Frank Bunker Gilbreth: Building Contractor, Inventor and Pioneer Industrial Engineer

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Introduction

Innovation in methods of construction has occurred throughout history; methods of management, theories and principles have evolved since the industrial revolution. The Scientific Management movement had considerable political and social impact during the early years of the twentieth century. What is rarely appreciated is that one of the pioneers of Scientific Management, Frank Bunker Gilbreth had earlier achieved considerable success as a building contractor and inventor. His ideas of motion study and Scientific Management developed from his observations while a bricklaying apprentice and his subsequent experience as construction superintendent in the USA. He applied his ideas when running his own firms. His wife, Lillian, a noted psychologist, became the first professor of management at Purdue University. This paper describes both his early career as a contractor and inventor, and his second career as a pioneer industrial engineer and management consultant. His changing relationship with F W Taylor is documented. The relevance of his work to present day construction management is considered.

Frontier Society to Industrial Power

The last two decades of the nineteenth century were socially and economically a turbulent and fast changing era of American history. The frontier had only recently been tamed and Frank Gilbreth was a schoolboy when George Armstrong Custer and his entire command were "wiped out by Indian tribes led by Crazy Horse" at the Battle of Little Big Horn during the Sioux Uprising of 1876. The rapid pace of change in America can be judged from the fact that Gilbreth's wife Lillian was born only two years later, yet lived to see a man walk on the moon. The United States was urbanising and industrialising at an unprecedented pace, and with all the hectic and undisciplined recklessness that one would expect with the opening of vast new territories, huge new markets and a super-abundance of untapped natural resources.

It was onto this nascent industrial structure that the exponents of Scientific Management attempted to impose order. As America strived to move from a frontier society to a modern industrial power there was an ideal opportunity to try new methods, new ideas, and make a fresh break from the industrial practice of the Old World. Frederick Taylor, the pioneer of Scientific Management, defined it as "knowing exactly what you want men to do, and then seeing that they do it the best and cheapest way", and it was this definition that Gilbreth was to quote when he started writing on the subject himself.[1] The aim was to get any given piece of work done as quickly, as cheaply, and as efficiently as possible, and so to increase the rate of pay for the workers and the profit for employers.

Apprentice and Construction Superintendent

Gilbreth did not start out with the idea of becoming an efficiency expert as no such profession existed when he started work in 1885 at the age of seventeen. Although he had passed the

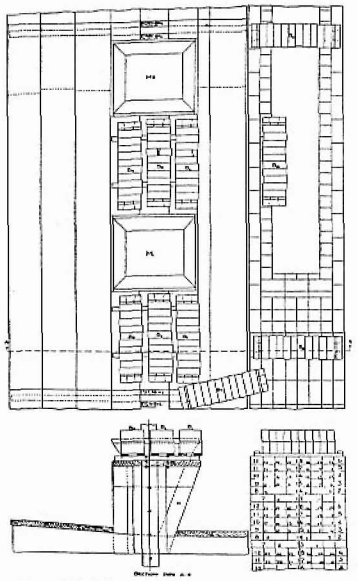


Fig. 2. — Gilbreth's patent non-stooping scaffold for bricklaying.
The numbers show the correct sequence of courses and tiers as laid from the non-stooping scaffold for the fewest, shortest, and most economical motions under the "Pack-on-the-wall" method.

Fig 1: Positions of mortar trays and palletised bricks on a non-stopping scaffold (from *Applied Motion Study*, 1917)

entrance exam for MIT he wished to start practical work as soon as possible, and so worked as a bricklayer's apprentice during the day, whilst receiving his technical and engineering education by studying at night.[2]

He was to stay with the firm he was originally apprenticed to, the Whidden Construction Company in Boston, for a full ten years. This gave him the opportunity to study the construction business from virtually every angle. He not only learned about cost estimation and accounting, but was able to branch out into such fields as railway construction. His time spent with the firm, and the rapid series of promotions his hard work and study earned him, meant that he was able to work his way "through trade after trade until he had mastered all the arts of construction."[3] It was during Gilbreth's very first weeks with the firm that he had made an observation that was to help see him on a train of thought which determined his whole approach to construction and indeed his whole life. Whilst learning the art of bricklaying from a time-served bricklayer he noticed that his instructor had used three different sets of motions, one for working quickly, one for working slowly, and yet another one for teaching apprentices. Gilbreth's curiosity was aroused, and it was through the development of motion study that he was to make his name and secure his long standing reputation; it was an event that was to influence industry and management ideology the world over. From the day he questioned why his bricklaying instructor used these methods to perform the same, supposedly simple task, he was determined to find out which was the most effective and efficient, and which of them – in a phrase which was to become the Gilbreths' trademark – was "the one best way".[4]

The rapid series of promotions that Gilbreth earned meant that ten years after starting as an apprentice with the Whidden Company he was chief superintendent with responsibility for

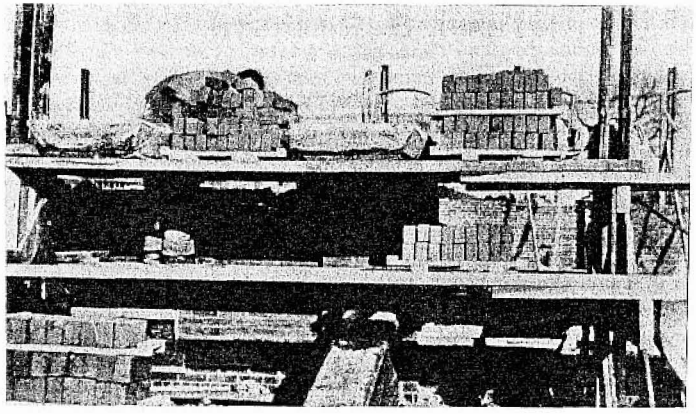


Fig 2: The non-stopping scaffold for handling packs of bricks with the fewest and shortest motions (from *Applied Motion Study*, 1917)

overseeing projects carried out away from the company headquarters. He had also won a prize from MIT for designing a new scaffold.[5] It was a "prototype" Gilbreth invention that characterised the work and ideas that were to follow, its chief characteristic being that it reduced the amount of bending and reaching that users had to perform. It became known as the Gilbreth Scaffold, and it featured in his later books (Figs 1, 2) as part of an integrated, holistic system. In the system Gilbreth's views on construction method were firmly linked to, and integrated with, the technological improvements he developed. Chief superintendent was as high as Gilbreth could reach without having to wait increasingly long periods for each successive promotion and this coupled with his own natural drive prompted him, despite an understandable nervousness, to go into business for himself.

General Contractor

In April 1895 at the age of twenty seven he set up on his own as a general contractor in Boston. His early speciality was in waterproofing cellars and in developing a reputation for "speed work" which reflected the talents and interests that he had developed whilst working his way up the ladder. He advertised by circulating a calendar showing the high tide dates for Boston and carrying the slogan "High Tides Make Cellars Wet – We Make them Dry".[6] He studied advertising and carried on an advertising campaign that increased as the business grew. (Fig 3). He soon began to take on larger projects. He determined to adhere to his practice as apprentice, foreman and superintendent, to furnish always absolutely the best materials and workmanship; to allow no job to pass his inspection that was not the very best he could make it in every possible respect. He was very successful. The high standard that he set for himself began to bring results, not only in repeat orders from former customers, but for work of every kind all over the country.

In order to make sure that the cost would be satisfactory to both owner and contractor, a Cost-Plus-A-Fixed-Sum contract was designed. This took the question of cost entirely out of the field of discussion, after it was once definitely agreed and the contract was signed. From that time on the contractor became to all intents and purposes the representative of the owner.[7] The firm moved offices to New York City in 1904 and began to obtain contracts for work along the east coast and north to Montreal, Canada, as well as throughout the south. It obtained work in

Fig 3: A typical Gilbreth advertisement (from *Quest for the One Best Way*)

California, over three thousand miles away, on large contracts following the earthquake of 1906. The type of work undertaken increased in variety and multiplicity and included dams, canals, houses, factory buildings and industrial establishments. Whole towns such as Woodland, Maine were constructed. The firm built in stone, brick and reinforced concrete, helping to create the modern industrial landscape. The firm even expanded abroad, having offices at 29 Victoria Street, London. Gilbreth developed contacts in high places and was on the list of approved contractors of both the British War Office and the Admiralty, as well as acting as a consultant to the American army in the development of coastal fortifications in New England.

The direction of a large body of men of various degrees of ability, working in different localities far removed from headquarters, required experience, intelligence and expertise in the art of handling men. The control and co-ordination of many contracts simultaneously, each different in purpose, size and construction method, required clear instructions on standards of workmanship, and systemised instructions to site management on company methods, as well as a simple and comprehensive system for reporting to head office on costs incurred and progress of works on site. Gilbreth encouraged the use of photographs for advertising, recording conditions of adjoining buildings and in case of lawsuits and of conditions at the time of an accident.

The Field System[8] contained the distillation of Gilbreth's twenty three years in the construction industry and gave methodological advice on record keeping, accounting, cost estimation and site management. It showed how loose-leaf reports from the field were made to serve the place of an elaborate set of books and eliminated the need to employ book keepers. It also presented Gilbreth's system of employee records which in such a transient field as the construction industry provided a basis for continually selecting the men who had the best

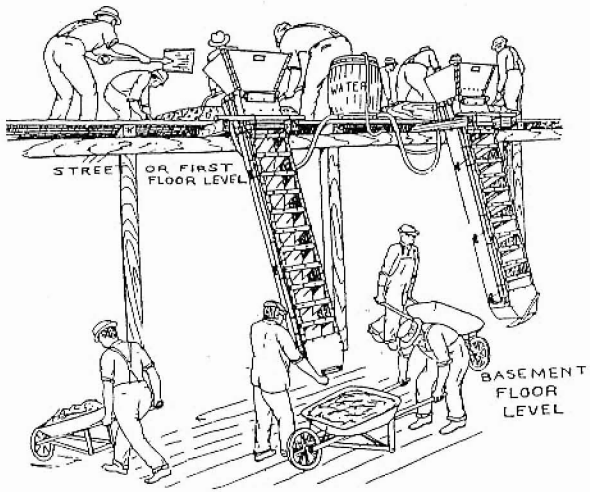
work records in the past. This worked both ways. It ensured that his firm only hired good men, and at the same time ensured that hardworking and reliable craftsmen and labourers always had a good chance of being able to find work. On reading the Field System today we may find it curiously dated. His suggestion of competing gangs of men against each other to speed up production on the assumption that men would do their work "with the same spirit of rivalry as a college trained team" seems a little naive if not physically dangerous, and his idea of dividing the gangs by race or national origin positively harmful to a cordial working atmosphere on site.

Similarly, those ideas that do seem acceptable today appear almost painfully self evident and we may wonder why they needed to be published in book form. This simply shows the immense influence of Gilbreth's innovations in the construction industry. Prior to its publication, copies of the Field System were kept locked in Gilbreth's office, and only trusted employees were given access to it, and even they had to leave a cash deposit should they take it off the premises. Rival contracting firms even went so far as to bribe Gilbreth employees for access to it and publication only added to Gilbreth's reputation in his field. One simple example should suffice to show that what are now accepted as the most obvious methods of site practice were considered as innovations when the Field System was published. Until Gilbreth's time bricks had simply been delivered to site in a cart and dumped in a heap at the feet of the bricklayers, forcing them to sort through the pile every time they collected a new batch of bricks. It was Gilbreth who began the practice of having bricks delivered on a pallet, and thus in a neat and orderly stack.

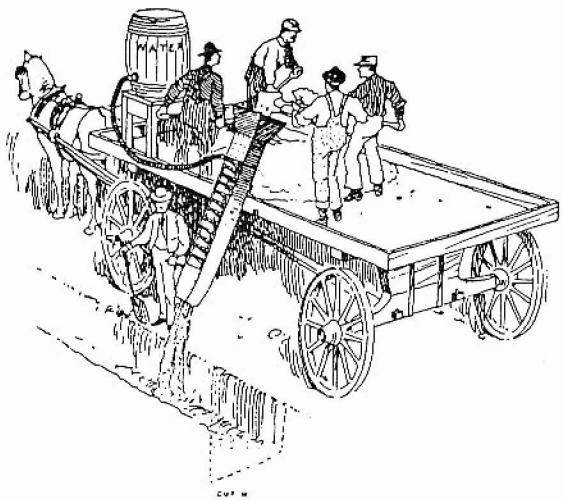
Concern with Methods of Work

His first years as an independent contractor allowed him to further develop an interest in concrete technology which had begun whilst he was still an apprentice at Whidden. Despite the fact that his name is more commonly associated with the technology of brickwork, it was in the field of concrete technology that he enjoyed much of his initial success. Indeed his *Concrete System*[9] was published the year before his perhaps more famous *Bricklaying System*,[10] and his very first article to be published in the *Transactions of the American Society of Mechanical Engineers* was on "Stresses in Reinforced Concrete Beams".[11] His *Concrete System* was innovative for in the first decade of this century concrete technology was relatively new, and Gilbreth's work provided a useful technical guide. His patents in concrete technology also secured him a reputation in the field. The work was comprehensive, including for example over 50 instructions and procedures for the mixing of concretes, ranging from the safe bracing of equipment to the best way to heat and prepare aggregates. As usual, Gilbreth's system was an integrated one and specified how to use the Gilbreth Portable Gravity Mixer.[12] The systems described by Gilbreth are detailed lists of practical procedures for use in combination with his own patented inventions. They were prepared by him at head office and distributed to the individual project sites. They are almost a report of what a successful contractor said to his site foreman and workmen on the management of sites and the production of concrete work and brickwork. They contain his mandatory orders, his cautions, his instructions on methods of work to achieve best quality and best speed of output. When a certain way of doing a thing was fixed as the company standard then a written instruction would be issued. The rules gradually accumulated.

Employees were encouraged, paid money and given public recognition for suggestions that would improve the systems. They were required to follow the rules to the letter unless they had received written permission to suspend them; employees who failed to abide by the rules were warned that they would not receive promotion.



Figs 4-5: Different ways of using the Gilbreth Portable Gravity Mixer (from Jane Morley in *Concrete International*, 1990)



Inventor of Construction Equipment

As his wife wrote in her biography of him: "He invented concrete mixers, conveyors, reinforcement – everything that had to do with making concrete construction both a science and an art". All in all Gilbreth filed 14 construction related patents, the subject of recent research by Jane Morley.[13] Perhaps the most notable of his early ones was his Portable Gravity Mixer, for which he filed a patent in 1899. Capable of continuous, rather than batch mixing, the Gilbreth

Portable Gravity Mixer was an ingenious variation of hand-mixing methods in which a line of men shovelled materials together along the length of a board, turning and mixing the concrete as it moved towards the desired area on the site. The mixer consisted of a vertical chute of variable length made of wood or sheet metal with a hopper at the top to receive the dry cement, sand and aggregate. A pipe, perforated on its underside and running across the front of the chute under the hopper, sprayed water on the materials after they had entered the body of the chute, more or less pre-mixed. The wet materials were mixed by inclined pins or rods protruding from the inside back of the chute and attached to crossbars running at intervals down its front. These pins divided the materials, repeatedly throwing them against each other and into the back of the chute as they travelled down its length; the back of the chute was curved to form a trough to better catch and hold the materials as they moved. For best results, the mixer was to remain as horizontal as possible so that materials flowed slowly yet freely. The mixer's front panel was left essentially open so the quality of the mix could be monitored, the view of the interior obstructed only by the crossbars that held the ends of mixing pins. With an open front and removable mixing pins, the mixer was easily cleaned (Figs 4,5)

Gilbreth introduced several improvements in a second patent filed in 1901. The contiguous chute was replaced by a series of sections fastened together that could be added or removed depending upon the length required for adequate mixing and a second water pipe was added for the lower sections. The mixing pins were secured to the front crossbars in a way that allowed them to vibrate, and vibrating internal deflectors helped to throw the materials to the back of the chute. At the bottom of the chute, a swinging door held the concrete in the mixer prior to release. In this second model, the vibrating pins and deflectors improved the mixing of the materials and vibration was increased further when the entire mixer was shaken by workmen or by a stationary steam engine. It was used in projects as diverse as the New York Subway system, the London and India Docks and the Buenos Aires sewage system.

Gilbreth advertised that the mixer could be set up in less than eight minutes and pay for itself in eight months. Costing under $500 it was one of the cheaper mixers on the market at the time, but in an independent review in *Engineering News* in 1903 it came in next to last out of 12 tested patent mixers. Gilbreth was obviously disappointed in this result. Gilbreth had one of his own engineers write articles in trade journals recommending the mixer. In 1907, Sanford Thompson, an associate of both Gilbreth and of Frederick Taylor, indeed he first introduced them in December of that year, wrote Taylor a letter that included the following passage: "He is a great bluffer and has a reputation of not always being 'on the square'. He once told me just before we got our book on concrete out that when it was published I would probably receive suggestions from manufacturers of mixing machines for making a test of their machines and if in a competitive test his mixer came out ahead he would give me $1000."[14] Clearly he was not a man to accept defeat easily!

The Portable Gravity Mixer however represented only a small part of the growing Gilbreth empire. Apart from the original contracting company set up in 1895 there existed a number of subsidiary companies with responsibility for different aspects of the construction business. The Underwriters Engineering and Construction Company, for instance, was an "in house" engineering consultancy mainly responsible for concrete work, and the Corrugated Concrete Pile Company specialised in concrete pile foundations work.[15] This represented yet another Gilbreth innovation and one that was universally praised by the contemporary technical press. His patented concrete pile system was an improvement on existing methods in that it could be cast on site, manufactured above ground, and thus tested and inspected before driving. Gilbreth filed this patent in 1905, exactly ten years after starting his own business. He had been very successful.

Meeting with Frederick W Taylor

Gilbreth's interests in motion and efficiency which had begun twenty years earlier had not diminished, and when Sanford Thompson introduced him to Frederick Taylor in the Engineering Societies Building in New York in December 1907, it acted as a spur to his enthusiasm.[16] Both were aware of the other's work. Gilbreth had read Taylor's pioneering work on what was to become known as "Scientific Management" (the term was coined in 1910) and had referred to it as a "work of genius". Taylor for his part had written a text on plain and reinforced concrete[17] in 1906 which had referred to Gilbreth's expertise in the field. This made for an initially cordial relationship. Taylor saw Gilbreth as a useful addition to his growing circle of business experts, and Gilbreth saw Taylor as a fellow traveller on the road to industrial efficiency. Taylor's method of timing how long it took to do work was new to Gilbreth while Gilbreth's method of studying motions as part of better methods leading to "The One Best Way to Do Work" was new to Taylor. Each was enthusiastic about what the other had to offer. Indeed Taylor had devoted eight pages of his magnum opus *The Principles of Scientific Management* entirely to Gilbreth's system of bricklaying.[18] Gilbreth's initial meetings with Taylor soon convinced him to introduce Taylor's notions of business efficiency based upon time study and incentive payments into his own contracting company. They coincided so closely with his own ideas that it seemed only natural that they should work in the construction industry.

Introduction of Time Study to Gilbreth's Firm

In November 1907 Gilbreth allowed Thompson to make time studies of his employees and was pleased enough with the results to install selected parts of Taylor's incentive wage scheme on a factory he was constructing in Gardner, Massachusetts, in the following April. There were immediate problems however. Delays and confusion over the new system, and especially over the incentive pay scheme, meant that the unionised bricklayers were soon voicing their discontent. By May they went on strike and Gilbreth was forced to withdraw the system.[19] However by November he was ready to introduce a similar system to another of his construction projects, a factory in Chelsea near Boston. This time he had been involved in prior consultations with the unions, and the incentive wage scheme went ahead without any trouble. The main bone of contention had been the use of Taylor's system of timing employees with a stopwatch. Once Gilbreth agreed to drop the idea the unions were fairly co- operative. Quite possibly Gilbreth's years of experience as a bricklayer himself had helped him to see things from both sides of the fence – certainly he thought so himself. An entry in his diary when he installed the new system at Chelsea reveals that he told his workers that "I have been a union man and I know what is good for you". He was clearly was not pleased with the fact that he had had to concede part of his system to get the rest accepted by the unions. An entry for the same day notes his determination to "raise the pay of the bricklaying mechanics throughout the United States in spite of the ignorant pig-headed men in Gardner"![20]

Despite his frustration with his employees Gilbreth's attitude towards unions was relatively liberal for his time. Certainly he had a much more tolerant attitude than Taylor who had served his apprenticeship in the tough world of the steel mills of the 1870s and consequently considered hard work in harsh conditions to be the norm, and had little sympathy for anyone who thought otherwise. Taylor went so far as to recommend all college graduates, whatever their vocation, to spend at least twelve months at the end of their freshman year "in actual hard work ... under careful and constant supervision". The article in which this advice appeared was brusquely entitled "Why Manufacturers Dislike College Graduates".[21] In spite of these hiccoughs the installation of a combination of his own and Taylor's efficiency systems seemed to be going well

enough, and Gilbreth's increasing successes and growing reputation meant that in the same year he was able to publish his first two books, the *Field System* and *Concrete System*. They both extolled the virtues of efficiency, rationalisation and systematic procedure.

Recognition of Motion Study

It was the publication of Gilbreth's *Bricklaying System* in 1909 that set the seal on his reputation. Bricklaying had, after all, been the field in which Gilbreth originally devised and developed his theories and systems of motion study. His studies of bricklayers and their movements and motions convinced him that even this oldest, most traditional of crafts could still be open to innovation and improvement. In laying exterior bricks for example he reduced the number of motions employed from 18 to four-and-a-half per brick laid, and on interior bricks from 18 to two. This resulted in an increase from 120 to 350 bricks per man per hour![22] He described the methods of work organisation to achieve these staggering improvements. They included the delivery to site of bricks on small pallets, the use of conveyor rollers for off-loading from wagons and well balanced hand barrows for moving bricks about the site. (Fig 6)

Fig 6: The two-wheeled trucket for carrying 12 brick packs. This trucket is so perfectly balanced that it causes less fatigue than an ordinary wheelbarrow (from *Applied Motion Study*, 1917)

It was in this work that Gilbreth first published his ideas on the concept of motion study. He predicted that "the motion study in this book is but the beginning of an era of motion study" and provided a series of charts and tables showing the method by which he expected to reduce the number of motions that bricklayers used. He was careful to emphasize that the intention of his system was not only to increase the productivity and profit of the employer; his experience at Gardner and Chelsea had taught him it was necessary to secure the co-operation – or at least to avoid the hostility – of the labour unions. "It is our intention", he stated, "to increase the wages of those men who lay brick in the manner described in this system".[23]

Once again the concept was of an integrated and interlocking system. *Bricklaying System*, *Field System* and *Concrete System* were all designed to be inter-related, and to integrate with Gilbreth's own innovations. *Bricklaying System* specifically referred to the use of the Gilbreth's Scaffold and the Gilbreth Packet System of brick delivery in the same way that *Concrete System* had referred to the use of the Gilbreth Gravity Mixer.[24]

Gilbreth's success with his publications and his very enthusiasm for developing Scientific Management were however beginning to be seen as a potential threat by Taylor and his circle of close friends. Gilbreth was only a recent addition to the clique, and it appears that Taylor did not fully trust him. Taylor's private correspondence during November 1908 (the time when Gilbreth was installing part of the Taylor System in his job at Chelsea) indicates a concern that Gilbreth was out to make "a further reputation for himself" and that he was therefore "not a man whom it would be well to place a good deal of dependence upon".[25] Despite such misgivings the two men seem to have co-operated well enough. Although some degree of mutual mistrust did exist it was not enough to sour a close working partnership.

A Working Partnership with F W Taylor

In 1910 both men were part of a delegation from the American Society of Mechanical Engineers which convened in Birmingham (England). Taylor lectured on both his own and Gilbreth's innovations in time study and motion study, but was met with a lack of enthusiasm.[26] British businessmen seem to have been initially slow to realise the importance of Gilbreth's and Taylor's work. The July 1911 edition of the *Review of Reviews*[27] seems to have been one of the first journals outside those specifically confined to engineering to chart the growing awareness of the potential of Scientific Management (as it was by then called). Even then the review consisted of only 150 words.

The two men were also called as consultants on the "Eastern Rates" case in 1910. The matter at issue was the right of the railroads to pass on wage increases direct to the consumer in the form of higher freight rates. The lawyer who contested their right to do so, one Louis D Brandeis, did so on the grounds that the railroads were inefficient, and that if they had used the Taylor system, could have easily saved more than the money they had lost in paying higher salaries.[28] Brandeis won the case, which had caught the popular imagination, and helped get Taylor's and Gilbreth's ideas noticed. The term "Scientific Management" itself had been coined during the case in order to give a memorable title to the series of principles involved. The press picked up the title, and Gilbreth was fully aware that the case was "going to put Scientific Management on the map".[29] He became one of the prime organisers in consolidating the ground that Scientific Management had won through the case, and in November 1910 he met five other enthusiastic men in New York to form a permanent society to promote the movement. This initially consisted of an informal group with no name and no meeting hall, but in December 1911 the "Society to Promote The Science of Management" was formally inaugurated.[30] Surprisingly Taylor was against it, even though Gilbreth wanted to call it "Taylor Society" (which it was after Taylor's death in 1915). Taylor believed that a society *within* the American Society of Mechanical Engineers should be formed, and that a separate one might conceivably fall into the "wrong hands" and go its own separate way.[31]

In the meantime, despite lecture tours, legal testimonies and forming the Society, Gilbreth still had his ever-growing contracting business to run. Although his business was comfortably profitable he was still having union problems when it came to applying either his own or Taylor's work methods. In early 1911 he had taken on a contract to build a paper mill for the Union Bay Company at Hudson Falls, New York. He had implemented his full arsenal of management and production techniques, but it was his production-related pay scheme that this time caused the problem. Union leaders argued that pay varied from 55 cents to 75 cents an hour, and that this was divisive, and should be scrapped in favour of a standard 65 cents an hour per man. Once again Gilbreth was forced to back down and drop his beloved bonus pay system. This time however, due to the recent publicity of the "Eastern Rates" case he enjoyed a good deal of public support and *The New York Times* went so far as to give him front page billing, and in the same week devoted their weekend supplement to his innovations and ideas.[32]

This seems to have been a turning point. Faced with continued opposition from the very unions from which he felt he should be getting the most support and with national publicity for his work on business efficiency and productivity at the maximum, he withdrew from his construction business. By the end of 1911 he had been happily married for seven years to a wife whose interests complemented his own, and was beginning to raise a young family. We do not know how he disposed of his substantial business or his reasons. His wife in her biography of him suggests a combination of: the death of a daughter; the desire to move house; her desire to study for a PhD; a realisation that their best work lay in the field of handling the human element, and feeling that contracting was failing to hold its own on the professional scale while management engineering was bound to rise in importance and dignity. At any event, he took the momentous decision to leave the contracting business altogether and become a full-time management consultant. That same year had seen the publication of his most famous book to date, *Motion Study*, in which he summarised and consolidated his ideas on improving productivity by careful analysis of the motions involved in a given task. Such was the growing popularity and potential of Scientific Management that he must have considered himself sufficiently well placed to turn what had been an interest into a profession.

Pioneer Industrial Engineer and Management Consultant

Gilbreth's first large scale job was ironically both a resounding success and consequently the cause of a good deal of trouble. In May of 1912 he began a contract as an efficiency consultant to the New England Butt Company of Rhode Island. He was assisted by other associates of Taylor who were themselves keen to further the cause of Scientific Management, and the project was completed by June of the following year, considerably ahead of schedule.[33] Gilbreth was delighted. Taylor and his associates had mixed feelings. Although they admired Gilbreth's work on bricklaying they had become increasingly concerned that Gilbreth was out to make a name for himself. Taylor's personal correspondence reveals a doubt as to Gilbreth's commitment to the "Taylor System" of Scientific Management, and a belief that Gilbreth might seek to take more than his fair share of credit.[34]

This distrust came to a head on Gilbreth's next large contract as a Scientific Management consultant, for the Hermann Aukum company of New York who manufactured handkerchiefs. In March of 1914 Milton Hermann visited Taylor to complain that Gilbreth was overcharging him for his advice, which in any case was doing the company very little good. Gilbreth disagreed, arguing that he had reduced the motions necessary to fold and pack handkerchiefs from 150 to 16, and that Hermann was simply unwilling to give increased pay for increased output. Taylor sided with Hermann and Gilbreth was replaced by Horace Hathaway, an associate of Taylor of longer standing than Gilbreth. Gilbreth was naturally furious, and although he and Taylor maintained an outward show of loyalty (simply for the sake of not publicly discrediting the whole Scientific Management movement) it was the end of any further friendly contact between the two men.[35]

The incident at the Hermann Aukum Company, however, had simply served to highlight the points of departure of Gilbreth's work from that of Taylor. Taylor, with justification, considered himself the pioneer of Scientific Management. It was he who had laid the foundations that Gilbreth and others were to build upon. The problem was that this view of himself as the leader of the field meant that Taylor was unsympathetic to those who developed his work (Gilbreth was by no means the only man who started from Taylor's original premises but eventually found them too narrow).[36] Taylor's work had consisted simply of timing how long it took a man to do a particular task. Gilbreth went a crucial step further. He sought to time the individual motions that went into a task, and thus provide an infinitely more detailed and precise guide to how a given task was performed and consequently how it could be improved upon.

The Split with Taylor

Taylor had been singularly unimpressed with these innovations, and much to Gilbreth's disappointment had simply claimed they were a minor extension of his own work, and although they were "good where one was investigating the minutia of motion" had little relevance to "proper" efficiency analysis. Gilbreth believed that Taylor had missed the point entirely, and that these "minutia of motions" held the key to detailed, scientific analysis of work studies.[37]

Gilbreth's work from 1911 onwards had started to leave Taylor's simple stopwatch studies far behind. He was one of the very earliest advocates of the then infant motion cinema camera as a tool of motion analysis. It naturally provided a permanent record which would be studied again and again and frame by frame. To overcome the variable speed of early handworked cameras Gilbreth developed the "microchronometer", a clock placed within the picture frame capable of recording time to one two-thousandths of a minute. Workers being studied were placed in front of a gridded scaled background and had minute electric lightbulbs attached to each finger, in order to more precisely follow each movement made in a given task. The result Gilbreth christened a "cyclegraph" film. It was improved by putting an interrupter circuit on each bulb which caused it to flash on and off at a given rate, and with the aid of the gridded background and microchronometer this provided extremely accurate measurements of the time taken for any given movement. This "chronocylograph" was developed by means of two linked cameras used simultaneously into the "stereochronocyclograph". Gilbreth used his films to make 3-D models of given movements and the pattern a hand or finger might follow in the performance of a given movement, again using a gridded background for measurement purposes (Fig 7). He and his wife devised an entire vocabulary of graphic symbols, so that movements could be recorded. Motions like "hold", "reach" and "grasp" were all given a visual symbol to allow a graphic presentation of the results the films generated.[38] Taylor was proved wrong in his assumption that observing such

Fig 7: Frank Gilbreth with a three dimensional wire model of motion paths based on stereoscopic chronocyclographs (from *Quest for the One Best Way*)

minute motions was irrelevant. Eighty years later Gilbreth's film analysis technique is still in use to train athletes and others and to dissect and compare their tiniest motions.

The examples given in *Motion Study* all pertained to the art of bricklaying, but as Robert Kent (editor of *Industrial Engineering* magazine) wrote in the book's introduction "the principles laid down were applicable to every trade and industry". Gilbreth readily confirmed this; his ideas were "not for one class, they are not for the trades only, they are for the offices, the schools, the colleges, the households and the farms".[39]

The Influence of Lillian Gilbreth

Motion Study both stuck to the direct and precise stylistic format of Gilbreth's previous works such as *Field System* and *Concrete System*, and also showed the increasing importance of his wife Lillian's work to the field of Scientific Management. Frank's concise instructions were still there, for example in demonstrations of where a bricklayer should stand in relation to the mortar tray, and how the patent Gilbreth Scaffold should be deployed, but there are clear indications that Lillian made important contributions to the book. The importance of colour in the working environment was emphasised, not only for the convenient labelling of tools, but also for its "stimulating effect" upon workers. Lighting, heating and ventilation were all discussed, and it was emphasised that each could "greatly increase the workman's comfort". Even music at work was said to be something for employers to look into, for its "inspiring and stimulating effect".[40] All these factors are taken for granted today, but in 1912 they were distinctly avant-garde, and considered to be rather indulgent and pretentious experiments. In a working environment in which ten hour days and six day weeks were the norm, hard headed businessmen were sceptical about gramophone music for their workers, and it is a tribute to the Gilbreths that they succeeded in getting their message across. The reason that Frank Gilbreth was able to do so was that his reputation in the construction industry was rock solid. His firm had overseen contracts all over the United States as well as Europe, and had an impeccable reputation for efficiency, reliability and profitability.

Gilbreth's move from contracting to consultancy allowed his wife to take a greater interest in her husband's work, and apart from the *Primer of Scientific Management* published in 1912 all subsequent books were published under both their names. Indeed the field of management study as a whole is fortunate that the Gilbreths' interest and talents dovetailed so well. Daniel Wren, a prominent management historian, describes their relationship as "reminiscent of the Curies".[41] Lillian combined raising their children with writing her PhD on "The Psychology of Management" (eventually published in its own right in 1914). Frank's steadfast and undoubted reputation as a hardnosed construction engineer, self-made man, and no-nonsense building contractor meant that Lillian's insights into work psychology and ergonomics were able to get exposure that they might otherwise not have. Certainly her ideas seem to have slipped in "on Frank's coat tails" to begin with, but they increasingly gained acceptance in their own right. By 1935 Lillian had become Professor of Management at Purdue University, and had blended efficiency in the workplace with a humanism and concern for the individual to produce a synthesis of ideologies that still informs mainstream management thought today. Clean, healthy, well lit and well ventilated workplaces with staff canteens and company sports facilities, are like bricks stacked on pallets, something we take for granted today, but were first suggested by the Gilbreths. Similarly, their emphasis on safety in the workplace was pioneering in this time, but now forms part of standard industrial practice and is codified in law.

Frank's theories of motion study and business efficiency departed from Taylor's in the respect they paid the worker as an individual. Taylor preached a doctrine of hard work by hard men in a hard environment, and he respected "the real monotonous grind which trains character". He consequently had very little tolerance for trade unions, regarding them at best as a necessary evil,

and more commonly as an institution that did nothing but disrupt his plans. Gilbreth had often locked horns with unions himself whilst still a contractor, but was not as absolute in his conviction that they were nothing but a hindrance. His attitude to unions seems to have been ambivalent – on the one hand he had been a union man himself whilst a bricklayer, yet on the other had found that unions were often reluctant to embrace the new systems of management he advocated.[42] His stance seems to have been that it was perfectly right that unions should exist for the purposes of collective bargaining, but that such negotiation should stop short of being able to interfere with the implementation of Scientific Management techniques, and that no one could "install Scientific Management and similarly participate in a debating society".[43] The whole point of Scientific Management, argued Gilbreth, was that it set pay rates and productivity bonuses on a scientific and logical basis (the result of motion studies) and that workers would therefore be asked to work (and be paid) on a fair, reasonable and straightforward basis. If this was interfered with by unions it would simply disrupt the "square deal" that "does and must exist" under his system. Managers were warned as strictly as unions that their interference in the system would only be detrimental, and labour leaders were advised not to oppose Scientific Management. Rather, they were to study it themselves to make sure they were getting the best they could and that managers were implementing the system honestly and efficiently.[44]

It is perhaps ironic that a system of business efficiency developed by a self-made man who believed firmly in the God-given right of every American to turn an extra dollar should be enthusiastically received by the Communist party. By 1915 even Lenin had read Gilbreth's work on motion study and described it as "an excellent example of technical progress under capitalism toward socialism".[45] Frank and Lillian continued to research and publish their findings at a fast pace. Lillian's work on Management Psychology had proved to be a success, and the years 1916 and 1917 saw the publication of *Fatigue Study* and *Applied Motion Study* which again primarily used examples from the construction industry to illustrate their message.[46] By now the Gilbreths' work had become a small library on construction, efficiency and management, dealing with everything from the effects of fire on various building materials to the best way to cope with the idiosyncrasies of individual workers.[47] The central message was that Scientific Management was a precise science, "the result of accurately recorded, exact investigation", and that it could be applied to any industry, and integrated with the Gilbreths' recommendations on almost every aspect of business, including the training of apprentices, systematic promotion plans, productivity charts, health and safety initiatives, bonus pay schemes, employee motivation and management organisation.[48] Frank's prodigious output on management theory did not prevent him from maintaining his interest in the construction and engineering industry. Even after becoming a management consultant he submitted over twenty published articles to the American Society of Mechanical Engineers ranging from the standardisation of engineering tools to the manufacture of cement.[49-50]

War Service

By 1917 his massive output in construction, engineering and management had secured him a national and international reputation and when the USA joined the First World War he was commissioned into the army and put his skills into the war effort. These included, for instance, using his motion-analysis films to help speed up the rate that soldiers could be taught to assemble machine guns. More disturbingly perhaps they included the use of Gilbreth's film expertise to produce military propaganda films designed to train recruits to hate the enemy.

His posting as a major in the Army Engineering Corps came about from his typically direct attitude.[51] The day America entered the war he sent a telegram to President Wilson which read "Arriving Washington, 7.03 pm train. If you don't know how to use me I'll tell you how". He was met off the train and taken to the War Department! After putting much effort into efficient

machine-gun assembly Frank and Lillian undertook considerable research into time and motion studies of what could be done by war-injured veterans. The work by the Gilbreths did mean that veterans thereafter were able to choose a wider range of occupation than before and their rehabilitation programmes were systematic and rational, rather than ill-considered and piecemeal. Typically, the Gilbreths did not confine themselves to half-hearted studies, but in 1920 published a sizeable and well-researched book on the subject. Sensibilities were not spared. They were, for instance, quite sure that the work of a dental assistance could be performed "by a one-eyed, one-armed, legless cripple.[52]

Family Man

The Gilbreths' contribution to the construction industry, the engineering profession, the science of management and industrial productivity should not however blind us to the fact that they were real people (Fig 8). It may be assumed that such hardworking and dedicated professionals must have been quite dour, but this was far from the case. Two of their twelve children combined to write two best selling books on the necessarily bizarre life of a family of fourteen and both were made into popular comedy films.[53] The problems involved in taking a dozen children on picnics, of arranging a rota system for the bathroom and of often moving house can be easily imagined. Charts were set up in the bathroom for each child to tick once they had brushed their teeth and jobs done for extra pocket money had to be tendered for in a sealed bid! The whole family existed in a constant state of organised chaos, and both books give a picture of a close-knit group in which only those with a tremendous sense of humour and a fondness for the absurd could survive.[54]

Fig 8: The Gilbreth Family in c. 1920 (from *Quest for the one Best Way*)

A Premature Death

Frank was not allowed the reward of seeing his family grow up; he died suddenly in 1924. At the time of his death he was acknowledged as the first person to recognise the value of the moving film camera as an aid to industry[55] and as a leading figure in the fight to have management recognised as a major division of engineering. "His progressiveness was labelled dangerous radicalism by some of the older members, but it is worthy of note that things that were radical when he first advocated them are commonplace today." His obituary noted that "His earnestness in debate in the professional sessions (of Spring and Annual Meetings of the American Society of Mechanical Engineers) was only equalled by his entertaining reminiscences and love of fun ..." Although extensive publications on motion study and Scientific Management and co-authorship with Lillian were noted, his early inventions are not mentioned and his early business success was dismissed in two sentences. It would seem that the mechanical engineers' view of the status of contracting has remained unchanged in seventy years.

The Gilbreth approach to business efficiency has had enormous effects. His work in the construction industry left him with over a dozen patents filed under his name, and he made a significant individual contribution to concrete technology, and especially to the field of bricklaying. Between them the Gilbreths published over 60 books and articles, and their contribution as catalysts to the field of management, efficiency and business organisation is incalculable. Their works were translated into over a dozen languages and the repercussions of their ideas were enormous. Even the design of the desk in your office is a result of the office efficiency movement which grew up from Scientific Management.[56] Whether it is a prototype design for fireproof concrete, a better way to arrange scaffolding, or the model for Soviet Russia's first Five Year plan, it has something to do with Frank Gilbreth and his search for "The One Best Way".

Relevance Today

Gilbreth's research into bricklaying has provided the basis for a series of studies in the UK which have extended over eighty years, both at the Building Research Station[57-59] and at the University of Liverpool.[60-63] During the 1960s when brickwork was perceived as being threatened by replacement by prefabricated components a brochure[64] aimed at reducing the cost of brickwork, based almost entirely on work study techniques deriving from Gilbreth's work, was published but had little practical impact on site works. In Holland the Stichring Arbeidstechnisch Oonderzoek Bouwnijverheid (Research Institute for Labour Economy in the Building Trade) continues Gilbreth's work into all building operations. In particular it has shown, using work study techniques, that for modern thin walled brickwork the use of profiles to locate the corners of brickwork produces significant labour economies.[65]

A trend in the UK over the past twenty years is for many building contractors to reduce the size of their employed operative labour force, preferring to concentrate on financial management linked to the co-ordination of trade contractors or even separately employed individuals. The perception of construction management by building contractors has changed from a primary concern with work organisation and labour management to a concern with financial management and the co-ordination of trades contractors. This undoubtedly reduces the risk in variability of performance of individuals and initially avoided liability for Selective Employment Tax. Although this tax is no longer levied, it prompted a change which has proved irreversible. The consequence of these changes is a lack of detailed interest, on the part of main contractors, in how the operatives actually work; the optimum workplace, devices and power to reduce their effort and overcome fatigue, and lack of

interest in training for production. Most trade and subcontractors lack the organisation, resources and expertise to fill the management gap left by the withdrawal of larger contractors from responsibility for labour productivity; they simply "muddle through".

When studying the writings of the Gilbreths one is aware of their recognition of basic concepts concerning the mutual responsibility of the employer and employee: they would not have recognised the piece work (labour-only) culture prevalent in Britain today. Though the impermanent nature of employment has not changed they placed greater emphasis on "steady pay men" and apprenticeship training than do present day main contractors. They recognised the importance of feelings, sentiments and emotions in the motivation of individual workers and while adapting the slogan "the one best way" acknowledged that the best way may be different for different people. Frank recognised that bricklayers, if in the habit of working inefficiently, bending, stretching and using many movements, might not be able to modify their working practices. He emphasised training apprentices in the best, scientifically analysed and developed working methods and was a researcher and teacher who encouraged through publication and personal habit the search for the one best way to perform a task as a means of greater production.

Gilbreth's motivational techniques of strength and speed competitions grouping men and boys by religious and national origins might be regarded as offensive by some today. Nevertheless, his introduction of bonus payments and his awarding tools as prizes and emphasis on simple motions would be widely appreciated. His early work on concreting system showed concern for design with production in mind – Buildability. His field system for maintaining records provides a basis for what have more recently become known as Quality Management systems. This, combined with his recognition of the importance of the engineering dimension in building, provides a focus for the current debate "that building is an engineering discipline".

Almost all of Gilbreth's ideas on training, mechanisation, management, incentives, materials distribution, work organisation for minimum effort and physical movement remain valid. He always followed the scientific method: select a topic for investigation, observe, record, develop a hypothesis, conduct an experiment, analyse results, install and re-assess to improve the efficiency and effectiveness of the process. He was fully aware of the literature and clearly stimulated by his wife's interest in psychology.

Authors' Footnote

The precise reasons for Gilbreth retiring from contracting to become a management consultant may well never be known. His early business success is evident from his forming his contracting company and its subsequent expansion. The history of his company and what happened when he resigned does not appear to be documented. Most accounts concentrate on his conflicts with Taylor and his collaboration with his wife.

The Gilbreth papers are now archive material at Purdue University. In the course of preparation the authors have received helpful correspondence from Ms Jane Morley, Department of History and Sociology of Science, University of Pennsylvania. She comments that the Gilbreth papers are "A huge, rich, idiosyncratically arranged collection". There would appear to be scope for original archive research into Gilbreth's contracting firm.

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References

1. Frederick W Taylor, "Shop Management". Paper presented to the American Society of Mechanical Engineers (ASME), 1903.
2. Claude S George, *History of Management Thought* (New York, 1972), p99.
3. Leon Urwick, *Making of Scientific Management* (Vol 1), (1987), p129.
4. Lillian M Gilbreth, *Quest for the One Best Way* (Easton, NY, 1973), p16.
5. Ibid., p14.
6. Ibid., p20.
7. Ibid., p21.
8. Frank B Gilbreth, *Field System* (New York, 1908).
9. Frank B Gilbreth, *Concrete System* (New York, 1908)
10. Frank B Gilbreth, *Bricklaying System* (New York, 1909), p71.
11. Frank B Gilbreth, *Stresses in Reinforced Concrete Beams* Transactions of the American Society of Mechanical Engineers, 31 (1909), p543.
12. Gilbreth, *Concrete System*, Directive 221.
13. Jane Morley, 'Frank Bunker Gilbreth's Concrete System', *Concrete International* (USA) No 11, Vol 12 (Nov 1990), p57.
14. Charles W Wrege, *Frederick W Taylor: The Father of Scientific Management* (Irwin, Illinois, 1991), p212.
15. Morley, 'Frank Bunker Gilbreth's'.
16. Daniel Nelson, *Frederick W Taylor and the Rise of Scientific Management* (Madivan, 1980), p131.
17. Frederick W Taylor, *Principles of Scientific Management* (New York, 1911).
19. Wrege, *Father*, p214.
20. Milton J Nadworny, *Scientific Management and the Unions 1900-1932* (Cambridge, Mass. 1955), p22.
21. Samuel Haber, *Efficiency and Uplift: Scientific Management in the Progressive Era 1890-1920* (Chicago, 1964), p7.
22. George, *History* p49.
23. Gilbreth, *Bricklaying System*, p16.
24. Ibid., p14.
25. Milton J Nadworny, 'Frederick Taylor and Frank Gilbreth: Competition in Scientific Management', *Business History Review*, 31 (1957), p23.
26. Urwick, *Making*, p94.
27. *Review of Reviews* (July 1911), p71.
28. Daniel T Rogers, *Work Ethic in Industrial America 1850-1920* (Chicago, 1981), p56.
29. Wrege, *Father*, p217.
30. Ibid., p218.
31. Nadworny, *Unions*, p47.
32. *New York Times* (29 March, 2 April 1911).
33. Edna Yost, *Frank and Lillian Gilbreth: Partners for Life* (New Brunswick, 1949), p217.
34. Nadworny, 'Frederick Taylor', *Business History Review*, p23.
35. Wrege, *Father*, p219.
36. Gerald A Cole, *Management Theory and Practice* (Guernsey, 1982), p23.
37. Haber, *Efficiency*, p38.
38. Gilbreth christened these motion units "Therbligs" (virtually "Gilbreth" reversed). See Frank B Gilbreth & Lillian M Gilbreth, *Applied Motion Study* (New York, 1917), Chap. 3.
39. Introduction to F & L Gilbreth, *Motion Study*.
40. Ibid., Chap 3.
41. Daniel Wren, *Evolution of Management Thought* (New York, 1979), p170.
42. Nadworny, *Unions*, p54.
43. F B Gilbreth, *Primer of Scientific Management* (New York), 1914, p85.
44. Ibid., p 87. L M Gilbreth, *Psychology of Management* (New York, 1914), p121.
45. For an analysis of the dialogue between American Communists and advocates of Scientific Management see: Judith A Merkle, *Management and Ideology: The Legacy of the International Scientific Management Movement* (Berkley, 1980). The quotation by Lenin is from this work, p103. Gilbreth was even sent a presentation copy of his own work (in Russian) by the Central Institute of Work in Moscow. Yost, Partners, p290. Also see Haber, *Efficiency*, pp102- 38.
46. F B & L M Gilbreth, *Fatigue Study* (New York, 1916). F B & L M Gilbreth, *Applied Motion Study* (New York, 1917).
47. L M Gilbreth, *Psychology*, Chap 3.
48. F B & L M Gilbreth, *Applied Motion*, p3.
49. F B Gilbreth, 'Session on the Standardisation of Tools', *Journal of the American Society of Mechanical Engineers*, 44 (1923) p727.
50. F B Gilbreth, 'Symposium on Cement Manufacture', *Transactions of the American Society of Mechanical Engineers* 33 (1911), p186.
51. F B Gilbreth (junior) & Ernestine Carey (nee Gilbreth), *Cheaper by the Dozen* (New York, 1948), p74.
52. Gilbreth & Carey, *Cheaper*, F B Gilbreth & E Carey, *Bells on Their Toes* (1950).
54. Gilbreth & Carey, *Cheaper*, p2, 24, 27, 35-7.
55. Anon., 'Necrology: Frank Bunker Gilbreth', *Transactions of the American Society of Mechanical Engineers* (1924), pp1300-2.
56. Adrian Forty, *Objects of Desire: Design and Society 1750-1980* (1986), p122-40. The ramifications of the Gilbreths' work were many and varied. As Forty points out the Scientific Management movement fostered an entire industry geared to efficient design of office space and office furniture. The results of Gilbreth's thinking eventually spread all over the world. See W A Lewchuck, 'The Role of the British Government in the Spread of Scientific Management and Fordism in the Interwar Years', *Journal of Economic History* (1984), p355. Lillian Gilbreth even marketed the world's first tampon. Vern L Bullogh, Merchandising the Sanitary Napkin: Lillian Gilbreth's 1927 Survey, *Signs* 10 (1984), p615.
57. D G R Bonnell, D W Aldred & L W Baldwin, 'Methods of Bricklaying', *Builder* 167 (1944), p75-7.
58. W Kinniburgh & L S Vallance, 'A Work Study in Bricklaying', *National Building Studies Technical Paper 1* (1948).
59. J F Nuttall, 'Production experiments in brick and block laying', *Work Study* (9-20 March 1968).
60. D J Mortlock & B Whitehead, 'Productivity in Brick and Block Construction – A literature survey', *Building Science* 4 (1920, pp179-97.
61. B Whitehead, 'Productivity in Bricklaying', *Building Science* 8 (1973), pp1-10.
62. B Whitehead, D J Mortlock, D W Holloway, M W Jepson, D J Catt, 'Development and Trials of an Alternative Method of Bricklaying', *Construction Industry Research and Information Association Report 42* (1972).
63. D W Cheetham, 'Bricklaying – the Problems of Translating Research into Practice', *Proc CIB 90 International Symposium on Building Economics and Construction Management* 6 (Sydney, 1990), pp107-18.
64. C A Francis, 'Bricks and Efficiency', *National Federation of Clay Industry* (1966).
65. C P Versburen. Private Communication and SAOB documentation and data files.