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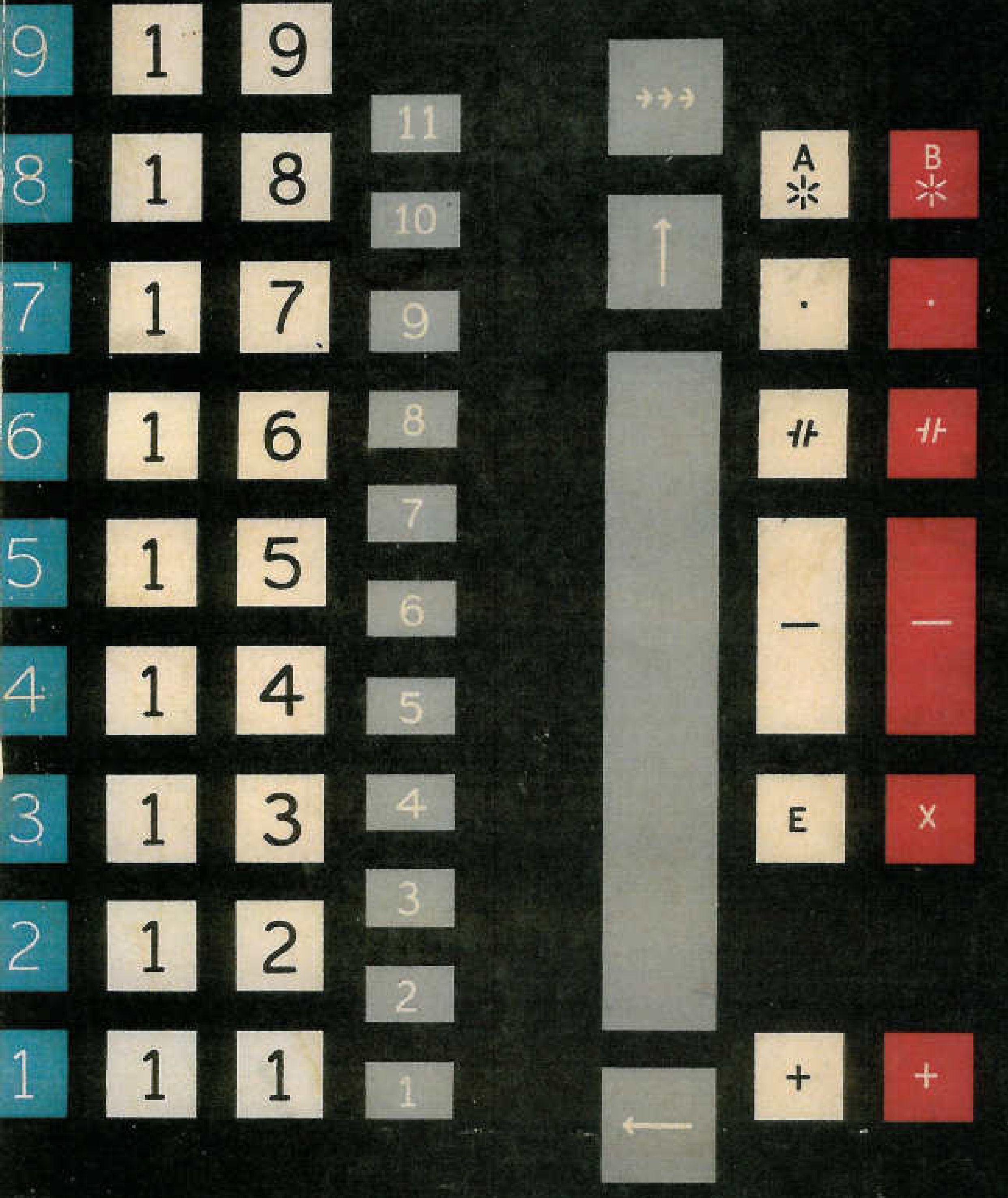

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TOTAL TO DATE

The Evolution of the Adding Machine: The Story of Burroughs

By Bryan Morgan

BURROUGHS ADDING MACHINE LIMITED LONDON

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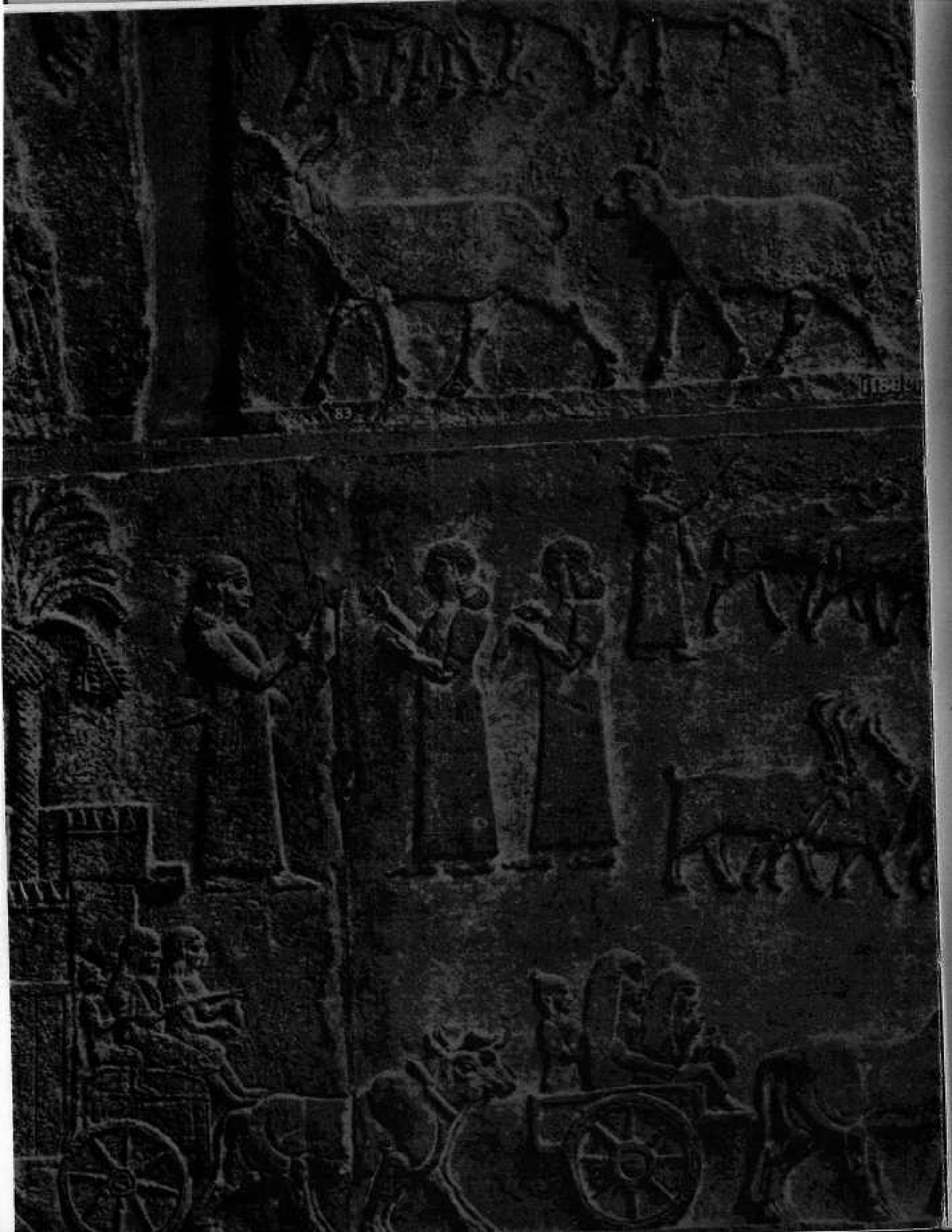
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THE OPENING BALANCE

It began in Babylon, nearly 5,000 years ago. Tired of arguments about how much tax he owed or when the interest on his loan became due, some unknown merchant scratched the reckoning with a stylus on a slab of wet clay under the baking Sumerian sun, and so became the world's first accountant.

For bookkeeping is far older than books – though the jars in which the later Babylonians stored their tablets dimly foreshadowed our ledgers and filing cabinets. It is older than coinage, for until the ninth century before Christ the world's transactions were all in barter. It is only a little younger than number itself. Accounting is one of the prime necessities of civilisation and has developed side by side with civilisation.

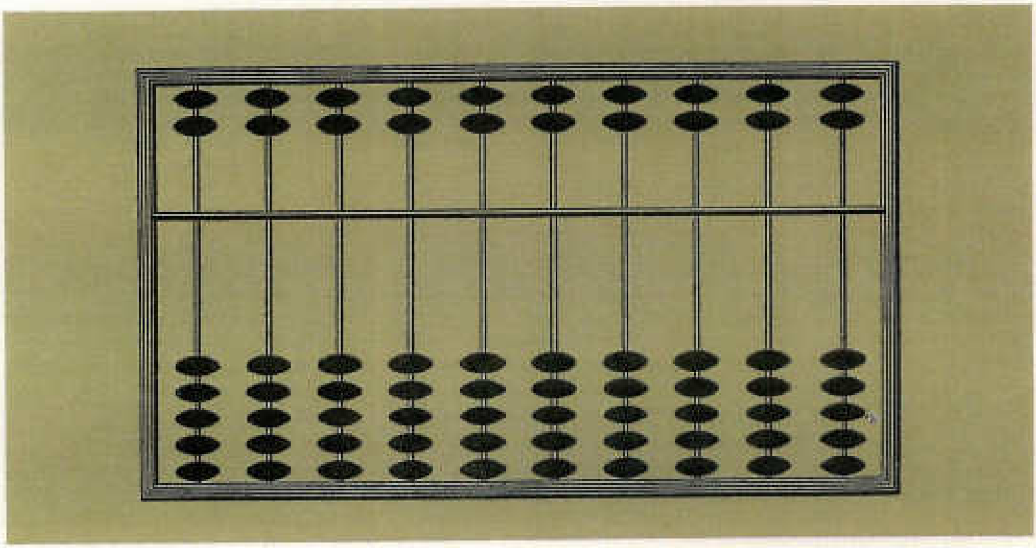
The Romans knew this. The brilliant Greeks might have been wrapped up in the mystical significance of *arithmetica*, but the Romans, who at the centre of a great trading empire floated the first joint-stock companies, needed *logistica*, a practical mathematics. Their trouble was their clumsy notation. A number like DCCCXLVIII might look fine on a monument, but when you wanted to find how much XXXVI beasts would cost at ii *librae*, ix *sestercii* and viii *denarii* each, it was time to call in the clerks.

The clerks had two ways of lessening the labour which the simplest multiplication sum in Roman numerals implied. One was by using their hands – for their decimal system, like ours, derived from the almost universal tendency to count on the fingers. They did this, not as a child counts, or like the African tribes who still have to line up three patient men every time they want to count above ninety-nine, but by an elaborate system of gestures. For instance, the left hand with the fourth finger turned in, the other fingers extended and the thumb sticking out, signified 'one'. With practice these gestures became automatic – which almost transformed the hand into an independent, and fairly fast, calculating machine.

Their other device was to move pebbles on the ground. After a few dusty centuries this became the board with movable beads which was called the abacus. The Romans were not the first to use such a device, nor the last; and even today an oriental clerk, faced by a simple long tot, may reach for his *swanpan* and give an adding machine a close race. For the abacus, though not strictly a mechanical calculator, aided the human brain in attaining far greater speed and consistent accuracy.

In the dark centuries that followed Rome, commerce, like other civilised

After the conqueror came the scribes: Assyrians taking an account of the spoils in a captured city



The Chinese abacus was invented about 2650 BC *and reached Greece from Asia Minor in* 535 BC

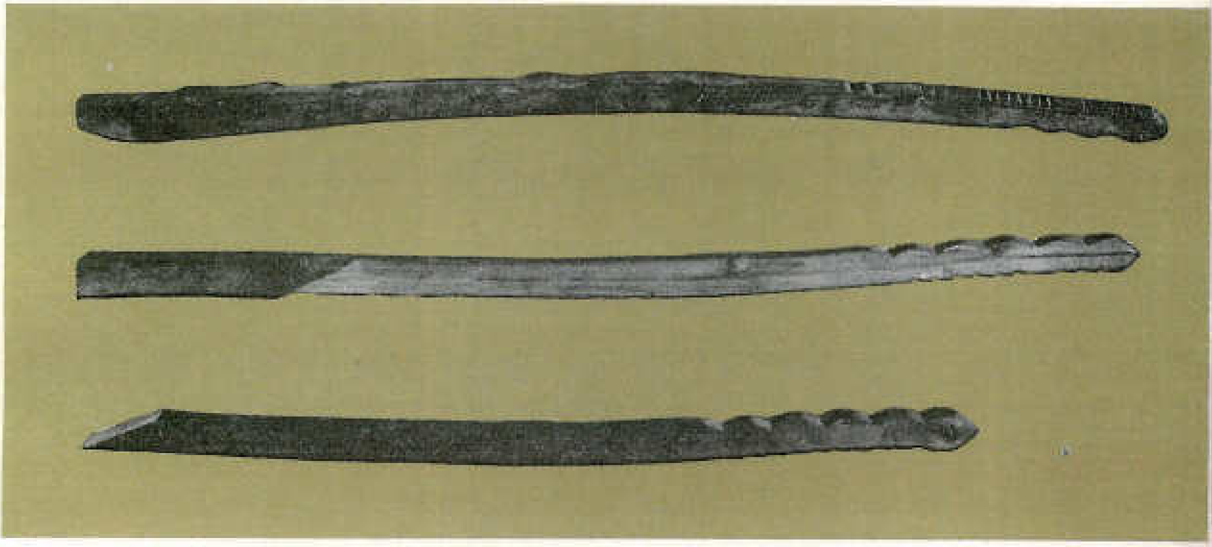
activities in the West, was at a low ebb. Certainly in the one patch of light at the court of Charlemagne, professional accountancy was practised; but by then the Middle Ages were near and trade was expanding again.

At first, office methods lagged behind trade in northern Europe. Through the period of 1066 and all that, through Doomsday Book and the Hanseatic League, hard cash in the treasure chest was prized above bills of credit. The illiterate barons deputed their affairs to scribes, who kept a check on angels and marks in a pointed Gothic hand, using corrupt Roman numerals or abacus patterns, and a mixture of Norman-French, Latin and Middle English. The Church was little more systematic: in the accounts of Westminster Abbey they entered, *Pour le turning de xiv columpnis*, vj *s*.

The one ingenious device of this period was the tally – a stick cut to record a debt. A notch as thick as a man's palm was worth £1,000: the thickness of a thumb, £100: of a little finger, £20, and of a barley corn, £1. Scratches took care of the shillings and pence. When this stick was split down the middle, so that creditor and debtor could each retain a half to compare at settlement, the tally became an eminently sensible bit of business equipment.

But by now a much more important invention had reached Italy from the East. It was, literally, the invention of nothing.

The Greeks had had separate symbols for each unit from 1 to 9. The Romans had had a rough idea of modifying the value of a cipher by its position. To combine the advantages of both systems, a sign for zero was needed. The

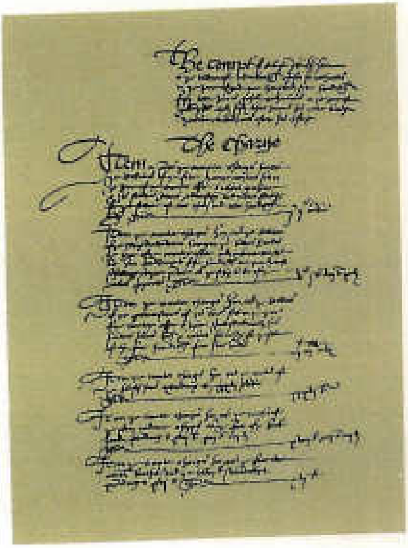


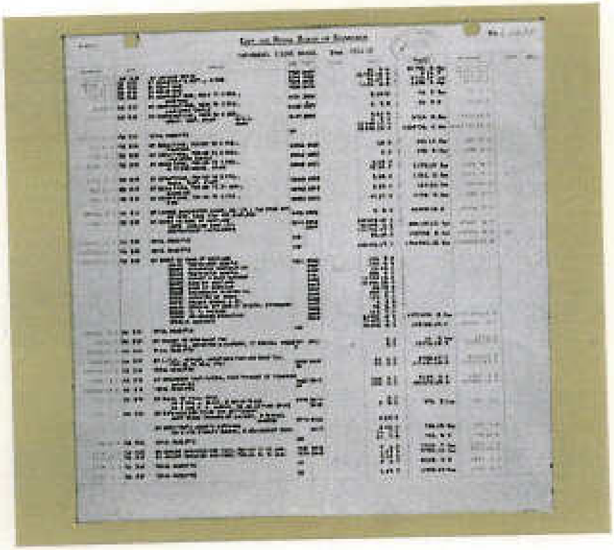
A medieval tally (top) showing notches and (below) a tally split into two for debtor and creditor

Hindus spotted this, the Arabs took the idea over, and it entered Italy in about 1200. The now familiar system of reckoning that this discovery led to brought immense freedom to pure mathematics, and hardly less freedom to the great world of commerce.

The centuries around this time belonged to Italy, in finance as well as in the arts. In 1157 the first bank of the modern world was established at Venice. By 1300 something like a double entry bookkeeping system was in use; and 100

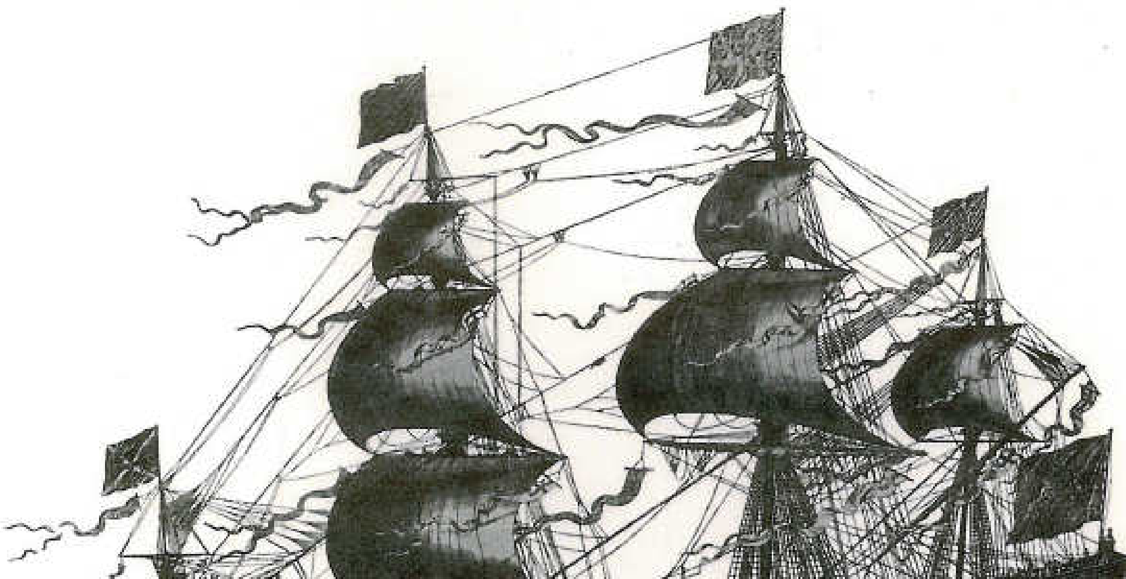
Accountants in the seventeenth century: from a Dutch work on bookkeeping published in 1672





1591 *to* 1953*: the Common Good Account of the City of Edinburgh – by hand and by Burroughs*

The Royal Soveraigne, *built in* 1637*: her navigators looked to the mathematicians for assistance*

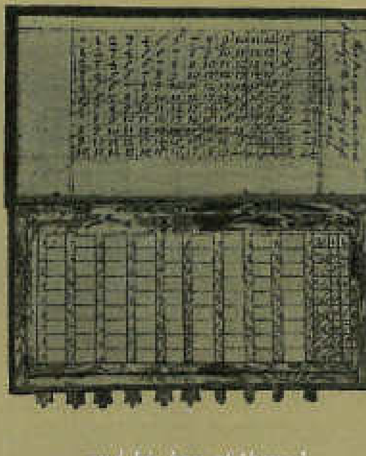


years later credits and debits were being written out in parallel columns. Professional auditors – paid by the number of mistakes they detected – were checking the work of professional accountants; and the latter, soon to be established in their first corporate body, considered themselves as of a higher rank than mere bookkeepers. Finally, in 1494, Luca Pacioli's historic treatise on double entry – called *De Computis et Scripturis* and included in one of the earliest printed books on mathematics – transformed the art of accountancy into a comprehensible and standardised science.

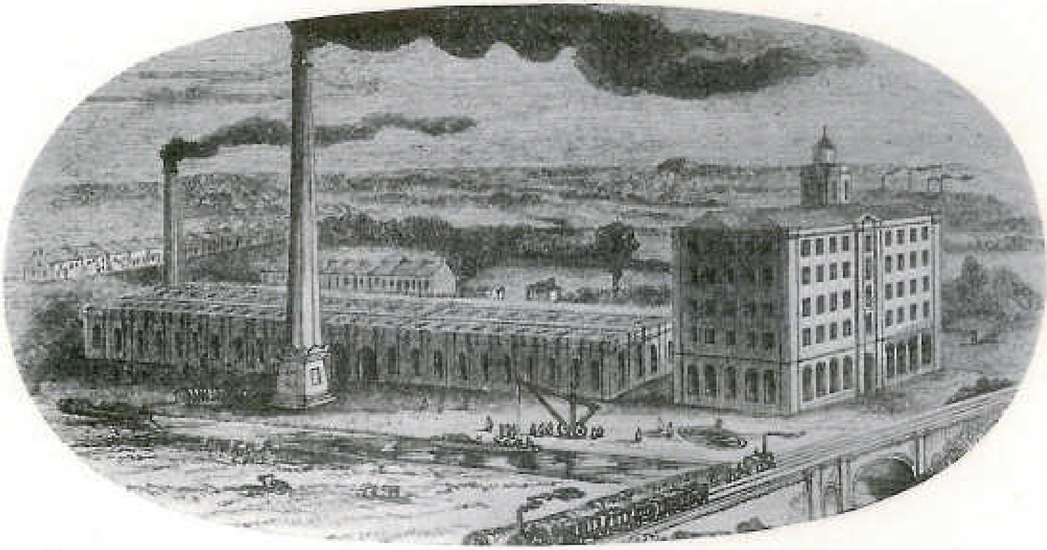
Britain's time was coming – but a long time coming. Algorism, the system employing the zero symbol, reached Scotland in 1230: in anything that touched on money the Scots were quick off the mark. But it was 300 years before London followed, and even then the business houses and wandering fairground hucksters took a century and a half to abandon their Roman numerals. Multiplication tables were still a mystery, and hand counting was employed. Simple division was still left to the higher mathematicians. Tallies were still being cut and sliced down the middle.

One of the arguments against the use of Arabic numerals was that they were easy to alter, and the abominable writing of late medieval England certainly gave force to this objection. But with the seventeenth century the full force of the Italian Renaissance reached the North. Companies and banks multiplied, and an ever increasing body of men followed George Watson of the Bank of Scotland. George Watson was Britain's first public 'accomptant' – though even as late as 1799 there were only a dozen accountants in London.

John Napier ...



and his box of 'bones'



Factories and railways, 1840: speed in production and transport demanded speed in accounting

Yet the world's oldest account book, which has lain in the Advocates' Library of Edinburgh for the last two and a half centuries, has quite a contemporary look, with its legible cross entries guarding against error. At the time that these accounts were being compiled, Dutch merchants were being admonished to marry women who could keep their books for them – which would seem to argue a fairly widespread knowledge of accountancy. Over a century later, however, an English tutor considered that, whilst double entry was a fit subject for schoolboys, young ladies should be protected from such stern studies and should be taught only single entry bookkeeping.

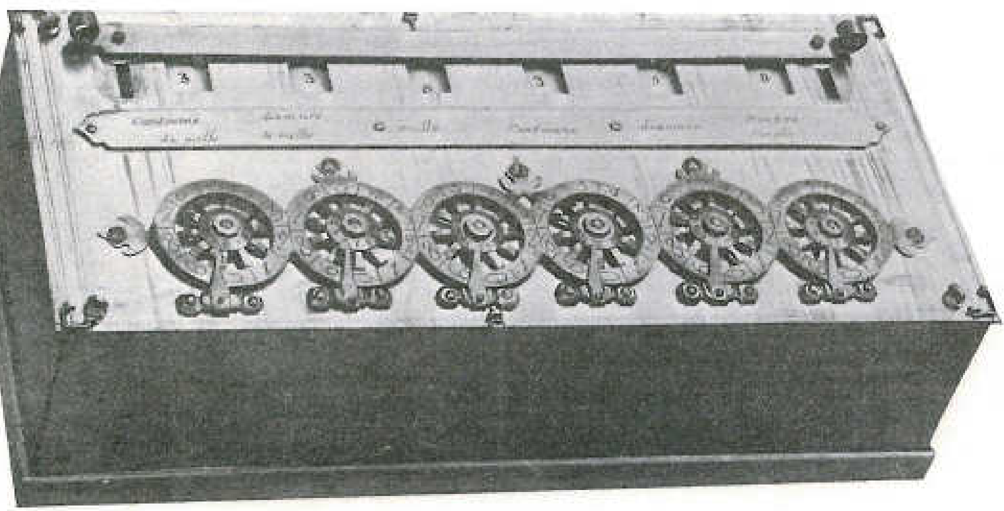
During the nineteenth century, business practice assumed its present form. From its opening years, interest and actuarial tables were available. In 1826 the Exchequer overhauled its methods and at last burned its ancient tallies – which went up in such a fine blaze that the stoves grew red hot, nearby woodwork was fired, and in a few hours the entire Houses of Parliament were completely razed. Still later in the century the Limited Companies and Bankruptcy Acts resulted in greater freedom of credit. In all but one respect, the businessman of today would not feel very much out of place in a bank or a commercial house of 1875.

But that respect is a most important one. Anyone with the slightest knowledge of office methods would, if he were projected back to the Victorian era, be struck by the lack of machinery – by the absence of not only the telephone, typewriter and duplicator, but of the adding and accounting and

Blaise Pascal

Samuel Morland

Baron Leibniz



Exterior view of a replica of the simple calculating machine that was produced by Pascal in 1642

calculating machines which form so conspicuous a part of the office scene today.

Apart from the abacus, there were no attempts to produce mechanical aids to calculation until that great century of mathematical progress, the seventeenth, though it would have been surprising if the great Leonardo had not thrown out a few ideas on the subject. But then, in 1617, John Napier, the Scot, produced his 'bones'. These took advantage of a curious property of numbers to perform multiplication, but were more of interest than of real use.

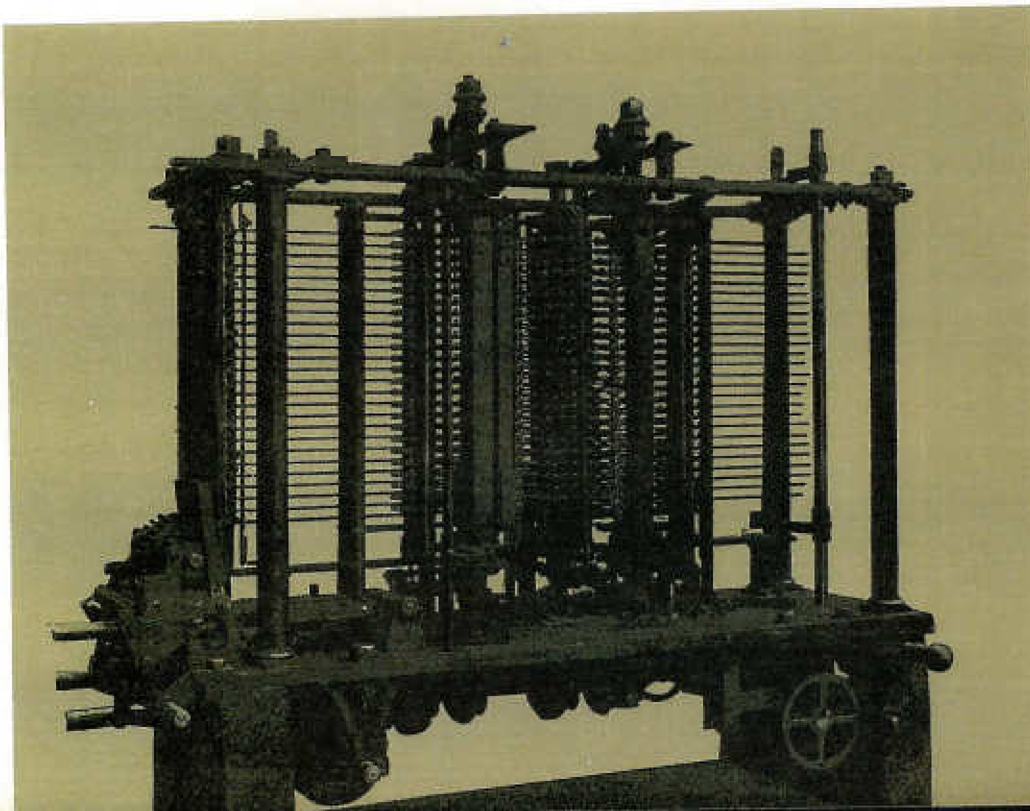
They were developed in the following century, but Napier's far greater discovery to aid multiplication was that of logarithms.

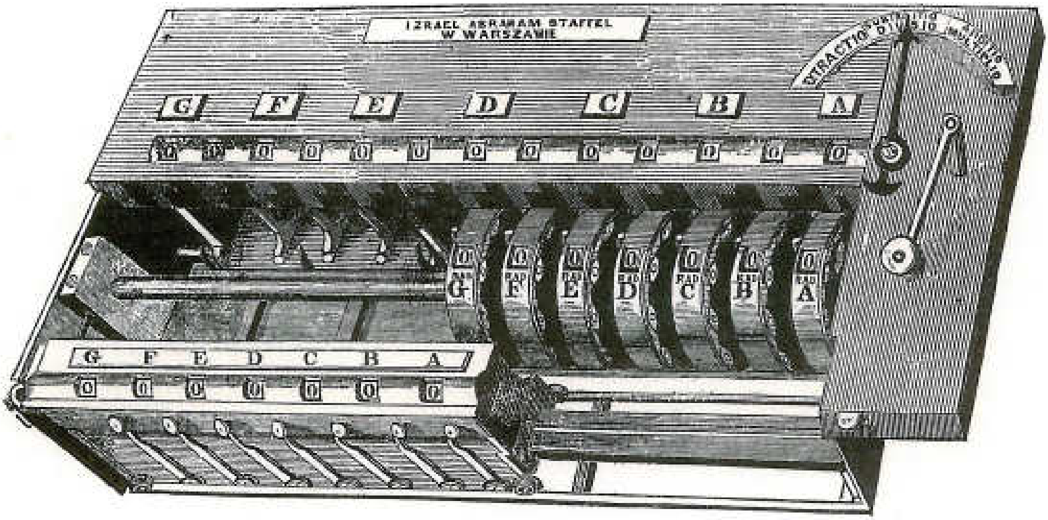
'Log tables' – and their immediate embodiment in slide rules – were of immense help in certain fields. The engineer requires to multiply more often than to add, and is often content with the degree of accuracy which the highly portable slide rule provides. But the businessman needs to add, and an error of one tenth of one per cent in a million pounds represents a lot of somebody's money. To add figures exactly it is no use measuring an *analogy* of the quantities as the slide rule does: you must count actual *digits*.

There is another reason why, unexpectedly, a useful multiplier came before a useful adder. 'Analogy machines' need take no account of decimal points or of zeros at the end of a number. To the sums 12·3 × 45 and ·0123 × 450 a slide rule will give the same answer – something between 553 and 554, leaving us to put in the decimal point. Since the actual answers are 553·5 and 5·535 respectively, this is fair enough. But the sums of these pairs of numbers are completely different – 57·3 as against 450·0123.

So the slide rule found its place in the drawing office rather than in the counting house. Yet astronomers and navigators, as well as businessmen, needed to carry out long additions – and in the seventeenth century astronomers and navigators were men of great importance. It was eventually their

Babbage's 'folly': the great engine that was meant to do so much, and did everything but work





A calculating machine from Poland: shown at the 1851 Exhibition by the maker, I. A. Staffel

needs which supplied the incentive to devise digital counters, as they simultaneously supplied an incentive to horology, and as they had through the centuries supplied an incentive to pure mathematics.

The first success was that of Blaise Pascal, who in 1642 produced a series of wheels with the numbers from 0 to 9 in order round each. The first wheel represented units; the second, tens; and so on. If you turned the first, say, five spaces, then 5 showed in a window at the top of the machine. You turned it two spaces more, and got a total of 7. Then you added seven more, and the units indicator went right round through 0 to 4. Meanwhile a lever on the units dial had clicked the tens wheel round one space for its own whole revolution, so that the machine had 'carried one'. The total $(5+2+7)$ showed as 14, and Pascal's machine scored ten out of ten for arithmetic.

It was a simple idea, more akin to a mileage measurer or revolution counter than to a modern computer. But it pointed two universal principles – that the 'carry over' should be automatic, and that one could perform subtraction by turning dials in reverse, and multiplication by successive adding (thus, twelve dialled three times gave thirty-six).

Similar machines were developed throughout the century, sometimes by other pure mathematicians like Leibniz and sometimes by inventors like Sam Morland, who presented to Charles II 'a new and most useful instrument for additions and subtractions of pounds, shillings, pence and farthings without charging the memory, disturbing the mind or exposing the operator to any uncertainty ...'. By the end of the eighteenth century, machines were avail-

From warehouses to the Bank of England, the adding machine made its mark

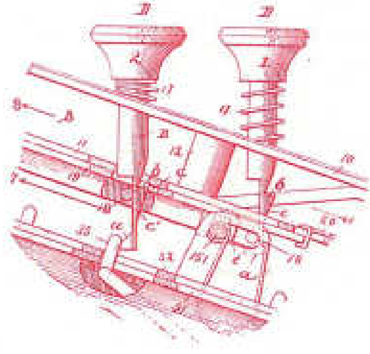
able which – when in a good mood – could solve elaborate equations by repeated addition: and by the early nineteenth century, Charles Babbage was at work on what unkind critics called his 'folly'.

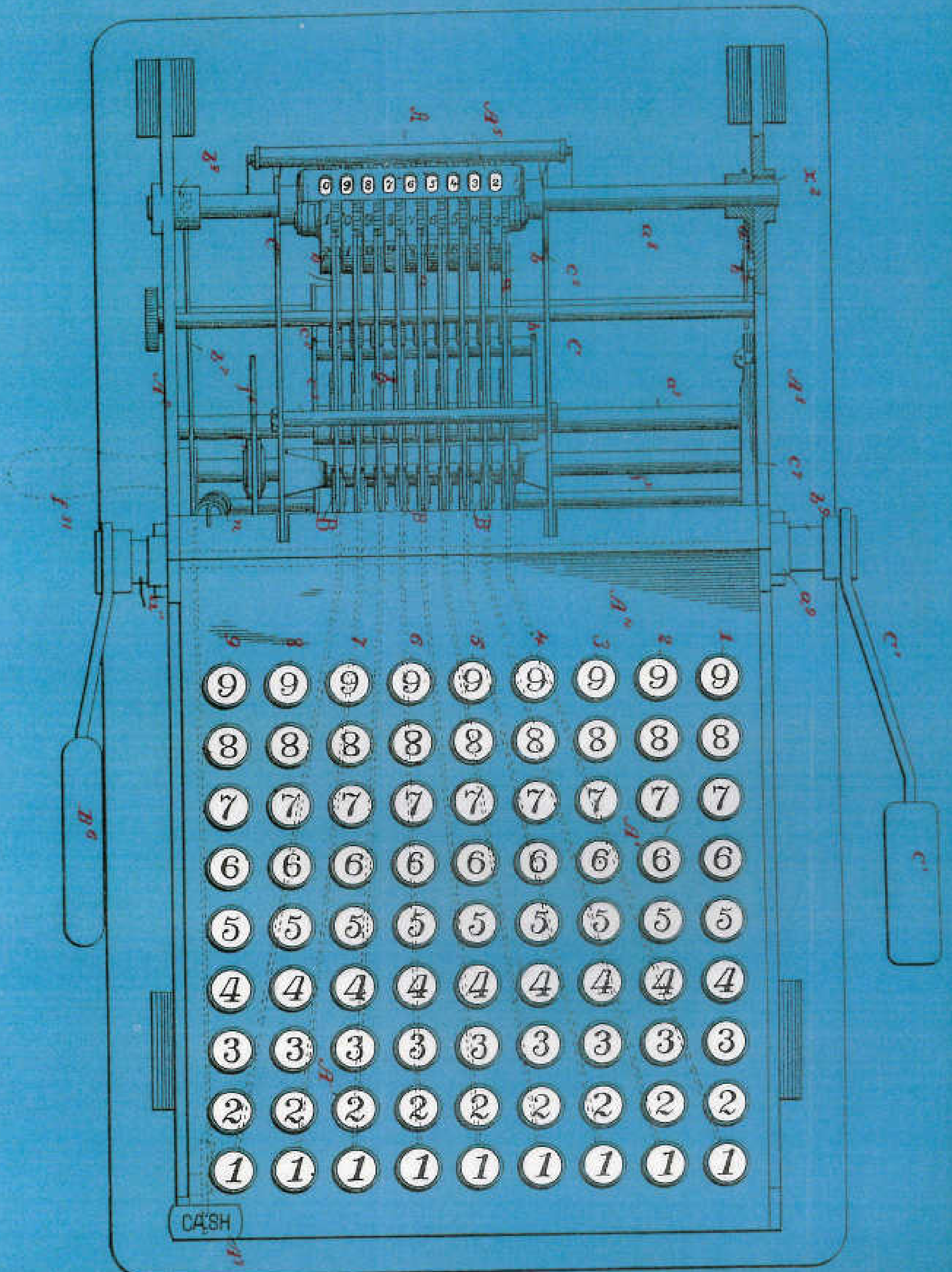
This huge machine was designed with many far reaching innovations, one of which was that it would make an automatic record of its results. We shall return to it later, since many of the problems it posed were not solved for a full century. But it must be confessed here that Babbage's ingenious machine did everything except actually *work*.

The first model with possibilities in this field was that of the Alsatian inventor, Thomas – but in 1820 there were no mass production methods to put it on the market. A little later Parmalee took a considerable stride in replacing the turning of dials – a slow, fiddling and chancy operation – with the pressing of a key, and so brought a step nearer the familiar outward form of most of today's office machines. But these experimental models went on breaking their inventors' hearts: they behaved perfectly until they were demonstrated to a backer, or they waited until they were in the hands of an enterprising customer before insisting that $2 + 2 = 5$.

In 1880 the practical office calculator seemed as far off as ever. Throughout the world an army of clerks – some in their first job, some ancient in the art – laboured amid the copying presses and the dusty files. Black-jacketed and stiff-collared, perched on high stools and leaning across steep hillsides of mahogany and polished brass, they cast up their masters' accounts. ... Down the page, tot, back to the top for a check. ... The foot again, checked, carry forward. ... Late into the evening they counted, and on into the night as quarter day approached. ... Bring forward to another endless column, tot, check, carry forward. ...

Thousands of such clerks must have dreamed of an end to their tedium. Only one had the genius to bring it about.




CASH

THE KEY TO THE ANSWER

In the town of Auburn, in the state of New York, near Rochester where he was born, William Seward Burroughs lay awake in his bed.

It had been a tiring day, especially for a man who, though only twenty-five, was in poor health. As Burroughs lay thinking, long columns of figures swam before him. For he was a bank clerk, and hence dedicated to a lifetime of counting, checking and re-counting.

Through most of the waking hours of his life, he supposed, he would sit crouched at a high desk with a green shade over his eyes. He tried to reckon just how many months and years those hours would add up to, for his mind had got into the habit of reckoning everything, and he decided that it was something like twenty years – twenty years to be spent in the same routine activity.

It was not the monotony of the task which irked him so much as its lack of economy. After all, half his days were spent in guarding against errors and half of what remained in hunting for such errors as *had* been made. So three-quarters of his time was, at best, unproductive. For fifteen of those twenty working years ahead there would be nothing to show at the end.

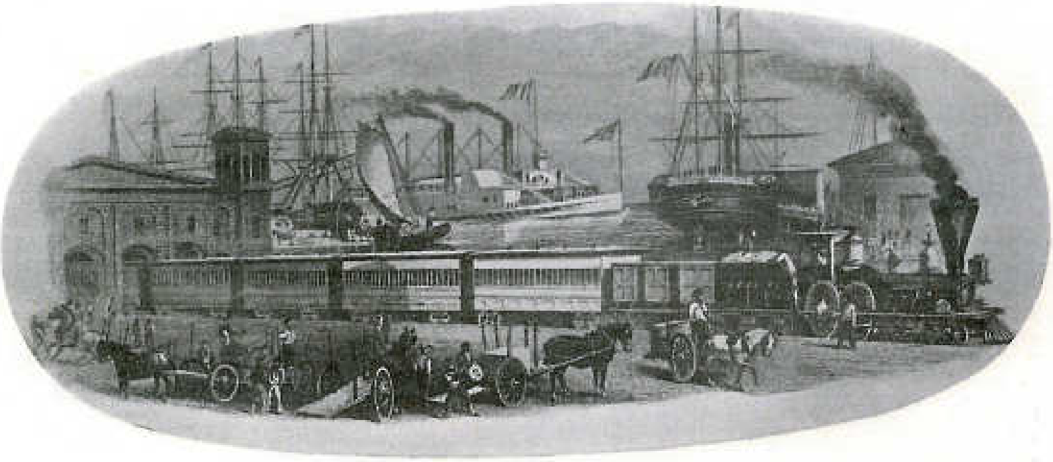
How many clerks and bookkeepers were there in the world spending nine-tenths of their business life working at figures – with nine-tenths of that work simple addition? Were there half a million in his own country? Or a million? Or two? And how many more were there in Canada, in Britain, in Europe and Asia and Africa and Australia? Were there ten million men on earth engaged at his own repetitious task – or were there twenty?

And in that year of 1882 the pressure was increasing. Goods and mail were moving more swiftly on the trans-continental railroads, demanding centralised and up to date records. Soon Mr Bell's new telephone would be in every office, reducing the time available for preparing statements of account or hunting errors buried deep in day books. More staff would be needed, more men to spend their lives on all that work which would be better done by a machine.

A machine – a substitute for his own pen, which should add as it wrote – that was it. When you came down to it, there were only a few simple operations involved in the longest addition. Surely it should be possible to build a mechanism capable of carrying out those operations – not an elaborate experimental one such as the scientists and mathematicians had long played with, but a robust commercial article which any clerk could handle.

Well, someday and somehow and somewhere, somebody would make such

Plan view of Burroughs' machine: from the US Patent Office specification of 21st August 1888



Accounting had to keep pace with commerce – and commerce began running on powered wheels

a machine. Meanwhile calculation remained, 'subject to many slippery errors': and meanwhile, for Burroughs the bank clerk, it was time to sleep. Another day was drawing nearer, one more of those thousands in which he must sit at his desk and cast up the figures, over and over and over....

But it did not work out that way. A few months later Burroughs' health broke down, impaired by the long hours and the close work of his trade. The doctors ordered a warmer climate and a more active occupation: the patient chose the city of St Louis and engineering.

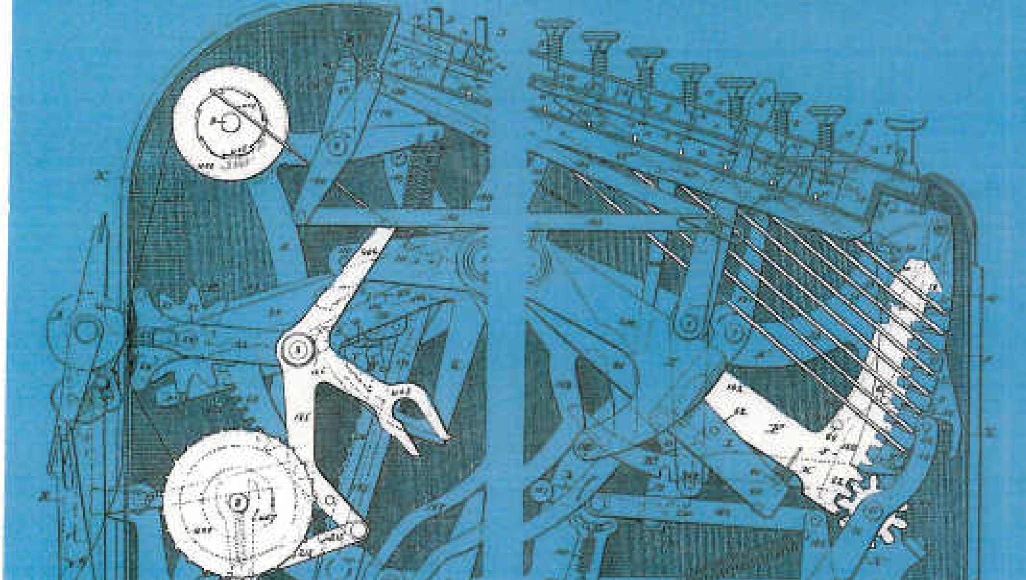
His father had had something of a mechanical bent, but William Burroughs had never received more than an elementary education and knew little of mathematics, design or the properties of materials. But his new work gave him general experience; and it taught him, too, a most important lesson that concerned himself. Burroughs learned that he had the special genius of an inventor for thinking through his fingers.

Many of the world's benefactors had devoted their lives to a single technical problem. But Burroughs was unusual in that he was always conscious of the social as well as the mechanical importance of his dream. *He* had worked in a bank, *he* had cast up hundreds of balance sheets, *he* had the incentive as well as the ability to produce the first office adding machine.

But he lacked the facilities; and during those early 1880s there was little he could do but sit in his room in St Louis late at night, pencil in hand, brooding on his problem. The basic principles from which he had to work were clear enough. There would be some mechanism by which numbers could be set. Then they must be transferred automatically to another mechan-

Wall Street, in the day of . . .

William Seward Burroughs



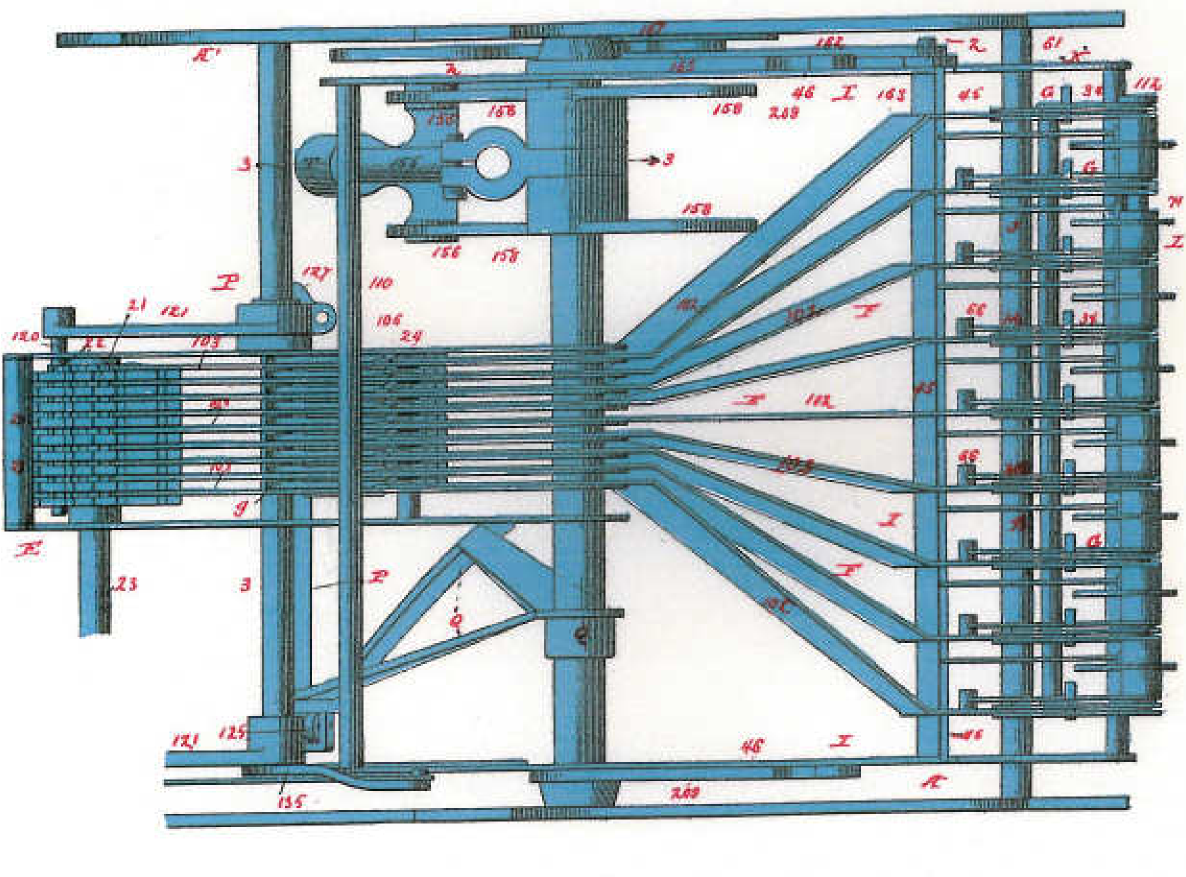
Side view of Burroughs' mechanism, from the patent specification of 1888: showing (left) the register, or recording mechanism, connected to (right) the key-actuated adding mechanism

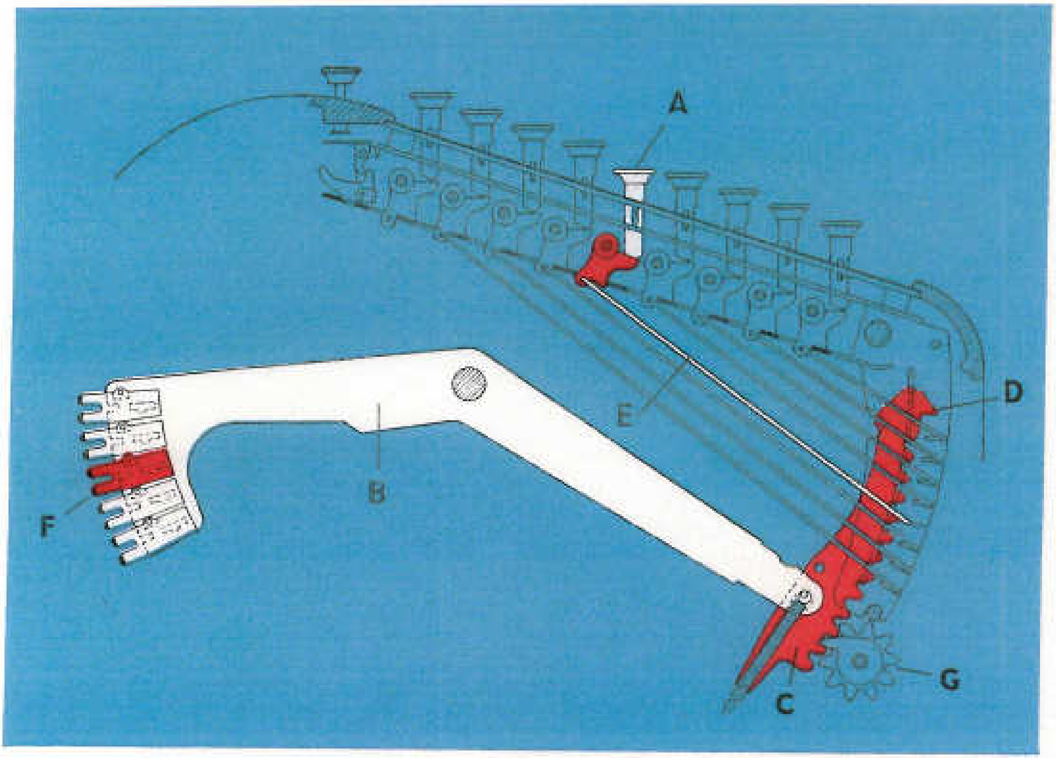
ism that could 'remember' them, so that when the whole process was repeated with a new number this would be added on. 'Carrying' would be accomplished automatically by some sort of gearing, and finally the machine would print the numbers fed into it, and their total when required.

It does not belittle Burroughs' achievement to point out that these principles were well known, or that other men were then working on them with more or less success – Burkhardt in Germany, for instance, or Felt in America, or Odhner in Russia. The principle of flight had been known for centuries, and the principle of the turbine was as old as Greece, but in each case the world had to wait for a Wright or Parsons to transform a vague idea about a principle into a sound and practical mechanism.

So Burroughs set himself to produce his perfect machine – on paper. At times he forgot his health, staying up all night between two days in the machine shop and then working late into the following night. Typical of the problems he faced was that of the 'carrying' when, say, 1 was added to 999,999. Earlier

Burroughs' machine: plan view of adding and recording mechanism with the keyboard removed





The pivoting sector: fundamental to Burroughs' invention and to many present day machines

machines had wilted in that hour of trial, when all the forces of friction seemed to be working together. But Burroughs was undismayed.

He decided that there should be a separate column of keys for every decimal place – seven columns would do for a start. It was quite possible to construct a more compact machine with a 'ten-key' keyboard, in which the place would shift automatically. But such an arrangement would lay itself open to the danger of the operator pressing a key twice, or not hard enough, so throwing out the whole reckoning: and, furthermore, it meant that the zeros would have to be indexed separately. So Burroughs resolved on a full keyboard, however much repetitious machining that meant for him.

He was determined that his mechanisms should be proof against the mistakes of even an inexperienced operator, for anything less than 100 per cent reliability would be only a small improvement on the human mind. To that end he hedged his machine about with safeguards so that it was like a sound national constitution, with every part vigilant over the action of every other part. For instance, he designed it so that its keys would stay down when struck, because the operator could then glance at the completed number for an instant before pulling the handle; and there was also to be a 'locked keyboard', on which any attempt to punch two keys in the same column would freeze the whole mechanism. Finally, there was no point in a device that produced the right answer but left a fallible clerk to copy it down – so the adding machine must also be a printing machine.

At last, after many long nights, many intimations of illness, many discouragements and many failures, Burroughs believed that he could go ahead and build his machine round a simple mechanism which would, of course, be repeated for each column. One of these units is illustrated here because it was – and remains to this day – the heart of every Burroughs adding and listing machine. Its operation is ingenious, but hardly mysterious.

When, after a key (a) has been depressed, the handle of a machine is pulled forward, a sector (b) swivels round on a pivot at its centre (so eliminating the sliding friction which was a bugbear of pre-Burroughs machines), and the rack (c) attached to it descends until the projection (d) at its top is brought to rest by whichever of the wires (e) is linked to the key that has been depressed. Thus, if this were the 5 key, then the sector will turn by the space of five teeth exactly – and no further.

Simultaneously the other end of the sector rises, until, when the movement stops, its 5 typeface (f) is opposite the printing space. At the end of the handle's forward stroke printing takes place, and that is all there is to *that*. To follow the reverse stroke, we must change ends once more.

The first thing that happens is that a wheel (g) engages with the toothed rack. Then, as the rack returns to its starting position, this adding wheel turns through just five spaces – *unless* the wheel to the right of it has just completed a revolution. In that case, we shall find that the normal limit for the return of the sector to its home position has been most cunningly removed by a cam, allowing our sector to rise one more space and the 'carried' 1 to be added on.

This process is of course repeated at the right place and time for all the digits of all the numbers indexed. Then, when a total is required, it occurs in reverse. The racks are allowed to descend from the neutral position in mesh with their wheels, turning these backwards until they reach their respective zeros. Then the total has been cleared and the wheels disengage: but the sectors have turned through distances corresponding to their several digits, and the typebars have risen to the right positions to print the answer.

This, then, was the heart of the Burroughs mechanism. But it was only the heart, and round it there were all kinds of interlinked devices performing with the precision of chorus girls surrounding a star. For example, the zeros had to be automatically printed only on the right of the first figure that was *not* a zero. If an operator pressed, say, the 3 key in the hundreds column he did not want just 3 printed, even in its rightful place. Equally, he did not want

J. Boyer's machine shop in St Louis, where W. S. Burroughs perfected his first adding machine

0000300 or worse. He wanted 300, and Burroughs arranged that he got it.

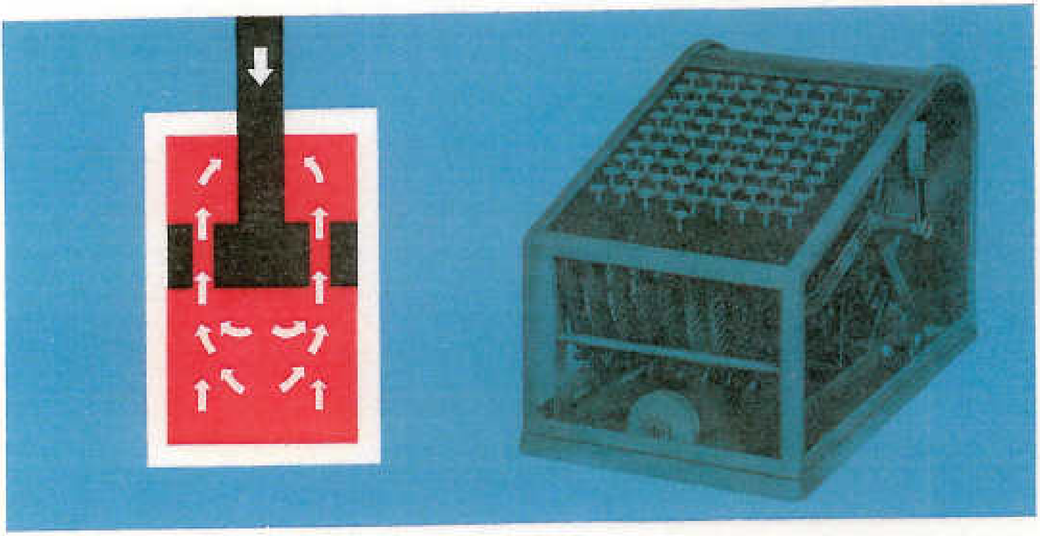
By 1884 only one more thing was needed for production to start, and that was money. It came through one of those fortunate meetings between the right men at the right moment. Sent on a mechanical job to a local store, Burroughs fell to talking with one of its staff. He found the man not merely interested in the machine but willing to invest in it – and willing to persuade his friends to do the same. Almost before he knew it, Burroughs was installed in a small, single storey, brick workshop which specialised in hiring out a few feet of bench space, and the services of assistants, to inventors. Its proprietor was a Joseph Boyer, but he was too busy inventing a pneumatic hammer valve to give much attention to Burroughs – whose chief assistance came from a youth name Doughty who had left Wolverhampton a few years before. Burroughs now had a capital of about £150, in return for which he had presented his backers with shares in a company that was as yet non-existent.

Burroughs prepared his master drawings in his own way – not on paper, but engraved on copper plates under a magnifier so that no error would be possible. Accuracy was all-important, that quality which the quiet-spoken, retiring inventor defined in a rare moment of articulateness and in a phrase that summed up his whole philosophy.

Accuracy – said Burroughs – is only truth, filed to a sharp point.

As the months passed he made swift progress, but his money was more swiftly exhausted and further issues of stock were continually needed before the pilot machine was finished in 1884. Despite its known imperfections, Burroughs agreed to exhibit it in the same year.

Eight years earlier, the telephone had made its bow. Three years later, the



The principle of the oil-filled dashpot which modified and improved Burroughs' first machine

first radio message was to be transmitted. But the appearance of a prototype key-set adding and recording machine was hardly less historic.

In the following year application was made for basic patents, and in the year after that the American Arithmometer Company was founded. By 1888, when further improvements had been made, Burroughs was almost ready to put his machine into production. Unfortunately, the stockholders were more than ready; and it was their pressure which persuaded the inventor to order jigs and patterns before he was quite satisfied that they would produce the foolproof machine he had all along demanded.

The designing and tooling took two years, but by 1890 the first of a batch of machines were leaving Boyer's workshop and finding their way to business houses. After a few weeks the reports on their performance began to come in. And – as Burroughs had half feared – they were bad reports.

The trouble lay in the main crank. For numbers to be satisfactorily accumulated, the handle had to be pulled steadily forward and then released – hardly a highly skilled operation. But the customers, new to the contraption, pumped or pummelled or yanked or caressed it, and then complained that they could not get the hang of the handle.

Burroughs investigated these complaints, and showed how easy it was to operate even a machine that had already been maltreated. All that was needed was to pull the lever – *so* – and there was the right answer. But his witnesses shook their heads. You couldn't fool *them*. They reckoned Burroughs had worked out the answer mentally and slipped it into the mechanism somehow.

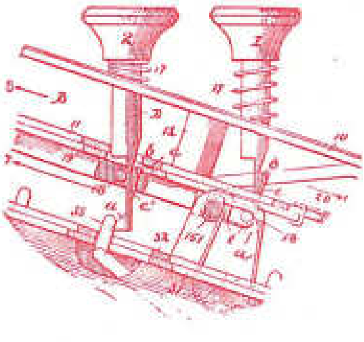
That night Burroughs went up to the room that had seen so many despairs and triumphs, and locked himself in. When he emerged again he was seventy-two hours older: but, haggard though his face was from lack of food and bright though his sleepless eyes were with tubercular fever, his hands held the sketch for a new device.

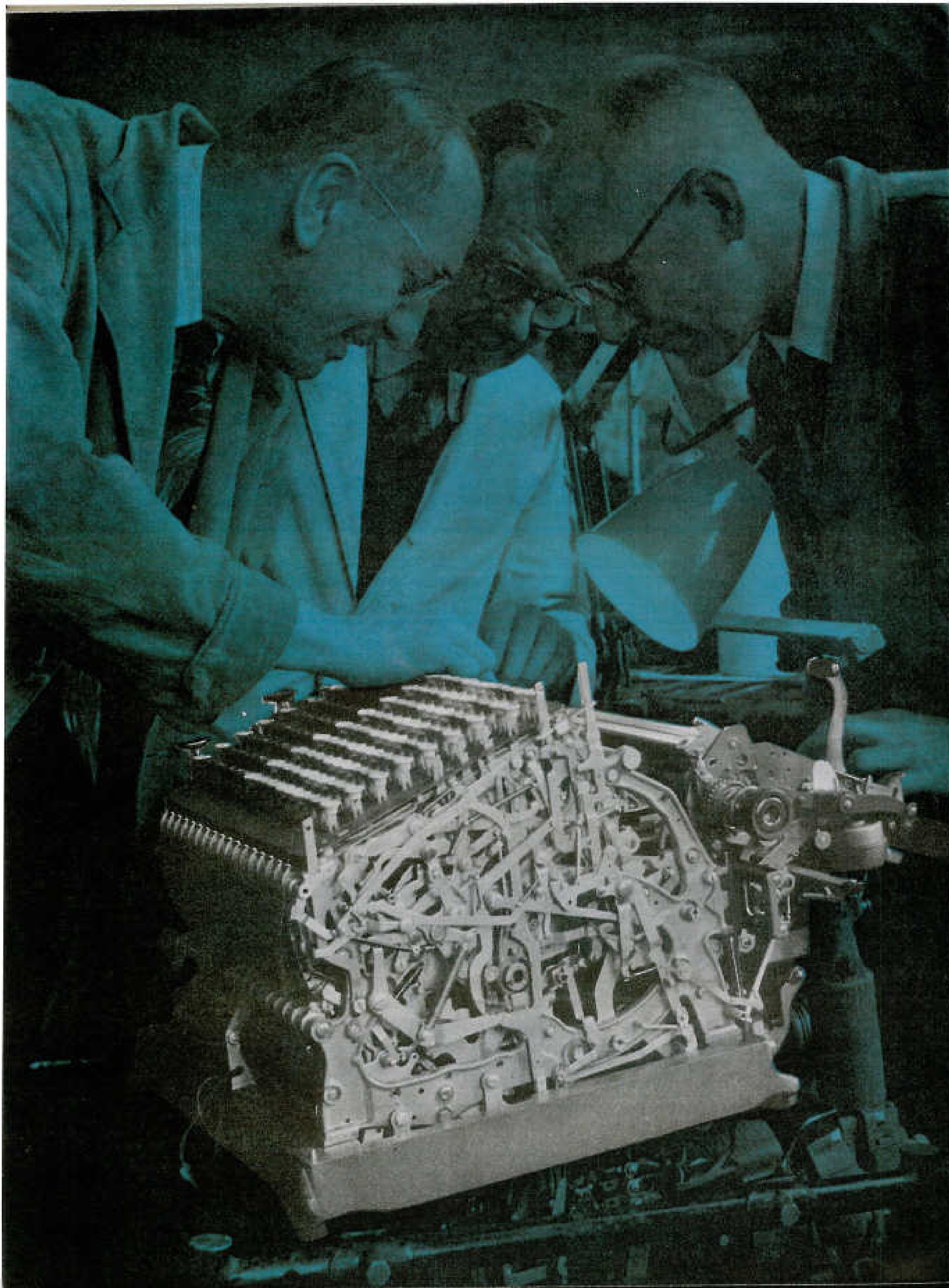
In essence this was an oil-filled dashpot, similar to that which ensures that a door closes steadily. Fitted to a machine, it would smooth out inequalities of handling and ensure perfect results, whether the handle was worked by one of those delicate, tight-waisted and whale-boned young ladies who were beginning to invade offices, or by the right arm of John L. Sullivan himself.

This automatic control, like other of the inventor's improvements, still forms part of many Burroughs models. But its introduction meant some re-tooling, and by now the backers were becoming disheartened. For many months Burroughs was left to refine and to tinker: then, at last, new funds became available. Up till now the company had spent about £60,000 without producing a wholly satisfactory machine, but the batch of 100 which left the workshop from the summer of 1891 onwards passed even Burroughs' scrutiny.

The failures were recalled and stored away. But their builder could not quite forget them. One day he entered the storeroom, opened its window, and, picking up the machines one by one, hurled them with all his failing strength to smash on the pavement below. As the last crash sounded, Boyer entered. 'There,' said Burroughs, 'I have ended the last of my troubles.'

Indeed, it seemed so. The ten years' fight was over and won, and the gleaming new machines were ranged on the benches. All that genius and dedication and grinding hard work could do had been done. It only remained now to find the customers.





MANY INVENTIONS

Some time in the 1890s an advertisement appeared in a St Louis newspaper. It began by retailing a recent news item from Belgrade where a station-master had shot himself, believing that there was a deficit of 6*s* in his accounts though it was, in fact, only his arithmetic that was at fault. Then came the pay-off. 'The American Arithmometer Company's Machines,' it stated, 'may be procured from Mr Jay Ward.'

To such alarming reminders of the inadequacies of machineless book-keeping was the early Burroughs company reduced: for sales were slow. 'The bookkeepers did not raise their voices in a cry of liberation,' recalls today's President of the American firm. 'As a matter of fact, not much of anything happened.' In hard figures, in the first years machines were sold at a rate of less than one a week. Burroughs himself never expected spectacular sales, and in fact believed that 8,000 machines – one to every bank in the United States – would about saturate the market. But surely better results than this could be achieved. . . .

The early sales promotion campaigns had certainly been somewhat haphazard, with the inventor himself spending valuable time in travelling to demonstrate models or entrusting his representation to untried men. There was, for instance, that unsoothing affair in Albany, New York, where the Burroughs representative vanished off the face of the earth – together with his demonstration machine. He was eventually located in a bar. Beside him was a wheelbarrow, and in it was the adding machine. When asked how sales were going, he showed mellow surprise. He had been giving Burroughs fine publicity, he said: there wasn't a bar for miles around where he had not been. And in every one he had wagered and won a drink on the machine's accuracy. That machine could beat any man in the house, he said.

Such methods left room for improvement, and in 1895 the company's first three selected salesmen sat down and solemnly divided the great Republic between them, into territories of rather over a million square miles apiece. It was nothing for these men to travel 1,000 miles through outlaw country and to be gone for a week, in order to sell a single machine at a profit of a few dollars. For instance an enterprising youth of nineteen took on the entire Dominion of Canada for pocket money. (He was R. N. Ahern, who in 1924 was appointed Managing Director of the English company and who for twenty-five years did so much to bring the company to its present position

Final inspection of a Series H High Speed Accounting Machine in Burroughs Nottingham factory

Joseph Boyer ...

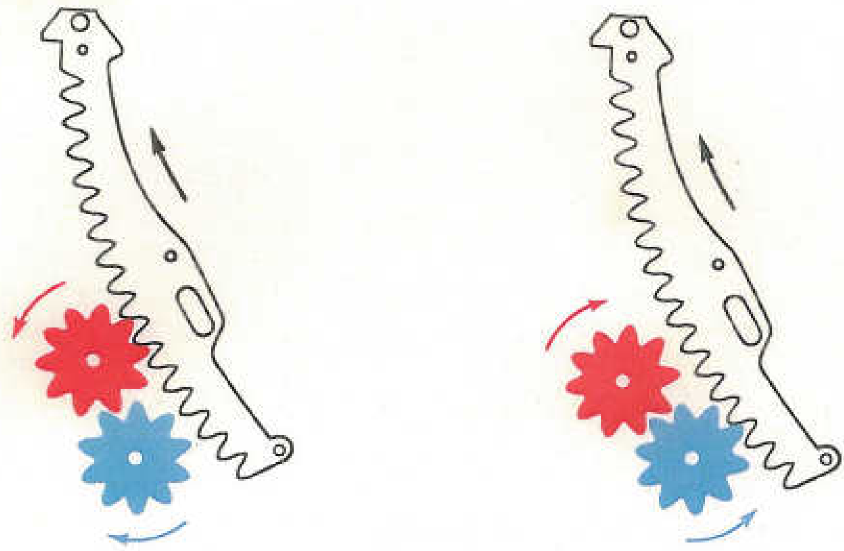
and an early machine

of leadership.) This policy created goodwill and brought results; in a year sales were up to over 400, and two years later to over 700. But still the company owned little more than a single idea.

Then, in 1898, a significant event occurred. A few years earlier Burroughs had visited England without being able to interest anyone in his product; but now, as a result of a meeting with Sir John Turney of Nottingham, an agreement was reached which was to prove profitable to both gentlemen and to the world. Turney acquired the rights to manufacture Burroughs machines, not for Britain or Europe only, but for all the countries and continents of the Eastern hemisphere.

The first directors of Burroughs of England knew little of mechanics. They were paint or lace or leather manufacturers: but they were businessmen and knew when they were on to a good thing. At the start their factory in Nottingham – a converted furniture warehouse – was limited in staff and installation, and production was a mere trickle of some forty machines a year. But even then complete machines were being built – and built to Burroughs' own exact specifications, so that parts from an English and an American model should be interchangeable.

It was an arrangement after the inventor's own heart, for complete interchangeability was a principle of his. If any one of the seven wheels in his first model needed replacing, he saw no reason for the mechanics to trouble with re-assembling them in their original order. From making his parts fully



Machines were geared for subtraction by a wheel (blue) which reversed the main wheel (red)

interchangeable, it was a logical step to ensuring that a Nottingham-made part should fit naturally into a St Louis-made machine.

But Burroughs had little time to enjoy his well-earned triumph. For in that summer of 1898, in which – only twelve years after the parent company – the English firm was founded, the father of both sat quietly in the tree-shaded sunlight of Citronelle, Alabama, as his doctors had ordered. There, at the age of forty-one, he awaited September, the final stroke of tuberculosis, and his last journey to St Louis.

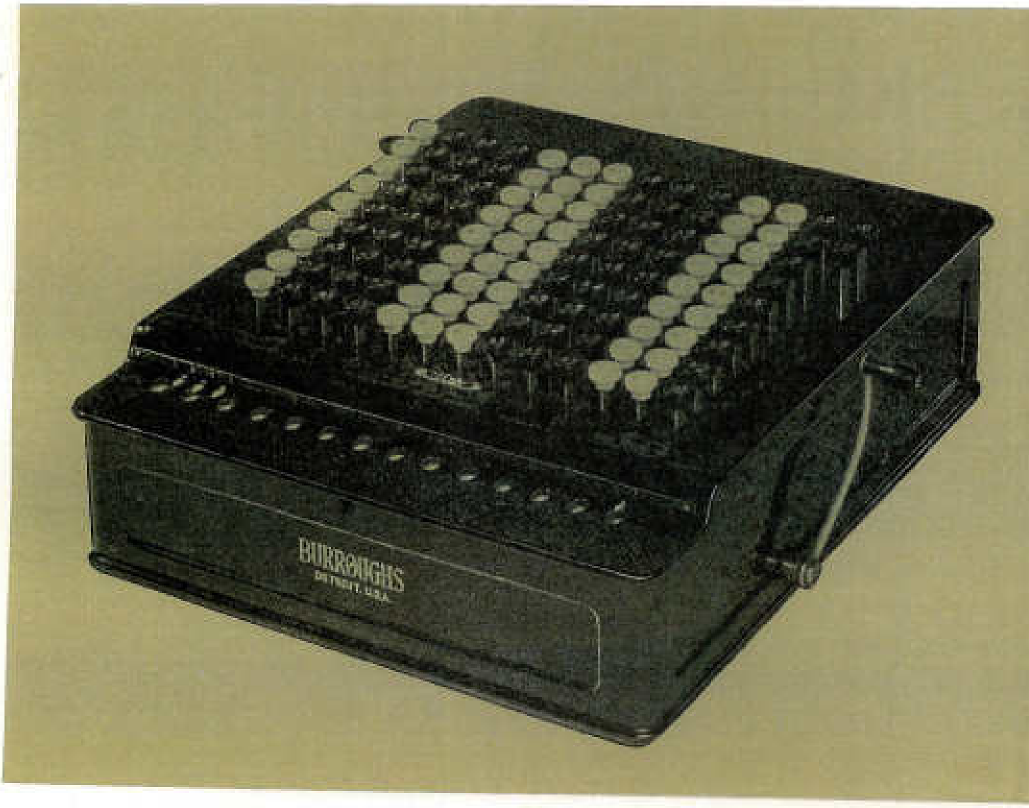
A few years after his death, Burroughs' company passed into good hands – those of Joseph Boyer, from whom, sixteen years before, Burroughs had rented a few square feet in which to build. Boyer was an inventor in his own right (as well as the pneumatic hammer valve, a speed recorder of his design is still in use), and he celebrated his accession to the direction of the firm with a pleasantly Goldwynesque gesture. He set up a department called, simply, 'Inventions' and told his employees to sit down and invent something.

At the turn of the century the business was at last firmly established. Sales were still not spectacular, being about 1,000 machines annually in America and somewhat less in England. But they were increasing, and from now on there was no looking back, technically or commercially. With English and American skills at work, the models were developed in a dozen directions. One of the first demands of the British market was a machine that could handle pounds, shillings and pence as well as more civilised numbers. Burroughs had had the advantage of living in a land of decimal coinage, where any machine that could digest plain figures could live equally healthily on a bank diet of dollars and cents. Had he had to contend with British coinage from the start, the great invention might well have been delayed for several years. However, the modification did not prove too difficult and models were built that could handle pounds, shillings, pence and even farthings if necessary. From sterling models it was a logical development for Nottingham to devise one that reckoned avoirdupois weight: and then came fractions, foreign currencies, feet and inches, areas, and hours and minutes.

The familiar array of the keyboard was expanded to seventeen columns when required, and round its edge new controls were added to the familiar *Correction* and *Total* keys. For instance, one did not always want to destroy a total when it had been printed, so a *Sub-Total* key was introduced. Then there was a *Non-Add* one for excluding any given items from the addition, and later a *Non-Print* one. A further control repeated entries as often as the handle was pulled, whilst others corrected errors or restored normal service.

Another line of improvement was towards incorporating devices for dating or numbering entries. This was normally done by dividing off columns with the special Burroughs device of an 'unlimited split', and then arranging the carriage so that it shuttled straight from one list to another. This meant modifying the carriage, perhaps so that it accommodated two quite different documents. But whilst the carriage blossomed forth on some machines it disappeared entirely on others, and the 'Calculator' range of models was introduced about 1908. These allowed a wide range of mathematical operations to be performed, especially if the models were of the 'Duplex' variety and had two separate totalling mechanisms or 'registers' which could, for instance, take care of debits and credits simultaneously. Many smaller innovations, such as item counters and horizontal totals, came from behind the door marked 'Inventions' during these opening years of the twentieth century: and one major one. This – almost essential considering how machines had grown in size and complexity – was electric operation.

Motor drive passed through three stages, beginning about 1906. In the first, the motor was kept continuously running and a clutch was engaged when one wanted an addition. But the quiet-running motors led to cases of an operator leaving for a cup of tea, or even for home, with the machine still ticking over. So, next, a self-stopping mechanism was incorporated, by which the power cut off unless it was called on to make itself useful every few minutes. Finally, the electrical engineers designed motors with so high a starting power that they ran only when they were actually performing an operation.



An early Class 5 Key-driven Calculator: the handle cleared the machine after each operation

Soon all but the smallest models were available with optional electric drive. The larger machines had the motor fitted outside their cases, but in the smaller it was eventually fully built-in – which was rather like pouring a quart into a pint pot which already held a miraculous gallon.

Meanwhile, a great milestone had been reached in 1909. Five years before, the American company had outgrown St Louis and moved to Detroit in a remarkable overnight migration. In charge was young Alfred Doughty from Wolverhampton, who in those struggling days of the company had sometimes had to take his weekly pay in the form of shares, but who was now well set on the road to the President's chair. Production by then had steadily run from 2,000 to 15,000 machines a year: for Burroughs' saturation value was long ago forgotten. He had not foreseen that banks would need more than one machine each, or that other concerns would soon recognise the advantages of mechanised accounting.

In Nottingham, with its 200 employees, production had remained at a lower level and the English factory was in need of re-equipment. Indeed, the whole of Burroughs was ready for a general dusting down and overhaul to fit it for the expanding demands which industry was making on it, and for the increasing services which it was rendering to industry. So in June 1909 the separate organisations on different sides of the Atlantic were amalgamated.

This re-organisation resulted in an immediate increase of British and European business. The 1908 production was doubled within four years and was trebled in six. But despite the goodwill of the Burroughs trademark, and the fact that most accounting departments now considered some form of adding machine as essential as a typewriter, such results would not have been achieved without an enthusiastic sales staff.

Perhaps Nottingham's methods were not as spectacular as those of Detroit, with their parades and junketings. And no English agent ever travelled up a river by private launch, wading ashore to effect a sale at an isolated bank, or drove round the Dukeries in his own horse and chaise with 'Burroughs' painted large on the sides. But he had his own sales resistance to meet.

For instance, one salesman climbed three steep flights to a Manchester draper's office, where he set up his machine and challenged the merchant to beat it at a long addition. His instructors had told him that the machine could not lose: but this time the salesman was barely half-way down the column when his prospective customer came up with the right total.

'You've struck a loser this time, lad,' said the draper. 'You've run into the only man in Manchester who can add up pounds, shillings and pence simultaneously.' But even he admitted that the machine would never tire: and for every such difficult customer there were many testimonials declaring that the machine had cut the time for a job by a half or three-quarters.

Even to the lonely Orkneys – where a grocer paid for his machine by hiring it to his neighbours by the day – Burroughs machines found their way: for their usefulness had spread far beyond the banks – though these were well equipped, with nearly 1,000 machines in the City of London alone. They were to be found wherever figures or goods were dealt with in more than the smallest of quantities. By the end of the first decade of the century, they were dealing with a wide range of commodities – chocolate, beer, stationery, hats, tobacco, soap, leather, shipping, chemicals, tea, lace and newspapers among them. The Inland Revenue Department, too, was pretty quick off the mark.

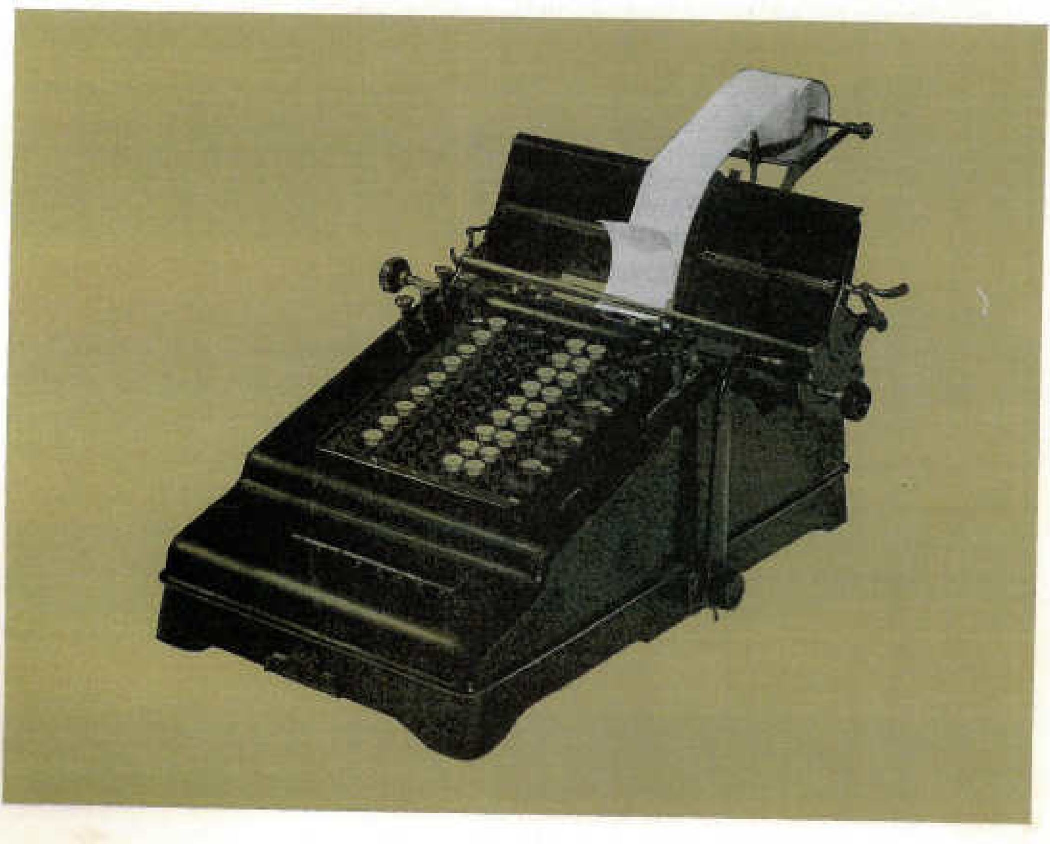
The same expansion was taking place in the Dominions and on the continent, one of the proudest achievements of the English company being the sale of 800 machines to the German Post Office. But it was not enough, the house of Burroughs had now realised, simply to *sell* machines: they had to be maintained too. And that demanded a service department which was just as efficient as the sales department.

In the very first days, if a machine happened to break down, it was first tinkered with by its owner and then, if the mechanism baffled him, it was turned over to an expert – who might be the local blacksmith, watchmaker or bicycle repairer. But after a few years of rough handling, it came to be realised that it was best to send for a man from the makers. While he was in the office he was asked to check the healthy majority of Burroughs machines – and so servicing became a full-time job, and one not restricted to the workshop. Where there was a high density of work the servicemen were found homes, and asked to settle down with a regular territory of repair and maintenance assignments.

From such accidental beginnings sprang up the world-wide Burroughs service of today, with its detailed life histories of every machine and its pooling of users' information. Regular skilled attention made for long-lived machines, and in fact models dating from the first years of the company are still in use, defying not only time but all offers of part exchange and suggestions that a more modern machine might really be an economy.

With so many innovations, it was not surprising that design in the non-mechanical sense began to change too. Burroughs had had a tidy mind, and in

Class 4 Simple Adding Machine; which was later developed into a simple bookkeeping machine



fact his very first machine looked a good deal more streamlined and – to the naked eye – free from gadgets than did any typewriter of the period. But he was enough of a human being to be rather proud of his ingenuities, and enough of a Victorian to want to expose the marvels of engineering to the world.

Accordingly he incorporated little glass panels into his machines, and instructed his salesmen to initiate customers into the delights of watching the pieces actually *moving*. It was one of his few miscalculations. Bankers proved disinclined to crawl about the floor inspecting cams and pawls: and in any case the news had spread that it could be assumed that a Burroughs model was mechanically above reproach. Users were satisfied that a machine worked: most would leave the whys and the wherefores to the experts. And so the glass was replaced by steel, and the ingenuity which had gone into displaying the mechanism was now devoted to such matters as the pitching of the keyboard at just the right angle for the hands and of the total-indicators at the right ones for the eyes, or the use of restful background colours combined with clear contrasts.

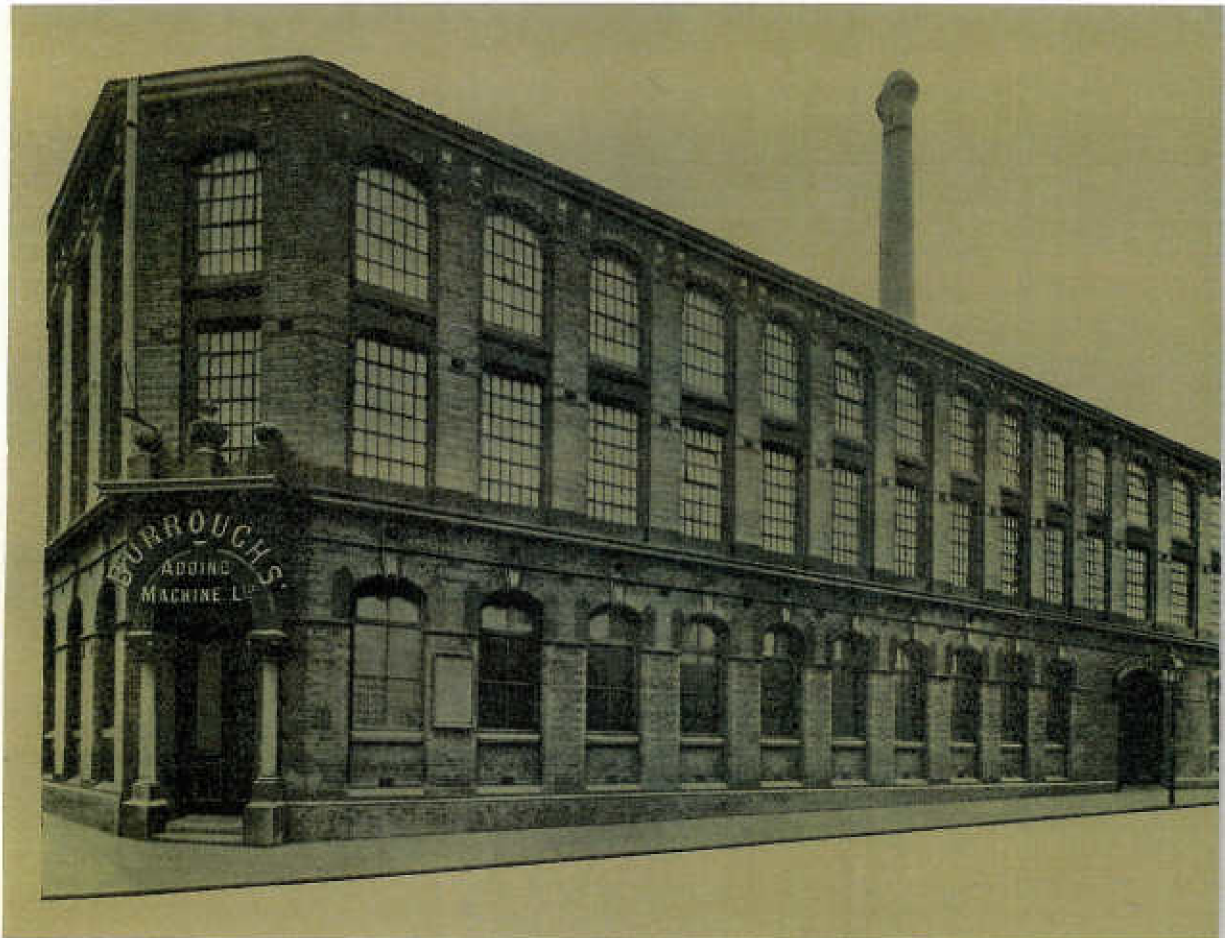
Many of these improvements, of course, greatly increased the intricacy of the mechanisms. The first Burroughs model had about 1,200 parts: within thirty years an average machine had nearer 5,000 – and 2,000 of these might be in motion at the same time. But it could not be allowed to become bulky; and it is hence not surprising that one mechanic remarked that, whilst he could practically throw his hat through an early machine without its touching solid matter, he couldn't worm even a corkscrew through the newer ones.

Yet a good deal, besides craftsmanship and much basic construction, had stood the test of years. Burroughs machines of the Edwardian era belonged to the same species of the genus *calculator* as did the first of all, and as do most today. This adherence was not due to any conservatism – the 'Inventions' boys had shown a dozen times over that they did not suffer from *that* – but was simply an acknowledgment of how well Burroughs had built from the very beginning.

When war broke out in 1914, the mechanical, sales and service departments were exploring new fields, and the expanded Nottingham works had set itself to produce 2,000 machines a year.

For the next four years the factory was devoted to a sterner production of machine guns and shell-making tools. It was hence not surprising that after 1918 it found itself ill-equipped to make the newer machines, or that for a while its main work was to be in assembly. But the machines it assembled grew steadily more sophisticated.

One of the first improvements to come in the post-war years was in sub-



The converted warehouse in Nottingham where Burroughs first started manufacture in 1898

traction. Pascal's early machine had simply run backwards for this operation, but Burroughs, in gaining so much, had inevitably lost a little flexibility. It was, in fact, not difficult to subtract on a standard adding-machine – all that was needed, apart from a bit of work on the 9-keys, was an additional key-chart with the 'complements' of the numbers marked on it. But for the benefit of offices that did a lot of subtraction, 'Inventions' used a good deal of artifice in an attempt to return to apparent simplicity. Eventually, pouring a little more of the wine of ingenuity into their pint pots, they came out with a gadget by which one simply pulled a lever which engaged a duplicate set of toothed reels – permanently in mesh with the main set – with the adding racks. One had then put the mechanism – 'carrying' device and all – into reverse gear, and could go happily ahead with direct subtraction knowing that 'borrowed' numbers would be taken care of.

So, almost monthly, the range of jobs that Burroughs machines could undertake was broadened. Sometimes the tendency was towards specialisation in a particular field: sometimes towards a more paradoxical specialisation in versatility. Even in 1912 there had been nearly ninety basic machines: and these, by permuting various features, could be transformed into well over 600 quite different models with functions ranging from simple addition to calculating the area of leather skins or preparing bank statements in Indian rupees and Portuguese reis. A decade later the variety was greater still.

Certainly for some of these models – such as the standard desk adder-and-lister with which it had all begun – there were many equally suitable uses. But for any given use there was only one best machine. The promotion of such a varied range could not be left to the blockbuster methods that had served when the primary task had been to make the world Burroughs-conscious. It had become that; and what was needed now was guidance in picking the right model for the right job, or perhaps in tailoring the job a little to fit a standard model.

And so the Burroughs salesman took the final step in a direction which had always been implicit. He had never been just a character who lived by a fast line of talk while his foot was stuck in a door; but now, whilst no less a true salesman than ever, he became something of an efficiency consultant also. He did not despise energetic sales methods, and was even willing to throw one of the new portable models across a level-crossing, to demonstrate its robustness, when closed gates separated him from a prospective customer. He was prepared to convince a Scots bank manager that he had something to learn from one of his tellers who had been noticed carrying his own machine to work each day. But he knew that there was more in salesmanship than that.

For he had been specially selected for his work. He had received special training. And he had a special and responsible task – to make a survey of the work of his customers, to study their needs and to prepare for them (even if it took many weeks) a chart that would show just how a certain number of machines of a certain type could revolutionise a certain office. If such a man was selling anything at all, he was selling methods rather than machines.

The modifications which this new office equipment had, from its earliest years, been bringing about in commercial practice were very real ones. For instance, the change from balancing books half-yearly to balancing them daily was only made possible by the machine, as were the present routines in bank clearing-houses and local government. Again, commerce today has largely reverted to the Babylonian practice of bookkeeping without books, the modern substitutes for ledgers being, not clay tablets, but cards and loose leaves – another change introduced by the machine. Owing to the lapse of a year or so between conception and production, it was always necessary for mechanical design to be a jump ahead of office routine; but more often than not the mechanical design not merely anticipated the new methods but actually provoked them.

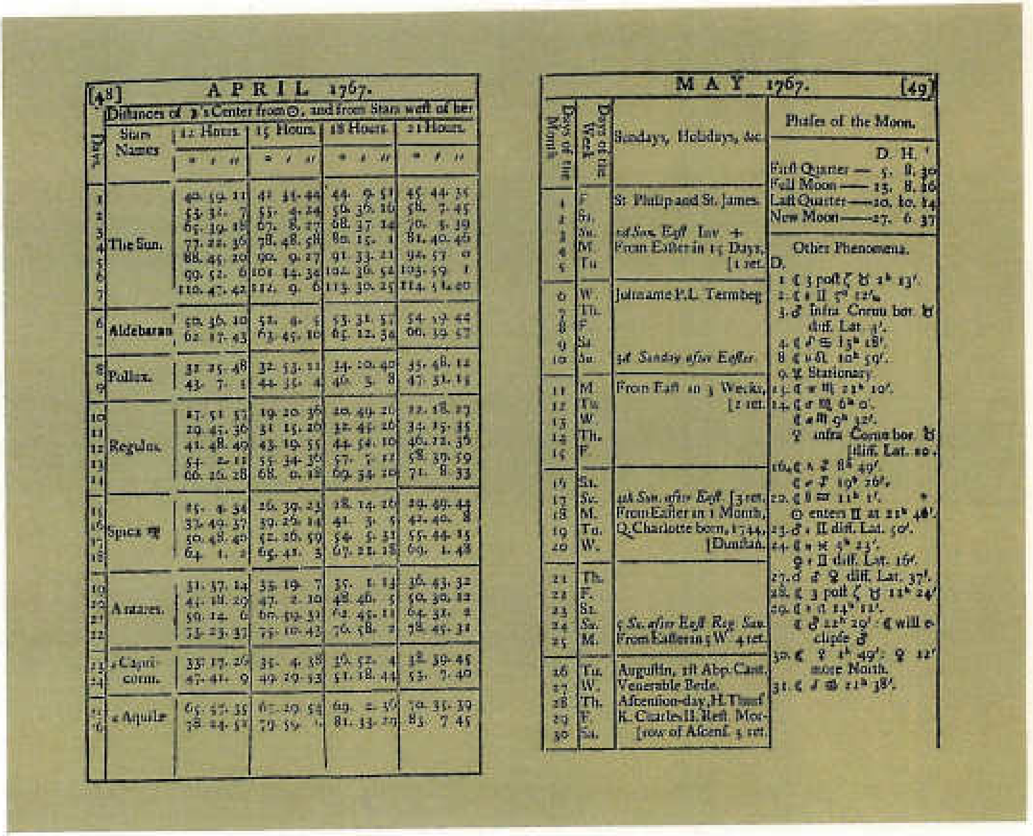
The revolution even spread to office stationery. Carbons that would not smudge were required, and ledger sheets that would not crumple when inserted in a machine, and cards that would bend easily round a platen but would straighten out when removed. With all the accessory equipment implied by this change, it saw the birth of a considerable new industry.

But everything turned on the machine: and mechanical design had never slowed its pace, though it had changed its direction somewhat in relation to the changes in commercial practice that it had itself brought about. The office machine had become less of a dangerous animal to be approached only by its keeper, and far more a part of daily routine. One perhaps heard no less of adding-and-listing machines, but certainly much more of ledger-posting and bookkeeping equipment.

These new models were pure-bred from the original sire. Not a few of their thousands of parts were even pressed or machined after Burroughs' own designs. But had the inventor returned to life and to Nottingham, he would probably have been grateful for the help of an experienced shop mechanic in understanding the latest of the products of his brain. For instance, there were all those *keys*. ... For some years, alphabetical abbreviations for procedure or dating had been incorporated in a number of models, but in 1924 the adding machine was wedded to a complete typewriter keyboard. For reasons of compactness, and out of consideration for the typist's rhythm, a 'ten key' keyboard was used in these machines.

It was in this double keyboard 'Typewriter Accounting Machine' – devised by two Burroughs mechanics – that the toughest problems of all were tackled; those of multiplication and division. The majority of machines, from Pascal's on, had seen multiplication as a process of repeated addition. To multiply 123 by 4, you added 123 to 123 to 123 to 123 – which, on a machine, took about as long to do as to say. To multiply 123 by 456 took a great deal less time to do than to say by this method; but it still took longer than the adding of the two numbers, owing to the need to shift the decimal place. Standard machines, in fact, were like those snakes which were loth to re-populate the world after the Flood: they said that they were adders and found it hard to multiply. ...

To produce a conventional office-style machine that could multiply 123 by 456 as simply as it could add them would have been a fantastic task, since even in that comparatively simple sum there were three multiplications – each a repeated addition – followed by a grand addition, and each stage affected



Two pages of navigation tables: reproduced from the first issue of the Nautical Almanac

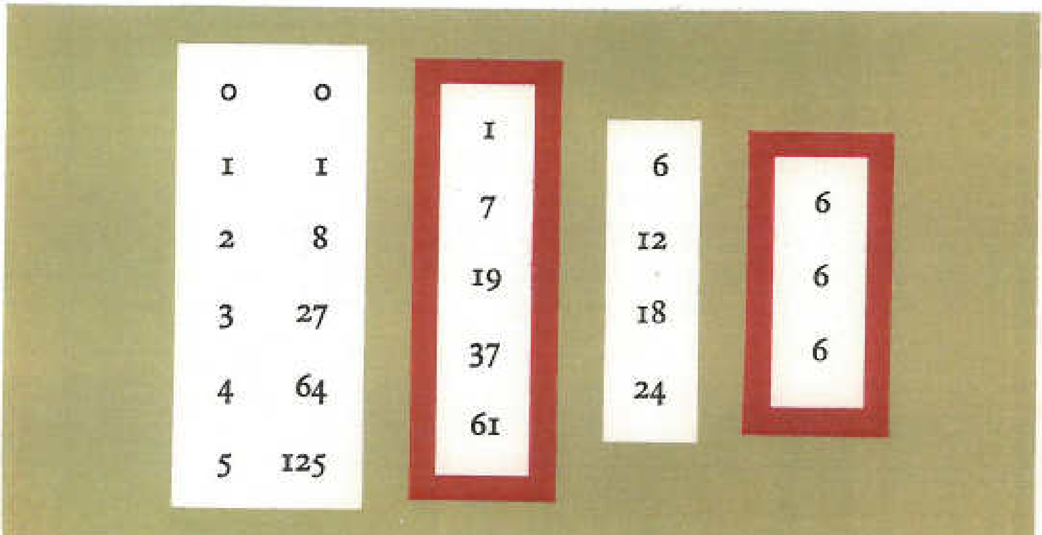
each other by 'carrying'. But a short cut was found by introducing a kind of 'Napier's Bones', in the shape of steel plates cut with the old school multiplication tables in a language that the machine could understand, and by multiplying from left to right. With such a machine one had only to set 123 on one keyboard and 456 on another, and press a motor bar, for the product to appear within a second. What had been going on unseen was, of course, nobody's business but the designers'. All that the user saw, as a result of their almost angelic wish to economise on labour and almost diabolic cunning and stratagem, was one more little key.

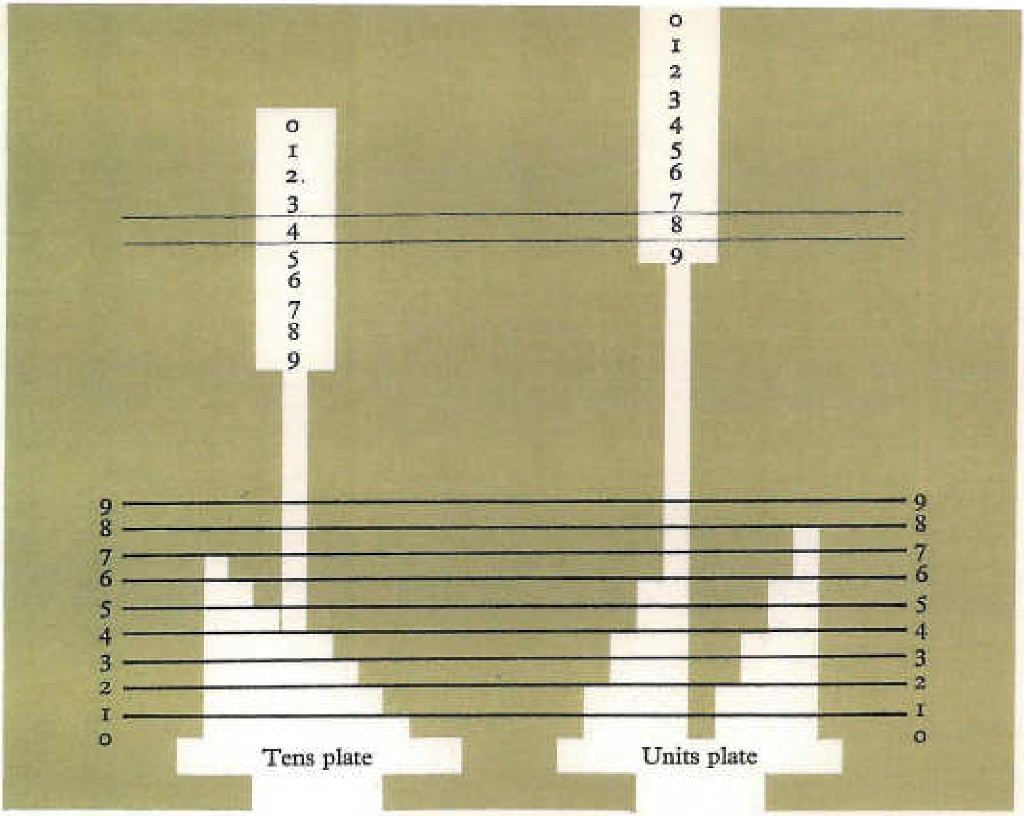
But there was one sort of multiplication that had always seemed to come naturally to Burroughs models, and that was the multiplication of their own fields of usefulness. Long ago they had left pure finance behind and had graduated to being servants of all kinds of businesses. So it was fitting that, in 1929, the Burroughs London office shifted from the City to the West End. But at that period, too, Burroughs was helping in a rather unexpected field – bearing a hand in the pure mathematical air of a computing room in the Royal Naval College at Greenwich.

This office existed for the purpose of helping to compile the international *Nautical Almanac*. Centuries before, five nations had divided the heavenly bodies between them: four had received assorted gift parcels of stars and satellites, and to Britain had fallen the task of predicting the movements of the sun, moon and planets to the degree of accuracy needed by navigators and astronomers. It was a tough task, because of the complexity of the mathematical equations that described these movements, and because of the amount of data needed for each year. For well over a century men had dreamed of compiling the tables by machine.

It had been to tackle just such a problem that Charles Babbage had attempted his great engine at a cost of £17,000 and ten years' labour. He had failed, and had reverted to the less exhausting pursuits of inventing skates for the sea, baking himself in an oven to see what it felt like, and diabolism. After him Scheutz of Sweden had produced a machine that went part of the way, and Burroughs machines, too, had done many jobs in the office since the beginning of the century. But in the 1920s much of the calculating was still being done by hand: and everybody was getting rather tired of it.

The calculation involved was the working out of the values of a 'function of a variable' for different values of that variable. Or, in plain English, it was the kind of calculation involved in drawing up a table of cubes of numbers. Such a table is given by the first two left-hand columns in the illustration.





Multiplying plates: showing steps on the plates that determine position of printed numbers

Looking at these figures alone, we can see no way of getting a table of cubes other than by multiplying each number by itself and then by itself again – and certainly no method of getting it by simple addition. Yet this can be done by a most ingenious trick. The third column of the table shows the difference between each successive pair of cubes – but not much progress. The fourth shows the differences between these differences, and gives a hint of what is to come. For the fifth column – the differences of the differences of the differences – remains constant.

Now we had better look round for a calculating machine and set four registers on it to the last line of figures – 6, 24, 61 and 125. We engage the total to the first register and pull the handle. It shows $0 + 6 = 6$. So we shift the total 6 to the second register, operate again, and get $6 + 24 = 30$. This, transferred to the third, will give $30 + 61 = 91$, and this, in turn to the fourth, $91 + 125 = 216$. We can now uncross our fingers: 216 is the cube of the next number in our table, 6.

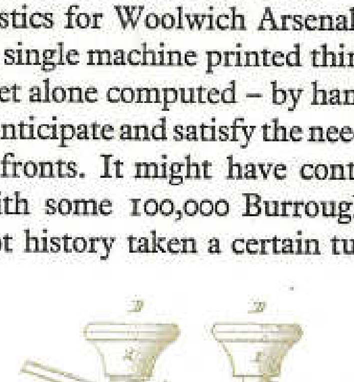
Now suppose that we had arranged things so that not only the total but the registers changed in each addition. These would then stand at 6, 30, 91 and 216. Repeating the whole process, we should (try it!) go through 6, 36 and 127 to arrive at the cube of 7, which is 343. No headaches: no sums on the edge of the paper: nothing but a slight strain in the right arm, and not even that if the machine we purloined was electric. Further, the results would be directly typed with no possibility of errors, as Babbage had desired.

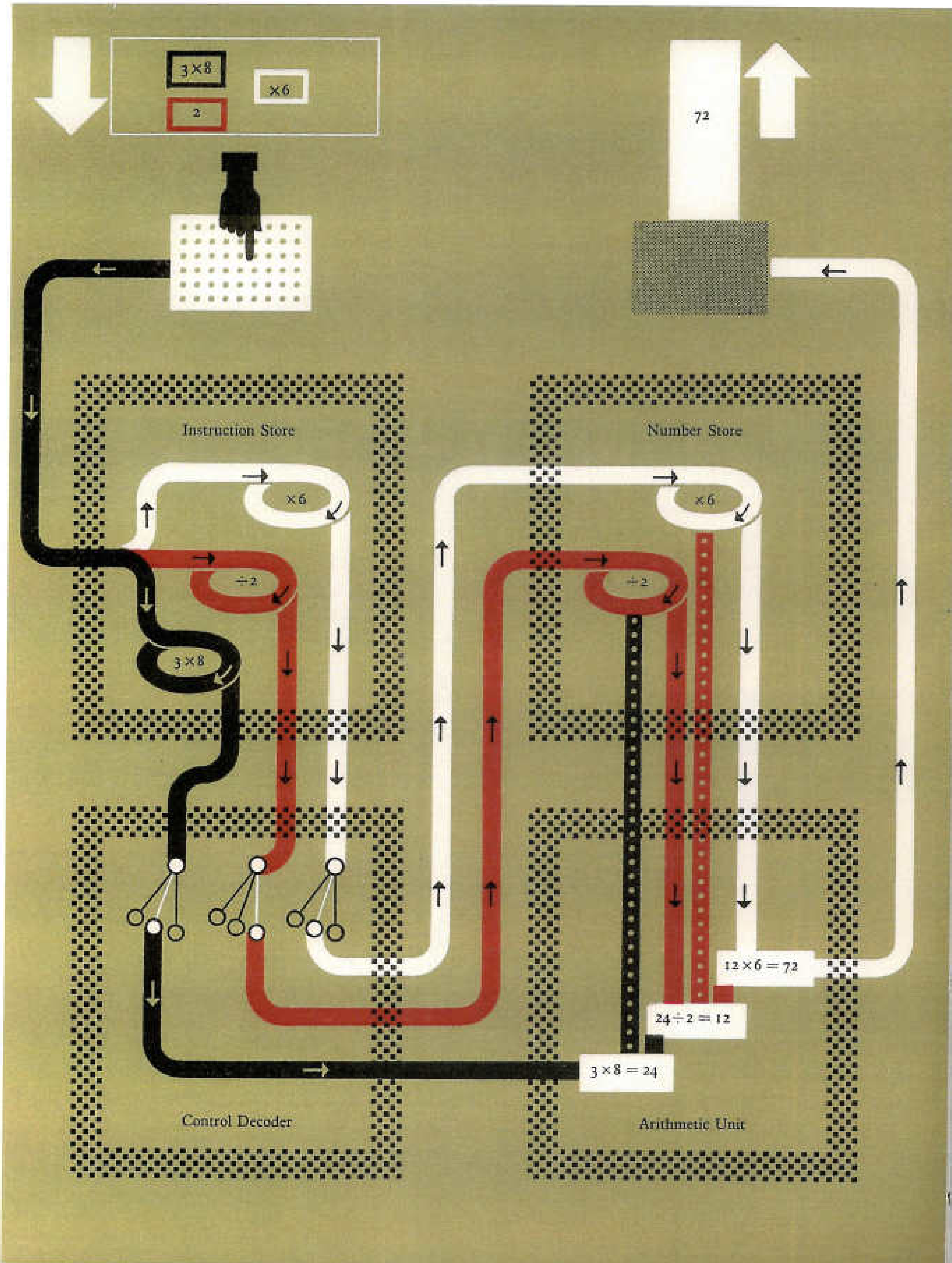
So, though a standard machine makes rather hard going of calculating the cube of 123,456, it can do it with no trouble at all if it has already found that of 123,455. In fact, it is ideal for compiling tables by 'integrating' from differences, and does so at a rate of up to 1,000 values an hour.

The tables needed in navigation are a good deal more complex than that of $y = x^3$: in some, the differences are not constant and must be independently calculated. But they are the same *kind* of tables. And so, when the Royal Naval College determined to mechanise its computing, this presented no great problem to Burroughs. An average of two production machines performed perfectly the task that had defeated Babbage and his 'Differencing Engine' as big as a barrel.

This history points a good many morals: for instance it shows how a run of the mill commercial machine, if designed on sound mathematical and mechanical principles, may easily be modified into a custom built model to perform highly specialised work. And in fact, through the 1930s, a great deal of computation and checking of functions – including trigonometrical tables and work in ballistics for Woolwich Arsenal – was done on Burroughs equipment. In 1931 a single machine printed thirty million figures, or more than could be copied – let alone computed – by hand in seven years.

But the main task, to anticipate and satisfy the needs of commerce, continued steadily forward on all fronts. It might have continued to do so, smoothly and unspectacularly, with some 100,000 Burroughs machines entering the world each year, had not history taken a certain turn in September 1939.





3×8
×6
2
72
Instruction Store
Number Store
×6
÷2
3×8
×6
÷2
12×6 = 72
24÷2 = 12
3×8 = 24
Control Decoder
Arithmetic Unit

WORK IN HAND

In one of those terrible white dawns which followed a night of fire, a London businessman picked his way ruefully across the ruins of what had a few hours before been his office. Then he saw, protruding from a pile of rubble, a familiar object – an ancient Burroughs adding machine which had been very close to its fiftieth birthday when it and the building that had housed it had together been smashed. ... If it *was* smashed; for on closer inspection it looked as if a few parts might miraculously be salvaged.

So the machine was taken round to the local serviceman. He removed the shattered cast-iron frame which had taken the worst of the shock, and from stock he produced a replacement. This fell into place as smoothly as if half a century had not elapsed between its manufacture and that of the rest of the machine: and, that done, the veteran began to add as confidently as if it had just come off the assembly line.

That incident might point the resilience of Burroughs machines to rough treatment, both normal and abnormal – for it is no isolated case of longevity, and today machine No 341, on the eve of its sixtieth birthday, is usefully at work in another London office. Or it might point the importance of the manufacturer's system of standards, in which specimen components from the very first assembly line are reverently preserved so that every new jig may be checked against them and so that accurate machine replacements are always obtainable. But equally it symbolises the survival and strengthening of an industry throughout difficult years.

For Nottingham was permitted to continue its work between 1939 and 1946 by a government which realised that calculating machines were as important a part of national life in war as in peace. It is true that, in the darkest days, its staff was reduced to a few dozen old timers and work was – as so often in wartime – mostly of the make do and mend type, such as the re-equipping of an office bombed on a Wednesday so that pay cheques could be made out for Friday. Yet even in this period a high army officer could confidently demand 1,000 portable machines with the peculiar quality of being operable in the heat of battle by men lying on their stomachs under lorries.

This order was made up from American parts, so satisfactorily that it is estimated that 3,000 soldiers were thereby released for combat duty. A few years later the RAF placed a similar order; but meanwhile, the senior – and silent – service had silently served itself with a battery of twenty machines, in

Schematic diagram showing the principles upon which a simple electronic computer operates

The Vale of Leven, sixteen miles from Glasgow, before building operations were started

The Strathleven factory: meeting place of Scottish labour and British raw materials

From 1898 to 1900	a period of 3 years	1,210 machines were produced
„ 1901 to 1905	„ 5 „	2,424 „
„ 1906 to 1910	„ 5 „	3,174 „
„ 1911 to 1915	„ 5 „	5,520 „
„ 1916 to 1920	„ 5 „	1,500 „
„ 1921 to 1925	„ 5 „	3,447 „
„ 1926 to 1930	„ 5 „	9,755 „
„ 1931 to 1935	„ 5 „	2,431 „
„ 1936 to 1940	„ 5 „	5,039 „
„ 1941 to 1945	„ 5 „	679 „
„ 1946 to 1950	„ 5 „	20,300 „
„ 1951 to 1952	„ 2 „	51,730 „

The English history of Burroughs is told in the record of production figures since 1898

order to handle the stock keeping of the 300,000 different articles that it needed to perform its multifarious duties.

Nor did the pace slacken in the immediate post-war years. On the one hand, the centralised national executives that had taken over the transport and coal industries demanded a steady flow of facts and figures from their dispersed offices, and new phenomena such as self service cafés brought new demands. On the other hand, the traditional calls of commerce were intensified in a radically changed social scene.

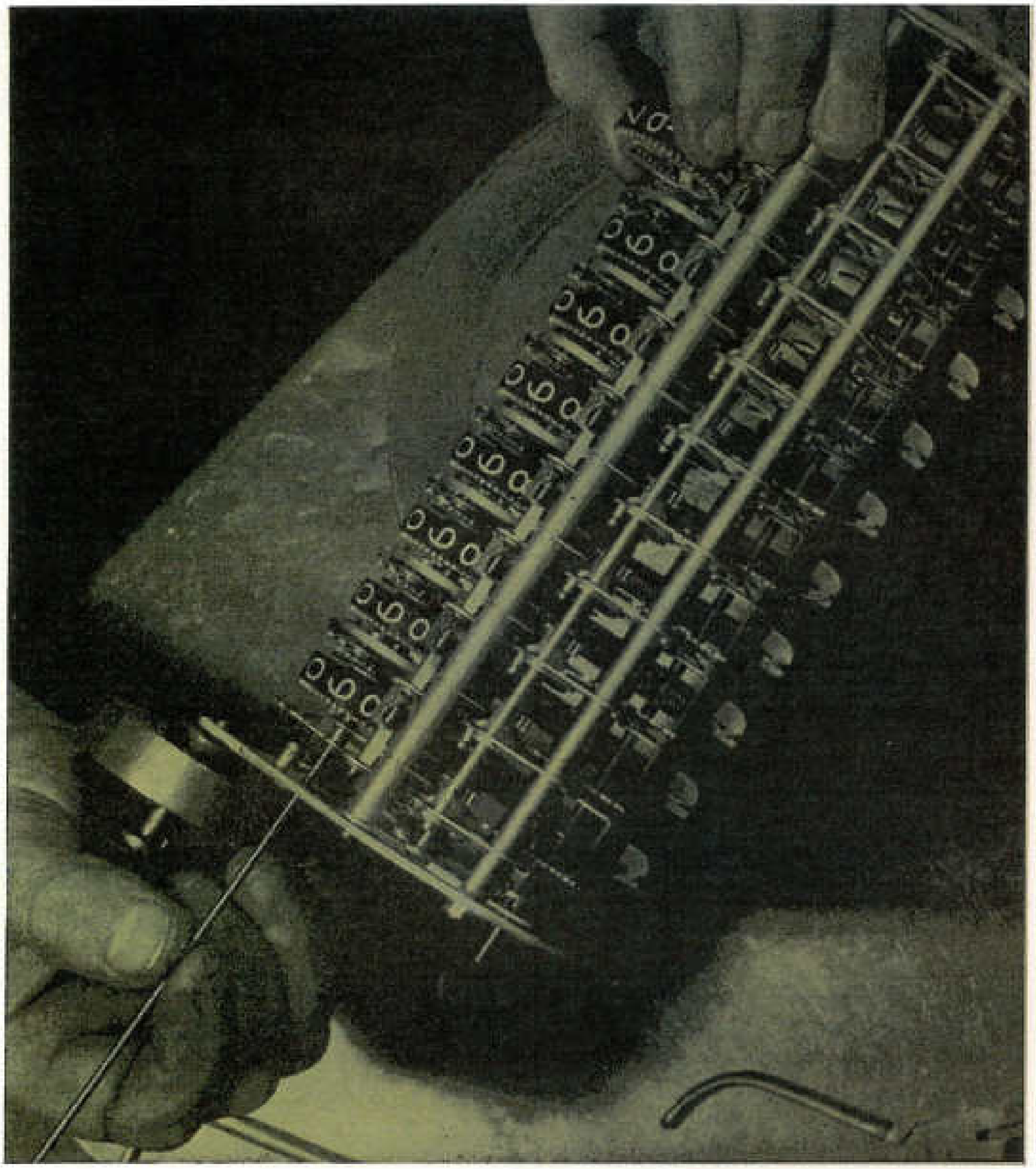
Full employment had created a shortage of labour and the legacy of bombing had created a dearth of office space. Acres of pen-scratching clerks were now hopelessly uneconomic – even had young men with recent experience of anti-aircraft predictors and computing bomb-sights, such as the Burroughs-made 'Norden', been willing to face the drudgery of mental figuring. Nobody doubted now that where there were figures there was a need for mechanical aid, and the most conservative of businessmen had to re-plan his work so that it could be handled by a few competent girls at a few compact keyboards.

A sales staff reverting to its pre-war strength – and soon to pass it – could hardly be expected not to take advantage of this situation; but production was getting a little out of breath. In an effort to diminish the backlog of orders for its products, the world's oldest Burroughs factory at Nottingham was re-arranged so that nearly 4,500 machines a year could be assembled there, many

Visual testing of a part: the long indicators prove the accuracy of parts machined to fine limits

of them of post-war design. But there was a strict limit to the capacity of the 25,000 square feet of the Nottingham plant: and when its walls began to bulge with double its immediate post-war staff, it was clear that something drastic had to be done.

By this time, however, a new and very unwelcome visitor had entered the front offices of a good many British industrial enterprises. It called itself the dollar gap; and it was particularly embarrassing to the English house of Burroughs, which before the war had imported component parts from America and built them into machines for sale in most of the Eastern hemisphere.



Assembly at Strathleven: close-up of the alignment of the adding wheels in a rear register

That had been sound practice in 1938 when a pound or a franc was as good as a dollar. It was not at all sound practice in 1948. In the paradoxical post-war economic climate, Britain could not afford to develop an industry that depended on the laying out of dollars for every article built. Equally, it could not afford *not* to develop an industry that already brought in currency from most countries except America and that could (if the rest of the world did not have to spend dollars on Burroughs machines) bring in much more: an industry, too, of the type the country most needed – light, mobile, with over seventy-five per cent of the cost of its product made up of labour and skill.

A 'Sensimatic' accounting machine: its 'sensing panel' gives it flexibility as well as its name

Something drastic had to be done about *that*, too; and towards the close of 1948 the transatlantic cables began to hum on the subject. The decision came in a few days. It was simple and spectacular. What was proposed was that a great new British factory should be set up which – so far as possible – should build machines with British materials from the ground up.

But fully to equip a factory able to make every part of every model would have meant a fantastic capital outlay, partly in dollars. It would also have implied an uneconomic duplication of resources. So for the moment Britain would continue to buy some parts from the USA: but in return America would stop producing certain models and would import these exclusively from Britain, paying hard dollars in return. The all-British machines would be those in the 'Calculator' range, chosen largely because they were assured of a steady sale everywhere in the world. To such details was the plan worked out: it was as fine a blend of transatlantic good sense and good will as lease-lend itself had been. But it was also, in a way, the repaying of an old debt.

For nearly twenty years before, it had been America which had reeled to unforeseen economic shocks. In those days of the slump a desperate message had gone out from Detroit to London, to the effect that the British company should sell every usable machine it could lay its hands on. So well had the British salesmen responded that one had even managed to dispose of an avoirdupois model to a bank that was interested only in pounds, shillings and pence. Perhaps he was a little *too* enthusiastic: but the result of these efforts was such that, though unemployment soared in America as a whole, Burroughs was able to keep its factories at work.

Now that Britain's own economy was sick, the vast sales resources of the American company were to help in the selling of an all-British product. The difference was that this was to be a permanent arrangement and was, in fact, part of a re-shaping of Burroughs methods in terms of a world-wide 'integrated production'. There were to be developments in Canada, too, for example, and a small plant was to be set up in Paris.

But meanwhile the new British factory was only an idea; even a site had to be found for it. At this stage the government took a hand, stressing a fifteen year old policy that new light industries should be located in places that relied on a single heavy one, or that had suffered depression in the past. Burroughs own requirements were only that the site should be near a port, have a reserve of adaptable if untrained labour, and provide good working conditions.

With three government departments and the British and American Burroughs companies interested, negotiations might have been interminable. But in fact a suitable site was found within a few months – and then the name of Strathleven began to figure on the Burroughs files.

The new factory was to be built in Scotland, where it would form part of a forty-five acre estate in the Vale of Leven, selected for development in 1946 – a fitting enough site, since for eight centuries the Scots had been pre-eminent in the fields of mathematics, accountancy and engineering. It would draw its labour locally; from the men and women of the grey villages nearby which were in a depressed state since their trade of cloth dyeing had moved south; from the nearby, rock-dominated county town and port of Dumbarton; even from Glasgow, some twenty miles off, where perhaps men would be found willing to exchange the heavy rivets of shipbuilding for those tiny ones used in adding machines – infinitesimal rivets of which hundreds can be (and are) stored in the shallow depressions of an ordinary kitchen bun tray.

So in the early months of 1949, whilst sleepy shorthorn cattle looked on, the first sod was cut from the virgin, oak shaded water meadows beside the Leven – a gracious river winding down through the rolling foothills of the Highlands and taking its time over a brief journey from Loch Lomond to the banks of Clyde. Under the auspices of the government sponsored, non-profit-making Scottish Industrial Estates the footings were laid and steel frames began to span wide, uncluttered floor spaces.

Strathleven's staff at this time consisted of two men and a girl, but almost immediately the equipment was to be bedded in. Today this is largely British, together with specialised machines from Belgium, Switzerland and Italy which range in size from 300-ton presses to tiny watchmaker's lathes; but the very first machines were American. So, for the second time in the history of Burroughs, consignments of plant crossed the Atlantic. But this time they rolled north through Scottish by-roads, and were accompanied by a task force of seventeen American experts to supervise the installations – and later to pass on sixty years of know-how to future British supervisors.

With happy relations between government and industry, between Americans and British, the skeleton factory spread out over 150,000 square feet and took on a fabric of brick and asbestos board which would not offend in that landscape. Only nine months after construction had begun – in fact, whilst flapping canvas alone separated many of the shops from the misty Scottish weather – production was under way.

It took two months to produce the first seventy-five machines. But less than a year later – on 4th October 1950 – John Coleman, President of Burroughs, was able to call a press conference in London and announce the formal opening of a plant that was then producing fifty machines every day and employing 500 workers. To assembled chiefs of government departments, industrialists and pressmen he gave the reason why the factory had been located where it had, when theoretically it might have been built in any soft currency country. It was because – he said, speaking as an American – 'We believe in Britain. Her people have a reputation for skill and determination. We want the best results from our operations, and we felt that here we had a splendid chance of obtaining them.'

A year later still, and Strathleven's 10,000th machine was in sight. It was actually built at the beginning of 1952; but that was only the signal for a great offensive to begin. Before the year was out, those 10,000 machines had become 50,000 – and the backlog of orders in Europe was completely wiped away. And all this was achieved by men and women who were new to their work, in a factory where if you had served two years you were an old stager.

Something like a military operation had taken place, and the objective had been gained. It was now possible for Strathleven to settle down to a more normal rate of production – and to turn its attention to the streamlining of the process. For instance, it was found that men in the shipping department had been walking nearly sixty feet to perform a certain job: the time and motion study experts cut that distance down to four feet, and were then turned over to finding some way to reduce Strathleven's annual cleaning bill of over £10,000. Meanwhile, in the production control offices, a wondrous chart had been completed on which the movements of 2,000 different components could be followed and demands could be foreseen ten weeks in advance.

Today Strathleven is concentrating on two basic models – the all-British 'Calculator' and a desk bookkeeping machine. Even so, life is hardly monotonous: to date, there are thirty-seven variants possible on the first of these and no fewer than 331 on the second. Further, some of the simplest looking sub-assemblies (such as the adding wheel) are in fact made up from ten parts and require 168 operations to fabricate.

But whilst all this was going on, a new development was under way. Side by side with what was now the 'old' factory, a sister factory was rising which would eventually double both the area and the labour force of Strathleven. It was started in March 1952: a year later, one third was occupied and there were high hopes of completion within 1953 – by which time Scottish Industrial Estates would have erected a new canteen in 'Festival of Britain' architecture and would have handsomely landscaped the gardens of the site.

This new plant will permit the separation of the two essential sides of Strathleven's work, fabrication and assembly. Yet, surprisingly, of the 1,000 present employees only 300 tend those ranked machines that are accurate, not to a hair's breadth but to a tenth of a hair's breadth: and only 120 sit at the horse shoe shaped assembly line. Those 120 are the front line soldiers who each need seven other men to keep them active. There are, for instance, the seventy toolmakers for whom the care and production of tools is a full time job. There are the inspectors who sample a year's output of fifty million parts to see that Burroughs standards are maintained. There are the engineers, who carry out maintenance work in the factory. There are the laboratory staff, at the moment mainly engaged on testing the numerous different alloys that go into Burroughs machines but equally ready to try to improve the non-fading qualities of plastic keys. And there is the shipping department, where the breadth of the Burroughs organisation is most vividly experienced, where the crates (economically made up by the joiners from old component boxes, and wrapped in waterproof paper against their long voyages) bear names like Valparaiso, Sydney, Vienna and Freetown, as well as the names of Detroit and New York.

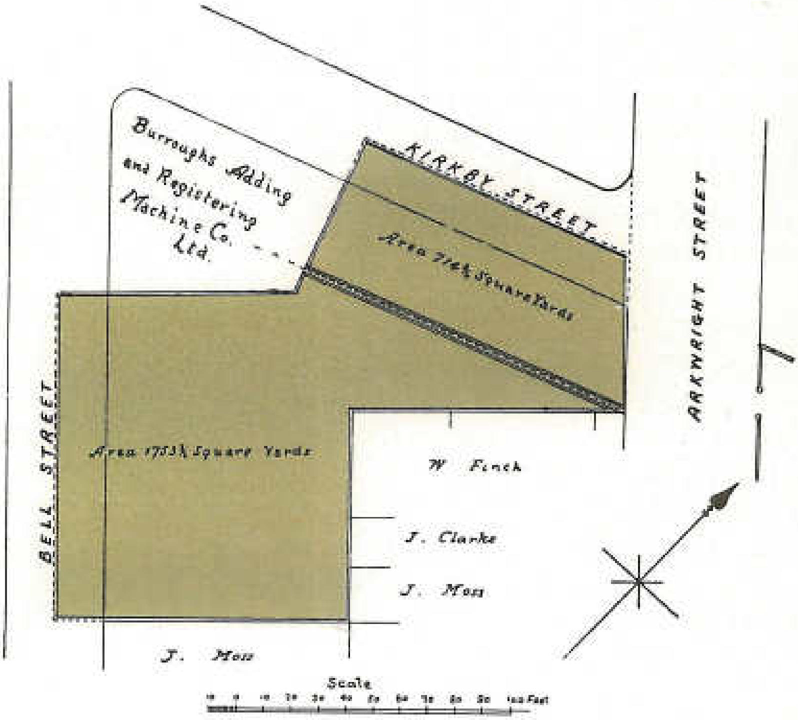
In a final whirl of statistics, the interpretation of which calls for the services of one of the more sophisticated Burroughs models, it can be mentioned that

Nottingham: oldest home of Burroughs in England, where the 'Sensimatic' machines are built

Strathleven's production now stands at about 25,000 machines annually: that over fifty per cent of these go to dollar countries and under thirty per cent stay at home: that of the 'Calculators' over eighty per cent cross the Atlantic: and that in seventy other countries of the world there are customers for this new Scottish industry.

Yet Strathleven, for all its impressiveness, is only a constituent part of British Burroughs and after its opening the Nottingham works were turned over to the assembly of the more complex models. But there are many similarities between the two factories.

Both, for instance, are equipped with workshops capable in an emergency of filling a 'one off' order for any part in the Burroughs range, from a tiny type-bar of hardened steel to a side-frame; and both are guided in this work by libraries of nearly 100 fat volumes of blueprints. In both, too, there is rapt attention on the faces of the men who build up from component to sub-



Burroughs acquires the freehold

THIS INDENTURE made the Twenty eighth day of September One thousand nine hundred and seven BETWEEN WILLIAM FOSTER of the City of Nottingham Cabinet Maker & Upholsterer of the one part and SIR JOHN TURNEY Knight and ARTHUR THOMAS ASHWELL Gentleman both of the same City of the other part WHEREAS the said William Foster is seised in fee simple free from incumbrances of the hereditaments hereinafter described and intended to be hereby conveyed and has agreed to sell the same to the said John Turney and Arthur Thomas Ashwell at the price of Twelve thousand five hundred pounds (£12,500) AND WHEREAS it was a condition of the said sale that the sum of £8,000 part of the said purchase money should remain upon Mortgage of the said hereditaments at Interest after the rate of £4 per centum per annum payable quarterly NOW THIS INDENTURE WITNESSETH that in pursuance of the said Agreement and in consideration of the sum of(£4,500) Four thousand five hundred pounds part of the said purchase money to the said William Foster paid by the said John Turney and Arthur Thomas Ashwell on or before the execution of these presents out of moneys assembly, from section to complete machine: they look for all the world as if they were constructing, for their own pleasure, some fantastically elaborate Meccano model. But there are differences between the two works, as well.

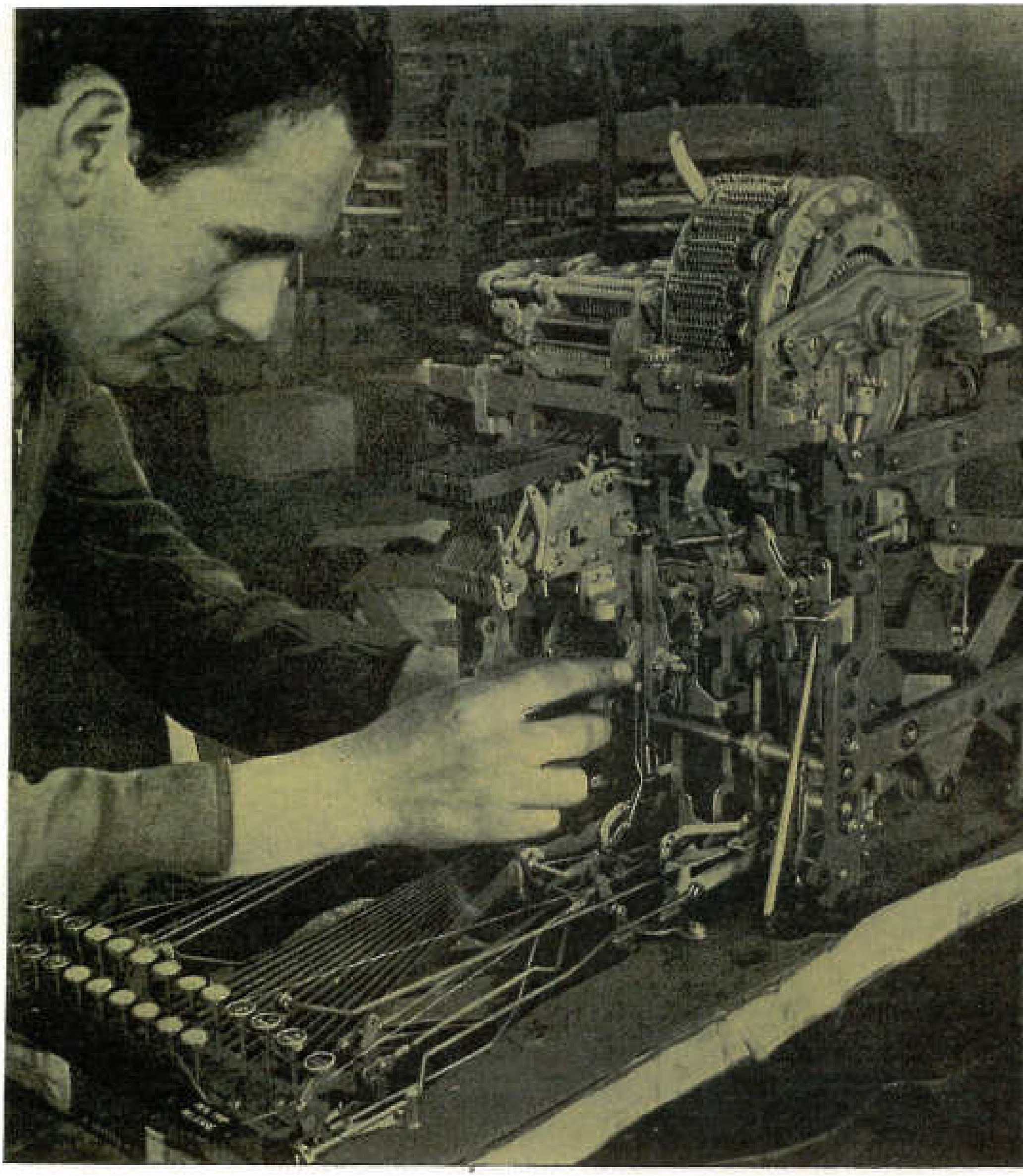
In Nottingham, for example, many machines weigh 100 lb or over, and hence they are not passed by hand from one stage to the next but are trundled around on ball-bearing turntables. Assembly is more specialised; and to eliminate the danger of bottlenecks forming in a production line scheduled to five minutes, machines at every stage of construction are kept in reserve.

It is not surprising that it takes the services of seventy men simply to assemble, say, a typewriter-accounting machine, since virtually every one of these is custom built to its future user's requirements after a conference between those two experts, the salesman and the customer. For instance, an Oslo bank with international trade may order a model with Norwegian letters but capable of handling sterling. The Finns like Roman numerals to denote the months, but they have quite different ideas in Fiji and Indonesia.

To take care of details like these, a fat dossier giving the exact specifications in coded blueprints passes from the sales departments to the Nottingham assembly shops, and accompanies every machine through the three weeks of assembly, the running-in under an oil spray, the three days of adjusting, and the final eight hours of testing – which is done on the user's own stationery.

Paper, in fact, is rather a speciality of Nottingham: in one of its small back rooms three machines slice up all the various-sized rolls of it for all the Burroughs machines of half the world. That is a small, but essential, part of the organisation. Equally essential, but far larger, are the mechanical servicing and sales departments which – at London head office or in the branches placed at thirteen strategic points in the provinces – employ an expanding force of some 500 men (and, on the instructional side, quite a few women too).

Any new applicant to join the workshop staff or the ranks of field service-men finds that, in the customers' interests, the steps to the entrance have been made very steep. He may pass a medical examination designed to ensure that he will be able to rise at dawn and travel to a rush job some fifty miles away without tiring of the weight of a little black bag filled with the spare parts likely to be needed. He may satisfy his superiors that he has the right psychological make up to approach with a calm smile not merely a faulty machine but an entire office in pandemonium. He may make a good showing on the gruelling mathematics paper with its six lengthy questions to be answered in ten minutes. But there remains the moment when he must face an adding machine for the first time, be shown briefly what makes it tick, be left alone to tinker with it for fifteen minutes, and then undergo a searching interro-



Machine assembly at Nottingham: order and accuracy emerge from intricacy and complexity

gation on what he has been able to find out about its elaborate mechanisms.

Still, if he should prove to be the one in a hundred who is accepted he will receive a year of well paid training at his branch. He will spend three months on company policy, three in mechanical training, three in apprenticeship to a service workshop, and a final three months on the road. Even then he is only qualified as an 'A' man, entrusted with the simpler machines: but in years to come he will take a 'B' course in London where – largely by self tuition – he will study the later models, in company with colleagues from all over Britain and from as far afield as Turkey and South Africa as well.

Nottingham, where the more complex models are built: a general view of the assembly line

By then he will know every machine and will be experienced in every aid he can render to Burroughs users. Sometimes he will be visiting the seventy per cent of them who have signed regular agreements and regard a calculating machine as they regard a telephone – less of an instrument than a service. At other times he will be answering the emergency calls that are dealt with through branch switchboards whose methods resemble those of a wartime operations room. He will be familiar with most of the 100,000 parts in the Burroughs range, each with its international code number, so that if called on he can deal with a fault in Sweden or Spain without necessarily knowing a single word of the language. But even so, his training will not have finished.

For the serviceman is called to London for a refresher course whenever a new machine is marketed, even if he has been at a bench for forty years. Furthermore, though ever since the regrettable affair of the dashpot it has been Burroughs policy to present a new style only after exhaustive tests over years, there is always something that can be learned only from actual use. And so it is part of the serviceman's responsibility to keep a special watch on new models in their first year, to report weaknesses to the designers, and then, if a change is made, to fit free replacement parts of improved design.

Nor has the serviceman's colleague in the sales department any lighter responsibilities; for he must be able to understand all his customers' needs. Furthermore, in the last few years he has also had to acquire a knowledge of the British built microfilm equipment marketed by Burroughs, which can record up to fifteen images every second. So he, too, is hand picked for his psychological and other qualities: he, too, goes through preliminary training in his branch: and he, too, after practical experience, is called to head office for advanced training. There, as a member of a small group under a full time instructor, he joins in discussions on sales methods, demonstrates and is demonstrated to, and avails himself of tape recorders, film strips, charts and less conventional visual aids – such as a remarkable blackboard on which all the operations of an accounting machine can be reproduced.

With such insistence from the start on high quality in sales and service personnel, it is not surprising that all the top executive positions in Burroughs are filled by Burroughs men. An employee may have worked his way up from tramping a territory to controlling a zone and then a branch. Or for some years he may have found himself alone in one of the twenty-eight 'service points' which serve more isolated localities, from Aberdeen to Cork and the Channel Islands. But either way he stands a good chance of sitting eventually behind one of the largest desks in one of the lushest offices in the Burroughs organisation – when he has time to sit down at all, that is.

Meanwhile it is little use his selling or servicing machines unless they are to be handled by operators capable of getting the best from them. From the earliest days of the Burroughs company, therefore, schools for operators have been attached to every branch. Today some 2,000 girls in Britain qualify from these schools every year, whether as private pupils or sent by their employers for free instruction, and whether in 'Calculator' operation or in the use of bookkeeping machines. In any case the girl who leaves with a credentials card in her handbag and a diploma under her arm will be able to command a good salary wherever she finds herself. And she has another great advantage:

for her benefit and for that of commerce, Burroughs follows her career and maintains a world-wide placement service. A girl who has once qualified may marry, emigrate to Australia, raise a family and, years afterwards, present herself at the nearest Burroughs branch with the assurance that part time or holiday relief work will be found for her without charge.

Beyond planning and production in all their aspects, beyond sales and servicing and training, Burroughs maintains all the other departments of a great concern – the personnel and welfare services which (together with a democratic approach by management and a lack of restrictive practices by workers) have always given the company a good name for labour relations, or the publicity and accounting and shipping offices which are all the more elaborate since they form part of a world-wide pattern. Yet, at the last, a business must stand or fall by the developing quality of its products – and in the field of design there are certainly no signs of stagnation. Perhaps the key to present and future trends is held by one of the most remarkable innovations in office equipment of post-war years. It went into production about 1950, and was called the Burroughs 'Sensimatic'.

The 'Sensimatic' was a compact, streamlined, fully visible machine capable of carrying out a wide variety of business calculations and with a highly developed faculty for detecting its operator's errors. But it was more than that. Throughout the years, there had been a steady development towards making various operations, such as non-adding and sub-totalling, take place automatically at the right position of a tabulating carriage, and ingenious 'control bars' had been incorporated to this end. The 'Sensimatic' carried further than ever before the ability to perform a series of operations automatically in set sequence. Thus, it could enter a sum, date it, add it to another number, carry the total, subtract this from another total, enter the answer in the appropriate credit or debit column, repeat all this in abbreviated form for a duplicate copy, and finally open the carriage – all without batting an eyelid and by the pressure of a single bar. Further, four different such sequences could be chosen at the turn of a knob, and the potential variety of them was almost infinite. The 'Sensimatic', in fact, did not merely compute but performed many different 'programmes' of operations.

Such detailed mechanisation was new in the office. It was not new in the laboratory – but there it had been achieved by purely electrical devices. And despite the mechanical triumph of the 'Sensimatic', the increasing complexity of this and some other later machines set the heirs of Boyer's 'Inventions' department thinking rather wistfully of those electronic computers which they had incorporated in wartime predictors or had custom built for

Modern desk machine, P.400: Multiple Total Machine, for simple adding or complex bookkeeping

special scientific purposes – of the new 'memory' which they had given to the celebrated 'mechanical mind' ENIAC, for instance.

They had seen digital electronic machines, of a type that might prove useful in commerce, emerge from their first teething troubles to the state of reliability that offices demanded. Could they now introduce them into everyday business practice?

The way the Burroughs research scientists in Philadelphia looked at it, there were three stages in using any calculating machine. There was the input of information, the output of it, and everything in between. Because the study of computing machines had become a science with its own vocabulary, a science whose experts regarded statistics as something as solid as cheese, this 'everything in between' was rather quaintly called the 'processing' of the information. Thus, on a conventional machine, you pushed down a few keys – input – and later saw the answer to your problem showing through a little window – output. In between, something had happened to the number you fed in, like its addition to another number already in the machine; and this intermediate stage was the processing.

But it had been accomplished by all kinds of wires and whirring wheels, even in a so called electrical machine. An electronic computer was something quite different. It still had a semi-mechanical input, taking its orders from keyboards or punched cards or tapes. It still had a semi-mechanical output, printing the results of its labours on a kind of teleprinter. But these were concessions to its human operators – everything between was electronic.

All that that mysterious and rather glamorous word meant was that the operations of adding and multiplying, of temporarily storing figures in a 'memory' and of transferring them from one sum to another, had been accomplished by pulses of electricity that were never converted to mechanical movements. Instead of racks and registers one had valves and condensers, performing in perfect peace. That this was possible was largely due to the kind of numbers that were used: for they were very different from our familiar ones, which have a 'root' of 10 (that is to say that there are ten symbols, including the zero). We can write ten different numbers using no more than one digit, 100 using no more than two, 1,000 using no more than three, and so on.

It is only habit – and the fact that we have ten fingers – which makes this decimal system seem the obvious way to count, and the electronic machines believe in greater simplicity. They work most happily with the lowest root possible, 2, and the only ciphers they recognise are 0 and 1.

Numbers written out on this 'binary' system (as the first few of them are here, together with their everyday equivalents) appear rather enigmatic. But they obey the ordinary laws of arithmetic. For instance, the binary forms of 1 and of 2, added together, make the binary form of 3.

0	0
1	1
2	10
3	11
4	100
5	101

And this is what 2×3 looks like in binary notation:

$$\begin{array}{r} 10 \\ \underline{11} \\ 100 \\ \underline{10} \\ \underline{110} \end{array}$$

For the benefit of those too alarmed by these familiar looking numbers with unfamiliar meanings to continue the table, 110 is the binary way of saying 'six'.

The system looks hopelessly impractical – for instance, our nice portable 17 becomes 10,001 on the binary scale. But it has the immense advantage of providing a kind of code by which numbers can be 'signalled' directly, using only two kinds of signals. These might be a dot and a dash, but are actually simpler than that – a dot and no dot. Electronic machines are interested in only two phenomena – something happening and nothing happening.

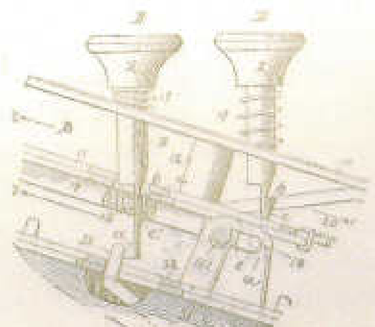
Such a machine when multiplying any two numbers is in a position that a schoolboy might envy. It has no tables to remember beyond $0 \times 1 = 0$ and $1 \times 1 = 1$. In actual operation the multiplier and the multiplicand are fed into the machine in the form of pulses of electricity that are carefully synchronised by the same kind of circuits that are used to keep a television image steady. When a pulse from the multiplier and from the multiplicand arrive together at a 'coincidence detector', a pulse is passed through to the product circuit: a pulse from either one alone will be blocked. In adding, single pulses go through and double ones are carried to a 'tens' circuit. Either way, these pulses of electricity that do all the work can be amazingly brief – normally they last under a millionth of a second – and the celebrated 'speed of thought' becomes a snail's pace by comparison.

Speed is the attraction of electronic computing from the commercial point of view, of course, despite the great initial cost of the machines (at the moment this is well up on the tens of thousands of pounds scale). Nobody foresees them replacing the desk adding machine in a branch bank, or envisages operators' training schools becoming institutions for the teaching of electrical engineering. But for the large concern with a mass of information that needs complex processing (for instance, the computing of a payroll involving overtime and tax and health deductions for thousands of employees) – well, Burroughs thinks it well worth keeping a very creative finger in the pie. Already machines exist that can compute such a payroll at a rate of nearly 2,000 cheques an hour. Even then, their electronic hearts are merely ticking over in order to keep pace with mechanical input and output. It is only tedious considerations of the older engineering, such as how fast hammers can strike paper, which impose the speed limit.

These, of course, are experimental models. Electronic equipment is not yet available for general commercial use, and it may be five years or ten before it is. But when that day comes, Burroughs will be in the lead in moving electronic calculation from the laboratory to the office, as it was in the lead in pushing mechanical calculation down the same path. Perhaps the human mind finds something rather frightening in the idea of great silent machines whose operations are so complex that they almost constitute 'thinking': but these will only be continuing a long established and fundamentally desirable trend. Already the industrial revolution has freed man's hands from much dull and repetitious work: today, as each new development in calculating equipment continues the clerical revolution, man's brain is also being freed.

At any rate, the electronic machines of the future will, like future models of more conventional design, be built at Strathleven – so fittingly near to Glasgow which has as strong a tradition in electrical as in mechanical engineering. They will be built by a company with ramifications from Iceland to New Zealand and from Patagonia to Fiji; with ten factories, hundreds of head and branch offices, service points and dealers; thousands of employees and tens of thousands of trained operators. And they will be built by a company that has always appreciated the special quality of British skill and has employed it for over fifty years.

They will be built, in fact, by those men and women whose work in the pleasant Vale of the Leven was not unworthy of the honour of a visit, in Coronation spring, by Edinburgh's technologically minded Duke and by that most gracious lady of Scottish descent, the Queen Elizabeth.



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THE ROYAL VISIT

When Her Majesty Queen Elizabeth, accompanied by His Royal Highness the Duke of Edinburgh, visited Dumbarton on 16th April 1953, she paid Burroughs a great honour by making the company's factory on the Vale of Leven Industrial Estate one of her first stopping places. This was her first visit to a Scottish Industrial Trading Estate. For the 1,000 Burroughs employees at Strathleven it was an occasion they will remember for the rest of their lives.

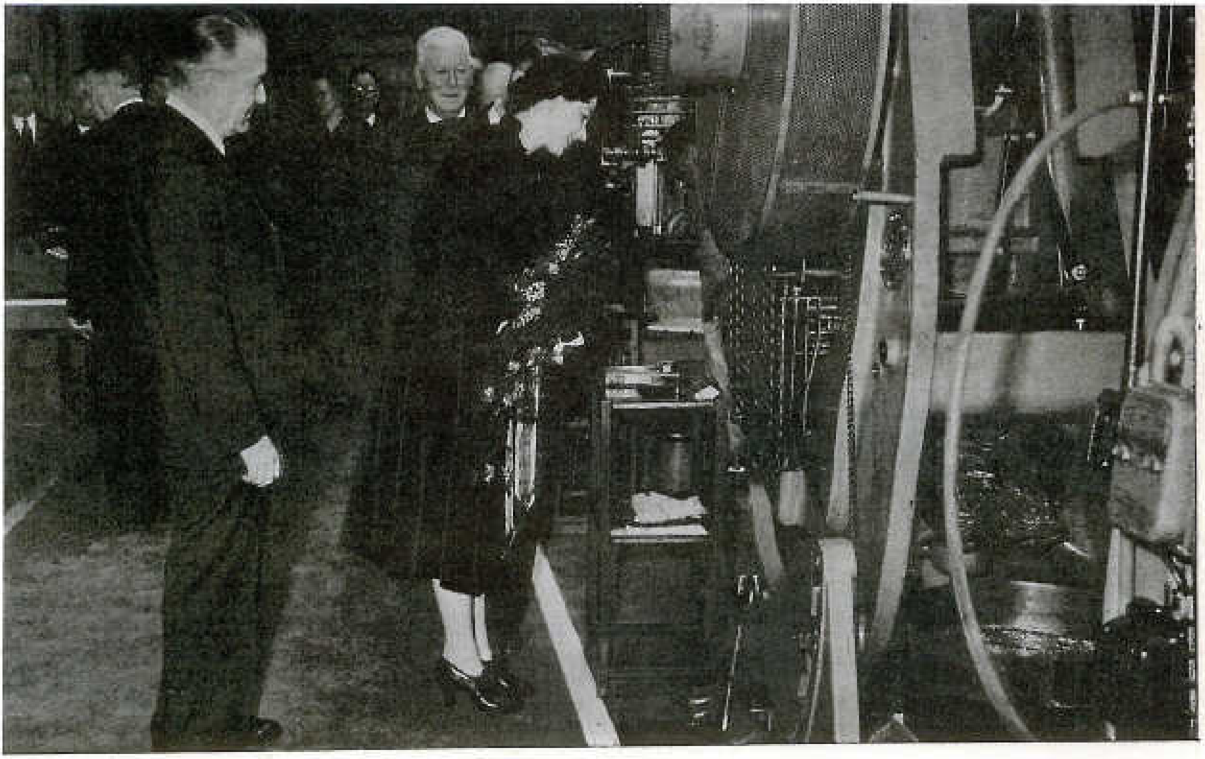
Mr John S. Coleman, the President of the American parent company, and Mr J. T. FitzGerald accompanied the Queen on her tour of the factory. Prince Philip was taken round by Mr W. J. Arris, Managing Director of the British company, and Mr Clarence Dunlop, a Vice-President of the American company. The Queen and Prince Philip stopped at several places in their tour of the factory and asked the employees many questions about the various production processes. They were keenly interested in the modern equipment used for making the many thousands of precision parts necessary for the production of Burroughs adding, calculating, and small accounting machines. Prince Philip plied his guides with a number of technical questions and requested that both the Duplex electric calculating machine and the small bookkeeping machine be demonstrated to him.

The tour took Her Majesty from the first production stages, the making of parts, to the assembly and final testing of the finished products. She was keenly interested in all she saw, on one occasion calling on Prince Philip to join her to hear an explanation of the principles of electric induction and reminding him that this was what they had seen on television two nights before.

At the end of the visit, Her Majesty was presented with a special leather-bound copy of this book, which she examined in detail. The Duke of Edinburgh, having asked during his tour of the factory to have the mechanical operation of adding explained to him, was pleased to see that the principle of Burroughs' original invention was clearly illustrated in the book.

Two 'baby' adding machines, one in cupid blue for Prince Charles, the other in mayflower pink for Princess Anne, were also presented. With each machine was a leather-bound book of instructions in nursery rhyme form.

The interest of the Royal couple in the factory was so great that they spent more time there than they were scheduled to do, and, when they left, they were greeted by tumultuous cheers from the Burroughs employees and from the thousands of men, women, and children lining both sides of the road.



Above: One of the punch pressers held the interest of Her Majesty on her tour round the Burroughs factory at Strathleven. She paused here to watch a shave operation, while Mr John S. Coleman looked on. Below: An electric induction heater caught the attention of Her Majesty, who called over the Duke of Edinburgh to hear Mr Clarence Dunlop (second from right), a Vice-President of Burroughs Adding Machine Company, explain the properties of induction heating

Above: The Queen took a keen interest in the work of assembling the thousands of parts that go to make up the Burroughs calculating machines, and here she is seen inspecting what is technically known as the second adjustment operation. Below: The Queen, accompanied by the Rt Hon James Stuart, MP, Secretary of State for Scotland, is here watching an employee assemble parts into a Burroughs duplex calculator. Mr John S. Coleman and Mr J. T. FitzGerald are also accompanying her

on the left, the Duke of Edinburgh and Mr W. J. Arris discuss the various stages involved in assembly

The Queen, accompanied by Mr J. S. Coleman, asks a question of a girl testing an assembled machine, while

Above: Mr W. J. Arris presents a leather-bound copy of this book, specially written to commemorate the Royal visit. Below: Group taken in the entrance hall. Left to right: Mr J. T. FitzGerald, Factory Manager, Mr Clarence Dunlop, Vice-President of Burroughs Adding Machine Company, Mr W. J. Arris, Managing Director of Burroughs Adding Machine Limited, HRH the Duke of Edinburgh, Her Majesty the Queen, Mr John S. Coleman, President of the parent Burroughs Adding Machine Company, and Mr W. C. Fletcher, deputy Managing Director of the British Company