Partnership established between Richard Hattersley and Thomas Binns. Transferred from their previous firms:

(Binns) iron, brass, scrap, tools and equipment including anvil, bellows and hearth and vice benches £28 8s 5½d

(Hattersley) Stocks, dies and taps, vice, cutting engine, brace and bits, files and hammer etc. £10 10s 10d

10 June 1816:	Stock in trade	£1311	11	0¼
	Book debts	£1744	8	7
	Fluting engine	£30	0	0
	Iron chest	£4	4	0
	6 horse engine with apparatus	£508	15	6
	TOTAL	£3598	19	1¼
	Debts owing	£643	10	3
	Net difference	£2955	8	11¼

1 Jan. 1820:	Debts owing by firm	£1125	4	4
	Stock in trade	£2477	15	7½
	Book debts	£3869	4	4½
	Balance in cash book	£200	18	6
	Steam engine	£508	15	6
	New Mill	£604	10	0
	Various houses	£1018	0	0

July 1829: noted after the death of Richard Hattersley that the firm had book debts of £2044 and stock in trade of £2117 10s 0d

The three surviving partners, Richard's three eldest sons, were bankrupted in 1832. George Hattersley took over the firm's premises in Keighley and re-started, as he later noted, 'with 500 borowed money ... I used to reel up every week to see whether I lost or gained ...' When George took two of his own sons into partnership in 1860, the business was conservatively estimated to have had a net worth of £16,840. Hattersley's was incorporated in 1888 with a valuation of £100,000 in 10,000 shares of £10.

SOURCE: WYAS Bradford, 32D83/5/1; 32D83/2/2; 32D83/2/2 and 2/4; 32D83/2/5; 32D83/33/8; 32D83/42; 32D83/41.

TABLE 5.4
Hattersleys of Keighley: Capital employed

Zebulon Stirk, once a renowned steam engine builder as well as textile engineer, had descended in his old age to employing a mere half dozen. There was also a middling sector, of engineers whose businesses were smaller or slightly peripheral to the mainstream, like Jonathan Hattersley's roller and spindle-making factory with 134 employees, and millwrights Stephen and John Whitham who employed 270 making fulling and washing machinery at their Kirkstall Road foundry in 1854.[17] The major Lancashire engineering centres showed a similar spread, with 115 firms in 1841 averaging 91 workers, a figure which included Hibbert and Platt's with 900 and Nasmyth with 500.[18] It has been suggested that the average size of establishment in Lancashire had fallen to 85 workers by 1871.[19]

Keighley showed a spread of large, medium and small shops similar to that in Leeds at the mid-century, though on a different scale. To illustrate this, George Hattersley, at the apex of textile engineering in Keighley, had fewer engineering employees than the medium sized firm of his lesser known younger brother Jonathan in Leeds.

Figures for an earlier period are harder to come by, except for the very largest and least typical, like Matthew Murray who employed 160 workers in 1802, and 200 in 1826.[20] For smaller enterprises, Richard Hattersley's records show the futility of trying to find precise numbers of employees where heavy use was made of casual and subcontract labour. After nearly twenty years in business, in 1808 Hattersley himself was the only employee on the firm's books who consistently received a full-time wage, even though at times as many as a dozen men were employed.[21]

Pollard identifies subcontract, not as itself a stage in industrialization, but as a system compatible with capitalist development which served technical and commercial requirements and management needs in many different industries.[22] Pollard's interest is particularly in the application of subcontract to management issues, but in textile engineering technical and commercial aspects were more important. Subcontract was a means of producing components with a maximum of precision and a minimum level of workforce for the main contractor, to whom permanent or full-time employees were potentially a heavy commitment. It could therefore be expected that a decline in subcontract and casual labour, as a proportion of total activity, would coincide with changing technical and commercial circumstances. These might include skill shortages and a need to secure the services of key workers, the availability of precision machine tools, and a desire to control quality and, perhaps, the workforce. This assumes that entrepreneurs came to possess the means to invest in machinery and in employing skilled labour, for the system of subcontract had been a way of spreading production costs.

Subcontract was never completely superseded but remained central to the workings of engineering. Whole sections of the industry, like roller- and spindle-makers and founders, were essentially subcontractors, while others concentrated upon assembling and fitting components. Though small workshops retained an important role, the trend was towards gathering a workforce and integrating processes within one establishment, for roller- and spindle-makers as well as for machine-builders. In Keighley, William Smith made constant improvements to his premises from 1829, building a foundry before 1835, but his notable achievement, according to a later commentator, was in re-organizing the works. He was said to have been the first to apply planing machines and similar tools to the manufacture of worsted spinning frames in about 1830, 'giving a completeness, finish and beauty to the various parts of their machinery which hitherto had not been realised'.[23] Hattersley too was developing a greater formality in his organization, for example by starting in 1818 to indenture key workers for terms of years.[24] In Leeds, Peter Fairbairn had already gathered 550 employees at the Wellington Foundry by 1841,[25] when a highly methodical approach was apparent to a visitor:

> ... the bulk of the operatives are involved in turning small pieces of iron, adjusting them with files, or boring them for the admission of axles - all, as far as possible, aided by steam power, which is distributed by shafts with hundreds of belts throughout the various floors. Much is also done by a corps of blacksmiths, whom ... I found hammering away in first-rate style in a long apartment on the ground floor ... here all is cleanliness and order ... there are no visible bellows, each forge being blown when required by admitting air from a great bellows in another part of the house, and wrought by the steam engine. This ... must effect a considerable saving of time ... and is another instance of that remarkable economisation of means which distinguishes all branches of our manufactures.[26]

Fairbairn's establishment, founded only in 1826, was remarkable for the size of its labour force, which had grown to 1,400 in 1861 and 2,400 by 1876,[27] a scale which in turn dictated a high degree of organization. An establishment of over 500 artisans needed systematic planning in order to function efficiently, with work finely subdivided to achieve any possible economies of scale and maximize precision, especially in the era before machine tools. Peter Fairbairn was quite deliberate in his intention:

> In my works a subdivision of labour takes place; I require a good many very superior men, but I can do, by sub-dividing the work, with some inferior men.[28]

The economic and technical advantages of a fine sub-division of labour had been pointed out by Babbage in the early 1830s,[29] though Fairbairn and his peers would have been well able to draw the conclusion for themselves. The obverse of economies of scale possible in large factories was that small workshops, lacking a range of specialists and grades of skill, were forced to allocate relatively easy tasks to skilled workers as it was not economic for them to retain specialized semi-skilled employees.[30]

As products changed and specialisms grew, so the degree of division of labour was refined. Thomas Ashton considered that sub-division of labour gave Britain a major advantage over foreign machine-makers.[31] William Fairbairn thought that the French engineering establishments he had visited 'appeared very deficient in arrangements and method ... they appeared much more confused in their operations' than their English equivalents.[32] Peter Ewart attributed the superiority of British machinery to 'the high state of the subdivision of labour' and emphasised that the size of organization was vital to this process:

> We never had any subdivision of labour till it was carried on to a great extent, and it is impossible to have a great subdivision of labour, but in proportion to the extent of business.[33]

The scale of establishments was therefore closely linked to an ability to specialize, and hence to improve quality and efficiency.

THE ORGANIZATION OF WORK

The period after 1830 can be described as one of consolidation in machine-making, though the leading establishments did not cease to be technically and commercially progressive. There is an impression that the post-1830 industry was less dynamic than during its formative phase, when the idea of 'flexible specialization' dealing with an 'ever changing assortment of semi-customized products' had been a reality.[34] Berg, drawing attention to diverse ways in which work could be organized during early industrialization, has pointed to a middle way between those large-scale/ small-scale polarities which are commonly assumed.[35] Her notion of 'new departures in the workshop economy deploying extensive division of labour and multi-plant production processes' fits well with the development of machine-making, though the West Yorkshire equivalent of Birmingham's 'division of labour ... spread out between several separate units' would be neighbouring small workshops in separate ownership producing batches generally smaller than in the metal trades of Sheffield or the West Midlands.[36]

Berg's idea that some 'modern' features of industrial organization pre-dated the factory is convincing. It is certain, for example, that division of labour existed in late eighteenth century engineering workshops. How far those other innovations which are commonly associated with new forms of industrial organization, features such as mass production, specialization, standardization and interchangeability, were adopted in pre-factory workshops, is more difficult to prove. Were such 'modern' features compatible with a machine-maker's workshop of the late eighteenth century, where typically a master with a few journeymen or apprentices and little or nothing in the way of machine tools produced 'one-off' orders, alongside general engineering work, while specialist parts and castings were bought in from subcontractors? Even in 1850 when a few vast firms each employed hundreds of men on specialized tasks using sophisticated machine tools for large batch production, alongside them continued many small establishments where 'modern' systems would have been incorporated gradually, or not at all. There is a striking resemblance to the change which had come to Berg's Birmingham industry, which by the 1830s was starkly polarized into large and small. However, just as old methods of organization do not automatically preclude modern techniques, nor does industrial concentration necessarily imply a loss of flexibility, or even the end of flexible specialization. Collecting together the most modern machine tools under one roof gave tremendous scope for versatility. Engineers of the late nineteenth century have actually been criticised for over-flexibility, for their willingness to offer a product range too extensive to have made the best economic sense.[37] It is therefore feasible that a desire to be as versatile as possible was a driving force behind the establishment of factories.

There were, though, other more pressing technical and economic reasons for operations to be brought into factories. As a 'putting out' system had not operated in engineering, it was not problems of labour discipline or embezzlement which forced machine-makers to centralize their workforces.[38] On the contrary, the old system had offered great advantages to employers in optimizing the use of labour. Subcontractors and casual labourers worked intensively for short periods to deal with bulges in the workload, falling back on other local industries when textile engineering work was short. But such a system lost attraction as a mass market for machines developed, and skill and consistency in the labour-force assumed a premium.

Generally speaking, the rise of the engineering factory slightly postdated a series of breakthroughs in machine tool technology between 1815 and 1830.[39] This is not necessarily explicable as direct cause and effect. Integration and centralization need not have followed from process mechanization. In theory any specialist subcontractor could have acquired a small range of machines to improve speed and precision in his workshop. It is difficult to know how far this actually occurred. Much of the work carried out by small subcontractors seems to have been gradually absorbed into the factories of machine-makers and main subcontractors. By 1850 most textile machines and the components which went into them were made in such large establishments. Although small workshops continued to employ large numbers of mechanics, many of them apparently concentrated upon jobbing and repair work, or activities slightly removed from the mainstream of machine-making.

There is enough evidence of quality problems to suggest that efficient monitoring of production was one reason to bring processes into a factory. Process mechanization alone did not produce a complete solution to problems of quality. Factory organization was another means of improving standards, enabling work to be closely supervised, and also allowing a growing expertise built upon narrow specialization. John Lee Bradbury, a Manchester calico printer, attributed the superiority of his local engineering industry over that in London to the method of organizing work, for in Manchester 'a workman is frequently kept in a manufactory at one article, all his life, and consequently attains great skill in the production of such article'.[40] The result of this intensifying specialization was that by 1841 it had become unthinkable that one man could make an entire machine. 'There is not one man that could do the blacksmith's work and casting; a man could not make a spindle and a roller, but perhaps half a dozen men could do the whole'.[41] This was academic though, as half a dozen men could not produce a machine economically.

Another aspect of specialization was that firms narrowed their range of products: 'One machine-maker often makes one kind of machine his principal study, and another, another; by that means each is able to make cheaper and better than they otherwise could'. This was not merely driven by a desire for economy, but in an operation such as spindle-making which was still mainly a manual operation, was dictated by necessity.[42] Such specialization also offered greater potential to stimulate constant improvements to machinery.[43]

These new methods of organizing work were by no means revolutionary, for most had existed before process mechanization.[44] While division of labour is associated with efficiency, it need not involve the use of machines.[45] By sub-dividing tasks, increased speed of production or improved quality should be possible. Though often identified with factory organization,[46] division of labour is not confined to factories. Nor should it be assumed that it led to de-skilling of the workforce, though skills may have changed as a result.[47] As Berg has pointed out, division of labour can be spread between several separate units,[48] a pattern adopted by many of the early machine-makers and their specialist subcontractors. Before the 1820s, machine tools were rudimentary and subcontractors generally very small concerns, so it is likely that specialization then was intended to maximize precision when jobs were still done by hand. The move to factories and machine tools may have followed from the failure of this system to deliver goods of a quality and quantity required. Hattersley's files contain numerous complaints about late delivery and poor quality, such as this from Taylor and Wordsworth in 1824:

> We cannot think of sending such rubbish out of our Shop ... the man that made them must have been drunk ... instead of improving you are getting worse you formerly made a good Spindle how it is you are fallen off so much we cannot tell. We are not the only persons that find fault there are many worsted spinners that have made the same remark.[49]

But Richard Hattersley retained his customers, who continued to clamour for deliveries, which suggests that the products were no worse than anyone else's.

In itself, a factory could not solve the problems of precision, improve the 'clumsiness in all kinds of millwork before the introduction of machine tools' which Smiles described. James Watt had not been able to achieve sufficient accuracy with the best of Birmingham artisans.

> Yet better work could not be had. First rate workmen in machinery did not as yet exist; they were only in process of education. Nearly everything had to be done by hand. The tools used were of a very imperfect kind.[50]

Watt had attempted to overcome this by encouraging a high degree of specialization among his workmen, but results remained unsatisfactory. The casting and machining of components was so inaccurate that:

> Not fifty years since it was a matter of the utmost difficulty to set an engine to work, and sometimes of equal difficulty to keep it going. Though fitted by competent workmen, it often would not go at all. Then the foreman of the factory at which it was made was sent for, and he would almost live beside the engine for a month or more; and after easing her here and screwing her up there, putting in a new part and altering an old one, packing the piston and tightening the valves, the machine would at length be got to work.[51]

William Fairbairn said that when he arrived in Manchester in 1814:

> The whole of the machinery was executed by hand. There were neither planing, slotting nor shaping machines; and, with the exception of very imperfect lathes and a few

drills, the preparatory operations of construction were effected entirely by the hands of the workman.[52]

Though Fairbairn was prone to exaggerate in order to make his own work look the more impressive,[53] similar points were made by others such as Nasmyth:

> Up to within the last thirty years nearly every part of a machine had to be made and finished ... by mere manual labour; that is on the dexterity of the hand of the workman, and the correctness of his eye, had we entirely to depend for accuracy and precision in the execution of such machinery, as was then required ... [54]

It has been suggested that credit for developments in machine tools, including improved lathes and a rudimentary slide-rest, belongs to eighteenth century clock- and watch-makers.[55] Though machine tools were improving at that time, the real breakthroughs came after 1800. Jefferys believes that the years between 1800 and 1840 saw a transformation of machine-making from a trade relying upon manual dexterity to one where machines made machines.[56] Others pinpoint the 1820s as the period of most significant change, and which brought about a revolution in production methods for machinery.[57] The crucial changes were to the lathe and the planer, and William Fairbairn singled out the work of Roberts and Whitworth, who had made 'new and more perfect tool machinery, which has given not only mathematical precision, but almost a creative power - as one machine creates another'.[58] New machine tools appear to have been adopted by the textile engineering industry as soon as they became available.

Specialization was a feature of the division of labour, as workers concentrated on a limited range of tasks. It continued alongside, as well as within, the factory system, demonstrated by Hattersley's continuing to supply spindles in the 1820s to Taylor and Wordsworth, Fairbairn, Maclea and March, Lawson and Walker and other factory-based Leeds machine-makers.[59] Another aspect of specialization was the way in which machine-makers found a niche within the market. There was nothing new about specialized products, as local buyers required only a narrow range of machinery from the first machine-builders, but with expanding markets came the potential to concentrate and build a reputation in a chosen field. Whether intended or not, this was a means of avoiding head-on competition with neighbouring engineers, as shown by the two major firms in Keighley during the 1840s. George Hattersley made looms, William Smith spinning frames. This process of specialization may have gone further and occurred earlier than engineering historians have hitherto recognised.[60]

It is now acknowledged that some of the new techniques in engineering antedate by several decades the 1850s, where conventional wisdom had placed them.[61] The so-called American system of manufacture has been exposed as something of a misunderstanding, perhaps even a myth,[62] and was certainly not a novelty in the 1850s.[63] Henry Maudsley is now recognised as a pioneer of precision engineering and mass-production alongside his development of machine tools in the late eighteenth century,[64] and Musson believes that textile machines had been mass-produced for some years before 1845.[65] Nasmyth has been identified as the instigator of assembly-line production after 1836.[66] This debate is hedged with problems of definition and shortages of evidence. In particular, the concept of interchangeability is fraught with difficulty. A modern engineer would expect to work to tolerances of less than one thousandth of an inch, which was not possible in 1800. But rollers and spindles were produced to fine tolerances and seem to have been interchangeable with others made to the same specification, though not between different models of machine.[67] Some accounts of how machines were built abroad suggest that, to a point, parts were interchangeable, though considerable skill was needed in assembly.[68] It is not even necessary to have sophisticated machine tools and measuring devices to produce interchangeable parts, for Saul has shown that it could be achieved using handworking with emery cloths and 'go, no go' gauges. Saul concedes that there is doubt about the degree of hand fitting required in assembly.[69] Professor Farish had apparently achieved a system of interchangeability which enabled him to construct models of 'all the more important machines which are in use in the manufactures of Britain' during the early 1820s, for the purpose of demonstration during lectures in the University of Cambridge:

> I procured .. an apparatus, consisting of what may be called a system of the first principles of machinery; that is, the separate parts, of which machines consist. These are made chiefly of metal ... and so adapted to each other, that they may be put together at pleasure, in every form, which the particular occasion requires.[70]

Such a system may not have transferred to industrial use. The issue of the degree to which interchangeability was pursued before 1850 remains uncertain and may be a question incapable of solution by historians alone.

While it is clear that specialization and other 'modern' features of engineering had existed in some form during the industry's formative years, still the mass-production of identical products was far from the universal experience of machine-makers in 1850.[71] But one is left with an impression of the mid-nineteenth century as a time when smaller producers were becoming secondary, if not downright subordinated, to larger factory-based engineers. The issue of relationships between the large and the small in engineering needs further examination. Whether engineering could have taken an alternative organizational route is a question beyond the scope of this study, but it is essential to stress a continuing diversity within engineering, and consequent dangers in generalization. Even acknowledging that large firms possessed great advantages at the mid-century, in every aspect of their activities, it was still possible for a small machine-maker to enter the field and achieve great success. George Hodgson, who started in business in 1849 with an idea for a new loom, capital of £500, a workforce of two, and no foundry, is a case in point.[72] The overlap between 'traditional' and 'modern' was enduring, for just as 'modern' features are detected in the early industry, so flexible specialists and industrial swarms survived far into the nineteenth century.

ENTERING AND LEAVING

Choosing inferior or obsolete technology was not a realistic option for any machine-maker who wished to thrive in the mainstream industry.[73] It was essential to keep abreast of developments, as demonstrated by the rapid exit from the trade of all non-engineers soon after 1800. Technical competence was the primary requirement, and increasingly so from the 1820s, but the intending entrepreneur also needed finance, and connections into the local information network.

Saul has suggested that entry to entrepreneurial status in many engineering trades was relatively easy, and that one benefit of this was a constant rejuvenation of the industry.[74] Certainly initial capital requirements were modest. A figure of £500 has often been quoted: for George Hodgson in 1849, George Hattersley in 1832, Peter Fairbairn in 1826.[75] Hattersley, who took over the family's rented factory after the old firm's bankruptcy, had other assets: relevant skills, a knowledge of products and of the market, his contacts and credit. He rapidly made good. Others started with less finance, though as trained machine-makers they would have been familiar with the local market. There are instances of promising young men being sponsored by those who were better established. The Leeds flax-spinner

John Marshall helped Murray and Wood in this way in about 1794, may have assisted Taylor and Wordsworth in 1816, and financed Peter Fairbairn's expansion in 1828.[76] In each case the direct assistance was of short duration, perhaps only for a few weeks. But Marshall's purpose was to ensure his own supply of machinery, and his interest assured his proteges that orders were likely to follow on from the capital he had lent.

Many of the first entrepreneurs in machine-making were from humble backgrounds where family capital would not have been available. Joshua Wordsworth's relatives in Thurgoland were poor.[77] David Wood was the son of a rural blacksmith. In Keighley, Hodgson described Berry Smith as 'a poor lad without means', and told how John and Samuel Smith, sons of an overlooker, 'husbanded their means so as to be able to go into business on their own account' in 1818.[78] Not all claims of poverty should be taken at face value: Murray's son-in-law Charles Gascoigne Maclea, grandson of a Church of Scotland minister, was said to have been a 'self-made' man, but this was in the heyday of rags-to-riches mythology and is questionable.[79]

Hodgson's suggestions of modest beginnings are substantiated by information about the premises and equipment of the first machine-makers. William Smith started in 1795 in two rented cottages, which were extended enormously over the next seventy years to match the growth in his business.[80] William Carr rented a house with smithy and mechanics' shop in 1790, and in 1798 was able to have a house built for him, with a workshop on the top storey and a smithy behind, though he still relied upon human power to turn his lathes.[81] Berry Smith set up benches and lathes in his own chamber in a small cottage, employing boys to turn the machines.[82] Commonly engineers started in premises without steam or water-power. The Smith brothers used 'a half-witted fellow' and a blind man to provide power for their shop, though they had soon moved into the basement of a cotton mill where they could make use of the steam engine.[83] Thomas Smith also converted from human power to room and power, in 1820, while Titus Longbottom was able to start in 1809 with rented room and power.[84] In Leeds, Peter Fairbairn started out in a small room in Lady Lane in 1826, where a 'stalwart Irishman' powered the lathe.[85] At about the same time Thomas Armitage, a Cleckheaton machine-maker, used power 'supplied by a man who turned a large wheel'.[86]

The system of subcontracting helped reduce both fixed and working capital requirements to a minimum. By buying in castings and precision parts from suppliers like Hattersley, perhaps on extended credit, a textile engineer could manage without a foundry or much equipment. Entry to the trade was consequently eased for those with few financial resources but who nevertheless possessed essential skills and knowledge. Suppliers who were better established extended support through credit and through a flexible approach to the settlement of accounts. Richard Hattersley's earliest sales ledger shows that payments from many customers were spasmodic, with some years late in meeting their bills.[87] Others settled accounts with quantities of iron or engineering tools, wood, and even household items such as blankets, wool, a clock, bacon and butter. Hattersley was able to stand this by spreading the risk, retaining a large number of customers. Those who thrived, like Berry Smith, adopted more businesslike methods and paid promptly in cash. As for the rest, some goods were never paid for, and other debts were settled years late or in kind. Hattersley's acquiescence in granting credit and taking goods in lieu of cash, however reluctant he may have been in this, certainly helped young and struggling businesses, some of whom grew to become important customers.

The earliest of these small engineers were also helped by their versatility. When first in business Richard Hattersley was not above mending spades, clog irons or the church gates, at the same time that he was building expertise in repairing rollers, spindles and flyers.[88] William Carr also started in Keighley as 'a jobbing blacksmith and whitesmith', following the same route as Hattersley into machine-making via the repair of flyers and guides for cotton mills.[89] This 'dual economy' of general and more specialized work was a strategy for weathering fluctuations in the textile trade. As the market for machines grew, this was no longer necessary and general work fell away.

Many of the first machine-makers did not last long in the industry, though not all who gave up did so because they were unsuccessful. The new technical demands partly account for a high drop-out rate before 1810, but some pioneering machine-builders simply saw more profitable opportunities elsewhere, perhaps in their original trade. From the first fifty years of textile engineering in Keighley, only the eighteen firms listed in Table 2.1 have been identified, and it is unlikely that there were many more. Twelve of those firms had given up machine-making by 1805, including all five of the woodworkers. Only one is known to have been insolvent. Others returned to their own trade, though one, Lodge Calvert, made a very profitable career in textile manufacture. The six remaining Keighley firms, all operating in the second decade of the nineteenth century, were led by entrepreneurs with appropriate technical skills. Four of these were out of business by 1840, in each case because the entrepreneur was unable to continue and had failed to make adequate plans for the succession. Michael Merrall's children were too young to continue the business when he met an unexpected death in 1819. Though his widow persevered for a time, she was unable to carry the firm.[90] In other cases there may have been no need for the business to survive.

Titus Longbottom, who had experienced commercial problems in the 1820s, nonetheless pulled his business around but it died with him in 1831 as he had no heir.[91] Berry Smith, who also seems to have lacked an heir, increasingly turned to commission worsted spinning from about 1810 and had given up machine-making altogether by about 1830, but his business did not survive his death in 1835.[92] On the other hand, William Carr, who had long appeared the foremost engineer in the town, passed his business down to his sons when he retired in about 1817, but they failed to sustain it and it eventually fizzled out in about 1840.[93] One of these sons, Edward Carr, was still working in the trade as a journeyman at the time of the 1851 census, so perhaps his failings were entrepreneurial rather than technical.

The only two firms in Keighley which survived through the period, and with great success, were those of Hattersley and William Smith, both of whom had many sons and grandsons, from whom successors were chosen on merit. Both firms experienced problems with family members who were incompetent, extravagant or simply disagreeable, but the situation was managed so that these brothers were eased out and a degree of meritocracy prevailed.

The same trends are discernible in the Leeds industry, though less is known about the total size of the industry before 1810. Seven major firms were established in Leeds before 1830, of which three apparently failed for lack of suitable heir. Technical demands were too pressing to allow widows or executors to take temporary control, as was possible in other industries. John Jubb II had tried to arrange for his business to be carried on by trustees until his three young sons could take over, but the firm soon closed after Jubb's death at the age of 41 in 1816.[94] Zebulon Stirk, who had been a successful maker of steam engines as well as textile machines in the 1820s and 1830s, and a considerable exporter of spinning and preparing machinery to the continent in the early 1840s, was reduced to employing half a dozen men by 1851, when he was 69 years old.[95] This firm too died with its founder. The third firm which did not survive was, perhaps surprisingly, that of Matthew Murray. Because Fenton, Murray and Wood had enjoyed such early success, 'making a great deal of Money' as James Watt junior had noted in 1802,[96] David Wood's surviving sons were able to follow leisurely pursuits, and seem never to have become involved in engineering. The younger David Wood was described as a gentleman at the time of his father's death in 1820.[97] Murray's own son, Matthew, unable or unwilling to carry on the firm, spent most of his working life as an engineer in Russia, where he died in obscurity.[98] Control of Murray's firm passed to a son-in-law, Richard Jackson, but once the momentum of Murray's 'creative impulse' had exhausted itself, the business ceased to exist.[99]

A notable feature of the surviving Leeds firms is that they were partnerships. In the cases of Samuel Lawson and Peter Fairbairn, partners seem to have played a minor role in the firm's development, yet they provided some stability and continuity in management until the entrepreneur's only son had proved his worth. Maclea and March and Taylor and Wordsworth were both partnerships of brothers-in-law, in each case with a childless partner leaving some assets to the children of the other, who continued the business. Though the number of firms is small, common patterns are discernible. The industry had moved beyond the model of flexible specialization, where 'firms were not enduring units of production but rather temporary combinations of machines and skills directed to the achievement of particular tasks'[100] to a situation where, generally, efforts were made to ensure the continuation of successful firms.

Crucial to the long-term survival of these firms was conscious planning of the succession. The general pattern was that sons were apprenticed in the firm, and if they made the grade as tradesmen they would gradually be introduced to commercial aspects of the business. If there were no suitable son, then there was a problem in arranging the firm's survival, as illustrated above by the various firms which wound down or finished upon their principal's death or retirement. On the other hand, an engineer who lacked heirs altogether would not necessarily have seen any reason to keep his business alive, and may have chosen to wind down as he entered old age, in the way that Zebulon Stirk seems to have done. If an engineering entrepreneur had more sons than could be accommodated in the family firm, then other plans had to be made to ensure the survival of the main branch of the business. Richard Hattersley had five adult sons, only three of whom were designated to take over the family firm. The business came to grief within three years of Richard's death in 1829, as the sons could not agree. Bankruptcy in 1832 and a consequent relaunch as two separate branches, under George in Keighley and Samuel in Bradford, seem to have been used as an opportunity to elbow out the troublesome Levi, with whom George would not work. Levi never recovered his equilibrium, and eventually died in the workhouse. On the other hand, a younger brother, Jonathan, who had not been included in the original plan for the family firm but who possessed more skill and application than Levi, made his own way, settling in Leeds and building his own successful business with no help from his brothers. The fifth brother, John, worked in the family business for a time before eventually departing for Australia. The family problems of the 1830s were still weighing on George Hattersley's mind in 1858, when he urged his eldest son, Richard Longden, to tackle a spendthrift brother, William Henry, and save the firm from disaster:

... it appears he will get thro all we have been hard working for, for upwards of 25 years in two or three years more and we are ruined ...[101]

The threat does seem to have been a real one. William was quickly removed from the firm, going on to work as a salesman in the Bradford textile industry.[102] Richard and Edwin, who was the third son, formed a partnership with their father in 1860, though it was Richard who took control of the engineering side of the business while Edwin concentrated upon the family's growing worsted spinning interests in the Worth Valley. The second son, John, apparently had no aptitude for business, and was never included. A much younger half-brother, James Midgley Hattersley, whom George had been keen to bring into the family firm, was pushed out by Richard after George's death. Though ruthless, Richard's policy of concentrating power upon himself paid off for the family business. His major failure was in not himself producing a son to whom he could hand on the business, and eventually he had to groom one of his sons-in-law for that role.

The other major Keighley firm, that of William Smith, also suffered from an excess of heirs. The original firm survived its founder's death in 1850, continuing until some of his sons decided to retire during the 1860s. It then formally dissolved, with the largest section continuing under the direction of William's fourth son, Prince, and his own son, also Prince Smith.[103] Like the Hattersleys, William Smith's sons seem to have had conflicting aspirations, and only full control of their own firm was enough to satisfy the more enterprising of them. Although William Smith had no need to plan the succession, those of his seven sons and numerous grandsons who wished to continue machine-making had been forced to re-group.

NETWORKS

While the individual machine-making firm was the basic unit in the industry, there also existed a further, informal, level of organization. The networks which connected firms can be summarized as the training network which has been described in chapter 2; a trading network of subcontractors and customers; and more personal connections between the families of engineers. If an 'innovating community' could play its part in technical development,[104] so in the sphere of production it is logical that firms would seek mutual advantage in a degree of co-operation.

The training network, through which much was known about the work of different firms and the capabilities of individuals, served as backdrop to a trading network, which has also been extensively discussed. The case of Hattersley has shown how one firm with specialist skills could supply a local machine-making industry with precision parts, single-handedly and perhaps to the extent of supporting technically firms which otherwise could not have survived. Richard Hattersley both used subcontractors, and was himself a subcontractor, tapping into a wider trading network which included the main Leeds machine-makers, who though highly competent and specialized, continued to buy his rollers, spindles and flyers. It suited both the supplier, who could have made his own machines, and the customers, who could have produced their own parts, to continue in this position of mutual dependence. Later, Hattersley's knowledge of the industry and its markets enabled his firm to survive mechanization and a consequent loss of profitability in his own specialist field of component making, for the decision to move into making worsted powerlooms took Hattersley into a commanding position in a new division of textile engineering.

Training and trading networks are relatively obvious and easy to prove. The personal connections are not so straightforward, yet there is much evidence that machine-makers were linked through friendship and that their relationships extended beyond simple commerce. In Keighley the early industry consisted mainly of sole traders operating within a well-defined local community, and as they achieved success some of them assumed a role in town affairs - Richard Hattersley was a member of the Select Vestry by about 1815, Berry Smith on the Company of Keighley Waterworks which formed in 1816, and the two of them, along with Thomas Smith and many up-and-coming textile manufacturers, members of a new Keighley Improvement Commission in 1824, for which appointment they were required to show assets of £1000.[105] These groups, primarily charged with providing infrastructure and order, also acted as a forum for local industrialists. Outside this network of the most successful in the town, help was offered to those lower down the entrepreneurial ladder, as with Titus Longbottom, who received a loan in 1820 from Richard Hattersley and Thomas Mills, an ironfounder, using his new workshop as security.[106] This should not be seen as in any way altruistic, for Hattersley and Mills would receive a commercial rate of return on their investment, and in any case Longbottom was a customer of Hattersley. But such a transaction shows the interdependence of engineers, and that mutual advantages were recognised in the support of smaller firms.

The social life of Leeds engineers was markedly different. Leeds was a much larger town run by an established oligarchy to which even the wealthiest machine-makers, because of their lowly origins, could not gain admission until after municipal reform in 1835. Exclusion from the establishment was only one reason for engineers to form their own network. They had similar interests and backgrounds, and tended to cluster in the districts of Hunslet and Holbeck, south of the town centre, in the same way that Berg's Birmingham metalworkers had concentrated in certain areas of that town. The reasons for choosing Hunslet and Holbeck were practical ones: property was cheaper, coal supplies and the canal were close, there were several established foundries there, and some large customers, flax-spinners, were also in those districts. But additionally the earliest engineers, mainly newcomers to the town, may have chosen to be near other machine-makers so that they could feel in touch with commerce and technical progress. From such proximity and business dealings came closer relationships.

The family links between Leeds machine-makers were not dynastic alliances between firms, but rather marriages of female relatives of established businesses to young engineers who subsequently became entrepreneurs. So Murray, needing an heir in place of his reluctant son, married off all three daughters to engineers, of whom at least two, and perhaps three, had been his apprentice. Looked at another way, three ambitious young men married daughters of the great engineer and were helped, directly or otherwise, into entrepreneurship. Jackson took over Murray's firm, and the others, Maclea and March, set up as partners in 1825, their connection with Murray presumably helping them on their way. Taylor and Wordsworth also married sisters, through whom they came into relationship with an early firm of machine-makers called Drabble. They may even have taken over the firm of Drabble, which disappeared from records at about the same time that Taylor and Wordsworth appeared as a partnership.[107] Through their relationship with the Drabbles, Taylor and Wordsworth were also uncles to a later firm of textile engineers in Leeds, the Pollards, to whom they left property and of whom one was a trustee of Wordsworth's estate.[108]

Because many machine-makers started in rented premises, they were unable to finance business expansion through mortgaging property. Consequently we are denied information about industrial finance which would, in the case of a mortgage, have been formally recorded in the Registry of Deeds, and it cannot be shown to what extent engineers helped each other financially. But there are small pieces of evidence which show something of a network involving machine-makers and related tradesmen, and indicate a degree of mutual trust in these circles. This is striking where executors and trustees have been chosen from competitor firms. The elder John Jubb named William Varley, wire-drawer and one-time machine-maker, as his executor, with the power to dispose of all his real estate.[109] John Jubb (II) left his whole estate and the guardianship of his children in the hands of trustees, one of whom was John Raper of Holbeck, a carpenter. In 1820 Raper also became executor, trustee and guardian of the younger children of David Wood.[110] When Raper sold some of an estate in Holbeck in 1825 to Benjamin Jubb, who was a machine-maker and probably the younger son of John Jubb (I), one of Jubb's trustees was Joshua Wordsworth.[111] Wordsworth was also named as a trustee of Samuel Lawson in the purchase of property in 1835, at a time when these leading figures in Leeds engineering might rather have been expected to have been in keen competition.[112]

CONCLUSION

For the first forty years of its existence, machine-making was essentially an industry which produced high-tech products by handicraft methods. While processes remained unmechanized, the industry relied upon specialization to optimize the accurate and efficient production of components. There was necessarily a long overlap between traditional and modern systems of working. If, like Randall's woollen workers, textile engineers combined dynamism and conservatism, then it was for pragmatic and positive reasons, and not because any institutional constraints were being applied. It was an attempt to make the best of processes and systems which were not fully adequate to their purpose.

Productive association, perhaps a more useful term than 'co-operation' to explain the character of early machine-making, was a response by the industry which was intended to minimize some of these difficulties. There was nothing artificial about such a culture, for it descended from traditions of skilled workers whose instincts were to respect and assist others in their trade. Alongside the energy and ambition of entrepreneurs building a new industry ran a current of mutual support, bolstered in some cases by family links and training connections.

In the 1830s the network ceased to be adequate, and processes came to be integrated within factories. As with technological innovation, organizational change drew upon proven and established features, adapting them to suit new circumstances. The factory system emerged through an evolutionary process, and, proving Pollard's point that it was not in itself a stage of development, subcontract continued alongside as part of that system. There is an apparent paradox in the role of improved machine tools, which while making possible the continuance of a flourishing small-scale sector alongside the large, also offered economies of scale which could be fully realized only in a factory. The explanation of this seeming contradiction lies in the fact that smaller shops were not making complete machines, but concentrated upon specialist component manufacture, repair and maintenance work, or other peripheral activities. The mainstream industry had moved into factories to take advantage of the extra flexibility and economies of scale they offered. These benefits were achieved by re-ordering production to make best use, not only of specialist tools, but also of mechanized lifting equipment and other organizational improvements.

So to an extent the move to factories was driven by technology, and influenced by supplementary technologies relating to the handling of goods as well as by the primary production technology. A few exceptional firms had realized at an early date the significance of re-ordering production to achieve economies of scale and improved quality, but most of the industry was too small-scale to afford the necessary capital investment. Only after the 1820s, a highly successful decade for the industry both commercially and in process technology, did it become possible for other textile engineers to follow the lead of pioneers such as Murray. There is a sense during the 1830s that machine-makers left behind an artisan mind-set and started to consider immediate organisational needs as well as engaging for the first time in forward planning. The family firm was no longer personified in the tradesman who hoped to pass on his business to his sons, but emerged with a separate corporate identity. Emphasis shifted from a network of subcontractors on to the firm itself, and the sustenance of the firm became a central issue for its principals.

This does not explain the move to factories, as the emergence of the new family firm could have been an effect, rather than the cause, of change. The risk, the size of investment in factories, the potential profits to be made, would affect a family's view of their business. In other words, a decision to upgrade would force a more businesslike attitude towards raising capital and protecting the family's investment. An unsentimental approach to the future management of the firm, a realistic plan for the succession, was an important part of this. Such policies often paid off, and those firms which had taken decisions to integrate and expand around 1830 were the ones which dominated the industry by the mid-century.

Nor does Marglin's labour exploitation thesis adequately explain why factories were necessary, for organizational changes in engineering did not lead to de-skilling of the labour force and consequent savings in labour costs. The subcontracting system was not an entrenched one in need of reform. The move to factories actually brought new problems of organization to entrepreneurs, who had then personally to handle issues of work discipline and skill shortages which had previously been the responsibility of their subcontractors. While it is likely that centralized supervision brought about a better quality product, the volume of business had to increase to make the investment in factories worthwhile. It was an expansion of the market for textile machinery, and the economies of scale which that made possible, which triggered the investment in factories. The growth of a mass market in machinery gave small firms confidence to invest as they had not done before. With a maturing of products and of the market, energies could be directed into productivity improvements.

NOTES:

1. Sabel and Zeitlin 1985, pp.143-4.
2. Smail 1991-2, pp.792-3.
3. Randall 1991, pp.93, 285.
4. Berg 1993, pp.17-9.
5. Berg 1993, pp.20-1.
6. Berg 1993, pp.23-4.
7. Berg 1993, pp.24-5.
8. Scott (ed.) 1928, p.33.
9. Jenkins 1993.
10. Berg 1993, p.18.
11. Berg 1991b.
12. Berg 1993, p.18.
13. For further discussion of this point see Morris 1990, p.13, who is nonetheless able to make considerable use of probate evidence as his own subjects were wealthier and more numerous.
14. WYAS Bradford, 32D83/33/8.
15. See for example George Hattersley's census entry for 1851 which includes 39 women and 29 girls among his employees: Keighley census 1851, p.378.
16. Rimmer 1967, pp.158-78.
17. Ward 1972, pp.353-4.
18. Perkin 1969, p.110; see also chapter 6, below.
19. Perkin 1969, p.110.
20. Pollard 1965, p.80; Musson 1980, p.96.
21. WYAS Bradford, 32D83/10/1.
22. Pollard 1968, pp.39-47.
23. <u>Keighley News</u>, 29 March 1890, p.5; Keighley Library, Poor Rate Books 1829-1835.
24. WYAS Bradford, 32D83/12/1.
25. PP (HC) 1841 (201) VII, p.209.
26. <u>Chambers's Edinburgh Journal</u>, No 513, 27 Nov. 1841.
27. E.J.Connell 'Sir Andrew Fairbairn, 1828-1901' in Jeremy (ed.) 1984, 2, p.312.
28. PP (HC) 1841 (201) VII, p.211.
29. See for example Berg (ed.) 1979, pp.45-9.
30. More 1980, p.155.
31. PP (HC) 1824 (51) V, p.303.
32. PP (HC) 1824 (51) V, p.568.
33. PP (HC) 1824 (51) V, pp.251, 258.
34. Sabel and Zeitlin 1985, pp.134, 142-56.
35. Berg 1993, pp.17-20.
36. Berg 1993, p.22.
37. Floud 1976, p.56.
38. Berg 1991b, p.181.
39. Steeds 1969, p.26.
40. PP (HC) 1824 (51) V, p.547.
41. PP (HC) 1841 (201) VII, p.23, evidence of Thomas Ashton.
42. PP (HC) 1841 (201) VII, pp.98-9, evidence of William Jenkinson.
43. PP (HC) 1841 (201) VII, p.113 evidence of Matthew Curtis.

44. See chapter 3.
45. Court 1953, p.240.
46. Roll 1968, part 2, chapters 1 and 2.
47. Robertson and Alston 1992, p.331.
48. Berg 1993, p.23.
49. WYAS Bradford, 32D83/32/1.
50. Smiles 1863, p.180.
51. Smiles 1863, p.181.
52. Pole (ed.) 1970, p.vi.
53. Tann 1970, p.100.
54. R.Buchanan, 1841, quoted by Musson in introduction to Pole (ed.) 1970.
55. Usher 1982, pp.364-5.
56. Jefferys 1970, p.12.
57. Checkland 1964, p.81; Steeds 1969, p.26.
58. Pole (ed.) 1970, p.421.
59. WYAS Bradford, 32D83/15/1 and /2.
60. Floud 1976, p.5; Musson and Robinson 1969, p.477.
61. Rolt 1965, chapter 7; Rosenberg 1963, pp.427-30.
62. Smith 1985, p.42.
63. Mokyr 1992, p.332, draws attention to its origins in eighteenth century France.
64. Musson 1980, pp.90-1.
65. Musson and Robinson 1969, p.494.
66. Musson and Robinson 1969, p.495.
67. PP (HC) 1824 (51) V, p.304.
68. PP (HC) 1824 (51) V, pp.306, 343.
69. Saul (ed.) 1970, pp.145-7.
70. Brunton 1825, p.206.
71. Even as late as the 1970s, 70 per cent of metalworking production in the United States consisted of small batches: Sabel and Zeitlin 1985, p.137.
72. Bradford Central Library, 'Mr George Hodgson's New Loom Works, Bradford'.
73. Robertson and Alston 1992, p.346.
74. Saul (ed.) 1970, p.142.
75. Above; WYAS Bradford, 32D83/33/8; Ward 1972, pp.362-4.
76. Turner 1966, p.2.1; Commercial Directory for 1816-17, pp.144-5; Taylor 1865, pp.491-6; Ward 1972, pp.362-4; Walker 1884, pp.261-2.
77. There is evidence that he helped them financially in the 1820s after his own career had flourished: Wakefield Reference Library, Goodchild Mss, Thurgoland militia list 1806; WYAS HQ, Deeds KG 170 178; HM 347 307.
78. Hodgson 1879, pp.252, 256.
79. Leeds Mercury, 27 May 1864.
80. Hodgson 1879, p.245.
81. Hodgson 1879, pp.249-50.
82. Hodgson 1879, pp.253-4.
83. Hodgson 1879, p.257.
84. Hodgson 1879, pp.260, 263.
85. Walker 1884 II, p.261.
86. Cleckheaton Guardian, 15 Feb. 1884.
87. WYAS Bradford, 32D83/2/1, Sales 1797-1809.

88. WYAS Bradford, 32D83/2/1.
89. Hodgson 1879, pp.249-50.
90. Hodgson 1879, p.262; Keighley Parish Register, burial 1 Nov. 1819; Brotherton Library, Marriner Mss. Box 118.
91. Hodgson 1879, pp.59, 261.
92. Hodgson 1879, p.255; PP (HC) 1834 (167) XX C1, pp.220-1; Keighley Library, Rate books 1829-1835.
93. Hodgson 1879, p.250.
94. Borthwick Institute, Exch. Oct. 1816; Leeds Intelligencer, 8 April 1816.
95. Leeds census 1851; Ward 1972, p.412; PRO, BT6/152 January and May 1843.
96. Scott (ed.) 1928, p.36.
97. Borthwick Institute, Exch. Dec. 1820.
98. Scott (ed.) 1928, p.88-9.
99. Scott (ed.) 1928, p.81.
100. Sabel and Zeitlin 1985, p.149.
101. WYAS Bradford, 32D83/33/8.
102. Bradford Observer, 30 Dec. 1886.
103. Jeremy (ed.) 1984, 5, pp.213-5; Keighley News, 29 March 1890.
104. See chapter 4.
105. Dewhirst 1974, pp.26-8.
106. WYAS HQ, Deeds Vol. HF 304 331.
107. WYAS HQ, P68/4/9/1 and /2; Holden's Triennial Directory 1809-11, pp.251-8; The Commercial Directory for 1816-7, pp.144-5.
108. Borthwick Institute, Prog. Sept. 1846 and March 1848.
109. Borthwick Institute, Exch. Sept. 1809.
110. Borthwick Institute, Exch. Oct. 1816; Dec. 1820.
111. WYAS HQ, Deeds IL 338 372. Benjamin Jubb's mother had been a Drabble, so the two may have been related.
112. WYAS HQ, Deeds LY 363 425.

CHAPTER SIX

CUSTOMERS AND MARKETS

> Your opinion is, that in England we shall always keep the superiority, from our ingenuity and arrangements? - I hope we shall.[1]

A tone of complacency evident in 1824 may reflect nothing more than the success which those appearing before the Select Committee were then enjoying. Textile engineers were so inundated with orders that they did not bother to send the parliamentarians a collective view on lifting the machine export embargo.[2] An explanation for the apparent smugness of machine-makers could be that their 'ingenuity' had created its own market, with local textile manufacturers forced to replace plant frequently in order to remain competitive. In that situation, engineers could continue to trade in a pre-existing market, with no need to look further for work or fight hard for business. The threat to such a position would come only when the bubble burst, as the great waves of innovation subsided.

The suggestion of complacency may not be fair. For while there is some correlation between the industry's expansion and technological innovation, by the mid-century Yorkshire textile machinery was being sold far beyond the local region. This move to distant markets could have been an attempt to fill a gap left by the slowing of innovation, a recognition that most textile processes had been mechanized and that the pace of innovation must slow, leaving the local textile industry amply supplied with machinery which no longer had inbuilt obsolescence. On the other hand, markets extended beyond the immediately local area long before 1850, and a direct and consistent connection between innovation and the growth of the industry remains unproven. But the idea that technical progress stimulated a local market adequate to sustain the industry, and that serious efforts to build extra-regional markets came only after the stream of innovation began to dry, can serve as an outline hypothesis.

If there were a correlation between changes in the volume and location of the market over time, and the availability of new technology, then that may provide at least circumstantial evidence to support the theory. Of particular relevance is the size of the local market in relation to total sales. This local market requires definition, for the early textile industry spread into distant rural outposts. It could be that a 'local' market for machines was more widespread in the early period than later, when textiles concentrated upon major centres. There are other complications in trying to link sales and innovation. What was the effect of trade cycles? When at its most innovative, was textile engineering dynamic enough to override economic cycles and continue expanding in defiance of the general state of trade? If so, that may provide firmer evidence to support the hypothesis, especially if it can be shown that external markets were unimportant before the 1840s. When the export embargo was lifted in 1843, further complexities arise, and there is a need to clarify cause and effect in relationships between a declining home market, a decelerating pace of innovation, and the relaxation of the law.

Before turning to the historical evidence, there is a theoretical point to consider on the nature of the connection between technology and the market. Did demand stimulate technical development, or did new technology stimulate the market? In short, which is the major factor accounting for the industry's dynamism? Gilfillan has shown that demand, whether in the form of changing prices or other imperatives, is quite capable of stimulating innovation.[3] On the other hand, Musson is clear in believing that a product must precede its market.[4] Capital goods suppliers, though, are differently placed from promoters of consumer goods who have to convince the general public of their need for a new product. It is quite possible for the market to demand what does not exist, when the market consists of well-informed purchasers looking to mechanize existing processes, or to improve machinery. However it is equally feasible that engineers could create a market by vigorous promotion in the way that Boulton and Watt seem to have done.[5] As so little is known about the motives of innovators or the strategies of engineers in the nineteenth century, answers to this question are necessarily speculative. It is also a possibility that the process worked both ways, in that demand and new technology fed off each other.

Musson would not accept such an idea, for he believes that to credit the market with a role in generating technological innovation is to accept that inventions are 'inevitable', a sociological theory which he dismisses as 'naive and unhelpful'.[6] It is certainly easy to be wise after the invention, with what Musson calls 'easy historical hindsight'. He cites achievements which the modern public glibly assumes to be assured: travel to other planets and stars, and a cure for cancer. But with easy historical hindsight, we can see that considerable progress has been made in both these fields in the twenty years since Musson wrote. The progress is incremental, rather than cataclysmic, which is nonetheless what Musson might have anticipated in 1972. He thought that 'easy modern assumptions ... are of little help to the scientists or engineers who are faced with the detailed problems of finding out precisely how to achieve such goals'.[7] But on the contrary, the expectation that a solution can be found sets innovators on the road towards solving the problem. As engineers grappled with mechanizing textile processes and improving machinery, the strength of a prevailing conviction that solutions could be achieved must not be underestimated. It hardly matters whether this Zeitgeist preceded the first successes, or whether confidence grew out of technological breakthroughs in the mid-eighteenth century, for what was important was a belief that solutions could be found by the application of knowledge and skills. This belief carried the textile and engineering industries on the crest of a wave of mechanical improvements from the 1780s through to the last great challenge of designing a woolcombing machine in the 1840s, though by that time the wave had lost much of its momentum. As proof of the success of self-belief, a succession of innovations-to-order may be cited, from Cartwright's powerloom, an original idea which needed substantial modification before it would work, to Roberts's self-acting mule, technically successful though not entirely original. There are also thousands of innovations which cannot be referred to, as they were small and unrecorded, but nevertheless were improvements in response to the express or unstated requirements of an informed and discerning market.

So perhaps the idea that innovation stimulated demand is not an alternative to the idea that demand stimulated innovation, for there is no obvious reason to rule out either theory. If the importance of a local network of engineers and their customers is recognised, these views of how the market related to new technology may be complementary. The challenge then is to show more subtle mechanisms within local communities to explain how the market functioned.

Demand need not take a form as explicit as the request made to Roberts to design a self-actor. In a close-knit community of machine-users and their suppliers, certain needs would be obvious to all. Was there, though, a point at which engineers had progressed beyond those clear requirements and were forcing the pace of technology? In the same way that textile manufacturers encouraged the public to take new products, were engineers also thrusting new machines upon manufacturers? Or did the creative instincts of machine-makers instead turn inwards to refine their own tools and production processes? If the local market for machinery was becoming more difficult as possibilities for innovation diminished, engineers are likely to have looked for new ways forward, including increasing their own efficiency, and seeking out new markets.

The comparative experience of Lancashire may be instructive. In a concise but convincing account of machine-making in Lancashire, Farnie emphasises the complementary roles of engineers and spinners in the growth of the cotton industry, though competition retains a central role in his argument, with engineers 'too jealous of their compeers ever to consider united action, least of all in the maintenance of prices'.[8] Farnie stresses the importance of a vast local market for machinery, though the durable nature of the Lancashire engineers' products limited their own sales possibilities. The response to this difficulty included constant improvement and refinement of machinery, attempts to convince machine-users that technology was 'a progressive rather than a static instrument of production', and other less abstract incentives to spinners to upgrade their plant.[9] Then, from the late 1820s, Lancashire engineers increasingly turned to the export market. It might be expected that developments in Yorkshire would follow a similar pattern, though perhaps lagging behind the Lancashire engineers whose interests lay overwhelmingly in the more technically advanced cotton industry.

	1850	1856
Spindles	25,638,716	33,503,580
Looms	301,445	369,205

NOTE: Figures for the woollen mills of Lancashire appear to have been excluded from the 1850 totals, which should therefore show a further 223,778 spindles and 4,839 powerlooms (Jenkins 1978, p.60).

SOURCE: PP (HC) 1857 (Sess.1) III, p.572

TABLE 6.1
Spindles and Looms working in the U.K. Textile Industry

1836	1841	1843	1845	1850	1856
2,768(1)	11,458	16,870	19,121	30,856	35,298

NOTE: (1) A figure of 2,856 is given in PP (HC) 1836 (24) XLV, pp.150-1.

SOURCES: PP (HC) 1845 (639) XXV, p.477; PP (HC) 1857 (1) III, p.633

TABLE 6.2
Worsted Powerlooms working in the West Riding

THE SIZE AND VALUE OF THE MARKET

There is no accurate way to estimate the size of the market, or the size of the textile engineering industry, in this 'pre-statistical period'.[10] Even after 1850, Floud found considerable difficulty in producing such figures for machine tool manufacture.[11] That contemporary authorities had no idea of textile engineering's overall scale is demonstrated in the way that the 1841 Select Committee carefully recorded Peter Fairbairn's estimates of firms, workers and capital employed in machine-making in the biggest engineering centres in Yorkshire.[12] There was no attempt to make their own wider survey, or to collect information on the value of the market in machinery, though

POWERLOOMS

	1835	1836	1850	1856
England:				
wool	2,045	2,150	9,439 (1)	14,453
worsted	3,082	2,969	32,617	38,956
silk	1,714	1,714	6,092	9,260
flax	309	209	3,670/1,141 (2)	7,689
cotton	108,632	108,751	249,627	298,847
West Riding (3):				
wool	175 (4)	272		
worsted	2953	2,856	30,856	35,298
silk		nil		
flax		nil		
cotton		3,114		

SPINDLES

		c.1833	1850	1856
England:	wool			
	worsted		864,874	1,298,326
	cotton	9,333,000		
West Riding:				
	worsted		746,281	1,212,587

NOTES:
1. The figures for the woollen industry in 1850 should include a further 4,839 powerlooms (Jenkins 1978, p.60).
2. Contradictory figures for the flax industry are given in PP (HC) 1851 (1304) XXIII, p.232, and PP (HC) 1857 (Sess.1) III, p.574, though those for other branches of textiles are identical. The total used in Table 6.1 is based upon the figure of 3,670.
3. The information for 1836 relates to only part of the West Riding, though apparently including the major woollen and worsted areas (PP (HC) 1836 (24) XLV, pp.150-1).
4. This figure is clearly incomplete. There are also 226 looms said to have been used for both wool and worsted fibres (Jenkins 1975, pp.126-7).

SOURCES: PP (HC) 1836 (24) XLV, p.145; PP (HC) 1851 (1304) XXIII, p.217; PP (HC) 1857 (Sess.I) III, p.559; Baines 1835, p.431; Ure 1836, p.lxii; James 1857, p.536; Baines 1873, p.636.

TABLE 6.3

Powerlooms and Spindles working in England and the West Riding

this would have been pertinent to the committee's investigations.

To take a different approach and build an aggregate picture from local detail is equally problematic. The trade directories which Floud could use are incomplete for the earlier period, nowhere near universal in their coverage and not specific about firms' activities. Sales records of engineers, and purchase books of their customers, do not survive in sufficient numbers or suitable form to use as a basis for extrapolation. The difficulty is exacerbated by the way in which machine production was organized, particularly the supply of components to engineers who made complete machines. For example, the cost of rollers and spindles made up about one fifth the value of a machine,[13] and most of these were produced for machine-makers by specialist subcontractors, who also sold replacement parts direct to textile factories. So while concrete evidence is in very short supply, there is also a danger that sales could be counted twice.

Tables 6.1, 6.2 and 6.3 have been compiled from a series of parliamentary reports, which are in part self-contradictory. Particularly unreliable are the spindle figures for the 1830s, which the factory inspector, Baker, described as 'not in the least trustworthy'.[14] Even for the 1850s, figures for spindles are much more approximate than those for looms. Calculating the numbers of spindles working in the cotton industry in 1850 according to a formula provided by the Factory Inspectors, by multiplying 1,932 factories by 14,000, the average spindleage per factory, produces a total of more than 27 million spindles, while we are told elsewhere in the same report that the number of spindles working in all branches of the country's textile industry was 25.6 million.[15] By the same formula, the woollen and worsted industries would have had 4.4 million spindles in 1850, a figure which is inconsistent with apparently authoritative information used elsewhere.[16] Jenkins has shown that billy spindles, doubling spindles and spinning spindles were not separately listed, so that it is impossible to be certain about spinning capacity.[17] That may help explain the discrepancy between the various parliamentary figures, but it does not assist in valuing the size of the machinery market as the price per spindle of preparing and spinning machinery differed (see Table 6.5). Figures for cotton appear altogether more numerous and reliable, and illustrate the vast size of that industry compared with other branches of textiles. A significant proportion of the cotton industry was in Yorkshire. Of 1,000 mechanically driven cotton factories in England in 1835, 126 were in the West Riding.[18] But how much of their machinery was locally produced remains unknown. It is likely that most nineteenth century cotton machinery was imported from specialist centres in Lancashire.

So there are two major problems in using textile statistics to calculate the size of the textile engineering industry in Yorkshire. First, the figures are approximate, and perhaps inaccurate. Secondly they cannot account for the way in which the supply of machinery was organized, notably any inter-regional trade, nor how long machines were kept in service, nor how much discarded machinery was brought back into use. These points will be further discussed below.

The two parliamentary reports do contain other indications of the machine-making industry's size. Working at full capacity in 1824, the total value of cotton machinery produced, presumably in England alone, was said not to exceed £400,000, with a comparable figure for Scotland of not more than £40,000.[19] No values were given for other branches of textiles, whereas evidence presented to the 1841 Select Committee was in the form of a total for only the larger towns of Lancashire and Yorkshire and which did not distinguish between branches of the industry. Eleven towns in Lancashire were said to accommodate 115 'mechanical establishments', with a total of 1,811 horse power and a maximum capacity of 17,382 employees. This works out to an investment averaging £87.16 per employee, though ranging from about £70 a head in Blackburn and Manchester to £146 in Burnley.[20] Fairbairn's figures for machine-making in Leeds suggest that 18 firms employed 255 horse power, 2950 workers and £305,000 capital.[21] Furthermore, he estimated that Bradford, Bingley and Keighley had nearly 1,000 hands and over £60,000 invested. These figures do not exactly coincide with evidence from Lancashire engineers who thought that the four Yorkshire towns together amounted to 442 horse power and 5,000 hands.[22]

The average firm in Leeds in Fairbairn's list had 164 employees with £103.39 invested per capita. These numbers of firms and engineers are roughly what could be expected, as the engineering workforce in Leeds recorded in the 1841 census has been calculated at 3,741, which includes a growing number engaged in machine tools, locomotive building and branches other than textiles.[23] The average Leeds firm is similar to the Lancashire sample, which ranged from 40 or 50 workers per firm in the smaller towns, to 209 in Manchester, 280 in Salford and 321 in Bolton, averaging 151 over the eleven towns.[24] Averages conceal a wide variation, as in the Leeds industry where Fairbairn employed 550, and Lawson, Maclea and March, and Taylor and Wordsworth, each had several hundred employees.[25]

Fairbairn's evidence to the Select Committee seemed to suggest that an annual turnover roughly in line with the amount of capital employed could be expected. In Fairbairn's case, he had invested £50,000 to £60,000 and claimed annual sales of £60,000, or a gross income to the firm of over £100 per employee.[26] Fairbairn was noted for his modern and highly organized premises, but his level of investment appears to have been on a par with that of others in the industry.[27] The industry in general was working far below capacity; as a Lancashire witness to the Select Committee said, 'we could produce double the quantity that we have produced in the last twelve months, if it was required'.[28] But Fairbairn, specializing in flax machinery, was thriving, and a figure of £100 gross income and £100 fixed capital per worker, for a firm which kept busy and was equipped to a modern standard, may serve as a useful benchmark. By this measure, the Leeds industry, employing 2,950, may have had an annual turnover in the order of £295,000, and 1,000 workers in the Keighley/ Bradford/ Bingley industry could have produced machinery with a finished value of £100,000. The equivalent figure for eleven leading Lancashire towns would have been over £1.5 million per annum.

It is possible to suggest tentative figures for the value of machinery produced in the years before 1850. Whatever the service lives of machines in general, powerlooms were in such demand from their first introduction that it is unlikely that any had been scrapped by 1850. The total number of powerlooms given in 1850, if an accurate estimate, is therefore likely to represent the total produced to date (Table 6.3). The probability is that most of the worsted, woollen and flax powerlooms at work in England, a total of 50,565, were made in the West Riding. If these were sold at £14 each, a very approximate figure, then the total value of powerloom sales in Yorkshire before 1850, excluding exports, would have amounted to £707,910. These sales would have fallen in the fifteen years before 1850, with the majority in the 1840s, so that the value of the market in powerlooms during that decade would have been at least £50,000 a year.

Estimates for spinning and preparing machinery are even more problematic. There was an early survey of spindles used in the cotton industry, made by Crompton in 1811, though as he himself put it, 'this but a partial account of the cotton spinning - the extent of the Mule in the woollen trade is not mentioned, tho' extensive'.[29] The spindle figures do not show how many machines had been constructed, for mules could have between 50 and 500 spindles, water frames 48 to 160 and jennies 48 to 208.[30] If Crompton's figures are accurate for the section of the textile industry which they attempt to cover, it appears that a minimum of 290,000 spindles were then operating in Yorkshire.[31] As spinning frames then sold for around £1 a spindle, and most of those running in 1811 would have been recently produced, perhaps in the previous 20 years, the annual market in Yorkshire was upwards of £14,500. But there are serious omissions from this figure, such as the whole of flax-spinning in Leeds.

Similarly, at the end of the period a rough calculation indicates the size of the engineering market. Table 6.3 shows that 864,874 worsted spindles were working in England in 1850. As Keighley was approaching a monopoly on making worsted spinning machinery, most or all of those frames would have been produced in the town.[32] A tentative price of 15 shillings a spindle sets the total value of this machinery at £648,655. If its service life were as long as 25 years - and some of it would have been replaced much faster - then the annual value in the 1840s of the worsted machinery market, most of which concentrated upon Keighley, could have been in the region of £26,000. A similar exercise for 1856 when there were 1,298,326 spindles gives a value of £973,744, averaging £38,949 over the previous 25 years. However if the increase in spindleage between 1850 and 1856 is valued using the same method, ignoring any replacement of machinery during this period, the 433,452 additional worsted spindles installed amount to £325,089, or £54,181 per annum over six years. These figures, rough as they are, give an impression of massive expansion in sales by the local machinery industry, particularly at the end of the period.

	Mule	Water/Throstle	Jenny
Todmorden and district	69094	11984	
Halifax and district (1)	122640	69866	6300
Miscellaneous districts:			
Dobcross	1080		
Marsden	1080	240	
Todmorden	3888		
Warley	5184		
TOTALS:	202966	82090	6300

NOTE: (1) Included in the figures for Halifax and district are factories in Leeds, Huddersfield, the Spen Valley and outlying rural areas. There are also 17 factories in Keighley, where a total of 3312 mule spindles and 14560 water frame or throstle spindles were counted.

SOURCE: Bolton Library, Crompton Mss. ZCR/16a.

TABLE 6.4
Cotton Spindles working in Yorkshire in 1811

Buyer	Maker	Date	Machine	Price
			SPINNING AND PREPARING MACHINERY	
Dolphin Holme Mill (1)	Unidentified	1803	Drawing frame	£56.0.0
			12 sp. roving frame	£57.0.0
			14 sp. roving frame	£43.0.0
			Spinning frames:	
			48-60 sp.	£74.0.0
		1807	96 sp.	£84 5s
R.Clough	Titus Longbottom	1819	72 sp. spinning frames	18s 6d to 21s. per sp.
			16 sp. roving frames	£52.8s
			12 sp. roving frames	£36.18s
W.Sugden	Titus Longbottom	1820	84 sp. spinning frames:	
			8 at 19s. per sp.	£638 8s.
			2 x 24 sp.roving frames	£75 12s.
Zachariah Allen U.S.A.	Samuel Stead (quote only)	1825	200-250 sp.woollen mules	8s. per sp.
J.Hartley	Wm.Longbottom	1834	112 sp. spinning frame	£92 8s
Kellett, Brown	Hannah Wheatley	1835	60 sp. billy	£19.0.0
	J.& S.Wheatley	1837	60 sp. billy	£20.0.0

TABLE 6.5
Prices of Textile Machinery
(continued overleaf)

Buyer	Maker	Date	Machine	Price
Marriner	Benjamin Berry	1838	worsted spinning frame	14s. per sp.
			66 sp. worsted spinning frame (second-hand)	2s. per sp.
	Taylor & Wordsworth	1839	screw gill	£40.0.0
			carding engine	£110.0.0
R.Clough	Wm.Smith & Sons	1846-7	72 and 80 sp. worsted spinning frames (part exchange)	9s 1½d per sp.
		POWERLOOMS		
J.Hargreaves	Hattersley	1835	Powerloom	£14.0.0
Robert Clough	Fox and Bland	1836	Powerlooms	£100.0.0 for 7
Linton Mill	Hattersley	1837	2 x 6/4 powerlooms	£11.0.0 each
Various (home and export)	Hattersley	1860	100 powerlooms	£1369 15s

NOTE:(1) These are valuations, not sales, of new machines. The spinning frames were not throstles but 'water frames of superior construction'

SOURCES: Brotherton Library, Kellett, Brown and Co. I.1 Ledger A 1833-48; Loc.cit. Marriner Mss. Box 95; Smith 1982, p.41; Longbottom 1986, pp.2-3; James 1857, pp.365-6; WYAS Bradford, 32D83/2/6, 5/5, 15/3, 42; Rhode Island Historical Society, Zachariah Allen Papers, Journal of European Trip 1825.

TABLE 6.5
Prices of Textile Machinery

TEXTILE ENGINEERING AND TRADE CYCLES

Kirk, who studied five large textile engineering firms in late nineteenth century Lancashire, suggests that the textile engineering industry lagged about a year behind other trade cycles, with machine-makers responding to increases in demand by deferring deliveries. If an increase in sales were sustained, production could be expanded by recruiting more labour and working overtime, and only if the trend continued would capacity be increased.[33] But Kirk was examining long-established companies in a mature industry. The earlier industry, characterized by small production units, flexibility and rapidly changing technology, was so responsive to the needs of customers that at times it could take a lead and instigate development rather than trail behind overall economic trends. No neat synchronization existed between machine sales and general trade cycles.

Though precise information is missing, it is still possible to identify periods of growth and depression in the textile trade, and to relate the state of machine-making to those cycles. For example, the periods when textiles underwent massive expansion include a cotton mill-building boom of 1789-1802 in Keighley and elsewhere, a great expansion of the worsted industry in Bradford from 1818 until 1825, a wave of new mills during 1832-36, all of which coincided with a high demand for machinery.[34] Much of the evidence is anecdotal. The Select Committee was told in 1824 of 70 factories in the Manchester area, and eight or nine in Scotland, standing empty for want of cotton machinery.[35] Evidence given to the later enquiry, in 1841, concentrated upon the slump which then preoccupied engineers. The 'long, dreary depression' following a bank rate increase in September 1836, and which lasted until 1842-3, hit machine-makers hard.[36] One cotton spinner, Thomas Ashton, of Hyde, Cheshire, was moved to recant on the views he had expressed in 1824:

> There were many mills standing empty for want of machinery ... there is now more machinery than we can employ ... a very great increase [in machine-making] took place in consequence of the demand.[37]

William Jenkinson, who made cotton, waste silk and flax-spinning machinery in Salford, confirmed that trade had been 'in a very depressed state indeed' for the previous three or four years.[38] The cotton industry suffered severe downturns in 1825-6, 1836-42 and 1847-8 [39] which seem to have had immediate effects upon the engineering industry. But through the late 1830s and 1840s worsted machine-makers were enjoying a boom, based on the widespread introduction of the powerloom to the industry,[40] which may explain why they did not send representations to the 1841 parliamentary enquiry. They were still busy in 1843, when the Factory Inspector reported:

> The most extraordinary extension of any trade within a limited period is, perhaps, that which has occurred in the Bradford market ... The machine-makers have been for some time, and continue to be, fully occupied in the manufacture of both spinning frames and powerlooms ... [41]

Besides the possibility of new technology bringing prosperity to one branch of textile engineering against the general run of economic trends, there were other ways in which engineers could keep busy at apparently inauspicious times. An example is the period around 1810 when many Yorkshire cotton mills underwent conversion to worsted, and when new or adapted machinery would have been needed.[42] An engineer could also find bread and butter work - repair, replacement of parts, refurbishment - at any point in a trade cycle. As indication of the generally steady state of the machine-making business, the price of rollers, a ready measure of the buoyancy of the market, had fallen between 1810 and 1812, but rose steadily thereafter.[43]

The most important means by which engineers could break out of the textile trade cycle had been to devise new machines and new techniques. Innovations which saved labour or improved quality were attractive to manufacturers even when trade was bad, as increased efficiency might bring a larger share of a small market. The level of complaint raised to the 1841 Select Committee by machine-makers organised as never before, indicates that technological dynamism was diminishing, especially in the cotton industry. They then recognized the need for overseas markets to be opened. Previously, textile engineers had achieved a contracyclical effect that was entirely positive. When textiles did well, so did the machine-makers. They bucked the trend only when the textile industry was in the doldrums.

Peter Fairbairn's success proves the point that technical flair could triumph over adverse trading conditions. His business had grown without remission, from a back room in Lady Lane in 1828, when a mechanic and labourer were employed, to the Wellington Foundry and 550 workers thirteen years later.[44] This startling growth continued, with 850 workers in 1851, over 1000 in 1858, and doubling again by 1867.[45] The downturn from 1838 which had dire consequences for much of the textile trade had not affected Fairbairn's growth, and he attributed his success before 1841 squarely to recent developments in flax-spinning technology:

> The improvements that have taken place in flax machinery have been very great, and I think the extent to which the trade has gone [since 1828] has arisen chiefly from these improvements.[46]

A major engineering achievement could itself spark off a revival in the textile trade. When James described the 'extraordinary epoch' of 1818 in the worsted industry he suggested that innovations in preparation and spinning had come from worsted spinners in response to market conditions.

In particular, the price of wool had risen rapidly and the market for fine quality goods expanded. Improved spinning techniques were demanded to increase the output and quality of yarn.[47] James does not make clear whether the spinners had commissioned improvements in machinery from their engineering suppliers, but the new machinery quickly stimulated demand:

> With the production of this improved class of yarn, which, however, could only be spun by those who possessed the newest and best machinery, an extensive demand sprung up.[48]

The appearance of new machinery could have been part of the cause, rather than an effect, of the ending of recession. Thomas Ashton recognised that upturns in trade could result directly from innovations, describing the mechanists of Hyde in 1818 and 1819 as 'very fully employed, for the power looms were being introduced, and that kept them in full employment during that time'.[49] Textile engineers were immediate beneficiaries of succeeding waves of innovation which ran through the different textile processes and branches of that industry. A desire to stay on the innovatory bandwagon may account for some machine-makers' dabbling in different branches of textiles, for once an innovation had been successfully introduced to the cotton industry, then it could be adapted to the more technically demanding worsted, woollen and other fibres.

Others less innovative than Fairbairn were able to weather adverse market conditions. Richard Hattersley's success was relatively modest, and rested upon technical competence and adaptability. In fact he did not start to build machines until 1827, and not until the 1840s had his firm become primarily loom-makers rather than component manufacturers. The Hattersleys experimented and kept abreast of developments, but they were not risk-takers. In times of depression, they always had a core of replacement and maintenance work upon which to fall back. Berry Smith took a very different course, though also one characterized by versatility and an apparently intuitive response to market conditions. From a small start in 1800, Smith built a large business within seven or eight years.[50] Though not known as an innovator, he worked at the forefront of technology, moving from repairing cotton machinery in 1800, to building throstles the following year, producing his own spindles and flyers by 1805, and from 1809 manufacturing 'the modern worsted spinning frame' which he shipped far beyond the local region. In 1810 he started commission worsted spinning, and after a time gave up engineering altogether. Hodgson found that Smith was still repairing cotton spinning frames in 1809, the kind of routine work which ensured a regular income if the market for new technology slowed.[51] Even Murray and Wood, already skilled textile engineers by 1796 when their new foundry was advertised, offered a range of two or three dozen products, many of which had no connection with textiles or steam engines, as insurance in case orders for their main business failed.[52]

In general, though, the market for new technology held up. Farnie's observations on the cotton industry suggest that machinery was disposed of as it became obsolete, long before it wore out.[53] Writing to Joseph Bramah in 1802, Benjamin Gott summarized the pressures upon a manufacturer to stay in touch with the latest technology:

> Those who have tried any machines and found a realized advantage from the use of them will speedily consult their own interest by generally applying such productive power & the rivalship of their neighbours will bring them into general use.[54]

In a recession, the service life of machinery could be prolonged if necessary. Slumps were, however, short, and manufacturers knew that they could not afford to be left behind. A detailed study of service lives of machinery for a sample of New England companies concluded that machinery installed during the 1830s averaged about 35 years' life, with spinning frames and opening machinery replaced rather more quickly than looms and carding machines.[55] Less is known of earlier replacement rates, though McGouldrick believes there was 'very rapid replacement of much machinery installed before 1830'.[56] William Jenkinson thought that machine-users, if they wished to stay abreast of technical developments, usually needed new machinery.

> There are very few cases in which you can apply anything very new to an old machine... With regard to the self-acting mule, if the machine be good, we generally put the self-acting part on to it; but if the machine be an old one, the extra expense in attaching the new part to it is often considered as a waste of money, and parties prefer having new machines altogether.[57]

Cost savings and increased efficiency offered by new machinery would have made replacement worthwhile.[58] The Leeds flax-spinner James G.Marshall, after telling the Select Committee that 'a considerable portion' of old machinery still operated in England, and that flax machinery, while requiring 'frequent renewals' was of great durability, was forced by his questioner to be more specific.

> What would you say was the date of the oldest machines which to any extent are now in use; 20 years? - I should think there are not any to that extent.
> Then probably most of the improvements that have been introduced in the last 20 years are in general use? - Most of them, and that has led to the displacement of a considerable proportion of old machinery with great rapidity of late years.[59]

In 1832 Babbage had estimated that for textile machinery to be profitable, manufacturers would reckon to recover their outlay in five years, and scrap a machine in ten.[60] In the flax industry, Rimmer thought that by selling cheap machinery outside the immediate locality, Leeds machine-makers had enabled spinners elsewhere to compete with Leeds, in turn forcing Leeds flax-spinners to stay absolutely up-to-date.[61] Flax-spinning technology was at this time progressing rapidly - 'a considerable improvement each year', as Marshall put it. In the worsted trade, where the pace of change did not match that of flax, there are nevertheless indications that machinery continued to be replaced frequently. Robert Clough of Keighley was constantly re-equipping, though information in the firm's records does not enable precise calculation of the service lives of machines. Some spinning frames were replaced after perhaps fifteen years. By 1842 Cloughs had almost 100 powerlooms, bought from a number of Keighley suppliers over the previous six years, and they subsequently acquired large numbers of looms in 1843, 1847, 1852, 1853 (84 looms) and 1856. But in 1865 the firm owned only 98 looms in total, indicating that there had been a high turnover.[62] Clough's accounts show that many of the looms and spinning frames which they bought were part-exchanged against old models, though some old machinery was sold to other textile firms.[63] What the machine-makers did with part-exchange machines is not known, whether re-sold, exported, refurbished or scrapped. The part-exchange system may have been a way of removing second-hand machinery from circulation so that more machine-users were obliged to buy new equipment. For while some firms, like Cloughs, followed a policy of frequently updating machinery, others were reluctant to spend more than necessary on machines. Marriners, another Keighley firm of worsted spinners, while buying extensively from William Smith and Taylor and Wordsworth, 'were never averse to a second-hand bargain if it was available' and seem to have adapted machinery in their own workshops.[64] By judicious selection, it would have been possible to buy the latest technology and still find serviceable items second-hand, perhaps for processes where technology had ceased to evolve so rapidly.

There are other problems in trying to estimate normal service lives of machines. If machinery were in high demand and delivery dates deferred, probably at times when textile manufacturers were also busy, then one would expect old machinery to have been retained, at least temporarily, so that orders could be met. There were sometimes technical reasons for keeping old machinery, which may have been preferred for specialist work in the way that the mule was considered better than ring-spinning for certain grades of cotton later in the century.[65] Zachariah Allen described how old and new methods in cloth finishing continued alongside each other in a Kirkstall woollen mill in 1825:

> One of the shearers informed me that the old fashioned blades were used to make the first cut, and the last sort of knives [a new kind of spiral blade] to finish the face.[66]

In this way the best possible finish could be achieved. Handlooms continued to be used for speciality and sample work into the twentieth century, particularly in the Huddersfield fancy trade.[67] In the late 1830s, when worsted powerlooms were being extensively introduced, many firms continued to use hundreds of handloom weavers alongside the new technology.[68] This could have been a way of hedging bets, in case unforeseen problems arose with the powerloom, though as the technology had already been well-tried in the cotton industry, it is more likely than the hand method had to continue for a time while engineers worked to fulfil orders for powerlooms.

The pace of technology moulded the machinery market until innovation slowed and there was no longer reason for serviceable machinery to be scrapped quickly. When this happened machine-makers, no longer able to override trade cycles, were forced to confront slumps in home trade. How this was dealt with, by extending the market, is the subject of the remainder of this chapter.

THE LOCAL MARKET

The definition of a local market in machinery changed over time, but rather than grow outwards it contracted to match the growing concentration of its customer industry. The disadvantages of transporting machines over long distances provide an obvious explanation for the decline in such trade. Those outposts of the textile industry in the Yorkshire Dales and northern counties had little option but to buy from West Yorkshire engineers, despite the difficulties, and can be considered part of the local market, though a part which was declining. It quickly became apparent that machine-makers preferred to serve an immediately local trade, and that the reasons for this were technical as well as practical.

The first demands for textile machinery in Yorkshire were in fact answered from Lancashire. Robert Heaton in 1790 looked to machine suppliers in Bolton, Manchester, Burnley and Blackburn, and rollers from Ashton under Lyne, the first machinery at Pildacre Mill came from Manchester in 1792, Benjamin Gott in 1793 brought carding engines and jennies from Salford and Manchester, as well as items from Halifax.[69] A Preston agent was advertising worsted spinning frames for sale in the Leeds newspapers in 1789.[70] Much later, in 1834, some of the first powerlooms into Keighley were imported from Halifax.[71] It seems that in the early period of mechanization, textile manufacturers intent on having the latest machinery would go as far as they had to to obtain it, generally in a westerly direction to Lancashire or perhaps Halifax, if necessary adapting cotton machinery to process woollen fibres.

Longstanding trade routes in textiles would have facilitated these transactions. Halifax was an established worsted market centre where the stuff-makers of Keighley and Haworth 'principally exposed their goods for sale' in the late eighteenth century.[72] Outwork from the Bradford worsted industry extended into north-east Lancashire and the northern dales.[73] But although such trading routes existed, transporting bulky and heavy products such as textile machinery beyond the immediate area added difficulty and expense. Keighley, Bingley and Leeds, and hence the North Sea and all navigable points beyond, had been connected by canal in 1777,[74] but the waterway was of limited use when so many customers for machinery were not on its route. Even textile manufacturers in Leeds experienced inconvenience and expense when ordering machines from outside the town. When Ard Walker brought spinning frames and other machinery from Halifax to his new cotton factory in 1802, the cost of £168 was inflated by freight charges of £22 15s 0d, plus 15s 0d to bring the goods from the boat.[75] Gott paid £12 15s 8d to transport 95 cwt. of machinery from Manchester in 1793.[76] Purchasers of machinery therefore had good reason to prefer a more local source, and for suppliers there were also advantages in serving a concentrated local market.

In the way that Hunslet businesses traded wherever possible with neighbouring suppliers and customers,[77] so in Keighley everything possible was bought locally. Hattersley was supplied by founders, braziers and tinsmiths working nearby, and many of the Keighley machine-makers and textile manufacturers bought spindles, flyers and rollers exclusively from Hattersley.[78] Many early sales of machines which Hodgson recorded were to local factories by local engineers.[79] As the worsted trade mechanized and concentrated heavily in Yorkshire, Keighley and Bradford machine-makers gained an immense local market. In 1850 the West Riding had 30,856 of the 32,617 powerlooms in the U.K., or nearly 95 per cent. The comparable figures for 1856 are 35,298 out of 38,956 (90.6 per cent), and 445 of the country's 525 worsted factories were situated in the county.[80] Keighley itself, of which in 1879 it was said that it 'nearly monopolises the trade of making worsted spinning machinery and is also engaged in making looms' had on its doorstep a tenth of the mills, an eighth of the spindles and a twelfth of the looms of the United Kingdom worsted trade.[81] It seems incontrovertible that the engineers' main market was concentrated locally, and that the engineering industry grew up in proximity to major textile centres in order to serve the textile industry. But machine-makers may have been much less passive in determining the course of trade than such bland generalizations suggest. With their preference for local business, engineers had reason for a strongly pro-active role in satisfying, then further stimulating, a local market, rather than venture into uncharted waters of sales to other regions or abroad.

A certain antipathy towards selling outside the local region is detectable. Some of the resistance was ostensibly for practical reasons, though in expressing the problems Thomas Cheek Hewes indicated a lack of enthusiasm for solving them.

> When we send out a machine, it is taken to pieces like a bedstead, and there is no great care in packing it up; and it is sent to a mill, and set up the very afternoon it is taken out; but if it goes abroad, or even to Aberdeen, we are obliged to make it in a different sort of way, so that it will detach itself in a way that we can pack it, and we find it a very cumbersome thing, and the freight comes to a great deal, in comparison with yarn, and when it gets into the country, it is not portable; and if we do not know the kind of conveyance they have in the country, we may err in that respect.[82]

Hewes had recently declined an order from a former customer in Aberdeen, as he did not want the trouble of sending complete machines, nor would he supply components.[83] The local trade was booming at the time so Hewes had no need of the Aberdeen order. Henry Houldsworth, a cotton-spinner and machine-maker in Glasgow, confirmed the trouble and expense of transporting machinery over long distances, but had found ways to bring essential parts from Manchester, then three or four years ahead in cotton-spinning technology. He produced the bulkier components in Glasgow, and fabricated machinery by combining these home-produced parts with finer items from Manchester.[84]

There were other, positive, reasons for proximity between engineer and customer.

> ... wherever you can get the most profitable and extensive market, there a man would naturally settle ... [machine-makers] establish themselves in those localities where they are most required, provided they have the same facilities for carrying on their business.[85]

There is plenty of evidence that engineering entrepreneurs moved to the town, or even the part of town, where the market was: Murray, Lawson and Fairbairn are obvious Leeds examples,[86] and members of the Hattersley family set up separate firms close to customers, Samuel in Bradford, and Jonathan, after trying Burnley and Bradford, in Leeds. James Greenwood of Keighley moved to Leeds in the 1790s only to disappear without trace.[87] Benjamin Berry of Leeds was more successful as a machine-maker in the newly booming town of Bradford.[88] Once textile engineers had found their market, a clear preference for home customers emerged,[89] as Peter Fairbairn explained when setting out the concrete advantages of a local trade.

> ... the contiguity of machine-makers to large spinning establishments is of the greatest importance to the extension of that particular branch of manufactures, by the reciprocal feelings which thereby exist between the parties, by being able to come into connexion with each other, and so canvass different improvements, the one trying and suggesting, and the other executing the different mechanical operations.[90]

Hence important innovations were in production in Leeds months before the flax-spinners of Ireland, who depended upon Leeds for their machinery, had even heard of the improvement.[91] Established machine-making centres were in an insuperable position, said Fairbairn, with such a technological lead and no effective competition, for 'a person wanting machinery prefers taking all his machinery of one machine-maker, if he can get it, because the machines are nearly alike, and may be changed from one to another'.[92] Such were the advantages of an early lead, added Fairbairn, that Belfast could not establish itself as an engineering centre, flax machine-making 'having first taken root in Yorkshire'.[93]

Keighley and Leeds were exceptional in their concentrations of machine-makers. The worsted boom in Bradford around 1820 was not matched by any corresponding increase in machine-making there, though there were a few powerloom factories in the town later.[94] It was already difficult for newcomers to break into engineering. Richard Hattersley responded to the mushrooming Bradford trade by building a new machine shop there in 1818.[95] His judgement had been sound, and the Bradford business thrived for more than half a century under his son Samuel. But few textile engineers followed them into Bradford, and few newcomers succeeded in competing with established machine-makers in other towns.

If a town such as Bradford were forced to import much of its machinery, so too were outlying villages. When Kellett, Brown and Co. of Calverley equipped a new woollen factory during the 1830s and 1840s they were able to obtain some machinery locally, but much was transported from woollen machinery specialists in the Spen Valley.[96] Their card clothing also came from long established manufacturers concentrated in the villages around Cleckheaton. Those textile businesses in the Dales and other northern outposts, though still patronizing West Yorkshire engineers, were rapidly losing significance in relation to the total market. The local industry which provided machine-makers with the bulk of their work was very local indeed.

Specialization was proving to be a means of producing components and machines efficiently and quickly. Responding to an unprecedented demand which had led prices to rise by 20 per cent in less than a year,[97] the narrow field of spindle-making sub-divided into minor branches.

> ... there are two or three classes of spindle makers, separate and distinct trades, masters and men ... since the demand has increased so much, [the master] confines his work to one kind of spindles only; each man confines his work to a smaller variety of spindles, and by that means produces them better adapted to the purpose, and cheaper than others could do before.[98]

The local demand for rollers remained high, resulting in a 30 per cent price increase over twelve years.[99] In sectors where improved methods of manufacture had been introduced, prices of machines remained steady. Thomas Cheek Hewes cited carding engines as an example.[100] Profitable opportunities for specialization in shortage components were generally short-lived, as manufacturing processes themselves became mechanized. A breakthrough in spindle production came in 1840 with Ryder's forging machine.[101] Some specialist spindle-makers, rather than seek to expand their geographical market as a result of the technological changes, instead chose to rethink sales strategies. Hattersleys, perhaps anticipating changes in the components market, had made experimental forays into powerloom manufacture in 1827 and by the late 1840s were overwhelmingly loom-makers. By this means they entered a new and booming trade, avoided head-on competition with other Keighley machine-makers, and ensured that much of their custom remained local.

In a sense engineers were beaten at their own game, forced by process innovation within their own industry to reconsider product ranges and sales strategies. If comfortable local arrangements had existed between textile manufacturers and engineers when machine-makers occupied a commanding position in the application of technology, this changed as textile innovation slowed and engineering itself became mechanized during the 1820s and 1830s. The intimacy of previous relationships may have been a phenomenon limited to Yorkshire. Hewes in 1824 claimed that not only did no formal combinations of master engineers exist in Manchester, but 'so little do we know of each other, that I do not know more than two in my line, as townsmen, I do not know them personally'.[102] But if this were true for Lancashire, it was certainly not the case in the close-knit community of Keighley, nor in Leeds. Only when it was recognized that technical successes had brought a limit to the size of the local market, and that general trade depressions were beginning to affect textile engineering as never before, did machine-makers need to look outside Yorkshire for new markets.

REGIONAL MARKETS

There is little to indicate that Yorkshire machine-makers sought work in other textile regions before 1850. If local orders had been short, necessity might have dictated pursuing potential customers in Norfolk, the West of England, or the Scottish Borders, but such activity seems to have been very limited, perhaps because any potential market was so small.

Hodgson records instances of early Keighley machinery reaching outposts of the local market, and also into neighbouring regions: Edward Carr sold throstles to Chester and Whitehaven, Berry Smith equipped a factory in Stockton with spinning frames, both examples from perhaps the

1810s.[103] What little machinery was running in Norwich by 1824 had come mainly from Yorkshire.[104] In the way that Yorkshire manufacturers had gone to Lancashire before a local industry could supply their requirements, similarly textile manufacturers from other counties would order from Yorkshire if there were no indigenous engineering industry to which they could turn.

Richard Hattersley, though his customers were overwhelmingly local, retained strong links with suppliers in the South Yorkshire metal trades. He bought steel from Walker and Booth of Rotherham, and files from his native village of Ecclesfield, during the forty years he lived in Keighley.[105] After his death in 1829, his sons maintained friendly connections with these suppliers, one of whom actively helped protect the young men's interests while an assignee in their bankruptcy. This support was rewarded by many orders over the following years.[106] Whatever the motives involved, it illustrates the possibility of enduring and close links between businesses in different regions.

As South Yorkshire's specialist components and metals found a natural market far beyond their own region, so West Yorkshire machine-makers found a niche for their products. When local markets became more difficult, and especially during depressions in textiles, engineers were more active in trying to establish markets beyond their existing range of contacts. The textile communities of West Yorkshire traded extensively in distant markets, and trading links in the machine-making industry to an extent shadowed those of textiles, in the way that Matthew Boulton had used a marketing network built up in the toy trade to develop a market in steam engines.[107]

First indications of a more ambitious approach to sales by Hattersley emerge from records of a journey taken by his eldest son, Samuel, in 1821.[108] This was partly intended to chase unpaid bills, but was also an exercise in drumming up new business. Visits were made to established customers in Wharfedale and Lancashire but Samuel was also calling on potential buyers and noting details of their existing suppliers, Hattersley's competitors. The business trip was relatively unsuccessful, yielding only a handful of orders. It must have been judged worthwhile, however, for similar excursions followed. A younger brother, Levi, was despatched to Scotland in 1828, and a journey which he made to London in 1823 could have been intended to seek out business.[109] Other distant orders came through local agents, as in 1834 when flyers were sent to Dublin under an arrangement with Horsfall Brothers of Bradford.[110] A request for information on machine prices for the United States in 1847 shows that agents also handled export orders[111] though by that time George's sons, particularly Richard who went to the continent every year, were travelling extensively as sales representatives.[112] For Hattersley's, though, developing a regional market was not a half-way step to an export market, for the regional attempts did not amount to much. They did, though, form part of an experimental stage in the life of the firm during the 1820s and early 1830s, before and after Richard's death and the bankruptcy. The period of experimentation also included powerloom trials in 1827, and spinning frame production as late as 1833.[113] The decision to concentrate upon the new worsted powerlooms, fairly obvious business for a Keighley-based engineer, enabled Hattersley to break free from agents and main contractors, and stand alone as a machine-maker. The potential market was enormous, and so much of it was local that Hattersley no longer needed to bother with customers in other regions.

In the industry as a whole, more formal sales techniques were adopted from the 1830s, perhaps indication of a geographically developing market. Printed price lists were becoming common, though prices quoted were a mere starting point in negotiations:

> ... the printed list of prices of any machine-maker is not to be depended upon; it is well known to those who purchase machinery, that there is a great deal of difference between the printed list and the selling price ... They sell much cheaper than they print.[114]

The use of the 'package', where men, tools and materials were sent to equip a factory with machines, was also an attempt to cater for customers' needs in the home market as well as for exports, which technically at least were still illegal.

There is an impression that engineers were more conscious of chasing business in other regions from, perhaps, the 1820s, but the amount of trade which resulted does not seem to have been large. The regional specialization of machine-makers which was already well developed - a concentration of cotton machines around Manchester, flax centred in Leeds, for example - meant that the local market remained supreme, and there was a certain inevitability about the pattern of inter-regional trade. Fairbairn knew that Leeds, as 'the seat of the chief flax-machine establishments ... for the whole world' had an assured market in Scotland and Belfast, and that the waste silk machinery he made would sell in Macclesfield and other established centres of silk-spinning.[115] Any possible competition would come from engineers in those textile districts. London, which had been renowned as a superior engineering centre in the eighteenth century, was operating in entirely different specialisms by 1824 and had no hope of competing with textile engineers.[116] As far as other textile districts were concerned, the 'spirit of improvement in Norwich' which John Harvey in 1824 had predicted would 'produce, in a short time, a great deal more machinery than we have now in use', failed to manifest itself in concrete form.[117] The Borders woollen manufacturers, lacking an indigenous machine-making industry, bought most of their equipment from Glasgow and little from Yorkshire.[118] In the West of England some textile engineers were active, and inventive, perhaps in sufficient numbers to satisfy local requirements, for nothing has been found which would confirm a trade in Yorkshire woollen machinery until some time after the mid-century.[119] The only firm evidence of trade with the West Country comes from the other direction, for Benjamin Gott had bought fulling stocks and scribbling machines from the West in 1793.[120] In all, inter-regional trade in textile machinery, other than flax machinery, appears to have been very limited, with the West Country self-sufficient and the requirements of other woollen regions so modest that their orders for Yorkshire machines amounted to little.

SALES ABROAD

When local and inter-regional markets failed to provide sufficient business to enable engineering to continue expanding at its accustomed rate, machine-makers were encouraged, or compelled, to cultivate overseas markets. Without exports, the industry faced relative or real decline.

Considering that textile engineering had suffered serious reversals in 1825-6 and during the late 1830s and early 1840s, why did it take until 1843 for the export ban to be formally lifted? Musson's account of various parliamentary deliberations, and of the Manchester Chamber of Commerce's attitude to the question, is revealing.[121] The debate of 1824, carried out in two or three months in response to a question asked in parliament on the principle of Free Trade, would probably have had a different outcome had it been delayed by a year and consequently taken place during a recession. Once the discussion had concluded, and a limited concession made to Free Trade by lifting the ban on artisans' emigration, then it became difficult to revive the issue. During the 1830s attempts to enforce the law gradually disintegrated, and the repeal of 1843 was an acceptance of the inevitable.[122] Musson cautions against seeing the Free Trade debate in simplistic terms, drawing attention to the philosophical and practical considerations which caused such apparently contradictory postures among machine-makers and textile manufacturers.[123] The problem of machinery exports serves to illustrate the complexity of the Free Trade question. While the Manchester Chamber of Commerce claimed to represent engineering as well as textile interests in opposing change, some of its 'engineering' witnesses had closer links to textiles. For example, John Kennedy had been primarily a cotton spinner for more than twenty years, as M'Connel and Kennedy had made machinery only for their own use after 1800.[124] He no longer shared the interests of small-scale textile engineers who produced for sale.

Consequently it is not possible to know the views of the majority of machine-makers at this time. The textile engineering industry was not represented, except under a general industrialists' umbrella. Even in 1841, the machine-makers' committees, as might be expected, represented large and medium-sized firms in large towns. A significant sector of the industry did not come together to express an opinion. Though machine-makers might have welcomed a lifting of the embargo, the state of trade in 1824 meant that they did not consider it worth sending a collective view. Had there been a slump, they certainly would have done. But as machine-makers were heavily involved in their own communities, with local markets so important to them, and many of them with interests overlapping into the textile trade, it is by no means certain that their view in 1824 would have differed from that of the Manchester Chamber of Commerce.

The slump of 1825-6 was a watershed. It represented the first serious blow to the industry, a recognition that textile engineering could no longer ride out recession merely by innovation. Though still illegal, exporting was one way of countering a difficult market at home. The flaws in export controls had been publicly exposed. Apart from outright smuggling, which could take a number of forms - parts mixed with others to conceal their true nature, whole machines sent through ports where recognition was unlikely, plans and models hidden in hand luggage - British technology reached the continent and elsewhere through the migration of artisans and through a number of British firms which had established foreign branches, mainly in France and Belgium.[125] The later parliamentary report, of 1841, contained a similar list of enforcement problems and complaints about contradictions and impractical features of the existing laws. Final proof of the law's failure lay in the fact that, as Peter Fairbairn put it, 'they get all our inventions whether we will or not'.[126] The Lancashire machine-makers suggested, without much subtlety, that if they did not win the day in 1841, plans were afoot to establish a joint stock company on the continent 'and secure to ourselves the advantages which the law now gives to foreigners'.[127]

Between 1825 and 1843 a Board of Trade committee was charged with the job of issuing export licences. Their terms of reference included discretion 'as may appear to them not likely to be prejudicial to the trade and manufactures of the United Kingdom'.[128] The inconsistencies complained of by witnesses to the 1841 enquiry are apparent from the committee's records. Certain classes of machinery could be sent to continental Europe, while others were banned. These prohibited items were exported in copious numbers to the colonies, for example in 1825, when Alexander Galloway, acting as agent for an unnamed machine-maker, was granted leave to send to Egypt 500 (presumably cotton) powerlooms and other machinery. Licences for machines normally banned were sometimes issued if the applicant was sufficiently illustrious, as in the case of the Turkish minister who took away 'ten models of machinery for the manufacture of cloth' in 1836.[129] Sometimes stable doors were closed late, as in 1835 when it was noted that applications for waste tow preparing and spinning machinery were in future to be refused.[130] The goalposts moved, exporters often re-applied in the hope that there would have been a favourable change in the rules or that some carelessness by the committee might mean their licence would be granted.

How involved were West Yorkshire machine-makers in exploring this export market? They left no trace in early applications to the Board of Trade. Leeds textile engineers started to appear on the list only in the late 1830s, when Lawson, Maclea and March, and Taylor and Wordsworth, attempted, usually successfully, to gain licences.[131] That does not mean that they had not previously exported, as many of the committee's dealings involved London agents who were handling machinery made in the north of England. Much of this, though, was for the cotton industry and probably originated in Lancashire. It is also unlikely that the larger Yorkshire engineering firms would have first circumvented the export ban and then later start to use the official system, so they may not have exported at all before the 1830s. Smaller makers could have adopted a more casual approach towards export licences. Potential problems with officialdom were not mentioned by Zachariah Allen when he recorded prices and specifications of woollen machinery, clearly intended to be exported, in 1825.[132]

But in 1825 Yorkshire engineers had not developed much interest in selling abroad. They did not set up temporary or permanent branches on the continent in the way that some of the Lancashire cotton machine-makers had done,[133] though there are many examples of artisans working abroad, in France, Russia, Sweden and Switzerland, for example.[134] The fear of losing highly skilled employees to foreign companies may have been a further deterrent to firms' working abroad.

In the way that machine-tool manufacturers found that 'a good tool sells itself',[135] for a time many textile engineers relied upon a similar maxim. Sales efforts were characterized by a lack of activity outside the immediate area, though a few machine-makers did try. Matthew Murray, who had built links with northern Europe through selling steam engines there, was able to export flax machinery to Russia at an early date, around 1800.[136] But generally exporting was difficult, sometimes illegal, and involved extra expense and effort. To an extent British machines did sell themselves abroad. Technically they were in a league of their own, and they were also much cheaper than their inferior French and Belgian rivals, so they found their way abroad despite the lassitude of their makers on the export front. The northern engineers were not alone in a want of sales drive, for Babbage noted the preference of London machine makers for home orders, and the fact that premiums were added to prices quoted to foreign customers.[137] How many machines actually found their way abroad is impossible to say, as many were exported illegally and consequently unrecorded. The use of agents, which could have helped conceal the nature of the machine and avoid problems to the manufacturer of trading abroad, also serves to hide the volume of overseas trade. Table 6.6 shows the size of export business in machinery to four destinations on the continent during the early 1850s, but unfortunately there are no earlier figures, nor any breakdown to show the proportion of textile machinery included.

Some evidence of how, and when, an export market was developed by an individual firm comes from Hattersley's records, though Hattersley was at least ten years behind the larger Leeds firms in starting to export machinery. Levi Hattersley was sent to America in 1822-3, but there are no indications that any business resulted from this expedition.[138] It was in 1846 that a routine of sales trips and exports of looms to the continent began to be established, although Hattersley's parts had doubtless gone abroad in Taylor and Wordsworth's machines before then.[139] In 1847, Hattersley began to circumvent Taylor and Wordsworth, who had long been his biggest customer for components and latterly for complete machines, and started to sell direct to the continent in competition with them.[140] Summer trips by Richard L.Hattersley in search of orders and information in the Low Countries, Germany, and later further afield, became an annual ritual. When in 1860 Hattersley recorded the sale of 100 looms in two months, a third were to foreign customers. Of 829 looms sold during 1861, 298 were exported.[141]

	1851	1852	1853	1854
France	£71,016	£100,608	£168,856	£101,652
Belgium	£27,058	£35,517	£63,643	£57,959
Hanse towns	£128,611	£117,848	£197,409	£125,157
Holland	£25,604	£38,616	£68,455	£77,058

NOTE: The figures include all machinery exports other than steam engines.

SOURCE: PP (HC) 1856 XVIII, p.284.

TABLE 6.6
MACHINERY EXPORTED TO FOUR CONTINENTAL DESTINATIONS

A different view of the development of export markets in machinery is shown in Bruland's study of Norwegian purchases from Britain. The first significant imports of British textile machines were in the mid-1840s,[142] from which it is tempting to conclude that this was a result of the embargo lifting in 1843. But as the ban had been widely evaded, the importance of liberalizing the law can be overemphasised. It was a slowing of technological change, and decline in the home market as a result, which changed the law, and fired the sales effort into foreign markets.

PROFITS AND COMPETITION

If it were possible to prove that profits were falling and competition among machine-makers intensifying during the second quarter of the nineteenth century, then that may support the idea that engineers were being forced into export markets. If the industry was becoming more competitive, it was not because more firms were working, for there were no more in the 1840s than had existed earlier[143] and with the growth of integrated factories entry to machine-making had become progressively more difficult. Also, as demonstrated by Hattersley's changing products, firms chose to avoid competition where there was a less confrontational option. So if competitiveness were on the increase, the cause was not a change in conditions on the supply side of the industry, but was more likely to be related to a falling home market.

There is little concrete information about profit levels in engineering, though indications were given to the 1841 Select Committee of profits enjoyed by some Lancashire machine-makers, when work was supposedly very short. Thomas Marsden of Salford, nearing the end of a three year, £30,000 contract for flax machinery built in France, estimated that £6000 went on tools and materials, and over £16,000 had been paid out in wages.[144] The remaining £8000, while it had to cover fixed costs, left a healthy margin for profit. William Jenkinson described a Mexican order for cotton-spinning machinery and millwork, lost to Belgium because of the export ban. The gross value was £70,000 to £80,000, and the work would have employed 1,000 hands for six months. Eighty per cent of the amount would have gone to pay wages and profits, though Jenkinson did not distinguish further between the two.[145] Marsden had paid his workers on the French contract, who included local unskilled labour and apprentices, an average of not more than £50 per annum. Using the same formula, the Mexican order would have cost £25,000 in wages and yielded as much in profit. Matthew Curtis, a machine- and card-maker from Manchester, broke down the costs of a £27,000 order for spinning machines.[146] With £3000 for bought-in spindles and rollers, £11,000 on wages, fixed costs of £1,400 and £800 covering consumables such as tools and files, the total of £16,200 left £10,800 for materials, profits and depreciation. All these figures are approximate, and deliberately imprecise about profits, but it seems that a generous level of surplus was built into the pricing structure even at a time when the industry was short of work. Rather than compete for existing home business, which would have meant cutting margins, these machine-makers hoped to broaden the market by having the export embargo lifted.

Though this evidence covers only a limited section of the industry and consequently is not wholly satisfactory, it does suggest that profits remained high. If the Lancashire industry were still able to turn in a profit, then the position in Yorkshire remained healthier still. If it is true that the industry was still very profitable, that is not fatal to the argument that machine-makers were forced to seek markets abroad because home sales were declining. It would have been possible to anticipate changes in the home market and move into the export trade so that profit margins were protected. Engineers had had prior warning that they were no longer immune to market fluctuations, through their experiences from the mid-1820s, and by planning ahead could avoid sacrificing profits. The Yorkshire industry was better situated than Lancashire for this, for they had longer notice. They could see what was happening in the more technically advanced branch of cotton machine-making, where mechanization had run its course, and may have realized that they too would need to cultivate export markets to compensate for loss of home sales once machinery had been supplied to convert the last woollen processes.

CONCLUSION

To say that Yorkshire machine-makers had become complacent as a result of their early success is to understate the dynamism which still motivated the industry to innovate and to seek new markets. Rather they were keen to protect their interests and those high returns they had come to expect. The eventual solution was to develop an export market.

Through most of the period a local market had been of paramount importance. The textile industry determined the location of the engineering industry, and the presence of machine-makers subsequently helped centralize textiles in certain places, which in turn concentrated a local market for machinery. Because textile manufacturers were willing to replace plant as soon as it became obsolete, they were enthusiastic and immediate customers for any innovation. More than that, they contributed to technical progress by working closely with machine-makers and making known their requirements and ideas. The local market could stimulate innovation, just as innovation stimulated the local market. Under these conditions it was entirely rational that engineers should prefer local customers.

Inter-regional markets were insignificant, partly because of transportation difficulties. It is also likely that the West of England textile industry found it more satisfactory to have machinery appropriate to its own needs designed and built locally. Where machinery was sent from Yorkshire to other regions, it was to markets such as the Macclesfield silk and the Norfolk worsted industries, where an indigenous machine-making industry had not been able to establish itself. By the 1820s existing centres of textile engineering were so firmly established and had built such commercial advantages that not even such a huge new textile trade as worsteds in Bradford could generate much of an indigenous engineering industry.

The opening of export markets, which occurred rapidly during the 1840s, marks a real turning point. Yorkshire machine-makers, still busy equipping the local trade with powerlooms at that time, had benefited by witnessing the problems of their Lancashire counterparts at the end of the cotton technology boom, and acted quickly to develop an export trade lest advantages should slip away. The export ban was lifted in recognition of these changing home circumstances, and within a very few years exports had assumed an overwhelming importance to Yorkshire textile engineers.

NOTES:

1. Evidence of Peter Ewart, PP (HC) 1824 (51) V, p.258.
2. PP (HC) 1824 (51) V, p.346.
3. Gilfillan 1970, pp.47-8.
4. Musson (ed.) 1972a, pp.27-8.
5. Musson (ed.) 1972a, p.42; significantly, Boulton and Watt's strength in marketing came from sales experience which Boulton, the non-engineer, had gained in another trade: Tann 1978, pp.364-6.
6. Musson (ed.) 1972a, pp.45-6; see also the introduction to chapter 4, above.
7. Musson (ed.) 1972a, p.46.
8. Farnie 1979, pp.54-7.
9. Farnie 1979, pp.55-6.
10. Jenkins 1975, p.xiv.
11. Floud 1976, pp.4-9.
12. PP (HC) 1841 (201) VII, p.393.
13. PP (HC) 1824 (51) V, p.381.
14. Baines 1873, p.646; see also Jenkins 1973 and 1978.
15. PP (HC) 1857 (Sess.1) III, pp.572, 574.
16. James 1857, p.536.
17. Jenkins 1978, p.59.
18. Ure 1835, p.353.
19. PP (HC) 1824 (51) V, pp.253, 302, 380.
20. PP (HC) 1841 (201) VII, pp.95-6, 230.
21. PP (HC) 1841 (201) VII, pp.209, 393.
22. PP (HC) 1841 (201) VII, p.95.
23. Rimmer 1967, pp.158-78.
24. PP (HC) 1841 (201) VII, p.230.
25. See chapter 5.
26. PP (HC) 1841 (201) VII, p.208.
27. Chambers's Edinburgh Journal no 513, 27 Nov. 1841, p.354.
28. PP (HC) 1841 (201) VII, p.96.
29. Bolton Library, Crompton Mss. ZCR/16a/3.
30. Daniels 1930, p.110.
31. See Table 6.4. It is likely that some of those listed were worsted spindles.
32. Keighley 1879, p.255.
33. Kirk 1983, p.134.
34. Baumber 1983, p.39; Jenkins and Ponting 1982, pp.60-70; James 1857, chapter X; Heaton 1933.
35. PP (HC) 1824 (51) V, pp.379, 547.
36. Heaton 1933, p.564.
37. PP (HC) 1841 (201) VII, p.22.
38. PP (HC) 1841 (201) VII, p.94.
39. Musson 1972b, p.22.
40. See Table 6.2.
41. PP (HC) 1844, XXVIII, p.7.
42. Jenkins and Ponting 1982, p.61; Baumber 1983, p.39.
43. PP (HC) 1824 (51) V, p.341.
44. PP (HC) 1841 (201) VII, p.208 etc.
45. Leeds census 1851 2321/200; Ward 1972, pp.362-4.
46. PP (HC) 1841 (201) VII, p.209.

47. James 1857, pp.383-4.
48. James 1857, pp.391-2.
49. PP (HC) 1824 (201) VII, p.306.
50. Hodgson 1879, pp.252-6; Hattersley's sales records confirm the rapid increase in Smith's purchases of components, from a low base in 1800.
51. Hodgson 1879, pp.254-5.
52. Leeds Mercury, 9 July 1796.
53. Farnie 1979, pp.55-6.
54. Crump (ed.) 1931, pp.225-6.
55. McGouldrick 1968, pp.231, 224-7.
56. McGouldrick 1968, p.232.
57. PP (HC) 1841 (201) VII, p.101.
58. PP (HC) 1841 (201) VII, pp.210, 216.
59. PP (HC) 1841 (201) VII, p.194.
60. Checkland 1964, p.78.
61. Rimmer 1960, pp.233-4.
62. Smith 1982, pp.41-2.
63. Smith 1982, pp.42, 51.
64. Ingle 1974, pp.114, 55.
65. Saxonhouse and Wright 1984, p.514.
66. Rhode Island Historical Society, Zachariah Allen Papers, Journal of European Trip 1825, p.30.
67. Jenkins and Ponting 1982, pp.116-7. For an example of a handloom rebuilt in Huddersfield in the 1930s, see Colne Valley Museum collection.
68. Sigsworth 1958, p.35.
69. WYAS Bradford, DB2/6/3 pp.10, 27, 37; Goodchild 1971, pp.340-1; Crump (ed.) 1931, pp.21, 24, 211-3.
70. Leeds Intelligencer, 1 Sept. 1789.
71. Hodgson 1879, p.267, though other sources cite an earlier date, and Hattersley had been making experimental powerlooms in Keighley as early as 1827.
72. James 1857, p.292.
73. James 1857, p.324; Shutt 1979, pp.58-9.
74. Killick 1900, p.68.
75. WYAS Leeds, DB23.
76. Crump (ed.) 1931, p.21.
77. May 1993, pp.59-60.
78. WYAS Bradford, 32D83/6/1; Hodgson 1879, pp.255, 243, 59-60.
79. Hodgson 1879, pp.59, 261, etc.
80. PP (HC) 1857 (1) III, pp.632-3.
81. Keighley 1879, p.255.
82. PP (HC) 1824 (51) V, p.349.
83. PP (HC) 1824 (51) V, p.342.
84. PP (HC) 1824 (51) V, pp.378-9.
85. Evidence of Matthew Curtis, PP (HC) 1841 (201) VII, p.118.
86. See Table 2.5.
87. Baumber 1983, pp.43-4.
88. Koditschek 1990, pp.173-4.
89. PP (HC) 1841 (201) VII, p.218.
90. PP (HC) 1841 (201) VII, pp.219-20.

91. PP (HC) 1841 (201) VII, p.220.
92. PP (HC) 1841 (201) VII, p.223.
93. PP (HC) 1841 (201) VII, p.220.
94. Banks 1925-6, p.16.
95. WYAS HQ, Deeds GY 658 703.
96. Brotherton Library, Kellett, Brown, I.1 Ledger A 1833-1848 Purchasing accounts.
97. PP (HC) 1824 (51) V, p.341.
98. PP (HC) 1824 (51) V, p.253.
99. PP (HC) 1824 (51) V, p.345.
100. PP (HC) 1824 (51) V, p.345.
101. *Proceedings of the Institution of Mechanical Engineers* 1868, p.17.
102. PP (HC) 1824 (51) V, p.346.
103. Hodgson 1879, pp.251, 255.
104. PP (HC) 1824 (51) V, p.154.
105. WYAS Bradford, 32D83/32/1.
106. WYAS Bradford 32D83/15/3, 33/1.
107. Tann 1978, pp.364-6.
108. WYAS Bradford, 32D83/15/1.
109. WYAS Bradford, 32D83/6/2.
110. WYAS Bradford, 32D83/15/3.
111. WYAS Bradford 32D83/33/7.
112. WYAS Bradford, 32D83/33/6 and /42.
113. WYAS Bradford, 32D83/15/2 and 3.
114. PP (HC) 1841 (201) VII, p.45.
115. PP (HC) 1841 (201) VII, pp.208-10.
116. PP (HC) 1824 (51) V, pp.300, 305, 348; PP (HC) 1841 (201) VII, p.99.
117. PP (HC) 1824 (51) V, p.160.
118. Gulvin 1973. For further information on this point I am grateful to Dr Cliff Gulvin.
119. K.H.Rogers 1991, pp.15-8; K.H.Rogers *pers. comm.*
120. Crump 1931, pp.36, 21.
121. Musson 1972b.
122. Musson 1972b, p.41.
123. Musson 1972b, pp.17-22.
124. Lee 1972, pp.21-2.
125. PP (HC) 1824 (51) V, pp.6, 51, 16, 23, 36-7, 101, and see below.
126. PP (HC) 1841 (201) VII, p.218.
127. PP (HC) 1841 (201) VII, p.104.
128. PRO, BT6/151. For the reference and information on these records I am grateful to Dr David Jeremy.
129. PRO, BT6/151.
130. PRO, BT6/151.
131. PRO, BT6/151.
132. Rhode Island Historical Society, Zachariah Allen Papers, Journal of European Trip 1825, pp.27-9 etc.
133. PP (HC) 1841 (201) VII, p.86.
134. Turner 1966, pp.3.23, 8.25; Heaton 1960; Hodgson 1879, p.251.
135. Floud 1976, p.83.
136. Turner 1966, p.8.5.

137. Babbage 1835, p.371.
138. WYAS Bradford, 32D83/5/5.
139. WYAS Bradford, 32D83/42; 33/6; 33/7.
140. WYAS Bradford, 32D83/32/1.
141. WYAS Bradford, 32D83/42.
142. Bruland 1989, Appendix B.
143. See chapter 5.
144. PP HC 1841 (201) VII, p.85.
145. PP (HC) 1841 (201) VII, pp.101-3.
146. PP (HC) 1841 (201) VII, p.123.

CONCLUSION

The picture of early textile engineering which emerges from this study is one of an industry growing from an artisan base, acquiring its own distinct identity during the early years of the nineteenth century, and developing into something more modern and large-scale only after about 1830. The changes were accompanied, predictably, by a growing expertise among entrepreneurs, a new professionalism in the workforce, and modernized forms of industrial organization. Significantly, the changing attitude towards competitors shown by the adoption of new methods of innovation and by a growing tendency to restrict the free circulation of technology illustrates just how important had been a non-competitive form of productive association during the industry's formative years.

Those pre-established eighteenth century industries and professions - iron-founding, clockmaking, millwrighting, and middle-class engineering in a broad sense - which appear at first glance to have had similarities with mechanical engineering, were in fact unable or unwilling to involve themselves in machine-making. Consequently the new industry did not follow any middle-class or 'yeoman' tradition, instead developing an identity which, while it was founded upon solving immediate local problems with a degree of originality, built upon artisanal foundations and depended especially upon conventional metal-working skills. From these origins emerges the paradox at the heart of early textile engineering, that it was a 'high tech' industry at the leading edge of the economy, yet its antecedents lay in simple artisan skills, rather than having developed from what might be considered the most sophisticated engineering of the eighteenth century. The newest technology was produced by handicraft methods.

It is hard to imagine how machine-making could have developed in any environment which was not closely in touch with the community of textile manufacturers. That is why many of the first textile machines were produced by users, for they knew exactly what was required. They did not, however, find the mechanics of machine-making easy, which is why it was convenient to pass over to local smiths and other artisan-engineers who had a more appropriate background to execute the work. Such craft skills, along with an immersion in the local textile community, were pre-requisites for early success as a machine-making entrepreneur. Capital mattered less, though as the industry grew and concentrated, by the middle of the nineteenth century it had become much more difficult for a talented young engineer to set up as a full-scale machine-maker. Entrepreneurial abilities, the capacity to manage and plan, were also essential requirements by that time.

The development of the workforce mirrored the changes in management of the industry. Though there came to be less scope for mobility into entrepreneurship or even into self-employment, consistently high levels of skill and status and relatively good wages proved attractive to new generations of young men, who followed a formal apprenticeship path into the trade.

Fundamental to the success of machine-making throughout the period was the industry's ability to work on ways of mechanizing those textile processes still carried out by hand, to improve existing machines and to develop solutions to technological problems. Textile engineers' grasp of technology was not informed by formal education or science. For a time, it was adequate to have handicraft skills in metal-working, though the knowledge element, the design details of machines, became an increasingly important part of the trade. As opportunities to innovate became more limited by the growing complexity of skills and knowledge required, then technology became viewed less as the property of a wide community and more as a scarce asset to be protected. This development coincided with a move from 'community'-centredness to a 'firm'-oriented perspective, a change datable to the 1830s when the availability of new process machinery in engineering and a growing preference for vertical integration within factories meant that capital requirements greatly increased. As a result of such large investments, the maintenance of a firm became the overriding concern of its members, with forward planning a new and pressing issue.

The market for machinery, which had occupied an influential place in the early development of textile engineering, continued to exert its force. When some in the industry sensed that innovation was slowing, and consequently that local demand would diminish as machines were kept longer in service, they actively sought export markets so that turnover and profits could be maintained at accustomed levels.

Basic craft skills, open minds and a fairly free flow in technological information were the guiding lights of the industry during its earliest phases, for they were the optimum means through which mechanization could rapidly develop. After 1805 there is a sense of inevitability about the path which textile engineering would take. It was an increasingly exclusive club which was to become even more prohibitive to potential members, first because of the growing skills and knowledge content of the trade, and later when high entry costs barred most artisans from entrepreneurship in mainstream machine-making. Early success in the industry, or sponsorship by one who had been successful, were the best means of achieving success during the later phases.

By the second quarter of the nineteenth century, the general prosperity of the industry had also come to seem assured. The need for both customers and producers to remain in touch with developments ensured that accomplishment was a self-fulfilling prophecy. Self-belief brought achievement, which reinforced self-belief. The beginning of this spiral of improvement cannot be precisely dated, for it was probably a gradual result of accelerating innovation in textile processes during the first half of the eighteenth century. The end of it, and the accompanying changes in the textile engineering industry, came when the first clamour for powerlooms was dying away and further opportunities for profitable innovation were diminishing.

Inevitably the relationship between engineering and textiles altered at this time. Textile engineering had never been subordinated to its customer industry, but the two had operated in marked contrast before 1830, for whereas levels of productivity and investment were low in engineering, through the products of engineering the textile industry had been able to achieve high productivity. In theory, skilled labour shortages should have stimulated process mechanization in engineering. In practice, machine-makers coped with the inadequacy of machine-tools by attempting to refine hand processes, for example by an increasingly fine division of labour designed to achieve higher degrees of precision. For a while that was adequate, though perhaps the stream of quality complaints received by Hattersley during the 1820s signals that the time was then ripe for change. The market for machinery had become much larger and more consistent, between 1808/9 when Hattersley still could not carry a regular workforce of any size, and about 1820 when those complaints intensified. Process mechanization eventually became imperative, and the market large enough to justify investing in new techniques, though change had been long deferred while the industry's dynamism was directed towards product innovation.

Any discussion of the process of technological change is inevitably bound up with consideration of the nature of competition. In the industry's early phases, innovation took place because the community's needs were fairly obvious to those involved. Technological developments were aimed at improving the quality of products and the practicability of processes, rather than being motivated by explicit economic considerations. Most machine-makers did not possess any extraordinary talents of inventiveness, for flexibility was more the key to success in this, as in other industries.[1]

To be clear about the role of demand in the progress of textile engineering is not easy, for in a capital goods industry demand may be at one remove from the supplier. If the consumer market demanded a new type of textile product, requiring a new kind of machine, then the need for innovation would be filtered through to a machine-maker <u>via</u> his direct customer, the textile manufacturer, for textile manufacturers themselves rarely designed and produced machinery after the initial stages of mechanization had passed. But when a free-standing textile engineering industry existed, demand could have been direct and explicit, from manufacturers who understood their own markets and could see potential economies in mechanizing or re-organizing parts of their production. Such informed demand could provoke innovation. In an atmosphere of self-belief, given that the problem was an immediate and relevant one to the concerns of the industry, solutions could be found. On the other hand, having seen the commercial possibilities of new technology, engineers would recognise potential benefits which perpetual innovation might bring to them. Perhaps it is possible to discern over the period a shift from demand-led innovation, to the use of innovation as a means of stimulating sales. This would go hand-in-hand with an increasing professionalism and expertise and the growth of vested interests in machine-making. If it is correct that a self-sustained growth in technology existed from the 1760s,[2] that phenomenon matches early, experimental, amateurish excursions into machine-making, whereas a full-blown 'Age of Inventions' blossoming in the 1790s [3] coincides with the beginnings of a specialist machine-making industry. Additionally a new type of analytical approach to knowledge which appeared in about 1800 [4] may have been influential, possibly infusing and enthusing a wider society than educated science could reach. Innovation was stimulated, then, in a number of ways, directly and indirectly, and encompassing wider cultural movements as well as demand and supply-side factors. As for the role of competition in the process, it does appear that a more competitive spirit was abroad in this industry by the mid-nineteenth century than had existed earlier, and that this new ethos had a role in determining new directions in technological innovation.

None of these questions, about the relative importance of demand and supply mechanisms, or about the role of competition, can be adequately addressed outside the framework of the industry's very local community context. The nature of textile engineering differed entirely from those heavy industries, like coal and iron, which were connected to landed interests and large-scale capital and which were consequently divorced from community considerations. In fact, some of the features of machine-making were those which might have been expected of consumer, rather than capital, goods manufacture - constant product and process innovation, small firms, batch production of components and flexible work organization.

If interest groups and value systems can produce a negative effect, leading to 'technological inertia',[5] then the opposite must also be a possibility, that community energies can be harnessed towards a process of technological dynamism. In this case, innovation really does seem to have been the property of a wide community, at least for a time. The evidence of trading, training and social networks strongly suggests that this was the case, especially when these networks of entrepreneurs overlapped into the lives of a small key workforce which shared the same artisan background. The result is likely to have been an 'inventive workforce and a progressive technological stance'.[6] In fact, resistance to change is striking by its absence. One suspects that some of the oft-repeated stories of antagonism towards new machines may amount to less than meets the eye, especially if viewed in the context of the scale of whole communities. This is an issue which requires further research.

If constant change were the very essence of engineering, then the management of that change was crucial to success. The idea of managing change goes beyond the issue of planning a firm's succession. Some of the businesses which failed to survive the industry's gradual transition to new ways of working had been unable or unwilling to shed obsolete ideas, and their objectives lost touch with those of the mainstream industry. The significant period for this dislocation, a split between the flexible and the relatively inflexible, came during the 1820s and 1830s when the leading firms acquired a new status, leaving behind the craftsman's workshop and modus operandi to become an entity which possessed (perhaps) premises, a power source, machine-tools, and specialist human and technological capital. From this time change needed conscious management in order to sustain the firm and ensure its future by forward planning on a new scale. This was a significant breakthrough, a new frame of mind amounting to much more than an artisan's conventional ambition of merely passing his business intact to his sons. Some within the industry were well capable of managing the new situation, ensuring their longer-term continuation and survival by consciously planning to become more technical, to adopt new working methods, managerial control and workplace organization, and eventually, when it became necessary, by developing overseas markets. The survivors showed a combination of technical, managerial and entrepreneurial skills, though still generally contained within the family firm. So although some firms perished, and it was actually only a few which thrived, the industry as a whole responded efficiently to achieve what was required of it before 1850.

NOTES:

1. Griffiths *et al* 1992, p.898.
2. Griffiths *et al* 1992, p.893.
3. Griffiths *et al* 1992, p.901.
4. Pickstone 1993.
5. Mokyr 1992.
6. Maxine Berg, 'Technological and organizational change during the industrial revolution: new questions', paper given at the Annual Conference of the Economic History Society, April 1994.

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