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An Annotated Bibliography on the Origins of Digital Computers

by

B. Randell

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Abstract

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About the author

Professor Randell has been professor of computing science in the Computing Laboratory since 1969.
AN ANNOTATED BIBLIOGRAPHY ON THE ORIGINS OF DIGITAL COMPUTERS

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20 June 1979

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INTRODUCTION

This bibliography is a revised and considerably extended version of that appearing in 'The Origins of Digital Computers: Selected Papers' (Ed. B. Randell: Springer Verlag (1973)). It concentrates on the period from Babbage to the invention of the stored program electronic digital computer in the mid-1940's, but also contains items relating to earlier work on mechanical calculation and on devices incorporating sequence control mechanisms. The bibliography covers events up to about 1949 when the earliest stored program computers became operational, but no attempt has been made to cover the explosive growth in the literature on electronic computers which occurred after 1946 when a large number of computer projects were started in the U.S.A. and elsewhere based directly on the plans for the EDVAC or I.A.S. computers. All the items listed have been inspected, sometimes rather cursorily, by the author. (Some items which are still being sought are listed in Appendix 1, as a challenge to interested readers.)

The bibliography is listed in alphabetical order by author, anonymous items being listed last. In order to facilitate use of the index, when more than one publication is listed for a given author, the name of the author is followed by the year of publication in parentheses. If there is more than one publication in one year, the year is followed by a, b, ... Although the index is fairly detailed, readers are warned to check the more general works on a given subject, as well as those explicitly listed under a particular index entry.

In what follows a brief survey is attempted of some of the more interesting groups of items which are newly added to the bibliography, giving special attention to those which add significantly to the information given in the set of chapter introductions in 'The Origins of Digital Computers.' (The annotations given with the newly added items are, in general, more detailed than those for items which were in the original bibliography.) Brief comments are also given on some of the larger bodies of historical material which particularly merit study by historians of science. One such body of material, that arising from the so-called ENIAC patent suit, is described at some length in Appendix 2. Another large collection of technical and patent literature, covering broadly similar ground, is that donated by G. R. Stibitz to Dartmouth College Library (see Anon (1973b)). Also worthy of explicit mention is the well-catalogued and indexed collection of about five hundred of K. Zuse's technical papers, letters, patents, etc., held at the Gesellschaft für Informatik und Datenverarbeitung, Bonn. In general, however, the patent literature is not covered in this present bibliography. It is to be hoped that before long someone with the necessary specialist skills and experience will undertake the task of surveying this literature for material relating to the origins of digital computers.
GENERAL WORKS

In the last few years there has appeared a number of very useful books on the history of calculators and computing. The best known, at least in the English speaking world, is one from The Office of Charles and Ray Eames, edited by G. Fleck, entitled 'A Computer Perspective.' Quoting from the review by D. E. Knuth in Historia Mathematica: "The style of presentation is aimed at a popular audience and it is a fascinating way to present history; it depicts the spirit of the times, giving isolated details rather than stating a large number of organized facts. But it is also useful as a guide for scholarly research, since the picture credits and index at the rear of the book are quite complete."

The other books are as yet not available in English. This is particularly to be regretted in the case of that by Apokin and Maistrov, which incorporates a wealth of material on East European calculator and computer developments. In contrast, Adam's book includes interesting material on early work in Austria and Germany, namely that by Schäffler on punched card machinery, and the little known pre-Jacquard automatic draw loom known as a "Broselmaschine." One other book is in fact the proceedings of a conference to mark the 350th anniversary of Schickard's calculating machine. Relevant papers from this book are listed separately in the bibliography under the names of the authors - Howlett, Reinecke, von Freytag Löringhoff, von Mackensen and Zuse.

CHARLES BABBAGE

The revised bibliography contains a fairly large number of additional items relating to Charles Babbage, including contemporary commentary on his machines and further biographical material. One of the most interesting items is the book by Losano, which incorporates material from yet another cache of Babbage papers, namely those that we now find were left behind in Italy after his visit there in 1840. Even more surprising are the extracts from secret police files containing reports by the agent who shadowed Babbage and his travelling companion, Fortunato Prandi, although these give little information of importance.

The amount of extant Babbage material is indeed considerable. The British Library have a large number of volumes of his correspondence, the Science Museum Library his drawings and most of his sketch-books (others being at the Scientific Periodicals Library in Cambridge), the Museum of the History of Science at Oxford the important set of papers that he bequeathed to H. W. Buxton, and the Royal Observatory Library at Edinburgh his library. At least one other collection of Babbage letters, etc., is known to be in the hands of a private collector, Mr. A. W. van Sinderen. As shown by
Hyman (1976), all of this material merits much more study than it has had so far—indeed it seems incredible that no scholarly biography of Babbage has yet appeared, though there is now one on Lady Lovelace, by D. L. Moore.

Another new item relating to Babbage is the paper by Metropolis and Wakefield, entitled 'A Tract on Errors in the History of Computing.' This provides much more evidence to contradict the view that Babbage's work was almost forgotten after his death and rediscovered only after the electronic computer has been invented. It shows that a considerable number of descriptions of his work appeared over the years, although some authors evidently had a much clearer appreciation of the Difference Engine than of the Analytical Engine. As many of these further descriptions as could be obtained are now included in the bibliography.

VANNEVAR BUSH

The original bibliography contained only a few items relating to Vannevar Bush. Of these, the most important was his 1936 survey paper 'Instrumental Analysis,' the first half of which covered mechanical and electromechanical digital calculators. This included the proposal that a set of standard punched card devices be connected together and provided with a control device, so producing "a close approximation to Babbage's large conception." There was nothing else in the bibliography to indicate that Bush had carried out this idea any further, but it was noted that Norbert Wiener's book on Cybernetics, published in 1948, contained the claim that he had submitted a report to Bush in 1940 recommending the development of a program-controlled electronic binary computing machine. It will be seen that this long-lost report has now been found and is listed in the present revised bibliography as Wiener (1940). However, it turns out that this report contains little of substance with respect to a program-controlled computer.

Much more important is the evidence now found that after preparing his 'Instrumental Analysis' paper Bush went on to do some preliminary design work himself on a program-controlled electronic digital computer and that this work led to a research program at M.I.T., the Rapid Arithmetical Machine Project, sponsored by N.C.R. Bush apparently documented his ideas in a set of memoranda written during 1937 and 1938, which would constitute the earliest known proposal for a program-controlled electronic computer. Although these memoranda, which are referenced by Radford (1939) and Crawford (1939), cannot be found, one very interesting 1940 memorandum by Bush describing the research program has been located. Its contents are summarized in the bibliography entry. Bush himself in his later years had either forgotten, or consciously downplayed, the significance of his prewar work on digital electronics (see Bush (1970)). Perhaps this was because the work was abandoned in about 1942 and, as far as is known, did not have any influence on the ENIAC project, which started shortly afterwards. However, Professor Wildes' study of the Electrical Engineering Department at
M.I.T. makes it clear that immediately after the war people there made a deliberate and successful effort to resume the work on digital electronics, an effort which led to the development of the Whirlwind computer. Much material on this work has been collected by the Smithsonian Computer History Project - one (unpublished) book based on this material has been prepared, that by Redmond and Smith.

JAN RAJCHMAN

Another wartime effort which has received little attention in recent years was that led by Jan Rajchman at R.C.A. Work started there in 1939 on the use of digital electronics for anti-aircraft gun directors. This work was mentioned in Goldstine (1972) but now two original R.C.A. reports have been obtained (Rajchman et al (1941, 1942)) together with a retrospective account of this and other R.C.A. contributions to the development of computers (Rajchman 1963). These make it clear that considerable progress had been achieved by 1942 in developing many of the basic components that a computer would involve. Apparently when the U.S. Government decided it needed a large electronic computer for ballistics calculations the project was considered by R.C.A. This was the project at the Moore School which led to the ENIAC, a project on which R.C.A. acted as consultants.

CRYPTANALYTIC MACHINES

In the last few years, after many years of almost complete silence, a number of books and papers have been published which contain information about the work on cryptanalysis carried out in Poland, France and Britain before and during World War II and its effect on the course of the war. Several which contain mention or description of computers or computer-like devices used for cryptanalytic purposes, are included in the bibliography - see Brown (1975), Calvocoressi (1974 and 1977), Johnson (1978), Kahn (1974), Kozaczuk (1975), Lewin (1978), Rohwehr (1977), Whiting (1975) and Winterbotham (1974). Of these, the accounts by Johnson and Lewin are the most detailed and, one assumes, the most accurate. Both contain information about the cryptanalytic devices, such as the Colossus, used at Bletchley Park in Britain. Much more detailed technical information on the devices is contained in a lengthy paper by the present author on the Colossus, a paper made possible by the partial declassification in 1975 of this special-purpose electronic computer, which was put into operation in 1943. This paper gives details of the careers of the people involved, of how the basic concept of Colossus was arrived at and of how the first machine was designed and built, and then a Mark 2 version designed and manufactured in quantity. The impact of the Bletchley Park work, the subject of much speculation in several of the books listed above, is treated authoritatively for the first time in the official history of British Intelligence in the Second World War, by Hinsley (1979). The
first volume, covering the period until the summer of 1941, appeared just in time for citation in this bibliography.

Details are also now beginning to emerge of the U.S. wartime work on cryptanalytic devices. The papers by Campagne (1974) and Snyder (1977) indicate that a considerable quantity and variety of devices were made, and that there were important and direct links to some of the early post-war American electronic computer projects. Another paper that is newly listed is that by Jensen, which describes a number of largely electromechanical devices developed in Germany during World War II for cryptographic purposes, a subject also covered by Rohrbach, while photographs of a cryptographic decoder built out of relays for the Japanese Navy are to be found in Anon (1955a).

OTHER ITEMS

Of particular interest to the author are several newly-listed books relating to Torres y Quevedo (Rodriguez Alcalde (1966, 1974) Anon (1977, 1978b)) and a compilation of material on the Difference Engines of George and Edvard Scheutz (Losano (1974)). A number of other items relating to difference engines and early calculating machines are also newly included. Important additional items concerning early sequence control mechanisms are those by Bedini, Vaucanson and Walther, and the annotated translation of a thirteenth century Arabic work which contains detailed descriptions of an amazing collection of mechanical automata (Ibn al-Razzaz al-Jazzari (1974)). There is also a small set of papers describing a curious nineteenth century machine for composing random Latin Hexameters! Early twentieth century ideas on the use of automatic sequence control mechanisms, involving perforated tape, to control manufacturing machinery can be found in Suplee (1913) and Scheyer (1921 and 1922). Important additional papers and books on punched card machinery include Comrie (1933b), Feindler (1929), J. H. McCarthy (1924), and the Office Machine Manual (Anon 1938), which provide detailed surveys of then-available equipment, Anon (1910b) on the Pierce Automatic Accounting System, and Takahashi and Shoji (1924) on little-known work in Japan. There are also several new items relating specifically to the Powers-Samas Company.

At the other extreme of the time period covered by this bibliography there are, for example, papers on BINAC, a new group of papers on the first post-war computer developments in Britain that were published in the Radio and Electronic Engineer (by Booth, Clarke, Wilkes, Wilkinson and Williams) and an excellent analysis by Carpenter and Doran of von Neumann's and Turing's 1945 reports. Several papers relate to the ENIAC project, notably those by Brainerd (1976), Mauchly (1975) and Hughes (1975), and it has at last been possible to locate a copy of the original 1944 memorandum by J. P. Eckert on a "magnetic calculating machine," often cited as one of the earliest references to stored programs. (The disappointingly brief allusion to the concept of a stored program that the memorandum contains is quoted in full in the bibliography
entry.) There are also several additional papers on Zuse's pioneering work on computer design and on programming. Many of these projects, and others, are discussed in the excellent set of taped interviews, now available in cassette form from the Science Museum, London, and listed in the bibliography under the name of the interviewer and editor, Dr. C. Evans.

A number of items concerning Japanese developments have now been added to the bibliography, the most important of which are Jo et al (1972), Okazaki (1971), H. Takahashi (1972) and Anon (1955a and 1955b). Between them, these describe prewar work on relay counters and adders, several war-time and post-war relay statistical calculators and the start of work on electronic computers, prompted by news of Western developments.

Finally, mention should be made of the paper by Klir concerning the work by Bernard Weiner in the 1920's on an electric calculator, which mentions that Weiner went on to work on the design of a fully automatic computer; attempts to find out more about this prewar work have so far met with no success.

ACKNOWLEDGEMENTS

Many people, far too numerous to name individually, have contributed to the preparation of this bibliography, for example by locating items that were unknown to the compiler, or by assisting in the preparation of annotations for books and items written in various foreign languages. It should also be apparent that a great debt is also owed to the skills and persistence of a considerable number of librarians and archivists.
BIBLIOGRAPHY


A wide-ranging survey, starting with early astronomical instruments, ending with the use in Austria of early Hollerith equipment. Contains extensive discussions of Schickard's calculating machine, automated draw-looms, including the little-known "Broselmachine" (1680-1690), and of Schäffler's developments of Hollerith's machines.


Brief but well-illustrated account of the Difference Engine and Analytical Engine.


Undated memorandum, bearing the notation "Prospectus of Howard Aiken, Nov. 4, 1937," found in his files by Mrs. Jacqueline Sanborn Sill. Surveys the development of calculating machines, from Pascal to Babbage, and gives a detailed description of a machine to be based on conventional punched card machinery, controlled by a punched paper tape, a machine which later became known as the Harvard Mark I.


Starts with a brief but commendable history of the development of calculating machines. The major sections of the paper give a quite detailed account of the working of the Automatic Sequence Controlled Calculator and of its programming.


The first chapter 'Historical Introduction' is a very useful account of the development of calculating machines, difference engines, and Babbage's work. It includes mention of Müller and Torres.


A well-annotated and illustrated translation of a thirteenth century Arabic text, which describes a number of surprisingly complex mechanical automata, some of which incorporated pegged cylinder sequencing mechanisms. These mechanisms are in general driven by water-wheels, and themselves control the movements of model figures.

General description of the fifth Bell Labs. Relay Computer - the
first one which was a general purpose programmed computer.
Contains significant material on the programming (including
branching), and on comparisons of "set-up time" on this machine as
contrasted with the Harvard series, and ENIAC.

F. L. Alt. (1972) Archaeology of Computers - Reminiscences, 1945-
Anecdotes concerning the use of ENIAC, including a description of
the technique of setting up programs on the function tables.

T. Anderson. (1932) Första Svenska Räknemaskinen. Daedalus (1932)
An account of how Georg Scheutz learnt of Babbage's Difference
Engine in 1833, decided to design an improved machine, built a
first model (in perhaps 1840) and with his son designed a
difference engine that was built at J. W. Bergström's workshop in
Stockholm and completed in 1853.

A brief account of the life of Martin Wiberg (1826-1905) with
quotations from his own writings about his difference engine. It
is stated that he was inspired by the Scheutz difference engine to
make a much smaller machine, obtained official support for the
project, and afterwards was decorated and given a state pension.
He is quoted as indicating that his major difficulties had been
with the design of the printing portion of the engine.

E. G. Andrews. (1951a) The Bell Computer, Model VI. Proc. of a
Second Symp. on Large Scale Digital Calculating Machinery, 13-16
Well-illustrated general description of the Model VI.

E. G. Andrews. (1951b) A Review of the Bell Laboratories Digital
A useful, well-illustrated account of the series of Bell Labs.
Calculators.

E. G. Andrews. (1963) Telephone Switching and the Early Bell
An account of the historical development of the Bell Labs. Relay
Computers, and of the basic facilities of each model.

A description of some of the problems solved using the Bell
Laboratories Model V computer, including a brief description of
how the computer was programmed.

An account of the history of digital computing from the earliest aids to calculation to the modern computer. Chapter 1 includes discussion of the abacus in China, Europe and Russia, while Chapter 2, on mechanical calculators, discusses the work of Jakobson, Tchebichef and Odhner, as well as Schickard, Pascal and Leibniz. Chapter 3 covers tabulating machines and electromechanical desk calculators. The next chapter 'The Birth of Electronic Computing,' which names M. A. Bonch-Bruevitch as having invented an electronic trigger circuit in 1918, one year before the independent work of Eccles and Jordan, describes such projects as the Harvard Mark I, the Atanasoff-Berry Computer, ENIAC, EDVAC, etc. Chapter 5 describes early stored program computers, and states that the first Russian computers were the MESM (Lebedev and Rameen, 1948) and BESM (Lebedev, 1952). The final four chapters discuss transistorized and integrated circuit computers, computer applications, and the future of computer technology. A large number of references are listed, to both Russian and English language sources.

Brief general account of an accumulator, with multiple decimal digits, composed of electromechanical relays.

A brief bibliography.

Brief biography of George Scheutz and his son, and a very good annotated bibliography.

Brief biography of Wiberg, and discussion of the mathematical tables he produced using his difference engine.

Bio-bibliographical notes on 53 compilers of mathematical tables, including Babbage, Burgi, Comrie, and Napier.

Very brief account of the development of punched card machinery. Includes an illustrated survey of then-current Hollerith equipment.

M. M. Astrahan. See R. Serrel.

An illustrated detailed description of the machine, in which it is stated that a prototype consisting of a binary register, an addition/subtraction mechanism, and a decimal-binary converter had been operated successfully.

Detailed description of the use of a tabulator, to which a home-made 'cross-connecting board' was attached, on which numerical values could be set up.

A detailed description, with many circuit diagrams, of the BINAC, which is described as "the first computer of its type to be completed successfully in the United States." It is stated that the BINAC was built to solve an (unidentified) specific problem, for which a small amount of input/output was required relative to the amount of computation, but that it contained all the necessary elements for solving a great variety of problems. A sample program is given, but no mention is made of the status of the system, or when it became operational.


The first publication on the difference engine. Very brief, ending: "from the experiments I have already made, I feel great confidence in the complete success of the plans I have proposed."

A paper, which was read on 13 Dec. 1822, speculating on the value of removing the restrictions of the Difference Engine to functions with some order of difference being constant.

Indicates that Babbage had been working for six months on a new machine, and implies that the machine had the ability to execute sequences of arithmetic operations.

Makes numerous references to his work on calculating engines, and includes a short appendix describing the history of his efforts to
produce first a difference and then an analytical engine.


As far as is known this is the most complete description of the plans for the Analytical Engine that Babbage ever wrote.


Contains one chapter 'Calculating Engines' (reprinted in H. P. Babbage: 1889, and F. and E. Morrison: 1961), describing the then-current state of development of the analytical engine, and including a description of the method used for parallel assimilation of carries in the adder, and a chapter 'Intrigues of Science' which includes material on his dealings with the government regarding the calculating machines.


The first part is a description by Charles Babbage of the drawings made by his son, using the 'Mechanical Notation,' of the Scheutz Engine. The second part consists of further correspondence regarding the engine.


Contains several chapters relating to the difference engines and the analytical engine (which have been reprinted in H. P. Babbage (1889) and Morrison and Morrison (1961)). A fascinating book, which throws much light on the strange character of Charles Babbage.


From the preface: "The following remarks on contriving machinery were written by the late Mr. Babbage, of calculating-machine fame, 70 years ago, in a treatise on 'The Economy of Machinery and Manufactures.' Though so old, the whole forms a thoughtful and suggestive contribution, by a very able man, to the literature of a most important subject; and it may be read with interest and profit even by the advanced mechanician of today."


Describes the mechanical notation, but does not include the charts that it states were made of the Scheutz difference engine by Babbage using the notation.

Abstract of a paper given by Major General H. P. Babbage, which described Babbage's anticipating carriage, counting apparatus, and mechanical notation.


A reprinting of the writings of Babbage and others, on both the Difference and the Analytical Engine, edited by his son. Much of the material has been reprinted in Morrison and Morrison (1961).


Brief description of the work done by H. P. Babbage after his father's death, including the construction of the mill and printing mechanism of the analytical engine.


In the section dealing with his childhood, H. P. Babbage describes visits to his father's workshop where he learnt to handle tools and draw machinery, and got to know the workmen there including Jarvis, the draughtsman responsible for the drawings of the Analytical Engine. Most of the book is devoted to his military career in India. It states that during a visit to Britain in 1854-55 he studied mathematics, met Scheutz and his son, documented their difference engine using the Mechanical Notation, and worked with his father on cryptanalysis and on assembling a small model of the Difference Engine. He was back in London in 1871 when his father died, and retired to England permanently in 1874. A brief summary is given in the book of his work on the Analytical Engine after his father's death.


Consists almost entirely of quotations from Babbage's writings (including 'The Ninth Bridgewater Treatise,' and 'The Exposition of 1851') and from Lardner's article. Some of the quotations concern the difference engine, but most concern the analytical engine. It includes, from the 'Exposition,' a description of the carry mechanism that Babbage invented.


Mainly concerned with surveying the various types of mathematical tables for which the difference engine would be useful. At the end it includes the comment "It would not be very complicated to place three such machines by the side of each other, and cause them to transfer their results to a common axis, with which the printing
apparatus might be connected.”

C. Ballot. L'Introduction du Machinisme dans l'Industrie Française.
O. Marquant. Lille (1923).
Contains a very detailed historical account of the developments by Bouchon, Falcon, de Vaucanson, and Jacquard of the punched card controlled loom.

Includes a discussion of the work of Bouchon, Falcon, Vaucanson and Jacquard, and of Bonelli, Bolmida, and Vicenzia, who during the 1850's worked on the use of electro-magnetic techniques for reading the patterns, and controlling the loom.

This report on the 1867 Paris Exposition contains a very interesting section on Mechanical Calculation (pp.629-648). The main body of the section concerns the two calculating machines actually exhibited, a small pocket adding machine by Musina, and the Thomas Arithmometer. The section also includes an account of the history of mechanical calculation, apparently based mainly on a book prepared for Thomas by J. Regnier, and references to the work of Scheutz and Babbage on difference engines.

A very interesting and well-illustrated paper, covering both computer hardware and programming languages and techniques. The relationship between Zuse's work on computers and his ideas for the Plankalkül is explored, and the influence of his work on such people as Rutishauser is discussed.

A fairly detailed account of the language, and an analysis of it compared to modern programming languages.

A valuable descriptive catalogue of the extensive collections in the Science Museum, including many examples of early calculating machines, Babbage's and Scheutz's difference engines, and portions of Babbage's analytical engine.

Partly abridged from Baxandall (1926). Covers, inter alia, Napier, Pascal, Leibniz, Thomas, Odhner, Felt, Bollée, Hollerith, Babbage, and Scheutz.

T. Beck. Beiträge zur Geschichte des Maschinenbaues. Springer,
Berlin (1900).
An extensively illustrated history of machinery, from Heron of Alexandria to James Watt. It contains drawings and descriptions of Vitruvius' Hodometer, a device for recording the distance travelled by the controlled release of counting balls into a container, and of a similar device and also of a set of geared counting wheels, by Leonardo da Vinci.

An important survey, with many bibliographic references. It covers hydraulic and pneumatic devices, mechanical clockwork automata, pegged cylinders, etc., and gives special emphasis to the life and work of Vaucanson. Well illustrated.

Describes a small special purpose calculator incorporating sixteen electro-mechanical counting mechanisms.

Includes photographs of punched card machines by Kawaguchi and by Takahashi and Shoji (of the Electrotechnical Laboratory).

An illustrated account of the features and usage of a variety of current calculating and book-keeping machines.

M. R. Belden. See T. G. Belden.

An official biography of Watson, useful for its information about the growth of I.B.M., but with comparatively few technical details.

Includes a brief account of the development of punched card machinery, and illustrated descriptions of various items of Hollerith and Powers punched card equipment, including Powers and Hollerith card punches coupled to typewriters, and a Hollerith hand punch connected to a calculating machine.

A popular book on the design of computers, which includes descriptions of the Harvard Mark I and ENIAC. Extensive references.

K. J. Berkling. See W. H. Desmonde.

113p.
A popular introduction to computers, and discussion of the work of Babbage, Aiken, Stibitz, Eckert, Mauchly, von Neumann and others.

Description of the card reader and punching mechanisms, which perforated and sensed holes in cards by electrical discharges, designed "in conjunction with the development of a high-speed computing machine" - the Atanasoff-Berry machine.

J. Bertillon. La Statistique à la Machine. La Nature (1 Sept. 1894) pp. 218-222.
A well-illustrated detailed description of the machines invented by Hollerith and used in the 1890 U.S. Census. States that the system was also being used in Canada, Austria, and being tried out in Italy, France and Germany.

Describes form and punch card layout conventions. Includes the comment "I have watched with great interest the progress in developing and perfecting this machine, because seven years ago I became satisfied that some such system was possible and desirable, and advised Mr. Hollerith, who was then engaged on census work, to take the matter up and devise such a machine..."

"That the data ... might be recorded on a single card or slip by punching small holes in different parts of it, and that these cards might then be assorted and counted by mechanical means according to any selected grouping of these perforations, was first suggested by Dr. Billings in 1880. This suggestion was taken up by Mr. Herman Hollerith..."

This very readable biography begins: "Blaise Pascal was, simply, one of the greatest men that have ever lived. Having made the discovery of mathematics at the age of twelve, at sixteen he wrote a treatise on conic sections which is the herald of modern projective geometry. At nineteen he invented, constructed, and offered for sale the first calculating machine. He gave Pascal's law to physics, proved the existence of the vacuum, and helped to establish the science of thermodynamics. He created the mathematical theory of probability.... His prose style, novel in its strong simplicity, determined the shape and character of the French literary language... In the lucid moments of cruel illness he wrote his Pensées, in preparation for an apology for Christianity, thoughts which have affected the mental cast of three centuries, thoughts which still stir and work and grow in
modern minds. He died at 39." The section dealing with Pascal’s calculating machine, though brief, gives a reasonably clear description of the machine and its functioning, and of the circumstances surrounding its invention.


A very readable and evocative portrait of John von Neumann.


Brief description of the Harvard Mark I and of some of its applications, and of the subsidiary sequencing unit that had been added.


An account, based on primary sources, of Hollerith and his development of electrical tabulating machines.


This article is in the main taken from an M.Sc. Thesis on Hollerith by the first author. It contains few technical details of Hollerith’s tabulating machines, but instead concentrates on the progress of his career, incorporating hitherto unpublished information obtained from Hollerith’s family.


Brief written description of the Bollée machine, in particular of the method of direct multiplication.


The first of these wartime machines appears to be based on a planimeter mechanism, and is entirely analogue in operation. The second machine, the "cosine adding machine," incorporates a digital counter.


A survey, covering the Bell Labs. Model I and Model V, the Harvard Mark I and Mark II, and Booth’s own Automatic Relay Computer. It is stated that "the arithmetic unit of this machine has been in working order for 18 months but the memory is not completed and storage space for 8 numbers only is at present available. The machine has been in automatic operation computing a table of squares." The memory was a magnetic drum intended to have a capacity of 256 words, used both for numbers and instructions. It is stated that an electro-mechanical memory, of roughly the capacity of Zuse's mechanical store, is to be built.

Contains the comment "Charles Babbage is nowadays recognised as the pioneer of modern automatic digital computing machines. It came as a surprise to many of the early workers in electronic computing to find that the structure which they had built up on purely logical grounds for a digital computer was in fact precisely what had been derived by Babbage over a century before."


A well-illustrated description of the sequence of calculating devices and computers developed by the author, starting in the early 1940's, originally for the analysis of X-ray diffraction data. One wartime device involved a mechanical counter, the others being analogue devices. After the war he started to build a relay calculator. "Our work on the relay structure factor calculator was nearly complete at the end of 1945. Its circuit included what would now be called a many-one and a one-many function table for decoding and executing instructions." The author states that before the calculator was completed he learnt via Hartree of work elsewhere, particularly in the U.S.A., on electronic computers. He spent some months with von Neumann's group in 1947, and on return to Birkbeck College worked on the logical design of I.A.S. type computers, and developed various magnetic storage devices. He states that his first computer, the A.R.C., which was built from relays and incorporated a magnetic drum store, was completed in May 1948. Subsequently an electronic version, the S.E.C., was built and then the whole APEX series of computers. A commercial version of this series, the H.E.C. series, was manufactured by the British Tabulating Machine Company.


Contains a brief but interesting account of the origins of computers. On arithmetical machines, mentions Pascal, Leibniz, Moreland, Stanhope, de Colmar, Odierner, Roth and Baldwin. (States these latter two predated Odierner's variable toothed wheel.)


General discussion of the basic components of computers, and a survey of then-current American developments.

K. H. V. Booth. See A. D. Booth.


Contains much material on Babbage, including a reprint of the Lady Lovelace translation of Menabrea's article. The major part of the book consists of chapters on the then-current British computing machine projects.

Think (July 1960) pp.28-32.
An account of the author's search for information about Lady
Lovelace, and a biographical sketch of Charles Babbage.

B. V. Bowden. (1961) Charles Babbage, Father of the Mechanical
Condensation of Bowden (1960).


C. V. Boys. (1886) Calculating Machines. Journal of the Society of
A lecture describing the calculating machines exhibited at the
International Inventions Exhibition, and also other current or
earlier machines. Only half of the paper concerns digital devices,
but it nevertheless provides a very valuable account of the then-
current state of the art, as well as interesting descriptions of
machines by Morland, Stanhope, Thomas de Colmar and Babbage. The
main part of the account concerns a machine by Tate which is
described as an improved version of the Thomas Arithmometer, and a
circular machine by Edmondson.

A detailed description of the operation of the Felt and Tarrant
comptometer, with a fascinating account of its use, even for
operations such as multiplication and division, and comparison of
its merits as against those of arithmometers and slide rules.

C. V. Boys. (1909) A New Analytical Engine. Nature 81,2070 (1 July
Review of Ludgate (1909).

Comp. Reviews 6,5 (1965) 8065, p.284.
Brainerd was in charge of the ENIAC development. In this review he
states that development of ENIAC took place in ignorance of
Babbage's work on the Analytical Engine.

J. G. Brainerd. (1976) Genesis of the ENIAC. Technology and Culture
17,3 (July 1976) pp.482-488.
An important account of the technical and organisational
background to the starting of the ENIAC project at the Moore
School. It describes "ten different developments which prepared
the Moore School to undertake the first large-scale electronic
digital general purpose computer." These include the construction,
by 1934, of a differential analyzer, work in 1938 by Travis on
"the possibility of the ganging of desk calculators to create a
large mechanical digital calculator," and several military
research contracts. The respective roles of the various people
involved are described, including Burks, Chedaker, Eckert, Mauchly
and Sharpless. (See also Mauchly (1975).)

J. G. Brainerd. See also J. P. Eckert.

J. G. Brainerd and T. K. Sharpless. The ENIAC. Electrical
An account of the history and the development of ENIAC, and of its principles of operation.

A. E. Brandt. See J. V. Atanasoff.


A detailed chronology, mentioning dates of the invention or first manufacture of a very large number of different calculating machines. Illustrations include portraits of Pascal and Hahn, and a picture of a machine by von Gersten.


An account of the work of the Watson Laboratory, based on the laboratory's archives, and on tape-recorded interviews. Includes material on the early punched card installation, on the device for controlling groups of punched card machines, and on the small electronic computer built by John Lentz in 1948, which became the prototype of the I.B.M. 610 Autopoint Computer eight years later.


Contains a two page account of Babbage's Difference Engine, based on an account by Baily. Starts "the extraordinary machinery invented by Mr. Babbage, and now constructing under the patronage of Government, has excited so much interest in every part of Europe, that we have been anxious to gratify the curiosity of our readers by any details respecting the nature and progress of the machine."


A brief account, first published in 1832, of Babbage's Difference Engine, stating "the greater part of the calculating machine is already constructed, and exhibits workmanship of such extraordinary skill and beauty that nothing approaching it has been witnessed." A demonstration by Babbage of the speed and accuracy of a small trial difference engine is also described.


A detailed sales catalogue of a very important collection of abaci, adding machines, adding and subtracting machines, arithmetical machines, arithmometers, multiplication tables, Napierian rods and cylinders, Genaille's rods, slide rules, typewriters, etc. It is stated that the collection was started by M. Malassis, who exhibited the main items at the Société d'Encouragement pour l'Industrie Nationale in 1920, and was then purchased and greatly enlarged by M. Chauvin. The collection totals 442 machines, and includes a Bollée calculating machine, three Thomas de Colmar arithmometers, an Arithmaurel, and one of the first Felt and Tarrant comptometers. The collection also includes an enormous amount of documentation concerning
calculating machines, typewriters and various office machines, dating back mostly between the two world wars. Most items are catalogued individually, and 41 are illustrated, there also being 15 photographs giving general views of parts of the collection.


Menabrea's memoirs, written in French, contain several pages (pp.36-38) discussing his meeting with Babbage, the writing of his paper on the Analytical Engine, and the translation and annotation of this paper by Lady Lovelace.

L. Brillouin. See J. Pérès.

K. H. V. Britten. See A. D. Booth.


Scholarly account of the life of George Brown, and of his Rotula, which was a simple aid to addition, involving a single carry wheel.


Contains illustrated descriptions of the mechanisms used in "automatophonic" instruments, such as barrel organs, pianolas, and musical boxes.


An account of Babbage's correspondence (now held in the British Library) with various Italian scientists, which includes copies of several letters from Menabrea concerning the Analytical Engine. One particularly interesting letter, dated 27 January 1842, describes the machine as having its own language, and discusses speeding up the operation of the machine by having it obey a number of identical operations simultaneously.


A scholarly biographical sketch of Prandi, who became friendly with Babbage in London, and accompanied him to the scientific congress held in Turin in 1840. Copies of the secret police files describing the surveillance of Prandi during this visit are included.

L. Bulferetti. See also L. Briguglio.


This article provides very useful detailed description of the programing of a demonstration calculation on ENIAC. Well
illustrated with diagrams and photographs, including several of
the plugged programming facilities.

Detailed account of the electronic design of ENIAC.


The famous report, on the design of what is now known as the "von Neumann"-style machine. Gives a detailed description of the plans for the parallel binary I.A.S. computer, including great detail on the arithmetic unit.

A survey of calculating machines, both digital and analogue. Proposes a mechanical control device joined to standard punched card machinery which "would be a close approximation to Babbage's large conception."

A memorandum sketching the main characteristics of an electronic computing machine, based on "recent advances in the experimental development program at Massachusetts Institute of Technology, especially the work of Overbeck which has resulted in improved tubes and circuits for the purpose." The machine was to be controlled by a paper tape loop, and to have one paper tape input device, a read only table of constants (involving a changeable stationary paper tape) and a set of "storage reservoirs." Arithmetic was to be decimal, using electronic counting rings, and the time for multiplying two six-digit numbers was estimated at 1/10 sec. The memorandum ends: "While details are not filled in at all points in this description, it appears that an entire machine could be constructed along these lines. It would be highly versatile and amply rapid. While it would contain a large number of tubes, it does not appear that it would need to have a prohibitive number. There is no reason to believe that in bulk it would exceed present punched-card machines of the more elaborate sorts, and it would certainly weigh less. After development, which would be somewhat expensive, it could apparently be produced at a reasonable cost in view of its speed and range of applications."

A series of somewhat autobiographical essays in which Bush states that he had little to do with the invention of the digital computer, and does not mention his prewar work in digital electronic calculating devices, though a description is given of the Rapid Selector project.
A popular account of the development of digital computing and computers, containing a useful list of references and summaries of the logical design of ENIAC and the I.A.S. Computer.

H. W. Buxton. Memoir of the Life and Labours of the late Charles Babbage Esq., F.R.S., formerly Lucasian Professor of Mathematics in the University of Cambridge: Comprising a descriptive and historical account of his Analytical and Difference Engines derived principally from his posthumous MSS and papers. Unpublished manuscript, in two volumes (undated). (In the Buxton Collection at the Museum of the History of Science, Oxford University.)
Extremely valuable for the very extensive quotations from Babbage's unpublished writings on his calculating engines and Mechanical Notation.

Fairly extensive discussion of the Difference Engine - virtually no mention of the Analytical Engine. Includes much biographical material from the unpublished biography of Babbage by H. W. Buxton. In the discussion, Comrie describes difference techniques using then current machines, including the National, and using punched card machinery.

See S. Y. (1835).

Surveys the various rival automatic totalisator systems being developed for use at race-courses in the U.K. Three basic systems, in which merely the total bets on each horse are calculated, are described. An advanced system, in which the changing odds on each horse are continuously recalculated is also described.

A detailed personal account of wartime work at Bletchley Park on the analysis of information obtained by decoding German radio messages, which considerably supplements the information given by Winterbotham (1974). It states that the cryptographers "were incidentally helped by machines called bombses which were prototype computers."

This excellent account of the Enigma cipher machine, and the breaking of messages enciphered using it, contains only brief references to cryptanalytic devices. It does however state that by 1939 the Poles had developed two devices, one of which was called the Bomba, which was "a somewhat primitive, special-purpose, electromechanical, not electronic, computer."
The transcript indicates that the interview was by W. F. Luebbert, at West Point, New York, in preparation for a telelecture by Dr. Campagne on the Impact of Cryptography upon the Evolution of the Modern Computer. It contains a number of guarded statements about cryptanalytic devices built in the U.S. during the War, including specially adapted tabulating machines, a very large relay machine nicknamed "Madam X" that was built by S. B. Williams, some part-electronic part-optical devices built by Vannevar Bush and various colleagues, and a machine called Goldberg which was plugboard-controlled, and had a very early form of magnetic drum store. Campagne also states that such "rapid analytical machines" were made in great quantity (perhaps 1200 in all) and in great variety (approximately 140 different types). He also talks about interactions, in the immediate post-war years, between N.S.A. and the various electronic computer projects and their developers, in particular E.R.A., and suggests that N.S.A. had an influence on the move towards binary, as opposed to binary-coded decimal, number representations.

Contains brief mentions of cryptanalytic machines. It is stated that Alan Turing was responsible for the development of an "analytical electromechanical device - code named Bombe" used for the Enigma cipher, and that the Heath Robinson machines and Colossus computers were used for the Siemens Geheimschreiber cipher machine, known to the cryptanalysts as the "Fish" machine.

Describes the Mark II Calculator, which was a paper tape controlled calculator - it had four tape readers and could be switched automatically from one tape controller to another. The store could hold about 100 ten decimal digit floating point numbers.

Detailed description of 18 examples of the use of the Logabax book-keeping machine. The examples are in general from accountancy and banking, but examples are given of the use of the Logabax for harmonic analysis and the solution of simultaneous linear equations.

Provides an excellent analysis in modern terms of the original design for ACE given by Turing in his 1945 report, and a comparison of this report with the slightly earlier EDVAC report by von Neumann. It points out that, in contrast to the von Neumann report which is incomplete, with neither the I/O mechanisms or the details of the central control being spelled out, "Turing's paper,
on the other hand, is a complete description of a computer, right
down to logical circuit diagrams, with an exhaustive thirteen-page
analysis of the physical properties of the memory, and a cost
estimate of $11,200." Amongst the topics listed as discussed in
Turing's report, but not found in that by von Neumann, are address
mapping, instruction address register and instruction register,
microcode, hierarchical architecture, floating point arithmetic,
hardware bootstrap loader, subroutine stack, modular programming,
subroutine library, link editor, symbolic addresses, and the
ability to treat programs as data.

947p.

A popular account of the "cover and deception" operations used by
the Allies in World War II, which contains an account of Turing's
wartime work on the design of a cryptanalytic machine used for
breaking the Enigma cipher. It is implied that this machine was in
some way related to Turing's prewar concept of a universal
machine, but other statements seem to contradict this implication.

O. Cesareo. _The Relay Interpolator_. Bell Laboratories Record 23
Brief description of what was later to be known as the Model II
computer. Concentrates on the design of the adder (biquinary). The
computer was designed to aid development of test equipment for the
M-9 gun director. "It was initially supposed that the interpolator
would be used for this one purpose only and then junked. But
before the first job was done others were at hand, and as it
turned out the interpolator was kept busy for several years."


N. Chapin. _An Introduction to Automatic Computers_. Van Nostrand,
Contains a chapter 'Computer Fundamentals' which covers the
development of calculators, and, in considerable detail, American
computer developments during the late 1940's and early 1950's.

S. Chapman. Blaise Pascal (1623-1662): Tercentenary of the
Gives a fairly detailed biography of Pascal.

A. Chapuis and E. Droz. (1949) _Les Automates, Figures Artificielles
d'Hommes et d'Animaux; Histoire et technique_. Griffon, Neuchatel
(1949).
Describes and illustrates many mechanical automata, mostly
controlled by a rotating pegged cylinder. The earliest such
automaton described was constructed by de Caus (1576-1626). The
last chapter describes the workings of the chess-player built by
Torres y Quevedo, who is described as the first to build an
automaton which could accept inputs from its environment, and
alter its further behaviour accordingly.

A. Chapuis and E. Droz. (1958) _Automata: A historical and
Translation of Chapuis and Droz (1949).
Transcript, together with reproduction of some 60 slides, of a lecture, giving a very valuable survey of calculating machinery from the abacus, to the Harvard Mark I. Contains much material not readily available elsewhere on American pioneers such as Baldwin, Monroe, Avery, Priden, Hopkins, Grant, Burroughs, Dalton, Sundstrand, Ellis and Felt. Also discusses the relationship of the Baldwin and Öhner developments, Selling's machine, the Rechnitzer Autorith, Torres y Quevedo, partial product multiplying machines by Barbour, Verea and Bollée, Steiger, Hamann, Babbage, Scheutz, Hollerith, and Aiken.

A well-illustrated popular account, including chapters on Gerbert, Jetons and Logarithms, Pascal's arithometer, and the Campos book-keeping machine that Logabax were manufacturing. Several illustrations of the Campos machine and its mechanisms are included.

An account of the use of Hollerith-style tabulating machines, built by Schäffler, for the Austrian census. It is stated that this tabulation involved 24 million cards. Contains a brief account of the origins of the Hollerith system, but few details of the machines themselves.

Bibliography listing the artefacts, photographs, books and articles displayed in the exhibition 'The History of Data Processing' at the Museum of Industry and Technology, Vienna.

According to this review Sadovskii's paper deals mainly with the work of Tchebichef on a machine with automatic multiplication and division (1881) and with Öhner's machine (1878), as well as various analogue devices.

An article, written in 1951, about a machine for composing Latin Hexameter verses and its inventor John Clark (1875-1852). The title of the article is one of the verses produced by the machine, which had recently been restored. It describes how the machine was exhibited in London in 1845 as 'The Eureka' and quotes a letter from a visitor to the exhibition as stating "Clarke is a strange simple looking old man; Babbage said the other day that he was as great a curiosity as his Machine!" A photograph of the machine, showing one of its pegged cylinders, accompanies the article.

"At the end of the war Elliotts [were] developing an electronic digital computer intended to be the centre of the most sophisticated fire-control system of its day." This was the 152, which had a fixed program store, and 100 microsecond multiplier. The paper goes on to describe the later Elliott machines, including the 152, Nicholas, 401, 402, 403, and 405.


A careful account of man's fascination, through the ages, with automata. Just one chapter is on "the fabrication of actual automata."


"The invention is as novel, as the ingenuity manifested by it is extraordinary ... It substitutes mechanical performance for an intellectual process: and that performance is effected with clarity and exactness unattainable in ordinary methods, even by incessant practice and undiverted attention."


A valuable detailed study of Babbage's machines, and of the circumstances surrounding their development. Based on the Babbage Correspondence in the British Museum, the Babbage sketchbooks and drawings in the Science Museum, and the Buxton collection of Babbage manuscripts in the Museum of the History of Science at Oxford University.


An account of various calculating techniques, such as "shortcutting," and a lengthy "Consumers Association-style" report on all the calculating machines then available on the British market.


Starts with a description of the technique of using finite differences, and with a brief survey of the history of developments of difference engines (Babbage, Scheutz, Wiberg, Hamann and the Burroughs-built H.M. Nautical Almanac Office Anti-Differencing Machine), and then gives a detailed account of the features of the Brunsviga-Dupla manual calculating machine and its use for differencing.

Record of presentation by Comrie of a paper 'The Application of the Brunsvia-Dupla Calculating Machine to Double Summation with Finite Differences,' and the ensuing discussion, which includes the comment "I should like to congratulate Comrie not only on this considerable advance towards the practical solution of the Babbage problem, but also on the vigilance which enabled him to discover in the Dupla a latent and unsuspected capability."

Describes the facilities and operation of then current punches, tabulators and sorters, and the use of these for calculating Brown's Tables of the Moon. States that Hollerith equipment was first used at the Nautical Almanac Office in 1929.

An article on difference engines and techniques. The first part of the article discusses the history of purpose-built difference engines (Babbage, Scheutz, Wiberg, Grant and Hamann), including that built by A. J. Thompson, using four Triumphator calculating machines. The major part of the article discusses the use of various standard calculating machines as difference engines, including the Brunsvia-Dupla, the Nova-Brunsvia IVA, various Burroughs book-keeping machines, and the National Cash Register (Ellis) accounting machine.

An excellent well-illustrated account of the method of operation, internal mechanism, speed and cost of all the then-current Hollerith and Powers punched card equipment, including manual and automatic punches, sorters, tabulators, verifiers, combined sorters and tabulators, and the Hollerith multiplying punch. In describing the latest Hollerith tabulator, which allowed items punched in different fields of the same card to be added or subtracted, Comrie states: "This machine adds yet another to the list of commercial machines produced during the last six or seven years that are capable of mechanical integration and differencing. It will integrate a function from any order of finite differences up to the tenth at the astounding speed of 4000 values an hour. In other words, it will do what the classical Babbage difference engine was intended to do."

Brief account of the use of Odhner-wheel type calculating machines.

Comrie's introduction to the section dealing with the use of the National accounting machine surveys the history of special-purpose
difference engines, and indicates his preference for using standard commercially-available equipment.


An account of the main calculating devices then in current use – adding and listing machines, desk calculating machines, and punched card sorting and tabulating machines. Concentrates on the facilities provided, and operational characteristics, rather than the workings of the various mechanisms.


A survey of calculating instruments and their use for scientific calculations, including differential analysers, the National accounting machine, electrical and manual desk calculators, and punched card machinery.


Extended survey of the use of desk calculators, adding machines and punched card machinery, for scientific calculations.


Review of 'A Manual of Operation for the Automatic Sequence Controlled Calculator'.


Detailed description of an application using the various items of Hollerith equipment, including a multiplying punch, tabulator and sorter.


An account containing a mass of information about the growth of the punched card industry, and of the emergence of a computer industry in Europe. Nearly half of the report consists of a detailed chronology, covering the years 1880-1967, which concentrates on the activities of Hollerith, the British Tabulating Machine Co., Deutsche Hollerith Maschinen G.m.b.H. (Dehomag), Powers-Samas, Cie des Machines Bull and (especially) I.B.M. The report, although written in a rather casual style, is obviously based on detailed data from the companies concerned, although no references are given. Amongst the scientists and engineers whose work is described are Herman Hollerith, Charles Babbage, James L. Powers, Otto Schäffler, Gustav Tauschek, Frederick Bull, Ralph Lorant, James Bryce, and Konrad Zuse.


An interesting little privately printed book discussing the history of automata from ancient times. Well illustrated.


"This report makes a detailed analysis of such operations as addition and multiplication, and contains some discussion concerning the development of machines to carry out the operations. Descriptions of some computing techniques which will be useful at a later stage in the development of automatic computers are also given."


Reminiscences by Eckert and Mauchly about the origins and development of ENIAC.


Brief description, followed by commentary by d'Ocagne, of a machine that could perform the four basic operations, and permit the chaining of sequences of such operations. The possibility of connecting it to a typewriter or to a card punch is discussed. No details are given of the mechanisms used.


Describes current punched card equipment, and the possibility of linking machines together in order to achieve "a solution to Babbage's problem," i.e. general program-controlled calculation.


Argues the utility of representing numbers by binary notation in computers, and discusses the design of electrical calculators.


On the mechanical, or rather electrical, evaluation of logical expressions.


Contains a detailed description of an electro-mechanical program-controlled binary calculator.

Description of the binary arithmetic unit, and general discussion of the Institut Blaise Pascal Computer.


Provides a detailed description of the parallel arithmetic unit being developed for the machine.


Concentrates mainly on the hardware design of this experimental parallel binary computer.


Includes brief accounts of calculators (Pascal, Felt, Burroughs), punched card machinery, Babbage's Analytical Engine, Harvard Mark I, ENIAC, and the computer developed at the Institut Blaise Pascal.

L. Couffignal. See also J. Péres.


A readable account of the history of calculating devices and machines, with clear well-illustrated descriptions of the use of the abacus, Napier's rods, the Leibniz, Odhmer and Millionaire mechanisms.


Part V (pp.60-65) sketches the design of "an automatically controlled calculating machine," capable of performing a variety of matrix calculations, and incorporating means for scanning digital data represented on punched tape, for adding, subtracting, multiplying and dividing two numbers and for storing and printing or punching the data. A punched tape was to be used for sequence control, which would specify the selection of the numbers to be operated on, the operation to be performed, and the disposal of the result. It is stated that many of the details of a calculating system similar to that suggested by the above have been considered by Bush [in unpublished memoranda, and that the problem to be considered] was that of developing a data scanning system and a control system. Later on it states that "Electronic calculating circuits of the type proposed by Bush would be desirable, although the electrical operation of a mechanical machine would be suitable for preliminary work."

"It is the purpose of this thesis to decide the elements and operation of a calculating system for performing one of the operations in the control of anti-aircraft gunfire, that is, namely, the prediction of the future position of the target ... In this introduction, equipment for performing the operations occurring in automatic calculating is described. This equipment includes electronic switching elements, devices for multiplying two numbers, finding a function of a variable, recording numbers, translating mechanical displacements into numerical data, and for translating numerical data into mechanical displacements." The thesis goes on to give detailed design proposals for an arithmetical predictor, which in addition to the units mentioned above, used a primitive form of magnetic disk store.

E. S. Crawley. See L. d'Auria.


Clear descriptions of the principles of operation of Napier's rods, the Leibniz and Odhner wheels, the rocking segment, and the Millionaire machine.


Contains personal reminiscences about conversations with Charles Babbage and Lady Lovelace.


Records conversations with Babbage about the Analytical Engine and Lady Lovelace.


Records a visit to Babbage's house and conversation about the Difference Engine.


Contains a description and photographs of a special purpose relay computer based on that designed by Shire and Runcorn.

R. C. Curnow. See C. Freeman.


Contains illustrations and detailed discussions of the use of a wide variety of then-current accounting machines (Burroughs, National, Underwood, Remington, etc.), of the Power-Samas and Hollerith punched card systems, and the Campos machine. Apparently the Campos machine, or 'Ten Thousand Register Machine', had
recently been placed on the market by Powers–Samas. "The Campos
machine eliminates the human element to a greater known extent
than any other known device, and therefore, reduces to an absolute
minimum the possibility of error."

J. H. Curtiss. A Review of Government Requirements and Activities in
the Field of Automatic Digital Computing Machinery. Theory and
Techniques for Design of Electronic Digital Computers. Lectures
delivered 8 July 1946 - 31 Aug. 1946. (Ed. C. C. Chambers). Moore
School of Electrical Engineering, Univ. of Pennsylvania,
Philadelphia (1948) pp.29.1-29.32.
Extensive survey of then-current calculating needs, and of
existing and planned relay and electronic computers.

V. P. Czapla. The Inventor of the First Desk Calculator. Computers
Based on von Freytag Loringhoffs (1958).

K. H. Czauderna. Konrad Zuse - der Weg zu seinem Computer Z3 und
dessen Verwirklichung. Final Report, Fachbereich Elektrotechnik der
A very interesting report about Zuse's work on the Z1, Z2 and Z3
computers. Particularly valuable for its very detailed and well-
illustrated description of the operation of the mechanical
switching elements and binary storage system used in the Z1, and
for the personal reminiscences contained in letters from various
friends and colleagues, including several who assisted Zuse with
the construction of the Z1. The letter from W. de Beauclair gives
details of work at Darmstadt during the war, and of a visit to
Berlin during which he saw the Z3 in operation.

L. d'Auria, L. F. Rondinella, F. Leclere and E. S. Crawley. The
Hollerith Electric Tabulating System. Journal of the Franklin
The report of the committee that awarded Hollerith "the highest
award in the gift of the Franklin Institute" - the Elliot Cresson
Medal. The report gives a very clear description of the tabulator
and sorter invented by Hollerith, and of the results of the study of
the census commission which chose these devices for use in the
1890 U.S. Census.

C. A. Deavours and J. Reeds. The Enigma, Part I: Historical
Provides a detailed description, with many illustrations, of the
mechanism of the Enigma cipher machine, together with a brief
discussion of the cryptanalytical machines that were used to break
Enigma-enciphered messages.

A brief biography of Hermann Hollerith.

W. de Beauclair. (1967) Geschichte Entwicklung. Taschenbuch der
detailed account of their development until approximately 1960, accompanied by an extensive bibliography.


A detailed factual and lavishly illustrated account of the origins of digital computers, and of their development up until the early 1960's. Contains valuable chapters on the development of the various technologies, such as electronic components, magnetic recording devices, and input/output equipment. Contains brief tabulated data on hundreds of different computers.


A condensed but nevertheless fact-filled account of the origins and development of computers, covering such topics as mechanical calculating machines, tabulating machines, relay calculators, and electronic computers. Extensive bibliography.


Contains a one-page obituary tribute to Lady Lovelace, reprinted from The Examiner.


Describes the method of finite differences, and the workings of the Wiberg machine. Briefly compares it with the work of Babbage and Scheutz and concludes by praising the machine strongly.


Contains a few brief mentions of Babbage, and an account of a visit paid in the company of Lady Lovelace, "to see Mr. Babbage's wonderful analytical engine."


Brief description of Zuse's work. States that the Z3, a program-controlled computer, was in use at a German aeronautical research centre in 1941. Brief mention of the Z1 and Z2; more on the Z3 and its successors.


Survey of the then available calculating machines, briefly describing their functional capabilities, and a somewhat more detailed survey of Hollerith and Powers punched-card equipment, including key-punches, tabulators and sorters. Well illustrated.

A careful and detailed biography, covering inter alia Morland's work on pumps, steam engines, cryptography and calculating machines. Few details are given of the construction of Morland's two calculating machines, but a number of photographs are included.

A brief account of the Polish and British cryptanalysts' work on Enigma, on the occasion of the presentation of a captured Enigma machine to the Royal Signals Museum.

Contains a chapter on automatic pipe organs, and instructions on the method of setting up a pegged cylinder so as to play a chosen piece of music. Diderot gives a very amusing list of the advantages and disadvantages of such an organ, compared to a manual instrument. (Babbage's copy of this book is now in the Crawford Collection, Royal Observatory, Edinburgh.)

D. Diderot. (1751) *Arithmétique (machine).* *Encyclopédie, ou Dictionnaire Raisonné des Sciences, des Arts et des Métiers.* Paris 1 (1751) pp.680-64; plus Plate 2 of 'Algèbre et Arithmétique' in the accompanying Recueil de Planches.
Gives what Taton (1963) describes as the first satisfactory description of the mechanism of Pascal's machine, and in particular of the carry mechanism.

Contains much material on calculating machines, slide rules, nomograms, quite a bit on difference engines, and a brief history of Babbage's work. Chapter II on 'Arithmetical Machines' (pp.24-95) describes many machines, in particular those of Pascal, Burroughs, Felt, Leibniz, Müller, Thomas, Maurel, Tchebichef, Odhner, Selling, Bollée, and Scheutz.

Brief description of what is claimed to be the first direct multiplication mechanism, exhibited by Bollée in 1887. Gives brief details of Bollée's life. Mentions Thomas de Colmar's Arithnometer and Steiger's Millionaire.

Transcription of a speech by d'Ocagne at the opening of a public exhibition of calculating machines held from 5-13 June 1920 at the headquarters of the Society. General survey, dwelling particularly on Pascal, Leibniz, Thomas and Torres.

A detailed survey of the development of calculating machines, covering, among others, Pascal, Tchebichéf, Felt, Leibniz, Thomas, Maurel, Odhner, Burroughs, Bollée, Scheutz, Babbage and Torres.

Contains an entirely rewritten, and slightly shortened version of the account of the development of calculating machines given in the second edition (1905). The main addition is a description of Torres' electromechanical arithmometer.

Record of a speech made on the occasion of the unveiling of a monument to Thomas in Colmar. Contains a brief account of the work of Pascal and Leibniz, and then of the mechanisms involved in the Thomas arithmometer. It is stated that the first arithmometer was built under Thomas' direction by a clockmaker named Piolaine, and it is suggested that this work was done without knowledge of the prior work by Leibniz.

An obituary. Describes the work by Torres on radio control, mechanical analogue computers, aeronautics, aerial cableways, automata, and "analytical engines."

An obituary notice which provides an excellent summary of the life and work of Torres y Quevedo. Brief descriptions are given of his work on aerial transporters, airships, and radio control, as well as on analogue and digital calculating devices and chess automata. The section discussing his work on "Babbage's problem" also mentions the work of Couffignal and Valtat.

M. d'Ocagne. See also R. Mehmke.

An excellent summary of the life and work of Charles Babbage, with many extracts from his writings, and from an obituary notice written by Quetelet.

R. W. Doran. See B. E. Carpenter.

A massively detailed scholarly biography of Vaucanson, with much information on his work on mechanical automata, and on an automatic drawloom.

The thesis concentrates on the co-operative development of a
series of computers by Ferranti and the Electrical Engineering Department at Manchester University, starting in 1949, but contains one chapter on the origins of the digital computer, and the backgrounds of the first post-war British computer projects.

H.-J. Dreyer. See also A. Walther.

H.-J. Dreyer and A. Walther. (1946a) Der Rechenautomat I.P.M. Entwicklung Mathematische Instrumente in Deutschland 1939 bis 1945. Bericht A3, Institute für Praktische Mathematik, Technische Hochschule, Darmstadt (19 Aug. 1946) pp.11-15. (Reprinted in full in Randell (1973).) A brief account of the tape-controlled calculator, assembled using punched card equipment, which was under construction at Darmstadt until 1944, when it was destroyed by bombing.

A brief account of the programmed calculators developed by Zuse, and the applications that had been made of them, during 1939 to 1945.

A well-illustrated and careful account of the development of mechanical automata, concentrating on the work of Vaucanson, von Knaus, and the Jacquet-Droz family.

E. Droz. See also A. Chapuis.

A detailed and scholarly survey of Babbage's published and unpublished mathematical writings, together with one chapter (pp. 266-337) on his calculating machines, incorporating many quotations from his published accounts of the machines.

A very interesting essay on the mathematical thinking that lay behind much of Babbage's work. Contains separate sections on Notation, The Calculus of Functions, The Difference Engine, The Analytical Engine, and Algebra. It states that his ideas on algebra "were decisively influential, but characteristically he has received no credit for them at all."

The book concentrates largely on describing and assessing Babbage's mathematical work, and makes extensive use of unpublished Babbage manuscripts, including a recently discovered book entitled 'The Philosophy of Analysis.' However there is one chapter on Babbage and his Computers, but this is largely based on material in 'Passages from the Life...' and 'Babbage's Calculating

Provides much factual information about the equipment then installed at the U.S. Bureau of the Census, and typical processing rates achieved. For example, it states that the Bureau had one hundred tabulators, seven of which were provided with automatic card feed mechanisms, and that an improved printing totalizer—had just been developed to replace the printing counters that the machines had been equipped with for the 1910 Census.


Pages 146-154, and 5-6 of the supplement, list various calculating machines, in some cases (notably Mayer, Müller, Edmondson, Büttner, Brunsøva and Selling) giving somewhat brief illustrated descriptions of the machines.


An historic paper, describing "a one-stroke relay which when operated by a small triggering electrical impulse undergoes great changes in regard to its electrical equilibrium, and then remains in the new condition until re-set."


This memorandum contains a witnessed note stating that it had been copied from three typewritten sheets dated 29 January, 1944. It describes "a simplified method of constructing a numerical calculating machine... in which some of the mechanical features of an ordinary mechanical calculating machine are retained and combined with certain electronic and magnetic devices to provide a speedier, simpler machine..." The magnetic devices are rotating disks or drums, whose outer edge is made of a magnetic alloy, mounted on an axle along with engraved disks or drums (for generating timing pulses) and disks or drums for providing a visual display (by means of stroboscopically illuminated printed characters). The machine is to perform serial binary addition, subtraction, multiplication and division (electronically) and to have tape or card input/output. The total discussion of the means of control and of stored programs is as follows: "If multiple shaft systems are used, a great increase in the available facilities for allowing automatic programming of the facilities and processes involved may be made, since longer time scales are provided. This greatly extends the usefulness and attractiveness of such a machine. This programming may be of the temporary type set up an alloy discs or of the permanent type on etched disks."

An account of the plans for EDVAC, and a description of its intended order code. Discusses how the decision to provide a single common memory for constants, variables and instructions led to the concept of a stored program, and the implications of this concept on computer design.

Describes the work with Mauchly on what became ENIAC, and then on its successors. "We have been asked, many times, if we knew of Lovelace, or Babbage, and their work. At the time, I did not know of their work. When we started on the ENIAC, we did not know of the work on the Mark I." Includes a full discussion of the thoughts that led to stored programs and EDVAC.

A discursive talk, ranging over many aspects of electronics and the growth of the computer industry, but interspersed with a number of anecdotes about the ENIAC project, including interesting comments about the method of programming ENIAC (which allowed parallel activity, and nested subroutines), the 1944 magnetic calculating machine disclosure, and disputes with von Neumann.

J. P. Eckert. See also A. A. Auerbach.

The description of ENIAC contains detailed information on the arithmetic operations, on programming the machine, and on reliability considerations. Chapter 4 is on 'Design Principles for High Speed Computing Machines' and concerns plans for EDVAC. It concentrates on the question of serialism versus parallelism, and on the stored program concept.

The major part of the book describes various mathematical applications of punched card equipment. However detailed descriptions are given of various standard machines including tabulators, sorters, and multiplying punches as well as a "calculation control switch."

Fairly detailed description, from a programmer's viewpoint, of the relay calculator. "The first two machines of this type, were built during the war for the Aberdeen proving ground, were delivered in December 1944, and were in operation during the last eight months
of the war... For comparison with the I.B.M. Sequence Controlled Calculator at Harvard this machine is limited in internal storage capacity, number of significant figures, an flexibility of sequencing; on the other hand, multiplying speed is about twenty times as great.”

A well illustrated description of the I.B.M. Selective Sequence Electronic Calculator, and of its application. “The calculator has a total internal memory capacity of 400,000 digits... Electronic circuits are used for all arithmetic operations, for part of the control operations, and for part of the memory.”

“…The purpose of this paper is to outline briefly the electronic and electromagnetic measuring, computing and recording devices now in use on extensive astronomical projects and to point out some of the developments which will materialize in a short time.” Mentions that a machine incorporating an electronic adding unit had been in operation in the I.B.M. engineering laboratory before the war, and that it had led to the Type 603.

Contains a good account of the scientific calculations performed using punched card machinery, mainly at the Columbia University Statistical Bureau, from 1928 onwards.

Brief discussion of difference engines, mention of Morland, and Viscount Mahon (afterwards Earl of Stanhope), the inventor of three machines 1775 (using a stepped reckoner), 1777 and 1780 (on the lines of Morland’s instrument). There follows a somewhat more detailed discussion of the Thomas arithmometer, and of the method of carry assimilation, and mention of G. B. Grant’s machine (“somewhat on the lines of the Stanhope machine of 1777”). Ends by talking of the advantages of a machine with a circular form, permitting “an endless slide.”

Despite its title, concerns computer developments solely at Manchester, starting with a brief discussion of the Williams tube memory, and the first Manchester machine.

An illustrated account of the development and the principles of
operation of the interlocking mechanism used to limit the combinations and sequences of railway signal settings.


Survey of English machines, including the comment that EDSAC was working.


A scholarly analysis of Hollerith's character and business career, concentrating mainly on the period from 1890, when his punched card system was used successfully for the Eleventh U.S. Census, to about 1911 when his company became a part of the Computing-Tabulating-Recording Company, as I.B.M. was then known.


Contains a description of Napier's rods, and also of another device that he produced for aiding multiplication, the "multiplicationis promptuariam." This involved a more complex scheme in which multiple sets of the first eight multiples of a given digit were inscribed on a single rod.


A nice information-packed account, covering developments from Schickard's calculating machine to the first stored program computers.


This is a growing series of tape cassettes each providing a one hour recorded interview with a computer pioneer. The interviews are very well done, and the quality of the recording and editing is excellent. More than twenty interviews have been taped to date, and a number of edited recordings prepared and issued, those of A. D. Booth, D. W. Davies, J. P. Eckert, J. W. Forrester, T. Kilburn, J. W. Mauchly, J. Pinkerton, J. H. Wilkinson, F. C. Williams, and K. Zuse. Other pioneers who have already been interviewed for this series include J. V. Atanasoff, A. W. Burks, A. W. M. Coombs, T. H. Flowers, H. H. Goldstine, I. J. Good, G. M. Hopper, C. C. Hurd, H. D. Huskey, D. Michie, M. H. A. Newman, S. Ulam, M. V. Wilkes and M. Woodger. Copies of the cassettes are available from the Science Museum.


Detailed account of the relative contributions of Bouchon, Falcon, Vaucanson, Jacquard and others to the development of the Jacquard loom.
A brief account, based in part on an interview with Mauchly, which includes a description of his career prior to 1942.

A complete textbook on the operation and usage of then-current Hollerith equipment, lavishly illustrated with drawings and photographs.

A very useful set of 14 pamphlets, totalling 60 pages, each giving a well-illustrated account of some aspect of the history of manual or machine calculation. Includes coverage of the work of Pascal, Morland, Schott, Leibniz, Perrault, Poleni and Leopold.

An interesting little article, part survey of earlier machines (particularly the Babbage and Scheutz difference engines), part description of the Comptometer.

An original account of the development of mechanical calculating machines, with forthright comments on the practicality of several of the famous early machines, by the inventor of the Comptometer.

A highly entertaining account, which includes a brief description of the way in which punched card equipment was used at Los Alamos for calculations relating to the atomic bomb.

An account of the design and usage of the Hollerith key-punch, gang-punch, sorter, and tabulator. The sorter described is a 250 card/minute vertical sorter, the tabulator a 150 card/minute non-printing tabulator.

An account of Babbage's work, based in part on the author's discussions with Major-General H. P. Babbage, rather than solely the standard sources.

A good account of the discovery of Schickard's work, and of the principles of his calculating machine, the first to embody a
mechanism for carry assimilation.


A well-illustrated description of the invention, the functioning, and the method of use of each of the three machines.

J. P. Flad. See also R. Taton.


An article based on Snyder (1977).


A profusely illustrated book based on an I.B.M.-sponsored exhibition. Although aimed at a popular audience, it contains a vast amount of information, relating directly or indirectly to the origins of computers, that is not readily available elsewhere. Hundreds of rare photographs and documents are reproduced. An excellent book, which does a very fine job of attempting to portray the social and intellectual background against which the modern computer evolved.


A discussion of Pascal's activities and attitudes in inventing, defending, and trying to perfect his design for a calculating machine.


A detailed report on the functioning of the machine, and of the repairs required to make it operational. (These were in fact carried out.) The report reveals that the machine incorporated six wooden drums each with rows of wires projecting radially from it. Each wire represented (by means of its length) a letter, so that each drum had a fixed set of words encoded on it. These drums would be turned random amounts and then used to control the display of a set of six words, forming a hexameter latin verse. Each drum was therefore a rather sophisticated form of pegged cylinder, used to represent data as much as sequencing information.


Contains several brief chapters on automata, including those by Vaucanson, and Maazel.


Chapter 2 contains some information, not readily available elsewhere, on the activities of I.B.M. in Europe before and during World War II.

Proposes a design for an electromechanical calculating machine, intended for matrix calculations. It was to incorporate a number of interlinked desk calculators, and a specially-designed means for representing matrices, in which each digit of each element was to be represented by the lateral position of a sliding rod.


Contains a good summary of the origins of computers and of the growth of the computer industry.

J. K. Fuller. See C. Freeman.


A popular account of Babbage's life, based on his autobiography, which shows very little sympathy for his work on calculating machines.

A. Galle. Mathematische Instrumente. B. G. Teubner, Leipzig (1912). Pages 23-48, on 'Calculating Machines' cover Pascal, Leibniz, Thomas, the Mercedes-Euklid machine, Odhner, the 'Gauss' circular machine by Hamann, Selling, Steiger's 'Millionaire' machine, and, in a short section on difference machines, one by Hamann, which was used in 1910 to produce a set of arithmetic tables. A photograph, and detailed drawing of this difference machine are included.

R. O. Gandy. The Simple Theory of Types. Logic Colloquium 76 (Eds. R. O. Gandy and J. M. E. Hyland). North-Holland, Amsterdam (1977). Contains, in a section describing published and unpublished work by Turing on type theory, the statement: "As has recently been revealed, in 1940 he was engaged in breaking the code of the wartime Enigma encoding machine; later on (1944-1945) he had a less taxing job - building a speech encoder of his own invention."


A lavishly produced and illustrated introductory book, of some eighty pages, covering such topics as early methods of counting and calculating, mechanical calculation, sequence control mechanisms and automata, the work of Babbage, Hollerith and Zuse, Harvard Mark I, the S.S.E.C. and early I.B.M. electronic multipliers.


Discusses the evolution of machines for evaluating logical expressions. Covers the work of Lull (13th century), Stanhope, Jevons, and Kalin and Burkhart, among others.
A very readable account of the development of mechanical aids to reasoning and to solving problems in formal logic. It describes Marquand as the first to design an electrical logic machine (1885) and Burack as the first to actually build one (1936).

An article prompted by Judge Larson's ruling in the ENIAC suit, that includes an account of an interview of Atanasoff.

A brief but well-written biography of Charles Babbage.

Extremely brief account of a lecture by Genaille, and the ensuing discussion, on the system of rods which were a development of Napier's rods, but which avoided the need to compute the carry from one position to another.

A one-paragraph account of a 'piano arithmétique,' designed to verify whether certain types of numbers were prime. "Cette machine, qui peut arriver à faire automatiquement des calculs de la plus grande importance, réalisera un jour la solution d'une machine à calculer faisant seule les opérations arithmétiques."

After a brief survey of the work of Morland, Leibniz, Poleni, Leupold, and Pascal, Gersten states that his work was motivated by the Leibniz machine, but was developed independently of both the mechanisms of Leibniz and Pascal. Then gives an extremely detailed description of his machine, its inner mechanism, and method of use.

Translated selection from 'Rabdologiae seu numerationis per virgulas libri duo, Edinburg (1617),' in which the use of the rods to assist in the process of multiplication is explained.

An account of Turing's work on cryptanalysis and computers, which though readable suffers from many inaccuracies.

A popular account, covering Pascal, Morland, and Leibniz.


Very brief description, giving most attention to number format. States machine was delivered to the Ordnance Dept. in the fall of 1949. After modifications, in March 1952 it was considered to be a working machine.

D. Goddard. Eminent Engineers: Brief biographies of thirty-two of the inventors and engineers who did most to further mechanical progress. Derry-Gillard, New York (1906).

Pages 240-254 contain a few biographical details about Babbage, and very good general accounts of the Difference Engine and the Analytical Engine, including reprints of the General Plan of the Analytical Engine, and a "program" for the engine originally given by Menabrea. "The Analytical Engine was no dream of a crank. It was the ultimate result of the life-long thinking of the greatest genius for this sort of thing the world has ever seen."


A detailed description of the reconstruction of the Z3 at the Deutsches Museum, Munich. Illustrations include schematic drawings of the control and data paths of the machine, and of the floating point addition and subtraction unit.


Early sections contain mention of Pascal, Leibniz and Babbage, but the major part of the paper consists of detailed analyses, culled in part from U.S. patent literature, of mechanisms involved in various types of calculating machines. Inventors and companies whose machines are referred to include Castle (an 1850 ten-key adding machine), Riggs (an 1854 ten-key adding machine, Teasdale (an 1871 direct multiplication machine), Burroughs, Felt, Wahl, Brunsviga, Wales, Dalton, Moon-Hopkins, Grant, Millionaire, etc.


A popular account of computers, but with many details about early mechanical automata.

A. Goldstine. See H. H. Goldstine.


A detailed account of the ENIAC, EDVAC and I.A.S. projects by one of the main protagonists. Much background material is included, and many original documents are quoted, in this account, which tends to concentrate on the role played by von Neumann.

The first part of this book discusses the history of digital and analogue calculating devices, and concurrent developments in mathematics. However the main purpose of the book is to give an extensive account, from the viewpoint of a particular participant, of the ENIAC, EDVAC and I.A.S. projects. The account makes available for the first time a wealth of material, taken from contemporary documents. Particular attention is paid to the work of von Neumann, and to his role in the EDVAC and I.A.S. projects.

H. H. Goldstine. See also A. W. Burks and J. P. Eckert.

Reasonably detailed description of ENIAC, in particular of how it was programmed.

An extensive account of the methods of coding, and of the philosophy behind, the programming of the I.A.S. computer, followed by a set of detailed examples of programs.

A continuation of Goldstine and von Neumann (1947), giving further detailed examples.

Continuation of Goldstine and von Neumann (1948), giving a discussion of the concept of a subroutine, and some detailed examples.

This paper (previously unpublished) contains material from various lectures given by von Neumann, in particular one on 15 May 1946. It contains a general discussion of the concepts of electronic digital computers, and of the importance of the stored program concept.

Contains a brief history of the development of computers, which is however notable for the detail it gives of a secret electronic
computer built in Britain in 1943, and with which Turing was associated.


Contains a brief but fairly detailed description of the mechanism that Grant had demonstrated on a small model of a difference engine, and that he was using in the design for a full capacity engine.


After a brief description of the essentials of the Pascal and Thomas machines, gives a reasonably detailed description of Grant's machine, in which a digit was represented by the displacement of a single pin around a cylinder rather than by the stepped reckoner or Odhner wheel method. The article ends "The problem of the calculating machine is an exceedingly difficult one, as anyone acquainted with the immense labours of Pascal, Leibnitz, Babbage and Scheutz will acknowledge. The machine described above for the first time is the result of nearly four years of study and labour."


Contains one chapter on ENIAC and EDVAC. After discussing the difficulties of setting-up problems on the ENIAC states that "John von Neumann urged that all the machine units be connected ... so that the machine could be used as a computer of the Babbage type (provisions for this mode of operation had been made in its design). This was done and ENIAC was operated in this fashion until it was retired."

R. Grelet. See L. Malassis.


Informal account of digital computing activity in the Los Angeles area from 1942 to 1957. Describes the growth of the use of punched card calculators and early digital computers, but gives little technical detail. Valuable for the many dates and names of the people involved.


Discussion of the two Scheutz difference engines, and their use for the calculation and printing of the English life tables. Includes an extensive bibliography relating to difference engines by Babbage, Scheutz and Grant.


The first chapter 'Historical Perspective' is an unusually detailed account of the origins of computers. Especially detailed coverage is given of the efforts following Leibniz to make a commercially viable desk calculator, of American developments
following Parmalee in 1850, of difference engines (including
details of work by Grant) and of punched card machinery. However
virtually no references are given.

D. Halacy. Charles Babbage, Father of the Computer. Crowell-Collier,
A popular account based for the main part on Babbage's 'Passages
from the Life of a Philosopher'.

(1973) pp.382-394.
An excellent account, providing a very evocative portrait of von
Neumann.

Earl of Halsbury. Ten Years of Computer Development. Comp. J. 1,4
An account of computer development, mainly in Britain, starting
with the work at Manchester and Cambridge. Suggests that one of
the most important events in the developments which led to the
concept of a computer was a meeting of Turing and von Neumann
during the war, and that "computers are the peace-time legacy of
war-time radar."

Ch. Hamann. Uber Elektrische Rechenmaschinen. Privately printed,
Neu-Babelsberg (ca. 1932) 32p.
A booklet describing various electromechanical calculating
devices, mainly various forms of multipliers, but also including a
device for solving sets of linear equations, with data input from
paper tape.

F. Hammer. Nicht Pascal sondern der Tübingen Professor Wilhelm
Schickard erfund die Rechenmaschine! Buromarkt 20 (1958) pp.1023-
1025.
The author describes his finding of the letters to Kepler from
Schickard about his calculating machine and discusses the
operation and use of the machine.

J. M. Hammersley. The Technology of Thought. The Heritage of
pp.394-415.
In the brief section of the paper entitled 'Charles Babbage and
His Analytical Engine,' Hammersley claims that Lady Lovelace
"discovered for herself the importance of the technical tricks now
called nested subroutines and address modification," and that
Babbage realized that the Analytical Engine "would lack the true
power of a computer if it did not possess a stored program." However
it is admitted that the evidence for these statements,
which is based on Lady Lovelace's notes and her correspondence
with Babbage, is indirect and unsure.

C. J. E. Harlow. See C. Freeman.

Very much a popular account of the history of calculating machines
and computers, together with an introduction to present day
computer systems. The chapters on historical matters are: The
Abacus, Early Inventors (Before 1625), Blaise Pascal, Successors to
Pascal, George Boole and Boolean Algebra, Charles Babbage, Key-
Driven Calculators, Punched Cards, Electromechanical and
Electrical Computers, From ENIAC to EDVAC, and Alan M. Turing.

J. O. Harrison, Jr. The Preparation of Problems for the Mark I
Calculator. Proc. of a Symp. on Large Scale Digital Calculating
Machinery, 7-10 Jan. 1947. Annals of the Computation Laboratory of

Brief description of the successive stages involved in preparing
sequence-control tapes for the Mark I, ending with the comment
"one of the most important problems now facing us is to achieve a
reduction in preparation and set-up time proportionate to that
already achieved in actual computation time."


Brief description starting "The news has recently been released of
a major advance in the development of equipment for extensive
numerical calculations, in the successful completion of a large
calculating machine based on the use of electronic counting
circuits."


Description of ENIAC, written after the author had returned from a
visit during which he worked on the machine.

D. R. Hartree. (1947) Calculating Machines - Recent and prospective

Inaugural lecture, mainly about ENIAC.


General brief description of Babbage's Analytical Engine, the
Harvard Mark I, and ENIAC.

University of Illinois Press (1949).

Includes fairly extensive discussion of Babbage's work, the
Harvard Mark I, ENIAC and the I.B.M. Selective Sequence Electronic
Calculator.

D. R. Hartree. (1950) Automatic Calculating Machines. The

General discussion, and then more detailed description of the
programming of EDSAC.

G. B. Hay. See L. J. Comrie.


Brief description of work of Sir Francis Bacon, Gray, and Baudot.
A detailed, well illustrated, account of the development of mechanical calculating and book-keeping machines. Includes brief accounts of punched card equipment and of early relay and electronic computers. Inventors whose work is covered include Leibniz, Poleni, Roth, Odhner, Baldwin, Hahn, Müller, Thomas, Burkhardt, Hamann, Bollée, Steiger, and Burroughs.

Contains a section 'Historical Review' (pp.215-233) which in the main concentrates on the history of the development of logic machines.

The first official account of this subject, written with unrestricted access to wartime files, including files which are unlikely ever to be made public. This first of three volumes covers the period until the summer of 1941. Contains much authoritative information regarding the extent to which the various types of Enigma message were deciphered, but little on the techniques used, or the individuals concerned. Appendix 1 (pp.487-495), entitled 'Breaking the Enigma: Polish, French and British Contributions' indicates that the Polish cryptanalysts produced their first 'cryptographic Bombe' in 1937, and that the first of the British Bombes 'which were of quite different design from the Polish, and much more powerful' was delivered by May 1940.


A very valuable survey, well-referenced, of computers and their origins.

A scholarly account of the period when Leibniz "conceived his decisive ideas in mathematics," when his "philosophy, founded on mathematics and the natural sciences, was formed," when "his most significant and fundamental insights in psychology dawned" and when he completed his revolutionary calculating machine. Valuable for its discussion of Leibniz' life and mathematical research, even though few technical details are given of his work on the calculating machine.

B. D. Holbrook. *Bell Laboratories and the Computer from the Late

A very useful account covering both analogue and digital computers, and hardware and software developments. Of particular interest is the discussion of the relationship of the work on early relay-based digital computers to the digital techniques used in prewar telephone switching - it is stated that facilities for storing and sequencing semi-permanent subroutines in the Bell Laboratories Model V computer were based on the facilities provided for telephone number translation in the No 5 Crossbar Dial System.


"The Bell Telephone Laboratories exhibited a machine for computing with complex numbers. The recording instrument at Hanover was connected by telegraph with the computing mechanism in New York. This machine was available to members from 11am to 2pm each day of the meetings." (The meetings were held at Dartmouth College, Hanover, New Hampshire from Tuesday to Thursday, 10-12 Sept. 1940.)


Gives a lengthy description of the census system, and of the mechanical card punch and electro-mechanical tabulator and sorter that Hollerith had developed.


Brief but fascinating article, which describes the way in which tabulators and sorters were used on the more than 100 million cards containing the records of the 1890 U.S. Census.


A brief biography of Hollerith, written by one of his daughters. It briefly describes how he developed the first version of his tabulating system, and describes in rather more detail his travels during the next few years in Europe as the Hollerith system came into wide use.


An excellent account of Babbage and Lady Lovelace. Especially valuable for its discussion of the stages by which Babbage arrived at the idea of general programmed sequence control, and for its careful analysis of Lady Lovelace's program for calculating Bernoulli Numbers.


Contains a quite good survey of the origins of computers, starting with the abacus.

"Almost the first day I met a computer [in 1944], I met Babbage. Commander Aiken had a copy of Babbage's book, and at intervals advised us to read sections of it. I did not meet Lovelace's work until ten or fifteen years later." Describes the developments of programming techniques, such as (in 1944), what were later called 'relocatable subroutines.'

G. M. Hopper. See also H. H. Aiken.


Contains, in addition to the Ludgate article on 'Automatic Calculating Machines,' good descriptions of various then current calculating instruments and machines: Archimedes, Colt's Calculator, Brical Calculator, Brunsviga, Burroughs Adding and Listing machine, Comptometer, Layton's Arithmometer, Mercedes-Euklid Arithmometer, Millionaire and the Thomas Arithmometer.


An extensive discussion of the history and of the design of calculating machines. Covers the abacus, Napier's rods, Pascal, Leibniz, and mentions Moreland, Stanhope and others. Some detail is given on Thomas, and on difference engines. The sections on modern machines include detailed descriptions of the operation of arithmometers, Odhner-wheel machines, key-driven adding machines, and the Millionaire.


Covers the abacus, Napier's rods, Pascal, Thomas, Babbage's Difference and Analytical Engines, adding and listing machines, the Millionaire machine, and others. A very good, somewhat condensed account, both of facilities, and of principles of construction.


A useful summary and analysis of Babbage's work, based on the standard sources.


A description of the original version of the Thomas arithmometer, described by Mehmke and d'Ocagne (1908) as perhaps inferior to those of Hahn, Müller, and even Leibniz, but which was gradually improved until the perfected machine (Sebert(1879)) was produced, and became very successful.
H. G. Hudson. See L. J. Comrie.

Illustrated description of a 'difference engine' based on a Burroughs Adding Machine.

An excellent account based on primary sources, particularly the contemporary documents and correspondence assembled for the ENIAC patent suit, covering the period from the invention of the differential analyzer to July 1944, by when two accumulator units had been successfully operated. For example, details are given of the debate over the relative merits of the proposed ENIAC, work at M.I.T. on the Rapid Arithmetical Machine Project, and a proposal by Stibitz of a large Relay Differential Analyzer for Ballistics, and also of the search by the Moore School team for useful prior work on the design of reliable high speed electronic counters. Judge Larson's acceptance of J. V. Atanasoff's priority over Eckert and Mauchly is mentioned, but Hughes leaves this issue to others, merely stating that "... Priority in the case of the automatic digital electronic computer is a complex question... Historians and courts admit different kinds of evidence and judge by different criteria."

Description of an electrically powered special-purpose mechanical calculator, which would compute the sum of a set of products of numbers read from two perforated tapes. The machine could operate unattended, and when it stopped the result could be read from a dial. Little detail is given of the multiplier, but it is implied that the multiplication is performed by repeated addition, and that operands can have three decimal digits.

A collection of manuscript notes documenting extensive searches for primary historical evidence on Babbage, which has been deposited at the Marylebone Public Library. The collection includes extracts from correspondence (held at the Public Record Office (Ref. CREST/174 pp.310-319)) relating to Babbage's attempts to build a workshop in Dorset Street in 1842.

A brief description of the C.P.C. and of some of the applications for which it had been used.

"In summary, the ENIAC and I.B.M. electronic calculator are both in operation at the present time. The BINAC (500-word memory) is going through final checkout at the Eckert Mauchly Computer Corporation while the Mark III is scheduled for unveiling at Harvard University in September. As far as large scale electronic automatic sequenced digital computers are concerned, it seems as if EDVAC will be the first of these to be put into operation."

A general survey, concentrating on electronic computers developed prior to 1950, and in particular on ENIAC and EDVAC. Mentions the ENIAC converter code, a scheme for controlling ENIAC from punched cards, which was put into operation in late 1949.

A critical review, which concentrates on the controversy over the assignment of credit for the invention of the stored program concept.

A nicely written account, whose main sections are on Bletchley Park, Turing and the ACE, Cambridge University and the EDSAC, Manchester University and the University of London. Contains interesting personal reminiscences about the Pilot ACE project.

Contains rather terse entries on a large number of topics, starting with counting tables, including various calculating machines, weaving mechanisms, Babbage's work, punched card machines, etc. Contains an 82-item bibliography.

V. R. Huskey. See H. D. Huskey.

Letter giving, apparently for the first time, complete details of the place and date of Charles Babbage's birth.

Contains a considerable amount of little-known information about Charles Babbage and his various calculating engines, derived from first-hand study of Babbage's sketch-books and drawings. Hyman indicates that Babbage investigated the design of a surprising number of calculating engines - he identifies three difference engines, the first (circularly arranged) analytical engine (1834), a "great engine," a "small engine," a "double engine," an engine designed as a grid system (1858), an array processor (1859), the minimal analytical engine (1870), whose construction was started just before he died, and an algebra engine (1836), intended for the algebraic development of functions.
W. R. B. Hynd. See L. B. C. Cunningham.


Basically similar coverage to that of d'Ocagne (1905), but with quite a lot of material on difference engines, including Scheutz and particularly Wiberg. Not much discussion of Babbage's Analytical Engine — rather more on the work of Torres y Quevedo.


A detailed description of the various special-purpose devices, using photo-electrical tape readers, and electromagnetic relays, used for cryptographic purposes in Germany during World War II.


Detailed description of a mechanical device for evaluation of boolean expressions involving up to four terms.


The first half of the book is concerned with digital devices. It contains brief details of the history of calculating machines, and an illustrated survey of the operation and the mechanism of a variety of contemporary European and American calculating machines and punched card equipment. It ends with a brief account of the ENIAC. This description, which is based on articles published in Time and Newsweek, is believed to be the earliest Japanese language account of electronic computers. Extensive references are given to the Western literature.


Describes how, prompted in 1946 by news of the ENIAC, work started on the design of electronic counters, then memory delay lines, and a never-completed electronic computer, at Osaka University.


An illustrated account of the evolution of punched card machinery. Describes the introduction first of mechanical key punches, and then electrical key punches (1923), to replace the pantograph punch, of vertical and then electrical sorting machines, and of tabulating and listing machines.


The final chapter of this carefully researched and lavishly illustrated book, entitled 'Enigma,' provides a much more extensive account than was available hitherto of the wartime work of the Polish, French and British cryptanalysts. It includes
sketches, drawn from memory, and some brief details of the functioning of the electromechanical (not electronic) cryptanalytical devices (the Polish "Bomba" and the British "Bombé") used to break messages coded using the various types of Enigma cipher machine. The last part of the chapter describes the Siemens Geheimschreiber cipher machine, which it states was used only for messages which were too important to entrust to Enigma, but were broken using the Heath Robinson and then the various Colossus machines, photographs of which are included. The thyratron rings on the Colossus are stated to have simulated the rotation of the Geheimschreiber rotor wheels, the irregular movements of which prompted the provision of conditional (branching) logic on the Mark 2 Colossi. A fascinating account.

Contains a fairly detailed description of the EDVAC, and quotes in full the sections entitled 'Historical Introduction' and 'Contrast of the EDVAC with the ENIAC' of a report written by Eckert and Mauchly in September, 1945, on plans for the EDVAC.

An interesting account of the origins and use of Napier's Rods and of Genaille's Rods. It is stated that Napier also designed special rods for square roots and cube roots.

The author states that he worked with Alan Turing in 1939 on "a machine to recognise German language and thus to establish that a successful decipherment of Enigma had occurred."


An account of the Bell Labs. Model III Computer, which was, to a certain extent, a general purpose device.

A pamphlet, attributed to Joseph Jarvis in the catalogue of the Crawford Collection of the Royal Observatory Edinburgh Library. It contains a vigorous defence of Babbage, and an equally vigorous attack on the Government and the Royal Society for their treatment of him, which make fascinating reading.

Review of Winterbotham (1974) which criticizes his account of the breaking of Enigma, and summarizes the contribution of the Polish cryptanalysts. Kahn states that the Colossus was designed to solve machine ciphers used by various branches of the German armed forces.

A popular account, much of which is devoted to the development of arithmetic, but which includes some discussion of the development of calculating machines and computers.


A popular, but nevertheless detailed, account of the life of Lady Lovelace, and of her interactions with Charles Babbage concerning the Analytical Engine, and a gambling scheme.


Contains lengthy accounts of the development of ENIAC, EDVAC, ORDVAC, and BRLESC, based mainly on information obtained from personnel of the Ballistic Research Laboratories.


The first four pages contain a description of the pioneering use of punched card equipment for statistical computations, which started at Iowa in 1923, and of Atanasoff's special purpose electronic computer, intended for the solution of simultaneous equations.


From the historical note provided with the reprinted version: "This was the first formal report to be issued by the computer design group at Manchester University. About 50 copies were produced in December 1947 and were circulated widely in Britain and in America... The report represented the successful completion by Kilburn of about 12 months' development of a practical storage system... The ideas behind the hypothetical computer described in section 6 became the Manchester Mark I, of which the prototype first ran a program on 21st June 1948."

T. Kilburn. See also F. C. Williams.


"Part I consists of a brief historical introduction to modern calculating machines. Digital aids to computation, starting from the abacus and ending with modern punched card equipment, are described followed by a survey of the large scale automatic digital computers constructed in the U.S.A. and elsewhere... In all about 25 computing systems are described. Part II consists of a review of some of the techniques used at Birkbeck College in the course of the development of a simple electronic computer..." The historical introduction and survey are in fact quite detailed and extensive, and constitute the major portion of the thesis. The
description of S.E.C. states that construction started in 1949 and that at time of writing it had performed simple subroutines but did not yet have its intended punched card input/output equipment.

A largely non-technical article about the developments at Northrop which led to the I.B.M. C.P.C., and the use made of a number of C.P.C.'s there for engineering calculations. The article credits Rex Rice with the development of "highly successful" new internal programming techniques on the C.P.C., and with the design of an enlarged version of the C.P.C., incorporating an I.B.M. Type 604 or 605. Amongst other calculating equipment at Northrop is listed the EINAC. It is stated that this was due to be replaced because of maintenance problems and limited memory and input/output speed.

The last chapter describes Müller's proposed difference engine, and is in the form of a plea for funds to carry out the project. The machine was to be used for the generation, and printing, of mathematical tables.

A brief article on the patent that Bernard Weiner obtained in 1923 for an "Electric Computer and Typewriter," built from relays. It is stated that the machine had fixed built-in "programs" for the basic arithmetic operations, sin x, exponentiation, etc., which are described in the patent. A final paragraph gives a brief biography of Weiner, and states that a special department was set up at the Vitkovice Iron Works "where Weiner worked in developing his idea and designing a fully automatic computer. This work was stopped for good by the German occupation. Weiner... perished in 1942."

Brief illustrated account of the Electronics Research Laboratory where Desch and Mumma led the work on the N.C.R. Electronic Calculator Project.

Account of the history of the abacus, and detailed explanation of its use for the operations of multiplication, division, square root and cube root.

A fascinating detailed analysis of a sorting program written by von Neumann in 1945 in order to evaluate the proposed order code for what later became the EDVAC. Contains a brief, but valuable account of the developments which lead to ENIAC and EDVAC, and of their consequences.
A very interesting survey and analysis of early high-level programming languages, starting with Zuse's Plankalkül, and Goldstine and von Neumann's Flow Diagrams.

A brief survey of commercial applications of the Hollerith system, including photographs of installations at the Southern Pacific R.R. Co., the Carnegie Steel Co., and the Cleveland Electric Illuminating Co.

Translation of the manuscript "Machina arithmetica in qua numeri additi sunt, et subtracti subtrahuntur, et multipliatio nullo, divisio vero paene nullo animi labore peragatur (1685)," describing the first machine for performing the four basic arithmetic operations.

Describes a special purpose digital calculator, built in 1941 at the Hague Local Telephone Administration's Laboratory, to simulate part of a telephone exchange, in order to evaluate its probable performance.

A detailed account of the work of Polish cryptanalysts on the Enigma cipher, claiming that in 1937 they had "cryptographic bombs," which were "complex electronic units with tens of thousands of subassemblies and details [and] a special system of electrically connected revolving drums."

An account of the work by the Polish cryptanalysts, first in Poland and then in France, on the breaking of Enigma messages. A much longer and more detailed account than that given in Kozaczuk (1975a), though with only a few details of the cryptanalytic machines that were used.

The section of this paper dealing with calculating machines is notable for its illustrated descriptions of machines by Hahn and by Burkhardt, and of the Unitas, Archimedes, Brunsviga, Monopol, Mercedes-Gauss and Millionnaire machines.

A biography, including a brief illustrated description of his
calculating machine.


A description with photographs of a draw-loom incorporating a wooden sequence control mechanism involving small wooden pegs fixed to a piece of canvas, thus being somewhat akin to a pegged cylinder mechanism. The author suggests that this "Broselmaschine" was invented by a member of the Ortner family, of Muhlviertel in Upper Austria, in or before 1740, and that the invention was made independently of Bouchon and Falcon, Jacquard's precursors. It is stated that the machine is exhibited at the Heimatsmuseum in Haslach, Upper Austria.

D. Lardner. Babbage's Calculating Engines. Edinburgh Review 120 (July 1834). (Reprinted by H. P. Babbage (1889) and F. and E. Morrison (1961)).

Extensive discussions on mathematical tables, followed by a very extensive discussion of the mechanism of the Difference Engine.

J. A. Larrivee. See G. R. Stibitz.


A fascinating document, giving Judge Larson's findings concerning the validity of the ENIAC patent, and of possible infringements of this patent. Three separate chapters detail the findings concerning the earliest public use made of ENIAC, the attempts to commercialize the machine, and the influence of Atanasoff on Mauchly, all causing various aspects of the ENIAC patent to be invalidated. In particular Judge Larson states that "Eckert and Mauchly did not themselves first invent the automatic electronic digital computer, but instead derived that subject matter from one Dr. John Vincent Atanasoff." Other chapters cover such topics as the relationship of various ENIAC patent claims to work on electronics at R.C.A., I.B.M. and elsewhere, and the preparation and distribution of von Neumann's 1945 report on EDVAC.


An important paper, containing descriptions of many mechanical details of most of the major early calculating machines (Pascal, Morland, Stanhope, Thomas, Bollée, Steiger), accounting machines (Burroughs, Felt, etc.), and early punched card machines (Hollerith and Powers) and brief details of the work of Babbage and Scheutz.


This very useful booklet summarizes the history of five successive computer projects at Manchester University, during the period 1946 to 1975. The early pages give information, from primary sources, on the development of the first computer at Manchester, and on the roles of F. C. Williams, T. Kilburn, M. H. A. Newman, A. Turing
and others. Profusely illustrated.

A discussion of innovations in computer design introduced in Britain during the period 1946-1951, concentrating on index registers, the Williams Tube, and on early techniques for organising two-level stores.

A useful well-illustrated account of British computer developments during the period 1945-1955, particularly valuable for the details it gives of early negotiations and interactions amongst the groups at the N.P.L., Manchester, Cambridge and the Post Office Research Station. Other developments discussed include those at Elliott Brothers and at Birkbeck College, and MOSIAC and TREAC.

J. L. Lawson. See H. Lifschutz.

F. Leclere. See L. d'Auria.

A description of postwar developments at the Technische Hochschule Dresden, starting in 1948 with the construction of a magnetic drum store, and in 1949 an autonomous stack-based arithmetic unit, work which later led to the construction of the D1 computer.

A delightful description of a device, involving a set of co-axial gear wheels, with holes opposite each tooth, together with a photo-electric cell controlling a brake. Selected holes are left unplugged so that a given factorising problem can be solved rapidly by rotating the wheels at high speed, and using the photo-electric cell to detect when the holes are in conjunction so letting a light beam pass through them.

An obituary.

A discussion of binary representations and arithmetic, which includes a brief discussion of the possibility of designing a mechanical binary calculator which would use moving balls to represent binary digits.

E. Lemaire. See L. Malassis.
Lengthy account of the mechanical principles, and of the methods of use, of all the major then-current calculating and book-keeping machines. Very little on the history of their development, and no references.

Discussion, and detailed drawings, of the mechanism of calculating machines by Goldman, von Mayer, Felt and Tarrant, Burroughs, Brunsviga, Thomas, Selling and Baldwin.

D. Lewin. See M. Woodger.

A detailed and careful account, based on newly released official files, and many interviews with the people involved, of the work at Bletchley Park, the information obtained there by deciphering intercepted German radio messages, and its significance to the Allied war effort. Although the book contains little technical detail of the electromechanical and electronic cryptanalytical devices such as the Bomb and the Colossus used there, it provides a better description than any previously published account of the environment at Bletchley Park, of how deciphered messages were analyzed and distributed, and of the impact of this activity on various aspects of the 1939-1945 war.

Pages 302-340 constitute a popular account of Babbage's life and work, based in large part on his 'Passages from the Life of a Philosopher.' It provides an adequate account of the principles of the Difference Engine, but no details at all of the Analytical Engine.

Describes a binary counter stated to have greater reliability and speed than the original Wynn-Williams thyratron-based counter.

Contains detailed discussions of various trigger circuits, and binary and decimal counters, using gas-filled or hard vacuum valves. "The technique of electrical counting has grown as an essential aid in research in nuclear physics, and this book owes much to those who have pursued this science at the Cavendish Laboratory. The central chapters of this book... will I hope be of interest to many who have occasion to use valve circuits, but who may not be concerned with nuclear physics."

Pages 259-295 contain a detailed account of Napier's rods, and of
their use. This includes a description of the additional rods designed for assisting the process of obtaining the square and cube root of a number.

Detailed discussion of the history of the abacus. It is claimed that "the Chinese abacus as a physical device can be traced as far back as circa 1100 B.C.... [It] was originated and developed independently of all others."

L. Liagre. See A. Doyon.

Describes a binary counter that was approximately thirty times faster than previous counters based on thyatrons.

The two parts of the article concern digital and analogue calculators, respectively. The section on digital calculators covers the work of Pascal, Babbage, Thomas, Roth and others, and is notable for its attempt to relate their work to the prevailing conditions, and mathematical attitudes, of their day.

A very detailed, well-illustrated account of not just the main but also the various subsidiary mechanisms incorporated in current adding machines.

A companion article to Lind (1931a), with excellent illustrated descriptions of the functioning of the mechanisms in a number of calculating machines, including ones with direct multiplication features.

Gives a useful discussion of terminology, and a classification of calculating machines, and describes the work of Barbour and Odhner on what is now often called an "Odhner-wheel." However evidence is presented to show that this device originated with Barbour's work in 1872.

Contains a detailed description, and a number of pictures, of the direct multiplication machine invented by Ramon Verea in 1878. The mechanical multiplication table incorporated in his machine was a ten-faced prism, on each face of which were nine pairs of holes, whose sizes represented the digits 0 to 9.
Translation of an account written by Pascal subsequent to being granted a privilege in 1649. This was in essence an "advertisement," rather than a technical account of the machine.

Discursive but interesting comments on the various calculating machine inventors, including Leibniz, Grant, Baldwin, and Rechnitzer ("credited with having first attained the goal of a completely automatic machine for the four fundamental processes"), apparently prompted by the introduction of and the awarding of a prize to the Monroe Full Automatic KAA, "the first fully automatic key-set calculating machine to appear."

An important account of Leibniz' work on calculating machines. Locke argues that Leibniz actually had just one machine built (by a French mechanic, Olivier), which was completed in 1694, and that a very different design, described in a Leibniz manuscript dated 1685, was never built and indeed was infeasible. (The 1685 design was based on wheels with variable numbers of teeth, in contrast to the 1694 machine which incorporated the stepped reckoner mechanism.) It is stated that Leibniz was originally stimulated by learning of Pascal's work, "a description of which he requested and received from Carcavius," and that he began work in about 1671. Locke describes how the machine was lost until 1879, of how in 1893 it was analyzed and repaired by Burkhardt. He gives a detailed account of the operation of the machine, and of the inadequacy of the carry mechanism.

Discusses Babbage's ideas on what would now be called program control - derived mainly from 'Passages from the Life of a Philosopher'.

Contains hitherto unpublished papers and letters by Babbage whose originals are conserved in the library of the Academy of Sciences of Turin. The most interesting document is a French translation of a letter written to Planè, presumably in 1834 or 1835. It discusses the current state of the design of what became the Analytical Engine, although at this stage it was more akin to a digital differential analyzer, and the idea of program control by Jacquard cards had not yet arisen. The book also includes extracts from the Turin police files concerning the surveillance of Babbage and his travelling companion/guide Fortunato Prandi, a suspected revolutionary.

Contains articles on the life of George Scheutz by Losano, and on
his difference engine by Merzbach, together with Italian
translations of a number of original documents and papers,
including several by Babbage and his son. An extensive
bibliography by C. F. Bergstedt is also included.

M. G. Losano. (1976a) Le Radici Europee dell'elaboratore
An illustrated account of four European contributions to the
computer, namely those of Leibniz and Pascal, of Charles Babbage,
of Scheutz, and of Zuse. The section on Scheutz is particularly
detailed.

M. G. Losano (Ed.). (1976b) Machines Arithmétiques: Invenzioni
The book consists of a set of facsimile reproductions of 18th
century French articles on automatic calculating devices and
machines, taken from Galon: Machines et Inventions Approuvées par
l'Académie Royale (1735-1777) and Diderot: Encyclopédie ou
Dictionnaire Raisonné des Sciences des Arts et des Métiers (1751).
The articles cover a device to aid addition, by Perrault,
calculators by Lepine, Pascal, and Hillerin de Boistissandeau, a
tabular aid to manual arithmetic by De Mean and several automata
by Maillardet. The reproductions are excellently produced,
complete with original illustrations.

Describes the interconnecting of two I.B.M. Pluggable Sequence
Relay Calculators, one being used as extra storage for the other.

E. Loveday. George Stibitz and the Bell Labs Relay Computers.
Datamation 23.9 (Sept. 1977) pp.80,81,84,85.
An interesting well-illustrated account, based on an interview
with Stibitz.

Lovelace, Augusta Ada, Countess of. Sketch of the Analytical Engine
Invented by Charles Babbage, by L. F. Menabrea of Turin, officer of
the Military Engineers, with notes upon the Memoir by the
Translator. Taylor's Scientific Memoirs 3 (1843) Article 29 pp.666-
731. (Reprinted in Bowden (1953), Morrison and Morrison (1961), and
H. F. Babbage (1889)).
The single most important paper published on Babbage's Analytical
Engine. Lady Lovelace's notes are more lengthy than the original
Menabrea paper, which is itself a good description of the basic
principles of the Analytical Engine.

S. Lubkin. Proposed Programming for the EDVAC. Unpublished
A document which was originally in the N.P.L. Mathematics Division
library, listed in their bibliography as "an unofficial, privately
circulated report." It provides a lengthy description of a three-
plus-one address order code for the EDVAC, and its use on a number
of example problems. At this time the plan was to rely on offline
conversion of paper tape programs to magnetic tape by a relay-
based 'interpreter,' which would perform decimal-binary conversions, and address relocation for subroutines.


Description of a tapecontrolled calculator, in which multiplication is performed directly, by a form of logarithmic method. Intended, as Babbage's analytical machine, to provide facilities for iteration and conditional branching.


Brief description of the Babbage Analytical Engine, followed by comments on his own work on difference and analytical engines: "I have myself designed an analytical machine, on different lines from Babbage's... Complete descriptive drawings of the machine exist as well as a description in manuscript, but I have not been able to take any steps to have the machine constructed."


An interesting account of the cipher machines used by the Germans during World War II and the codebreaking activity at Bletchley Park. Lavishly illustrated by photographs of the Enigma and Geheimschreibere cipher machines, and of the Colossus and its developers.


A description of the development of the Heath Robinson and the Colossus, valuable for its first-hand account of the work on photo-electric paper tape readers for these machines.


Describes the then incomplete Z4 computer. At this date the memory held 16 numbers - the projected size being 1024.


A very detailed description of a special purpose device, based on uniselectors, for performing calculations involved in the use of Fourier Synthesis for crystallography.


The chapter on Babbage (pp. 71–83) is based on a lecture given in 1903. MacFarlane provides a very good summary of Babbage's life and work, which includes a clear account of the main features of Babbage's planned Analytical Engine, complete with an explanation of the sequence of Jacquard cards that would be needed for a small sample problem.

L. E. Maistrov. See I. A. Apokin.
S. Makinouchi. See K. Jo.


A valuable bibliography (over 300 items), on calculating machines, slide rules, etc., mainly but not exclusively of books and articles in French.


A very useful discussion of the situation in Britain immediately after the war, when work was starting at N.P.L., Manchester and Cambridge. It concentrates on personalities and attitudes, but includes a number of quotations from Turing's 1945 report proposing ACE. Turing's wartime work is hinted at, in a paragraph which mentions that the work was closely analogous to that "carried out by Bell Labs on the 10 L predictor." The final sections of the paper describe the various efforts at N.P.L. at building an electronic computer, culminating in the completion of Pilot ACE in late 1950.


Brief interviews with J. P. Eckert, Grace M. Hopper and K. Zuse.


Chapter 1 contains a highly idiosyncratic and somewhat intertempate account of the origins of computers, which nevertheless contains some interesting items and comments about Turing, Zuse, von Neumann and others.


Excerpt minutes of proceedings of the Institution of Civil Engineers, Vol. XV, Session 1855-56, at which H. P. Babbage presented his description of the Swedish machine. Charles Babbage is quoted as saying "The principle of calculation by differences is common to Mr. Scheutz's engine and to my own, and is so obviously the only principle at once extensive in its grasp and simple in its mechanical application, that I have little doubt it will be found to have been suggested by more than one antecedent writer."


A detailed description of the operation of the Difference Engine, based on a set of specially prepared drawings of the machine.


The first part of this book is a general survey of the various types of calculating machines that have been developed, and their basic principles of operation. The rest of the book (well over 250
pages) lists, in chronological order, over 200 different calculators, often with illustrations, and in many cases with detailed, well illustrated, accounts of their mechanisms. The listing starts Pascal (1642), Morland (1666), Leibniz (1672-1712), Grillet (1678), Poleni (1709), Lepine (1725), Leopold (1727), Poetius (1728), Hilleran de Boistissandau (1730), Gersten (1735), Pereire (1750), Hahn (1774), Mahon (1775), Müller (1783), etc.

A very readable popular account describing the machines built by Hollerith for the 1890 U.S. Census, and of the experience of their use. Very well illustrated.


Discusses the distinction between analogue and digital devices and the possibility of using vacuum tubes for digital calculation. "At present it may not be possible to build a commercial competitor for the desk-type mechanical computer, but larger machines for more involved, more lengthy, or more specialized jobs are practical."

The memorandum suggests the use of an electronic digital computer as a successor to the mechanical differential analyzer. It talks of the need for a program device to control the sequencing of operations, and calculates that 1000 multiplications, involving 9 decimal digit operands, could be performed per second.

Discusses advantages of the machines currently under construction, which had an extensive internal memory, a small, simple, order code, and the ability to store and modify instructions in the internal memory. Gives a brief discussion of problems of using subroutines (how to reference, initiate and terminate them, and how to revert control), and the need for standard linkage conventions. Mentions the problems caused by the fact that subroutines will not always be executed from the same place in memory.

J. W. Mauchly. (1975) Mauchly on the Trials of Building the ENIAC.
An important set of personal reminiscences, about the author's work with Mauchly at the Moore School on the ENIAC project. (See also Brainerd (1976).)

J. W. Mauchly. See also J. P. Eckert.

Includes an account of the evolution of punched card machinery, since the original equipment of 1890, and a description of the mechanism of card punches and verifiers.

The epilogue, by Mary, Countess of Lovelace, contains a brief biographical sketch of her husband's mother, August Ada, Countess of Lovelace.

An account of a circuit diagram, prepared in about 1885 by Alan Marquand, for an electrical relay machine for performing logical inference.

Contains a very brief account of the development of computers, including, however, the statement "As early as 1943 a British group had an electronic computer working on a war-time assignment."

Provides brief specifications of an immense number and variety of then-available business machines, ranging from Adding Machines to Wax Sealing Machines. Relevant sections include Adding Machines (pp.13-64), Calculating Machines (pp.65-85), Billing Machines (pp.422-435), Book-keeping Machines (pp.436-489) and Tabulating Machines (pp.353-360). Most machines are illustrated, and important machines or ranges of machines are described and compared in detail. Particularly extensive coverage is given to Burroughs Adding Machines, the Hollerith and the Powers Tabulating Systems, and the method of operation of the various rival book-keeping systems (Burroughs, Dalton, Elliott-Fisher, Ellis, Remington and Underwood). Provides what is probably an unparalleled survey of office machinery in the 1920's.

A readable account, based on standard sources.

Describes the use of punched card equipment for synthesis and
analysis of harmonic functions, for evaluating multiple correlations, determinants, etc.


The section 'Calculs rigoureux a l'aide de Machines à calcul propres à l'exécution de calculs simples' (pp.236-267) is a very good detailed account of the historical development of calculating machines, covering many different machines in more than the usual amount of detail, including Pascal, Felt, Leibniz, Hamann, Thomas, Maurel, Bollée and Steiger. The following section (pp.267-270) gives quite a lot of detail on the history of difference engines, and rather less on analytical engines. The whole account is supplemented by detailed references.


The first published account of the analytical engine, which became best known in the form of the heavily annotated translation by Lady Lovelace.


Brief description of Babbage's Analytical Engine; includes a reprint of the letter sent by Babbage to Menabrea, disclosing that the mysterious A.A.L., translator and annotator of Menabrea's article, was Augusta Ada, Countess of Lovelace.


Obituary notice for William Phillips. States that he and John Womersley of the National Physical Laboratory had started to design ACE in 1943.


Contains illustrated descriptions of the Seaton device for aiding tabulation, used in the 1880 U.S. Census, and of the automatic tabulator used in the 1900 U.S. Census.

C. W. Merrifield. Report of the Committee, consisting of Professor Cayley, Dr. Farr, Mr. J. W. L. Glaisher, Dr. Pole, Professor Fuller, Professor A. B. W. Kennedy, Professor Clifford and Mr. C. W. Merrifield, appointed to consider the advisability and to estimate the expense of constructing Mr. Babbage's Analytical Machine, and of printing tables by its means. Report of the Brit. Assoc. for the Advancement of Science. Dublin, Aug. 1878. John Murray, London (1879) pp.92-102. (Reprinted in full in Randell (1973).)

Fascinating. Concludes by praising Babbage for his ideas, but states that "we are also of the opinion that in the present stage of the design, it is not more than a theoretical possibility; that is to say, we do not consider it a certainty that it could be constructed and put together so as to run smoothly and correctly, and to do the work expected of it... We cannot advise the British
Association to take any steps, either by way of recommendation or otherwise, to procure the construction of Mr. Babbage's Analytical Engine.


An important paper containing careful analyses of the extent to which the developers of the early computers and relay calculators were aware of Babbage's work, and accounts of the development of the stored program concept, and the early history of the MANIAC. Evidence is presented that "awareness of Babbage's work has suffered no long gaps... What is surprising, then, is not that some people were aware of Babbage's work, but that others were unaware of his work." The discussion of the development of the stored program concept claims that Clipinger, rather than von Neumann, was the originator of the idea of controlling ENIAC by a sequential program stored in function tables.


Pages 53-122 give detailed descriptions of the mechanisms used in contemporary calculating and adding machines. In an appendix a brief account is given of German, British and American developments, including the work of Zuse, and at Darmstadt, and the Harvard Mark I, ENIAC, and ACE. The Russian language edition, published in 1950, has an extensive bibliography on East European developments, compiled by N. E. Kobrinskii.


Contains a brief reference to the author's wartime work. "During the war I was a member of Max Newman's group at Bletchley, working on prototypes of what we now call the electronic digital computer. One of the people I came most in contact with was Alan Turing, a founder of the mathematical theory of computation..."


Amusing first-hand anecdotes about Turing at Bletchley Park.


A popular but nevertheless useful article giving brief details and anecdotes about a number of little known digital and analogue calculators built in Britain during World War II. The digital devices mentioned include ones developed at T.R.E. for cryptanalytic purposes, and relay calculators designed by Shire and Runcorn, and by Barnes (also at T.R.E.) and Petherick at R.A.E. (Farnborough).


Contains an evocative though brief account of conditions at Bletchley Park, and of work on the breaking of Enigma messages.
W. Minto. See D. S. Erskine.

A fairly extensive account of the life and work of Atanasoff, based on personal interviews with him.

A carefully researched biography, which provides a very good account of the remarkable yet tragic life of Lady Lovelace. Her friendship and collaboration with Charles Babbage are covered at some length, though there is comparatively little technical detail concerning their correspondence and discussions about the Analytical Engine. Strong evidence is presented that Moseley (1964) was mistaken in her claims that Babbage and Lady Lovelace were developing a gambling system, with which the work on Analytical Engine was somehow related.

A well-illustrated popular account of the origins and growth of the Burroughs Corporation, and its British offshoot.

Although full details are given of the use of the machines, no details are given of their mechanisms.

E. Morrison. See P. Morrison.

Largely biographical, drawn from such sources as 'Passages from the Life of a Philosopher.' Very brief discussions on the Difference and Analytical Engines.

A valuable selection of material on Babbage's Engines, taken mainly from 'Passages from the Life of a Philosopher' and from 'Babbage's Calculating Engines.'


A biography of Babbage, but without much material on his technical achievements.

Contains on pages 19-20 a rather sad account of a visit to Charles
Babbage, commenting on the machines he had left uncompleted, having each time moved on to a new and more ambitious project.


A valuable and well-documented account of the life and work of Herman Hollerith. It includes detailed coverage of the patents issued to Hollerith, including those that relate to the evolution of the tabulating system up to 1914.


Contains a very good description of the workings of mechanical calculating machines, which is very readable and well illustrated (15 pages), and a somewhat shorter description of the fundamentals of electronic computers.


Contains a valuable account of punched card mechanisms.


An account of the life and work of Gustav Tauschek, including his work on book-keeping machines, punched card mechanisms, and on character recognition devices.


A very useful account of the origins, development and use by the U.S. Census Bureau of Hollerith tabulating machines. It is stated that in the 1910 Census tabulators equipped with simple printing devices were used for the first time, but that automatic tabulators (i.e., tabulators with automatic card feed mechanisms) were not used, even though such machines were in general use in private industry.


Brief discussion of the importance of the concepts of a stored-program, and of conditional branching.


An obituary.


Brief description, followed by a remark by d'Ocagne, of a machine which was based on the idea of Genaille's numbering rods, but was entirely electro-mechanical, using relays and commutators.
D'Ocagne describes it as being of most interest because of its difference from the Torres y Quevedo machine.

A very competent popular account of Babbage's life and work.

A brief biography of Aiken, written on the occasion of his retirement from Harvard University.

The author describes how his interest in computers was aroused by reading a 1948 Japanese article on the Harvard Mark I. He started to develop a computer, for ray tracing, using thyratrons. He later obtained more information about Western work on electronic computers from K. Jo, who had started to construct a computer at Osaka University. Okazaki's own design for a computer resulted in the FUJIC, whose assembly was started in 1952, and completed in March 1956.

Brief account of the 'Historical Session' at the 1967 Nat. A.C.M. Conference - an occasion at which many early pioneers reminisced on their experiences in the development of computers.


G. M. Patterson. See R. Serrel.

Discussion and analysis of Marquand's electrical binary logic machine.

Detailed descriptions, and accounts of the provenance of, eight copies of Pascal's calculating machine.

A report of a lecture by T. H. Flowers, describing work on the Colossus project. The title refers to a claim that "Britain lost a post-war lead in electronic telephone exchange technology partly because of the need to maintain secrecy about Colossus, the world's first electronic programmable computer."

H. Pengelly (Ed.). A Memoir of William Pengelly of Torquay, F.R.S.,
Pengelly was a friend and admirer of Babbage. A number of the extracts from Pengelly's correspondence reprinted in this Memoir mention meetings or correspondence with Babbage.


A well-illustrated account of a very sophisticated mechanical writing and drawing automaton made by Maillardet in about 1805, now in the Franklin Institute.

Part 1, by Pérès and Brillouin, covers Vannevar Bush's differential analyzer, the Harvard Mark I, II and III, and ENIAC. Part 2, by Couffignal, describes the plans for the computer then being built at the Institut Blaise Pascal, stressing that, in contrast to the various American machines, it was designed as a highly parallel machine, utilising multiple arithmetic units.


"This report puts the early contributions to computer development into proper perspective, giving credit to those pioneers of the formative years. The emphasis is on I.B.M. engineering development efforts and contributions covering the period up to the announcement of the 701."


A letter, prompted by Tropp (1974), which contains interesting details about projects on electronic calculators and computers at I.B.M. in the 1940's, and of the work of R. Palmer and of R. Seeber. Of Seeber, Phelps states: "When the Mark I was announced, he transferred to Harvard to work in the Mark I under Howard Aiken. While helping Aiken on the design of the Mark II, he proposed to Aiken that the Mark II use the same language for instructions as for data so that it might be possible to machine-modify instructions and addresses. His suggestion was summarily rejected, proving that even geniuses can have an occasional blind spot. Shortly thereafter, Seeber joined I.B.M. to work on the S.S.E.C. where he was successful in incorporating his ideas on instruction handling."

Advocates the keeping of actuarial data files in octal, and of performing calculations in binary. Demonstrates a mechanical multiplier, working in binary, and proposes a 'light-ray' machine, which would replace mechanical action by the action of a momentary light ray directed on a selenium photo-cell.

130).
Makes somewhat obscure references to the fact that the author ("propounder of the idea of an electronic computer in 1936") was highly conversant with Babbage's work.

A memorandum regarding the claims by Phillips to have started work on the design of ACE with Womersley in 1943, when they occupied war-time offices opposite each other, in Baker Street, London. It is stated that Womersley had started to design a decimal telephone relay computer in 1937, with the assistance of G. L. Norfolk from 1938.

In his reply, Phillips states that his 1936 paper had been based on a memorandum that had been prepared for the Dept. of Scientific Research, that the government had insisted on patents being filed, and that references to thermionic valves had been deleted from the paper. He also stated that Womersley learned of the paper in 1943.

States that work started on the design of Pilot ACE in January 1943, and that Turing did not join the team until the autumn of 1945.

Describes how he had been interested in Babbage's Analytical Engine since boyhood, and that having learnt about Eccles and Jordan, and about Wynn-Williams, conceived a plan of a binary electronic computer in 1934.

Contains a detailed account of the relative contributions of Bouchon, Falcon, Vaucanson, Breton and Jacquard to the draw-loom that became known as the Jacquard loom. It also discusses a draw-loom controlled by what was effectively a pegged cylinder which was invented by Regnier (1755) and an electrical draw-loom exhibited by Bonelli in 1853.

A book referred to by Lady Lovelace. Part 3 Chapter 4 (pp.232-261) on Figure Weaving contains a detailed description of the operation and use of the Jacquard loom, and of various improvements made to it by British inventors. "In the course of the very few years which have elapsed since its first introduction into this country, the Jacquard loom has entirely taken the place of every other
method of figured silk weaving..."

An introductory booklet, giving an illustrated history of the
development of calculating machines, particularly adding machines,
and concentrating on the Addo series of machines started by H.
Agrell in 1917. An adding machine developed by Boucher in France
in 1880 is shown, as are various Addo machines.

pp.321–379.
Contains a lengthy description of the machine tabulation

E. A. Posselt. The Jacquard Machine Analyzed and Explained: With an
appendix on the preparation of Jacquard cards, and practical hints
to learners of Jacquard designing. Pennsylvania Museum and School of
Industrial Art, Philadelphia, Penna. (1887).
Extremely detailed description of the mechanism of the Jacquard
loom, and of machines for preparing Jacquard cards. Lavishly
illustrated.

D. J. de S. Price. Automata and the Origins of Mechanisms and
An essay on the parallel development, since the time of
Archimedes, of astronomical and anthropomorphic automata. Provides
a brief summary of the evolution of the mechanisms used by
automata builders. It states that "organ-barrel programming" was
first used in the mid-sixteenth century by Augsburg and Nuremberg
clockmakers, and that punched tape was first used in sixteenth
century Augsburg hodometers.

Publicola (pseud.). Mr Babbage's Calculating Machine. *Mechanics
Magazine* 17,466 (14 July 1832) p.256.
A letter to the editor prompted by a review of Babbage's book 'On
the Economy of Machinery and Manufactures' which had appeared
earlier (No. 464(30 June 1832) pp.213–220). Cynically asks why,
despite the understanding the book shows of the planning and
execution of complex engineering works, Babbage has still not
completed his great calculating machine.

J. Pugh. Calculating Machines and Instruments. *Science Museum,
Revised and updated version of Baxandall (1926). Since 1926 the
Science Museum's collection has more than doubled in size. However
in this revised catalogue only minor changes have been made to the
very useful descriptions written by Baxandall, and the items added
to the collection listed in an appendix.

A very readable account of the origins of arithmetic, of the
Greek, Roman and Medieval abacus, and of jetons.

I. E. Pyne. See R. Serrel.


Describes one year's work on a project funded by N.C.R. to assess a machine proposed by Vannevar Bush. "The rapid arithmetical machine is to be an extremely flexible device for automatically and quickly performing extended and complicated computations involving all combinations of the four fundamental arithmetical operators." The machine was to have "a master control unit" which would receive its operating directions by some such means as punched tapes or magnetic coding on steel strips, although "in the case of a machine designed to handle restricted types of problems, the control unit might advantageously be arranged in the form of a key or plug board." It would appear that the Bush memoranda discuss such aspects of the proposed machine - Radford's report is largely concerned with a detailed account, including circuit diagrams, photographs and experimental data, of the various electronic components that had been developed, such as triggers, counters and registers.


"Computer research started at R.C.A. as far back as 1939. The impetus was the dire need to replace the slow and inaccurate "directors" then used for controlling anti-aircraft guns by rapid and accurate controls made necessary by the fast planes of the day... All the elements for a complete binary computer were conceived and incorporated in experimental prototypes. These included registers of flip-flops, shift registers, counters, adders and subtractors, multipliers and dividers, and generalized code converters." A resistive function generator (i.e. a read-only fixed memory) was developed in 1942, but the idea of building a complete fire-control computer was not pursued, because of the number of tubes needed.


"This project consists of a theoretical and experimental study of electronic means of performing some basic operations of mathematics with the view of replacing totally or in part the mechanical computing elements used at present in the directors for anti-aircraft artillery... The various operations which must be performed consist essentially of transforming the data obtained from optical or radar position-finding instruments in terms of mechanical motion into electrical data; of performing on them the necessary mathematical operations electronically,
i.e. transforming that electric data into new electric data; and finally of transforming the results into the mechanical motions of the gun and fuse setter. The primary object of the present investigation is the electronic computation itself, which involves addition, subtraction, multiplication, differentiation, integration, and generation of trigonometric as well as arbitrary functions of one and two variables. Most of the report concerns analogue techniques, but pages 44-52 describe work done on counter or impulse (i.e. digital) techniques for performing the various required operations. A decimal counting circuit had been demonstrated - "it has been shown that in principle counters can be used to carry out all the computations required in a predictor."


"Electrical numerical computing elements have been worked out and built which will perform the principal mathematical operations involved in prediction. Performance tests have shown that their speed and accuracy are adequate. Tentative designs have been made of complete directors using this type of equipment. These require a great many component parts, particularly a large number of vacuum tubes. There is every reason to believe that with continued work they can be greatly simplified and reduced to a practical instrument."

Discusses Ludgate's career, and his planned analytical machine. Includes reprints of Ludgate (1909) and Boys (1914).

A record of an investigation into the wartime work of Alan Turing, and of its significance to the development of computers.

The book contains a set of thirty-two original papers and manuscripts relating to the origins of digital computers... Introductory and linking text is provided in order to place the work of the various pioneers into perspective, and to cover such topics as early calculating machines and sequence-control mechanisms and the development of electromagnetic and electronic digital calculating devices. An annotated bibliography of over 350 items is also included."

(Presented at Int. Research Conf. on the History of Computing, Los Alamos, N.M., 10-15 June, 1976.)
"The partial relaxation of the official secrecy surrounding Colossus has made it possible to obtain interviews with a number
of people involved in the project. The present paper is in the main based on these interviews, but supplemented by material already in the public domain. It attempts to document as fully as is presently permissible the story of the development of Colossus. Particular attention is paid to interactions between the Colossus project and other work carried out elsewhere on digital techniques and computers, and to the role that those involved with Colossus played in post-war computer developments in Britain.


This account describes the history of the development of digital computers, from the work of Charles Babbage to the earliest electronic stored program computers. It has been prepared for Volume 3 of 'l'Histoire Générale des Techniques' and is in the main based on the introductory text written by the author for the book 'The Origins of Digital Computers: Selected Papers'.


A heavily condensed version of Randell (1976a).


A very detailed account of the way in which Schäffler's tabulating machines were used for the Austrian Census.


A reproduction of the manuscript of a book prepared in 1967 for the Smithsonian Institution. A fascinating book, although largely about the personalities, and the organisational aspects of the project, rather than the technical details. It describes how work started at M.I.T. in 1944 on an 'Aircraft Stability and Control Analyzer' project, led by J. W. Forrester and R. R. Everett, and how the project shifted from analogue to digital techniques, influenced by P. O. Crawford, and later evolved into Project Whirlwind.


A survey of the development of mechanical calculating machines in the nineteenth and twentieth centuries.

W. Renwick. See M. V. Wilkes.


Despite its brevity, a very useful account of Hollerith's life and work, based on original sources, and providing an unusually extensive bibliography.


D. Riches. An Analysis of Ludgate's Machine Leading to a Design of a Digital Logarithmic Multiplier. Dept. of Electrical and Electronic Engineering, University College, Swansea (June 1973) 94p. An interesting analysis of Ludgate's design, and a comparison of it with modern counterparts. Speculative drawings of the mechanism of Ludgate's machine are provided, and detailed designs are given for multipliers similar to that described by Ludgate, but using logarithms to base eight and base four, rather than base ten.

R. D. Richtmyer. The Post-War Computer Development. Amer. Math. Monthly 72, 2 (1965) pp. 8-14. Discusses how the modern stored-program computer evolved following the development of ENIAC. A brief account is given of the ENIAC Converter Code, which allowed manually-set function tables to be used to represent programs, and an accumulator to be used as an instruction counter. The idea of the converter code is attributed to von Neumann.


L. Rodríguez Alcalde. (1966) Torres Quevedo y la Cibernética. Los Sabios del Mundo Entero No 21. Ediciones Cid, Madrid (1966) 209p. A biography, which although intended for a general readership contains much information not available elsewhere. A number of photographs of Torres and his family, and of various of his machines, are included.

devoted to his work on chess automata and his paper on 'automática.'

Illustrated description of a strange instrumental aid to addition reminiscent of Napier's Rods, found by the author in Mexico.

Pages 247-249 contain an account of the machines used for cryptanalytic purposes by the German Foreign Office and Military High Command during the Second World War. It describes the use of punched card equipment, both specially built, and from the standard Hollerith range, and of various other cryptanalytic devices. These latter included a foreign office machine described as being similar to Lehmer's first factorising machine, and machines which though similar in principle were based on the use of optical pattern matching.

Contains, on p.368, a brief description of the basic functioning of the Geheimschreiber.

A fairly detailed account, drawing on unpublished as well as published material, of the development and use of the Enigma cipher machine. Contains some details of cryptanalytic machines, including the Polish Cyclometer and Bombe, and the British Bombe, which it claims was based both on the Polish Bombe, and on Turing's Universal Machine.

L. F. Rondinella. See L. d'Auria.

A readable, but not always reliable, account of the lives of various pioneers. Has chapters on Pascal, Leibniz, Babbage, Grant, Pelt/Burroughs, Hollerith, Watson, Mauchly/Eckert/von Neumann, Turing and Fano. Lists Sebert, Magnus, and Leonardo da Vinci as contributing to the invention of mechanical calculators.

Contains an account of the Royal Society's role in matters concerning Babbage's Difference Engine, and of the author's attempt in 1852 to persuade the government to finance the completion of the machine, claiming that the money spent earlier had been amply repaid by the improvements in mechanical engineering that resulted.
S. K. Runcorn. See E. S. Shire.

A detailed account of the design and programming of digital computers. Extensive references.

A moving tribute, obviously written from first hand knowledge of Babbage and his work.


Discusses the landmark patents relating to the origins and development of digital computers.

Contains a brief description and an illustration of what is in effect a "read-only memory" representing the Morse Code alphabet. The "memory" consists of groups of wide and narrow bands of conducting material, laid out in tabular form, and "read" by a hand-held metal pointer which is passed across each chosen group.

E. Scheyer. (1921) Control of Machines by Perforated Records Based on the Jacquard Mechanism. American Machinist 55,10 (1921) pp.743-747.
A very interesting paper, which argues that "perforated paper control of machinery" was capable of great development. Brief descriptions are given of Jacquard and player-piano mechanisms, which are characterized as simply controlling when various independent parts of a machine are to act. It mentions that the monotype machine and the Hooven automatic typewriter were also of this type. The paper however concentrates on the use of punched tape to control the various movements and operations of a single body. It describes and illustrates two existing machines of this type. The first of these, the Jacquard embroidery machine, used perforated records to control the movement of a possibly very large fabric frame relative to the set of embroidery needles. It is stated that such machines came into use toward the latter part of the nineteenth century, but that "to the world in general and even to the engineering world, little is known of these complicated and highly developed machines." The one other such machine known to the author was a massive metal-working machine, the automatic multiple punch manufactured by William Sellers and Co., Inc. The final section of the paper suggests applying these control techniques to a lathe.

A very interesting article arguing that Jacquard or pianola-like mechanisms could be used to automate many manufacturing operations. One particular application is discussed in some detail, that of cutting out cloth, and a drawing of a "kinautograph cloth-cutting machine" is given. There is no indication that any such machine had actually been built.

D. Schmid. See W. de Beauclair.

R. Schneider. See W. Goldbach.

After describing Zuse's mechanical and electromechanical computers, states that the design of an electronic version, intended to perform 10,000 operations/sec., had been started, but had been interrupted because of difficulties of obtaining components. A final section lists (mainly military) potential applications.

Contains a lengthy discussion of electronic valves and their use in switching circuits, but has only a brief reference to computers in a section on possible applications.


Provides a fairly detailed precis of an account of a calculating machine "built by an otherwise unknown Hebrew clockmaker and mechanic Jewna Jacobson at Nieswiez, province of Minsk, Lithuania, probably not later than 1770." The machine could perform addition, subtraction, multiplication (by repeated addition) and division (by repeated subtraction) on numbers of up to nine digits. "It is obvious however from signs of usage, that the machine was mostly - and for a long time - employed for the computation of numbers with no more than five digits."

Detailed illustrated description of the arithmometer, evolved from the original invented by Thomas de Colmar, by his son Thomas de Bojano.


A well-illustrated comprehensive account of the development of computers in America, prefaced by short accounts of the history of desk calculators, and Babbage's work. It gives much background information - dates of first delivery, numbers delivered, etc.

Shows how symbolic logic can be used in the design of complex circuits. One of the examples given is a circuit for the addition of two binary numbers.

Describes an experimental machine, sometimes called Shadrach, used for testing certain features of EDVAC. It consisted of a manual input device, an arithmetic unit, eight delay lines each holding eight 32-bit words, output display lights and a four-address control mechanism. The account ends "Shadrach was an experimental machine; it was not finished and probably never will be. It was used for testing in connection with EDVAC and gave some very useful information for EDVAC. It is expected that EDVAC will be finally complete about December, 1948."

Ends with the comment "The mercury delay memory tank described appears to be such a promising device that the Moore School's plans for a future large scale digital computer envisage the use of this memory means. It is hoped that within the year such a machine may be an actuality - a machine which will have a high-speed number storage equivalent to 1000 ten-digit numbers, computing speeds somewhat faster than ENIAC, and consisting of only 3000 tubes."

T. K. Sharpless. See also J. G. Brainerd.

A detailed description of the techniques of addition, subtraction, multiplication and division used in BINAC.

R. F. Shaw. See also A. A. Auerbach.

Fairly detailed, well-illustrated, account of the C.P.C.


S. Shoji. See Y. Takahashi.


The article on spinning and weaving in Vol. 3 describes, and has pictures of, Bouchon's and Vaucanson's looms.


The book, which was first published in 1863, has a chapter on Joseph Clement, which describes his work for Babbage, and a brief appendix containing an account by Babbage of his association with Clement.


A brief article based on a letter written by Babbage following a visit he paid to the widow of Laplace in 1840.


Discusses the work of many pioneers such as Pascal, Leibniz, Babbage, and Bush, and argues against a simplistic view of the development of computers as progressing linearly from achievement to achievement, and instead views the development as involving many concurrent activities, until ideas match requirements and technological possibilities.


Based on Redmond and Smith (1975).

T. M. Smith. See also K. C. Redmond.
Brief description of the use of sorters and tabulators for various statistical calculations.

Most of the report deals with work done by or for N.S.A. following the influential Moore School lectures, starting with such topics as E.R.A.'s Atlas 1 and Atlas 2 computers (which became the E.R.A. 1101 and the UNIVAC 1103, respectively). However a three-page section 'Pre-computer N.S.A.' discusses the use for cryptologic purposes of modified punched card equipment, and special purpose digital devices by N.S.A.'s principal predecessors, the U.S. Navy's Communications Supplementary Activities, Washington (C.S.A.W.) and the Army Security Agency (A.S.A.), starting in about 1935. It states that "it is worth pointing out that machines built in this 'pre-computer' era utilized high-speed digital circuits similar to, and definitely antedating techniques later used in electronic computer technology. During World War II Navy used Eastman Kodak, National Cash Register, and several other firms to plan and build these machines. M.I.T.'s Vannevar Bush provided some of the ideas for these early equipments. The A.S.A. utilized the services of Bell Telephone Laboratories during the war to design and construct a large complex of relay equipment which was dedicated to one particular problem. The A.S.A. and C.S.A.W. punched-card equipment installations grew phenomenally; of particular interest was a series of special-purpose attachments built for the most part by I.B.M. for operation with I.B.M. tabulators. These in effect multiplied many-fold the power of the standard punched-card complex." Other early work discussed includes that by E.R.A. on special purpose electronic devices involving magnetic drum storage, such as Goldberg, "a comparator-like system with statistical capabilities" started in 1947, and Demon, which used "data stored on the drum to perform a specialized version of table look-up." Five Demon equipments were delivered, the first in 1948 when it was probably "the first drum memory in practical operational use in the United States."

A. Speiser. See H. Rutishauser.

Personal anecdotes concerning computer developments at Northrop, with brief mention of BINAC and the fore-runner to the I.B.M. C.P.C.

The BINAC, short for Binary Automatic Computer, was developed by John Presper Eckert, Jr. and John William Mauchly during the years 1947-1949 under a contract from the Northrop Aircraft Corporation. It became the first operational stored program computer completed in the United States. This paper provides an historical analysis of the BINAC and the issues relating to its development. It also
considers factors relating to the Eckert-Mauchly Computer Corporation and its ultimate acquisition by Remington Rand." An excellent carefully researched account, which describes how BINAC was successfully demonstrated in August 1949, but never worked satisfactorily after being shipped to Northrop, perhaps largely because of Eckert and Mauchly's lack of funds, and involvement with the design of UNIVAC.


In addition to a summary of the development of the Bell Labs Series of relay computers, describes a tape-driven relay-based Automatic Message Accounting system, first installed in 1948, and a variety of analogue computers and calculating devices.


A memorandum, prepared by Stibitz sometime during 1940, apparently for publication in the Bell Laboratories Record. It describes the Complex Calculator, and in particular the use of binary-coded decimal number representations, and briefly describes the experience that had been gained using the machine.


An introductory account of the plans for what became known as the Bell Labs. Model V.


A broad informal discussion of the history of computing, and of the influences of technological developments, and of wartime attitudes and requirements.


Discusses, inter alia, the need for what we would now call index registers, and for more convenient forms of program specification, such as allowing parenthesized expressions.


An informal but detailed account of Stibitz's work on the Bell Laboratories Series of relay calculators and computers.

Has a short survey on desk calculators, and on Babbage's work. More detail is given of the development, in parallel with Aiken's work, of the Bell Laboratories Series of relay computers.

Includes a description of the Zuse Z4. States that it has been in operation ten hours a day since the end of August, 1950.


This book, prepared by the staff of Engineering Research Associates, Inc., evolved from a report written for the Office of Naval Research. It is concerned almost exclusively with the detailed design of computers, and their electronic and electromechanical components. It has a very extensive list of references. Subjects covered include desk calculators, punched card systems, and the then current relay and electronic digital computers.

E. L. Stoll. See W. F. Luebbert.

Discussion of Zuse's work on program-controlled computers.

Refers to devices such as music boxes, pianolas, Jacquard looms and the monotype machine as machines which involve a recording medium which can be used to recreate the recorded activity. It suggests that this is a useful principle: "when a number of machines are to be employed in making identical objects, it is entirely possible to use one master record for all, using duplicate records for the several machines, or, by electric or pneumatic communication, employing one record to govern all machines."

A sale catalogue, including sections on Pure Mathematics, Astronomy, Mechanics, Optics, Electricity, Pneumatics and Mathematical Tables. Over two thousand items are listed, some consisting of whole sets of books or papers. A few items relate to Babbage's work on calculating machines, including a book about Sir Samuel Morland.

Brief description of ENIAC, and mention of the length of time that
was spent plugging programs, and hence the desire for EDVAC.

A good account of the history of electronic computer developments in Japan until 1964. The early chapters discuss the development of calculating machines and computers in the U.S.A. and Europe. The earliest Japanese developments described are a statistical relay calculator (completed in 1947), the first E.T.L. relay computers (1952), the TAC electronic computer project (started in 1951), and FUJIC, the first electronic computer to be completed (1956).


From the English language synopsis: "A few years ago, the Department of Communications was asked by the Statistical Bureau to design and construct electrical tabulating machines to be used for the first census of Japan and it was agreed to produce 11 sets of machines as the first trial... After a considerable effort and careful experiment two of them were completed and tested with satisfactory results. They were capable of making the tabulations of any three sorts of items on a perforated card simultaneously, at the speed of 120 cards per minute. But, unfortunately, one completed set and nine sets under construction were burned, when the disaster of the big earthquake and fires broke out in Tokyo, last year, only one set being saved at the Bureau." A thirteeng-page report, with several diagrams and photographs, describing a vertical sorter, and a (non-printing) tabulator.

A detailed account of Pascal's development of his calculating machine. A short account of Schickard's prior work is included.

An account of the development of mathematics, and in particular arithmetic, from the earliest times to the first mechanical aids to calculation.

A valuable account of the development of aids to calculation, from the abacus to mechanical desk calculators, with a brief account of the early developments of digital computers.

L. Tatum. See J. W. Sheldon.

Vienna (Nov. 1930).
Gives a detailed description of an automatic book-keeping system based on specially designed card punches, sorters, collators and tabulators. The tabulator, which produced both printed and punched output, was controlled by a plugboard and by codes punched into special cards inserted amongst sequences of data cards, and included optional multiplication and division mechanisms.

Contains a wealth of anecdotal material on the development of computers in the U.S.A.

Contains (on pages 103-105) a somewhat confusing account of a railway signal interlocking machine, the Saxby and Farmer machine, started to have been developed in the 1850's, which it describes as a "non-numeric, symbolic logic simulator" which had to be programmed using an "early hybrid form of Boolean algebra." No references are given.

Includes an account of Babbage's machines (pages x and 134-145) and also brief sections on Automata and Speaking Machines, The Automaton Chess-Player, Sir Samuel Morland and his Inventions, and Jacquard and his Loom.

A description of a "program" for a National Accounting Machine, devised in 1943 by Todd and von Neumann, on the occasion of a visit by the latter to the Nautical Almanac Office.

Contains a summary of a description, written in July 1944, of a 'Rangefinder Performance Computer.' This device calculated the mean error and root mean square error made by the rangefinder operator, using a mechanism built from uniselectors and relays.

G. C. Toothill. See S. H. Hollingdale.

Extended description of the life and work of his father, including details of his plans for an electromechanical analytical machine, and the machine which he actually constructed along these lines, which permitted simple arithmetic operations to be entered, and the result calculated and printed on a typewriter. This machine was exhibited in Paris in 1914.
Describes the machines invented by Torres y Quevedo for playing chess and for remote control of a boat, (both electro-mechanical), and a mechanical analogue device.

Original version of Torres y Quevedo (1914).

Introduces and defines the term "automatique," which is essentially "automation," in the restricted sense of process control by digital techniques. Demonstrates that electromechanical devices can be combined in any required degree of generality, so as to control complex processes, by describing a small special purpose calculator, which is program-controlled, the program being represented by the presence and absence of contacts on a revolving drum, and which uses the results of a step in the computation to guide its further course. Makes several references to Babbage. Suggests that great savings in storage space would result from what is now known as floating point number representation.

Gives a very clear description of the principles used in his electromechanical arithrometer (capable of the four arithmetic operations, and controlled by a typewriter), which was built as a demonstration of a problem in "l'automatique."

Description of the various machines on exhibition at the Society's premises, including the Thomas arithrometer, Madas, Millionaire, Comptometer, Burroughs, Torres.

A summary of Babbage's life and his work on calculating machines, and in particular his visit to Turin in 1840, mentioning that letters and papers relating to this visit were still retained at the Academy of Sciences in Turin.

A popular account, based on a display produced by I.B.M. at the Institute for Contemporary Arts. Contains unusual photos of ENIAC and early Hollerith equipment.


A list containing about four hundred references, grouped under the headings: General Treatises; Graphical Devices, Slide Rules, etc.; Arithmetic Machines; Algebraic Equation Solvers; Integrators (planimeter type); Integrators (continuous and other types); Harmonic Analyzers; Devices for Ordinary Differential Equations; Miscellaneous Special Devices. The Arithmetic Machines section lists 71 books, papers and patents, including Babbage, H.P. (1899 and 1910) and Ludgate (1909).


A very brief account of calculating techniques, and of the development of analogue and digital calculating devices.


A well-illustrated advertising booklet describing the history of European calculating machines, and of Brunsviga machines in particular.


An account of American computer developments based on interviews with the pioneers. It covers the work of Stibitz, Aiken, Atanasoff, Eckert and Mauchly, and von Neumann, and discusses the role of U.S. companies such as I.B.M. and N.C.R.


The major source for information about the origins and early development of punched card machinery. Provides a detailed account of the respective contributions of Billings and Hollerith, indicating that, in all probability, the basic idea of using punched cards came from Billings.


Describes a device, based on an I.B.M. test storing machine, for aiding the multiplication of matrices. The individual rows of one matrix are represented by electrically conducting marks on test sheets (in binary notation), and the column of the other matrix is wired into a plugboard. A set of analogue multiplying devices are then used, two figure accuracy being claimed.


Concentrates on key-driven adding machines, and on their printing mechanisms, based on the American patent literature. It covers developments by Parmalee, Felt, Barbour, Baldwin, Ludlam and Burroughs. The last chapter concerns direct multiplication mechanisms.

The famous paper which introduced the concept of a "universal" computing machine.

A report, which also carries the title 'Proposed Electronic Calculator,' giving detailed plans for the ACE, known to have been written some time during 1945.

Biography of Alan Turing, by his mother. States that Turing submitted a proposal to the British Government for the construction of a computer, and that it was on the basis of this that he joined N.P.L in Oct. 1945. "Before the war he had already begun to build a computer of his own with wider scope, he hoped, than those then in operation." He visited America during the war and "probably saw something of the progress of computing machinery in the States."

A brief illustrated account of Babbage's work on the Difference and Analytical Engines. It quotes a letter written by Babbage to Arago in December 1839 explaining his use of the Jacquard card technique.

A lengthy biography, concentrating on von Neumann's mathematical achievements, but including a brief discussion of his work on the design and use of electronic computers.

Contains (pp.254-261) a quite detailed account of the work of
Bouchon, Falcon, Vaucanson, and Jacquard, on tape and card controlled looms.

Brief description of a proposed calculating machine which transforms its input into binary, before doing any calculation. Points out that binary digits could be represented by mechanical or electrical means. Followed by a comment by d'Ocagne, stating that he knew of no previous proposal for a binary machine.

A. W. Vance. See J. A. Rajchman.

A fascinating account of the mechanisms used in the automaton flute-player. The descriptions of the means of blowing and fingering the flute, and of the pegged cylinder used for controlling the sequence of actions, are very detailed but somewhat difficult to follow, since no diagrams are included.

Translation of Vaucanson (1738), together with translations of brief accounts of two further mechanical automata, namely a duck, and a figure playing a flute and a drum.

Includes a discussion of Babbage's work and its implications for the future, and of his personality.

Record of a lecture, which gives a useful summary account of the operation of a variety of machines, particularly those by Morland, Stanhope, Hamann, Burroughs, and Scheutz. No illustrations.

A good general discussion of the work of Torres y Quevedo, including a detailed description of his chess automaton, an electro-mechanical device for a chess end game of one king versus one king and one rook.

An illustrated description of the electromechanical devices used in Torres' typewriter-controlled arithmometer.

A detailed account of Schickard and his machine with extensive
quotations from his letters to Kepler, describing the machine.

An account of the descriptions of Schickard's machine that had been recently discovered.


J. von Neumann. First Draft of a Report on the EDVAC. Contract No. W-670-ORD-492. Moore School of Electrical Engineering, Univ. of Pennsylvania (30 June 1945) 101p. (Extracts reprinted in Randell (1973).) The historic account by von Neumann of plans for the EDVAC, covering details of the logical design, the order code, storage requirements, the relative merits of binary and decimal coding, etc. The report is believed to be the first detailed written account of a stored program computer, though only the address fields of stored instructions could be modified.

J. von Neumann. See also A. W. Burks and H. H. Goldstine.
A chronological account, with much information on Babbage and Scheutz, and on attempts to mechanize the calculation of actuarial tables.
A. Walther. See also H.-J. Dreyer.
A summary of the work by Zuse on mechanical and electromechanical programmed calculators, and the work on a paper tape controlled array of punched card equipment at the Institute for Practical Mathematics, Darmstadt, between 1939-1945.
Just one page on automatic calculating machines, in which the work of Zuse and of Dreyer is described.
Provides an illustrated account of the technique of using pegged cylinders, around which ropes were wound in complicated patterns, to control a sequence of movements by an automaton.
W. Walther. See also K. Ganzhorn.
A description of the growth of the Ballistic Research Laboratory, and of the development and use of ENIAC and EDVAC.
J. R. Weiner. See A. A. Auerbach.
Chapter 9 consists of an account of Babbage's dealings with the Royal Society and the government over his first Difference Engine and the Analytical Engine, and includes quotes from many of the original documents in the Society's files.
In addition to the reprint of the chapter from Weld's book, this booklet, which would appear to have been edited by Charles Babbage, contains reprints of two articles by de Morgan. The whole relates to Babbage's disputes with the government over the Difference Engine. De Morgan's verdict is that the government was to blame for the eventual abandonment of the Difference Engine.
A very detailed description of a machine, built from electromagnetic relays, for evaluating $3 \times 3$ determinants.

An important paper giving a detailed description of the first and second forms of program representation and loading, and of subroutine handling, designed for EDSAC.

"History of electronics industry is charted as a family tree in which roots represent basic research and branches represent resulting types of commercial tubes."

A popular account of Anglo-American intelligence operations within Germany during World War II with one brief chapter on the Enigma cipher. It claims that a "new Post Office computer," which was used to strip a numerical additive from the enciphered code, was operational at Bletchley Park by February 1940.

A proposal, sent to Vannevar Bush, apparently on Sept. 23, 1940. The memorandum is mostly about finite difference techniques for the solution of boundary value problems in partial differential equations. It suggest the construction of a special purpose electronic calculator which would mechanize a four-point relaxation procedure, using a binary adder and a tape scanning mechanism involving four reading heads and one writing head. Various possible technologies are mentioned, but magnetic recording is preferred. A final brief and vague paragraph suggests the possibility of "electronic machines capable of performing rapid sequences of operations such as addition and multiplication on the data read off, before printing the result on the binary scale."

Refers to a report that the author had submitted to Vannevar Bush in 1940, recommending the development of a program-controlled electronic binary computing machine.

This is part of a draft of a study of the M.I.T. Department of Electrical Engineering and Computer Science. Based on original documents, it provides considerable details of the early work on digital electronics at M.I.T. started by Bush, and then continued by Radford and Overbeck under the sponsorship of N.C.R. Crawford's associated work on electronic digital fire control devices is also covered, as is the post-war work on the (soon abandoned)
Rockefeller Electronic Computer Project, and the Whirlwind Project.

Short description of the plans for EDSAC.

A description of the programming of EDSAC, including discussion of subroutines, instruction modification, and loading.

An illustrated general account of EDSAC and an explanation of its use on a problem involving the numerical solution of a differential equation.

Detailed discussion of Babbage's Analytical Engine and in particular of the control facilities.

Concentrates on describing the experience obtained in working with the machine - its serviceability, diagnostic programs, etc.

Contains one of best early surveys and detailed discussions of the origins of computers. After a detailed discussion of the Babbage analytical engine, Ludgate is mentioned, and Torres y Quevedo's work is described very briefly. It then gives quite a lot of detail on the Harvard Mark I, ENIAC, EDVAC, the Bell Laboratories Computer Models V and VI and the Harvard Mark II. (The early part of the book is based on the Cantor Lectures given by Wilkes in 1951 (Wilkes: 1951a).)

Contains a brief discussion of the 1946 Moore School Lectures.

Contains many previously unpublished details about Babbage's plans for his Analytical Engine, gleaned from a detailed study of his notebooks.

Describes the origins of the Mathematical Laboratory at Cambridge, the author's attendance at the 1946 Moore School Lectures, the development of EDSAC, and the early programming techniques used.
Numerous illustrations, many taken from a 1951 film demonstrating how EDSAC was used.

Short description of the EDSAC, listing its order code, and describing its logical design.

A good description of the logical design of EDSAC.

Short description of the EDSAC, listing its order code, and describing its logical design. (A slightly revised version of Wilkes and Renwick (1949a)).

Concentrates on the advantages of optimum coding for reducing the delays caused by delay-line storage, and of the importance of building up a library of parameterized subroutines.

"This report gives a general introduction to the work carried out by Dr. Turing and his collaborators during the last two years at the National Physical Laboratory. The report covers the general principles of both the design of the machine and the method of programming adopted for it. It includes a number of schematic diagrams of the circuits needed for the logical control and the arithmetic units... As an example of a problem which requires the use of a number of standard routines, solution of a set of simultaneous linear algebraic equations by two different methods is given."

A comparison of the order codes of the Manchester and Pilot ACE computers.

Provides a detailed account of the trials and tribulations involved in developing the Pilot ACE Computer, whose first successful public demonstration was in December 1950. It describes how the design was based on that of the 'Test Assembly,' a prototype design by a team led by Harry Huskey, which was in turn based on what Turing described as Version V of his original 1945
proposal for an Automatic Computing Engine. It states that the term "Engine" was chosen "in recognition of the pioneering work of Babbage on his Analytical Engine," and that Turing was already at work on Version V in May 1946 when the author joined N.P.L.

Contains but a single paragraph on 'Mechanical Methods of Tabulation,' in which Billings is quoted as having suggested to Hollerith "there ought to be some mechanical way of doing this job, something on the principle of the Jacquard loom, perhaps, whereby holes on a card regulate the pattern to be woven."

Describes the genesis and development of Hollerith's ideas for punched card machinery.

A series of five illustrated articles describing the mechanisms used in various types of adding machines, calculating machines and direct multiplication machines. A lengthy bibliography is given, mainly listing articles on individual machines that appeared in Z. Instrumentente.

Pages 5-91 consist of chapters on calculating machines and on computers. The former contains a lengthy historical introduction and extremely detailed descriptions of the workings of then current machines, notably Brunsbriga, stepped-reckoner machines (such as Rheinmetall, Archimeades, Curta), Hamann, Mercedes-Euklid and Millionaire. The latter surveys relay and electronic computers (Zuse, Harvard Mark I and II, ENIAC, EDSAC, etc.), and describes their basic principles. Has a very extensive bibliography.

An account of the evolution of calculating machines, concentrating on the work of Pascal, Gersten, Leibniz, Poleni, Leopold, Hahn and Müller.

An article, which is both informative and entertaining, about the original 1948 prototype computer built to demonstrate the C.R.T. storage system, the larger 1949 computer (which incorporated index registers and a drum store) and Ferranti Mark I.

"A small electronic digital computing machine has been operating successfully for some weeks in the Royal Society Computing Machine
Laboratory... The machine is purely experimental, and is on too small a scale to be of mathematical value." The machine had a 32 word store, for numbers and data, and provided conditional branching. However it was so limited that only simple arithmetic routines devised to test the machine could be run — the machine "was built primarily to test the soundness of the storage principle employed, and to permit experience to be gained."

Contains an account of the working of the Scheutz difference engine, and its use for calculating various actuarial tables.

A useful popular account of various early mechanical automata, which includes extensive coverage on the workings of various automata by Vaucanson, von Knaus, Maillardet and Torres y Quevedo.

An excellent account, starting with Müller's 1786 proposal, and ending with an account of the use made by Comrie and others of commercially available desk calculators and accounting machines as difference engines. Brief accounts are given of proposed or completed difference engines by Deacon, Grant, Ludgate, Bollée, Hamann and Thompson. Much more complete accounts are given of the work of Babbage and of George and Edvard Scheutz, based on a great variety of early documentary sources. Brief explanations of the workings of their difference engines are included.

Account of an article by Williams in 'Zeit. Des Ver. Deutscher Eisenbahnk., (14-17 Feb.)' describing the use of Hollerith machines by American railroads. Describes the use of a 250 card per minute sorter, and a tabulating machine.

Despite its title, this is largely about the development of the LEO series of computers. This part of the paper has some merit, but elsewhere the paper is marred by numerous errors.

Well-illustrated detailed description of the Model V machine.

Bell Laboratories Record 25 (Feb. 1947) pp.49-54.
A well-illustrated general account of the Bell Labs. Model V computer.

D. Wilson. See A. A. Auerbach.

The first book to be published about the information that was obtained in Britain during World War II by "breaking" German messages in such ciphers as Enigma, which by implication claims that there was an electronic computer at Bletchley Park in 1940.

A bibliography, plus brief notes on the exhibits. Most of these were photographs of exhibits at the Science Museum, but there were also a number of artefacts and documents lent by Rhoden Partners Ltd, who had built two replicas of the fragment of the Analytical Engine for I.B.M.

Contains a brief account of the mechanisms of the Leibniz wheel, Odhner wheel, the Mercedes-Euclid, and the Millionaire machines.

Despite its brevity this section gives unusually detailed descriptions of several calculators, notably those by Pereire, Leupold, and Stanhope.

Describes the use of commercial machines in scientific computing, with many references to Comrie's work, and analogue machines.

A brief overview of, and expression of strong support for, Turing's plans for the ACE. It states that Turing's plans are based on those for the EDVAC. "Some of the basic ideas are given in Professor J. von Neumann's 'Report on the EDVAC' a secret report of the Applied Mathematics Panel of the N.D.R.C., but it contains a number of ideas which are Dr. Turing's own, and which are to be found in a paper published by him in the Proc. Lond. Math. Soc. 1937."

Brief description of a machine consisting of an interconnected 405 printer, 603 electronic multiplier and 517 summary punch, and of the applications for which it had been used.

Brief technical description of Pilot ACE, and account of its use on some test problems.

Includes a brief account of the genesis of Pilot ACE, starting "The history of digital computers at the National Physical Laboratory began when the late Dr. A. M. Turing joined the staff of the Mathematics Division at its formation in 1945. During his stay at Princeton University shortly before the war Turing had discussed with John von Neumann the possibility of constructing a high-speed automatic computer with radio valves used essentially as switches. Both men were experts in the field of mathematical logic, and while the subject had little direct bearing on the design of such machines it enabled them to see atonce how the general problems of control and manipulation of sequences of binary digits could be effected."

A fascinating collection of correspondence, from the 1945-1947 period, notable for a brief document by Wilkes describing a preliminary set of proposals which later became known as EDSAC (the document itself being entitled "Pilot Model ACE Type Machine" and attached to a letter dated 2nd December 1946), and for the note by Turing criticising these proposals on the grounds that the control system was unnecessarily complex for a pilot model machine.

Lists an important collection of papers and reports, mainly relating to ACE.

Transcript of a discussion concerning, inter alia, the origins of the stored program concept.

Describes an experimental system, installed in a department store, involving terminals connected over telephone lines to a set of tabulators and on-line typewriters.

R. E. Work. Automatic Calculating Machines. Interrogation Summary,
Air Interrogation Unit, Air Division, Headquarters United States Forces in Austria, APO 777, U.S. Army (8 Nov. 1946) 4p.

This is a report on automatic calculating machines that were utilized in Germany in the production of high speed aircraft and rockets during the war. The report is based as an interrogation of Dipl. Ing. Gerhard Overhoff, the partner of the inventor of the machines, a Dipl. Ing. Konrad Zuse. The report describes the use made of Zuse's aerodynamic calculating machines, and lists potential applications of his general purpose Algebraic Calculating Machine (presumably the Z4), which is described in some detail. "The two aerodynamic machines were delivered during the war and proved to be most successful. The algebraic machine was also completed and had passed its test runs successfully prior to the end of the war." A brief account is given of the firm Zuse Apparatebau, employing 15 people, established by Zuse and Overhoff in 1943, and of some of the people involved. Overhoff was chief of the testing department for remote-controlled rockets at the Henschel Flugzeugwerke during the war. Overhoff was interested in Zuse's work since 1941 and actively collaborated with him since 1943. Dr. Lohmeyer, a mathematician had joined Zuse in 1943. He principally assisted him in the development of the theoretical principles of the calculating machine. Dipl. Ing. Harro Stucken developed the wiring connections for Zuse's electromagnetic relay construction machines. Dipl. Ing. Georg Puchberger drafted the various applications for patents. The report ends "The end of the war suspended the development of the type of Zuse machines described above. Zuse is presently engaged in the theoretical development of inexpensive commercial machines and is located at Hinterstein 19, Allgaeu, Bavaria."


 Covers developments from the earliest manual techniques of calculating, to the electromechanical calculators of the 1940's, and includes a fairly detailed discussion of the various different types of abacus.

W. J. Worlton. See also N. Metropolis.


 An account of the demonstration of the EDSAC, by W. Renwick, during which tables of squares and of primes were calculated and printed. The flow-diagrams, coding and output of the programs are included.

H. Wössner. See F. L Bauer.


 Describes various schemes for using thyatrons as recording instruments and as unary counters, in association with mechanical
counting mechanisms, and suggests an entirely electronic counting apparatus, using multiple rings of thyatron, with carry propagation from one ring to its neighbour.


C. E. Wynn-Williams. (1957) The Scale of Two Counter. The Year Book of the Physical Society (1957) pp.56-60. A marvellously evocative account of Wynn-Williams' work at the Cavendish Laboratory, and later at Imperial College, on thyatron-based counters. He explains how an electronic ring counter was first built in 1930, and in the next year, a binary counter capable of recording events occurring at 1/1250 sec. intervals. By 1935 basic electronic counters had been provided with ancillary equipment, using relays and uniselectors, for binary-decimal conversion, timing of runs, and automatic printout. A second version of this apparatus at Imperial College was provided with the means by which it could be operated remotely, by telephone. "Finally, just before war broke out, a programme device was added, which could control experimental conditions and carry out cycles of pre-arranged runs by remote control of the equipment." All of this work was carried out with the minimum of funds and facilities - the resolution time counter was measured using "a glorious system of rubber bands, workshop nails, the inevitable Cavendish string, resistance wire, wooden laths and a long piece of strong catapult elastic" and the typewriter was a home-made affair using "a sixpenny toy printing set."

S. Y. Calculating Machinery. Mechanics Magazine 23,624 (25 July 1835) pp.317-318. This letter, and that of P.S.C. (1835) were written in support of Babbage and his plans for a machine capable of calculating and printing mathematical tables automatically. They were written in response to brief and unsubstantiated claims, noted in earlier issues of the magazine, of other people to have invented automatic calculating machines, claims which by implication were pouring ridicule on Babbage's efforts.

H. Yashui. See K. Jo.

V. Zeluff. EDSAC. Electronics 22 (Oct. 1949) p.124. A very brief article, accompanied by two interesting photographs of EDSAC, including one close-up of the display panel.

A brief illustrated article about Torres y Quevedo and his various electromechanical devices, including the arithmometer, and both chess players.

A brief account of the life and work of Schäffler who in 1895 patented a plugboard device, patterned after a telephone switchboard, for controlling the operation of punched card equipment.

A well-illustrated account of Schäffler and his work.

A valuable account of the life and work of Otto Schäffler. Contains an extensive bibliography, and numerous illustrations, including several relating to his improved method of "programming" a tabulating machine by incorporating a telephone-like switchboard.

A brief account of Atanasoff and his work on a special purpose electronic computer.

An informal account of Austrian contributions to the development of automata, punched card machinery, and programmed calculation, which concentrates mainly on the work of Otto Schäffler.

H. Zemanek. See also P. Goldschneider.

Describes an electromagnetic program-controlled calculator, whose program was represented on punched cards, and which used floating point binary number representations.

A brief discussion of his machines, and ideas on programming languages.

K. Zuse. (1950) Programmgesteuerte Rechenmaschinen in Deutschland.

After mentioning Babbage, gives a brief description of the various Zuse machines.


A description of the various Zuse computers.


Describes the sequence of programmed computers designed and built by Zuse. In particular describes a programmed computer, the Z3, which was operational in 1941, and the Z4, completed after the war and installed in 1950 at the E.T.H., Zurich.


A description, with ten drawings, of the special purpose electromechanical computer that processed flying bomb wing dimension data. The data was obtained on-line, using a form of analogue-to-digital converter, with calculations being carried out in binary under the control of a fixed program.


Informal discussion of work by Zuse, Schrever, and Dirks in Germany during the period 1935-1945.


An autobiography, with many technical details about his work, starting in 1934, on the design of program-controlled calculators. The work of his collaborator Schrever, who investigated the design of an electronic version of the Z3, and of Dirks, who developed a magnetic drum store, is also covered.


A partial reprint, and translation of, Zuse (1962).


A brief summary of the author's work, concentrating on the Z3, Z4 and special purpose machines.


Italian translation of Zuse (1970b), with a brief preface by the editor.

An English translation of the 200-page document written by Zuse in 1945 on his concept of an algorithmic language. It is accompanied by translations of a 1944 paper by Zuse entitled 'Statements of a Theory of General Calculation' and a commentary written by Zuse in 1972 which summarizes his prewar and war-time work, and serves as an introduction to the main document on the Plankalkül. In this commentary Zuse states that during World War II he designed "several theoretical models which utilized logical instructions, program selection, address computation, and the facilities of my Conditional Calculus. I already realized then that computers must also be able to store programs as well as data. But to me this capability seemed to be such a self-evident requirement then, that I omitted to apply for a patent for its realization."


A general account of his work on the development of computers and programming languages, interesting for the discussion of his early attitude to conditional branching, and stored programs. Zuse indicates that during the war he planned a "Planfertigungsgerät," a special computer for production of programs to control a conventional numerical computer. He indicates that this special computer was to undertake such tasks as formula translation, assembly of programs from subroutines, production of programs for particular sizes of numerical arrays, etc.


"... Mr. J. F. W. Herschel, who has been entrusted by Mr. B. to superintend the progress of this great undertaking during a tour which he is now undertaking on the continent, informs us that 'though the work continues in active and steady progress... a very long time must elapse, and a very heavy further expense be incurred, before it can be completed.' We are glad, however, to learn that 'no suspicion of failure has yet arisen.'"


Reprint of an article in Partington's British Encyclopaedia, which surveys calculating machines developed prior to Babbage's Difference Engine, explains the operation of the Engine and describes a successful demonstration of the small prototype difference engine.


Apparently based on Lardner (1834). Summarizes present problems over the Difference Engine, and calls for the Government to "appoint proper persons to inquire into and report on the proper state of the machinery; to ascertain the causes of its suspension; and to recommend such measures as may appear to be most effectual to ensure its speedy completion."
Brief account of Babbage's dealings with the government, and of the current state of progress of work on the Analytical Engine.

A brief account of the Machine for Composing Hexameter Latin Verses. It states that the machine produces about one line of verse a minute - "during the composition of each line, a cylinder in the interior of the machine performs the National Anthem."

Short account of the difference engine invented by George and Edvard Scheutz, including an engraving of a general view of the machine, and of a model of part of the mechanism and reproductions of plates produced by the machine of mathematical tables. Gives a very good idea of the working of the machine.

Commentary with extensive quotations on a number of pamphlets concerning Babbage, most notably 'Address of the Right Honourable the Earl of Rosse etc... Royal Society, Thursday Nov. 30, 1854 (printed by Taylor and Francis, London).'

Incorporates a reprint of the paper by Charles Babbage addressed to the Royal Society, describing the origins and development of the Scheutz difference engine, and recommending that it be awarded one of the Society's gold medals.

The eleven-page Preface provides a detailed account of the history of the development of the Scheutz Difference Engine, its public exhibition in England and France, and its sale to the Dudley Observatory. This is followed by an account prepared by Mr. Gravatt of the method of using the machine.

Contains a brief account of the history of the machine, and of the principles of difference engines, followed by a good description of the design of the Scheutz machine.

Mainly concerned with difference engines. Describes the method of finite differences, and the history of Babbage's efforts, and then gives an extensive description of the mechanism of the Scheutz difference engine.

An obituary notice, starting "There is no fear that the work of the late Charles Babbage will be over-estimated by this or any generation."

Anon. (1871b) The Late Mr. Babbage. The Times (23 and 30 Oct. 1871). An obituary, with a follow-up article giving further details on Babbage's parentage and early youth.

Anon. (1871c) The Late Mr. Babbage. Illustrated London News (4 Nov. 1871) p.423. A factual obituary and engraved portrait. "The death of Mr. Charles Babbage the eminent mathematician and inventor of "the calculating machine," was announced last week..."

Anon. (1871d). Mr. Charles Babbage. The Illustrated Times (28 Oct. 1871) p.267. An obituary notice, which describes in some detail Babbage's efforts at constructing a Difference Engine.


Anon. (1888) An Improved Calculating Machine. Scientific American 59 (1888) p.265. "There has lately been invented by Mr. Dorr E. Felt, of Chicago, a calculating machine which he has named the comptometer. It is a practical machine operated by keys for the computation of numbers and the solution of mathematical problems. The rapidity and accuracy with which computations are made on the comptometer when in the hands of a skillful operator are calculated to meet the approval and win the admiration of all." A brief description is given of the operation of the machine, accompanied by one picture of it.


account is notable for the direct analogies it makes to the operations performed by Jacquard looms and by railway signal interlocking mechanisms.

A rather general, but very enthusiastic, account of the use of tabulating machines for computing statistics.

A well-illustrated, detailed account of the mechanism.

Well-illustrated article on the card punch invented by James Powers, and on the tabulating machines which were the results "of the combined efforts of several experts employed in the Census Bureau."

A circular, stated to have been printed for private circulation, and obviously intended as a sales brochure. Contains a series of small schematic drawings of various card perforators, cash registers/card perforators, tabulators and a sorter. The machines look quite unlike contemporary Hollerith equipment. The perforating machines could simultaneously print and punch, and cards could hold 20, 30, 40 or 50 digits, depending on the card size.

Brief account of use made of Hollerith tabulating machines by the Portland Railway, Light and Power Company, Portland, Oregon for accounting and statistical purposes.

A well-illustrated article, concentrating on the chess player developed by Torres, and describing its strategy, and the mechanisms used.

"This book is designed to illustrate the application of the Duplex-Key-Controlled Comptometer to many principal lines of business. While primarily intended for the benefit of our sales solicitors, demonstrators, etc., and to equip the college student with a knowledge of the most efficient methods employed in the mathematics of commerce, its great value should also benefit all Comptometer users."

Anon. (1929) Herman Hollerith. Amer. Soc. of Mech. Eng. Record and
A brief fact-filled obituary.

Description of the mobile totalisator demonstrated at Thirsk racecourse on 28 Jan. 1930.

A useful sales catalogue of currently-available adding and calculating machines. Each machine is described in about a half-page of text and most are illustrated.

An illustrated booklet, containing brief sections on the history of desk calculating machines, current models of the Brunsviga, and on the Trinks-Brunsviga-Museum, as well as much material on the manufacture and world-wide sales of Brunsviga.

A one-column obituary notice, stating that Pierce had joined I.B.M. in 1922 when the company purchased the patents of the Pierce Accounting Machine Company of Woonsocket, R.I., a company specializing in mechanized accountancy, particularly applied to the insurance field.

Brief biographical note, concentrating on his work on astronomy.

Commences with the work of Hollerith on tabulating machines, Bundy and Dey on time recorders, and Pitrap on computing scales. The emphasis is on the growth of I.B.M. as a corporation, and comparatively few technical details are given.

This lavishly-illustrated publicity booklet contains many photographs of historic machines in the Trinks-Brunsviga-Museum, and a bibliography, of over a hundred items, listing the contents of the museum's library.

Provides an immense amount of information on then available adding, calculating, book-keeping and tabulating machines. Each major section starts with an overall account of the principles, and major varieties, of a particular class of machines. Detailed illustrated descriptions covering several pages are given of the operation, and in many cases, the mechanisms of each machine. The section on tabulating machines is particularly useful, and
includes an interesting account of their development. In addition to covering the Hollerith (I.B.M.) and Powers (Remington Rand) systems, it has one-paragraph descriptions of systems invented by Gore and by Pierce: "In the early '90's an actuary, John K. Gore, developed and produced an automatic card feed punch and a card sorter, or selecting machine. This equipment was used by one of the large insurance companies by whom Gore was employed, to punch and sort the exceptionally large volume of cards in their policy record files... Also in America about 1910-1911, J. Royden Pierce developed the 'Pierce Systems of Perforated Cards.' Pierce utilized combination hole punching in originating the punched cards, and in order to make them readable for reference purposes, each figure was printed on the card simultaneously with the punching of the hole... Pierce at a later date joined the International Business Machines organisation and many of his ideas were absorbed for use in the present I.B.M. machines." Another little-known machine described is an electro-pneumatic sorting machine, invented by Macadie and Ratcliff of the (U.K.) Post Office Stores Department, for sorting money and postal orders. Extremely valuable for the picture that it gives of office machinery in Britain and the U.S. in the late 1930's.


Catalogue of a very large collection of calculating machines and calculating aids. Many illustrations, and brief descriptions of the major machines.


This report was submitted to the Ballistics Research Laboratory, Aberdeen Proving Ground, and includes a reconstructed version of Mauchly's original 1942 memorandum. The report contains detailed descriptions of the various functional units, and worked out examples of the use of analyzer for the solution of problems in ballistics.


Short article, taken mainly from a statement published by the Dept. of Scientific and Industrial Research, on the history of calculating machines and on the work then in progress at the National Physical Laboratory.

Anon. (1946b) War Department Unveils 18,000-tube Robot Calculator; ENIAC. Electronics 19 (April 1946) pp.308,310,312,314.

Popular account of the ENIAC, with sections on Ballistics Applications, Industrial Uses, General Details, Operating Procedure, Arithmetic Elements, Memory Elements and Control Elements. Illustrated.

Similar to Anon (1946a).

Brief summary, plus a photograph.

An interesting brochure, which includes a brief summary of Comrie's career, and a bibliography of publications by Comrie, and by the Scientific Computing Service.

"...this account is based on a series of informal talks given by Dr. A. M. Turing and Mr. Wilkinson of the Mathematics Division of the National Physical Laboratory. It is by no means a comprehensive description of the A.C.E. but is intended only to serve as an introduction to the principles involved in the design and development of a digital computing machine."

A short article which gives a number of technical details about the design of the delay line memory for EDVAC.

An important 130-item bibliography, of unknown American origin, in the N.P.L. Mathematics Division Library. Covers analogue and digital machines, and cites both the published and the patent literature.

Brief notice of the dedication ceremony held 27 and 28 Jan. 1948.


Anon. (1948c) Bibliography on Electronic Computing Machines. Mathematics Division, National Physical Laboratory, Teddington, Middlesex (June 1948) 3p.
A valuable list of 52 articles, books, reports and patents, dated 1940–1947, mainly American or British in origin.

A bibliography of over a hundred items, mainly from the period 1946-1949.

Account of a demonstration of BINAC at the Eckert-Mauchly Computer Corporation in Philadelphia, at which solutions to Poisson's Equation, and square and cube roots of numbers typed in by the audience were calculated. Only brief details are given of BINAC, which is stated to be a twin computer system, with each computer incorporating 700 vacuum tubes, in which numbers and instructions are held in mercury delay lines.

A fascinating summary of the work of J. W. Bryce (1880-1949), one of America's most prolific inventors. "As far back as 1915 he foresaw the potentialities of the vacuum tube and made a complete analytical study of the subject. In 1932 he instituted research projects to develop methods of employing the electronic tube to perform arithmetical operations." He had joined I.B.M. as Chief Scientific Director, after inventing many mechanical devices. His work at I.B.M. included a self-regulating electric time recording system, an automatic multiplying punch, an accounting machine capable of subtraction, data recording using magnetized spots or pencil marks on cards, and using photographic film, and a counter read-out and emitter which permitted the transfer of balances in an accounting machine. He was closely involved in the design of machines for the Columbia University Statistical Bureau, of the Harvard Mark I ("which contained several of Mr. Bryce's major inventions, including his high-speed multiplying, dividing and cross-adding systems and also the read-out and emitter") and the S.S.E.C.

Provides a number of photographs of what it terms the "Manchester Automatic Sequence-Controlled Calculating Machine," i.e., the first Manchester computer.

A one-column announcement about Northrop's purchase of, and plans for using, BINAC.

A non-technical chronological account, concentrating on machine developments. "The range of machines [in 1919] comprised the Tabulator, Sorter Key Punch and Slide Punch, those machines at the time were the most advanced of their kind. The Tabulator was the only card-operated Printing Machine. The punching machines were more comprehensive and efficient than any others and the new Horizontal Sorter was a great advance on anything else."
A chronology, giving useful information concerning when the various machines were first introduced. It states that the Powers Machines were first installed in the U.K. in 1914, at the Prudential Assurance Co., who later acquired manufacturing rights, and in 1919 set up the Accounting and Tabulating Corporation of Great Britain. Multiple Counting Sorters were introduced in 1921, the Automatic Total Attachment in 1927, the Printing Counting Sorter (developed for the British Census) in 1931, the Multiplying Punch in 1941, and the Cross Adding Punch in 1943. The company became Powers-Samas in 1929 and was taken over by Vickers from the Prudential in 1945.

A valuable series of 34 captioned photographs which provide a chronological record of the relay devices and calculators developed by Fujitsu in the period 1940-1955. These are as follows: a totalisator (1940), a totalisator and adder (1941), a binary arithmetic relay calculator, used as the basis of a matrix calculator (1942), a cryptographic decoder, developed for the Japanese Navy (1943), a statistical computer, incorporating twenty input terminals (1951), a relay computer for the stock exchange (1953), an auto-correlation calculator installed at the Seismic Research Laboratory of Tokyo University (1954), the FACOM-100 general purpose relay computer (1954), the E.T.L. Mark II general purpose relay computer (1955) and the FACOM-415A and FACOM-416A statistical calculators (1955).


Brief description of the invention in 1916 by Charles Foster of a device which enabled "almost certainly the first alphabetical printing in the world to be produced from any kind of punched card tabulating equipment."

"Towards the end of the war I.B.M. built a machine called the Automatic Sequence Controlled Calculator (sometimes referred to as the Harvard Mark I)." Also covers the S.S.E.C. (1948), the Type 603 multiplier (1946), the C.P.C., the Type 628 (1958), and the
Tape Processing Machine (1950), as well as later developments.

An illustrated brochure, with sections on the origins and development of tabulating machinery, and on early I.B.M. electric calculators.

An illustrated account of the Hollerith's first tabulating system, and its use for the 1890 U.S. Census, and of the origins of the I.B.M. Corporation.

Includes a brief extract from the historic ENIAC patent.

Contains, amongst a welter of facts about company mergers, acquisitions, etc., just a few brief details about the Eckert-Mauchly Corporation (acquired by Remington Rand in 1949), and about the take-over in 1927 of the Powers Accounting Machine Company.

"Dr. Tomkins was one of the group of former Navy officer specialists who, in 1946, formed Engineering Research Associates of St. Paul, Minn... E.R.A., under contract to the Navy, produced one of the world's first three computers, a powerful top-secret intelligence computer known as Machine 13."

A set of six lavishly illustrated brochures, providing a very useful history of the development of calculating machines and computers, starting with Napier's rods, and ending with the first generation of electronic computers.

A brief account, written in "telegraphese," useful for its data regarding first deliveries of various punched card machines.

The main section of this booklet consists of a reprint of an article by Rosen on the development of electronic computers mainly in the U.S.A., which contains very little material on the earliest such computers. However the booklet is lavishly illustrated, and includes facsimile reproductions of articles in the N.Y. Times and the Illustrated London News on ENIAC.

A wall chart which contains previously unpublished material about
the development of the Analytical Engine, including facsimile
reproductions of the earliest general plan (1834) and of an
entirely different later version (1856).

Anon. (1973a) Three N.C.R. Pioneers cited by Smithsonian for
Brief illustrated accounts of the careers of Joseph Desch and
Robert Mumma, who worked from 1938 to 1942 on the N.C.R.
Electronic Calculator, and Don E. Eckdahl, leader of the MADDIDA
(Magnetic Drum Differential Analyser) project, which was completed
in 1949.

Anon. (1973b) An Inventory of the Papers of George Robert Stibitz
Concerning the Invention and Development of the Digital Computer.
A brief biography, and an inventory of a body of papers occupying
over twenty feet of shelf space in the Archives Department of the
Dartmouth College Library. "The collection consists, primarily, of
papers by Dr. Stibitz in the form of reports, memoranda, notes,
lectures, correspondence and patents, encompassing the period
1937-1962. Included also are manuals, advertisements, photographs
and minutes from small gatherings of individuals who were also
innovators in the development of the computer." The collection
thus contains much information about virtually all the early
American computer developments, as well as the Bell Laboratories
Computers.

Centro de la Informática, Técnica y Material Administrativos,
Contains reprints of a 1951 article 'Torres Quevedo y la
Automática' by G. Torres-Quevedo Polanco, and the catalogue of a
1953 exhibition of machines invented by Torres y Quevedo. Between
them these give accounts, in many cases illustrated with
photographs, of two chess automata, a gambling automaton, two
electromechanical arithmometers and an 'analytical machine',
stated to be intended to calculate a=(pxq)-B for a series of small
values of p, q and B.

p.80.
An interview with N. C. Metropolis, containing a brief account of
Clipping's and von Neumann's respective roles in the development
of the stored program concept.

Anon. (1978b) Leonardo Torres Quevedo. Colegio de Ingenieros de
A lavishly illustrated book, based on an exhibition devoted to the
work of Torres y Quevedo. Its sections include Biography and
Bibliography, Calculating Machines, 'Automática', and The Airship
and Aerial Transporter. That on 'Automática' includes a reprint of
Torres y Quevedo (1913) and brief details, with numerous
photographs and drawings, of his two chess automata, a 1914
analytical machine and two arithmometers.
Anon. (?) The Story of the American Totalisator Co. American Totalisator Co., Towson, Maryland (undated).

A brochure (apparently issued during or after 1961) describing the development of the Totalisator.
APPENDIX 1

The items listed below are interesting-sounding ones that the author has searched for extensively without success. In some cases this might be because the reference is inaccurate, or of course the search may well have been inadequate. Any information or assistance that leads to the location of these items, or regarding any other omissions from the bibliography, would be most appreciated.


H. Goerlitz. History of the Powers Machine (1934). Quoted from extensively by Connolly (1967), who states that "this was written in German but last year its translation into English was arranged".


This paper is listed in the Convention Program given in Proc. I.R.E. 37,2 (Feb. 1949). No proceedings were issued.

See Barnard (1869).


Torres-Quevedo (1951) refers to such a report which is on a presentation by Torres y Quevedo, and makes reference to the work of Charles Babbage.


Listed in Anon (1947c).

Listed in Anon (1947c).

APPENDIX 2

The litigation between Honeywell Inc., as Plaintiff, and Sperry Rand Corporation and Illinois Scientific Developments, Inc., as Defendants, in which the validity of the ENIAC patent was challenged, resulted in the accumulation of a huge amount of material of great historical value. The statistics of the case are staggering. The litigation commenced in May 1967, and it was not until October 1973 that District Court Judge Earl Larson issued his verdict. In the interval there was a total of 135 days of court hearings, and testimony or sworn depositions from over 150 witnesses. The transcripts of the hearings total approximately 20,000 pages. However, even this is only the tip of the iceberg, since the Plaintiff submitted over 25,000 pieces of evidence and the Defendants over 6,000, ranging in size from a single letter to a whole filing cabinet full of documents.

The case is summarized in a 420-page document entitled 'Findings of Fact, Conclusions of Law and Order for Judgment' (Larson: 1973). One finding which has attracted a lot of attention is the one which states that "Eckert and Mauchly did not themselves first invent the automatic electronic digital computer, but instead derived that subject matter from one Dr. John Vincent Atanasoff." It is the present author's understanding that here the term "automatic electronic digital computer" has the original definition given in the ENIAC patent, which was not challenged by the Plaintiff - there is no implication that the term necessarily matches the modern conception of a stored program electronic digital computer.

Derivation from Atanasoff's work is just one of the reasons given for invalidating the ENIAC patents; other arguments, for example, are based on the finding that the patent applications were delayed too long after the ENIAC was made available for public use. The Findings of Fact, etc., therefore cover matters concerned with the completion and use of ENIAC as well as its origins and relevant prior art. With regard to prior art, the main work investigated in addition to that of Atanasoff is that by Dickinson, Phelps and others at I.B.M., by Desch and Mamma at N.C.R., by Bush, Radford and Overbeck at M.I.T., and Zworykin and Rajchman at R.C.A. In addition to that on ENIAC, considerable material relating to EDVAC, BINAC and UNIVAC was amassed.

Initially the author gained the impression that, of all the documents in the case, only the Findings of Fact, etc., were available to the public. However, Judge Larson has indicated that the complete files are available for purposes of historical research. Moreover, at his instigation Mr. H. Halladay, of Dorsey, Windhorst, Hannaford, Whitney and Halladay, the leading attorney for the Plaintiff, very kindly made available his personal microfiche copy of the entire transcript and the Plaintiff's computerized lists. A brief description of this material follows.

The most readily usable aspect of the transcript is that each witness gives an account of his or her own career. In the case of the principal witnesses the amount of biographical material, together with technical details of scientific and engineering
achievements, is considerable. Mauchly's testimony, for example, covers over 700 pages of the transcript. Other pioneers who gave extensive testimony include J. V. Atanasoff, A. A. Auerbach, R. Clippinger, J. R. Desch, A. H. Dickinson, J. P. Eckert, S. P. Frankel, H. H. Goldstine, J. C. Mark, N. C. Metropolis, C. N. Mooers, R. E. Mumma, B. E. Phelps and J. Rajchman.

However, it is the various computerized lists which provide the major means of access to the contents of not only the transcript but also of all the trial exhibits. One such list is the Plaintiff's "computerized brief" which is itself over 4,500 pages long. It consists of a large number of "event statements," each typically consisting of a single sentence. In general, each such statement is accompanied by:

1. The Defendants' reply, which often denies the validity and/or relevance of the Plaintiff's statement.

2. Comments by the Plaintiff on this reply.

3. The Defendants' post-trial argument, usually rather more detailed.

4. The Plaintiff's response to the Defendants' argument.

5. The Defendants' final argument. This, and the preceding argument, are in many cases quite lengthy, with extensive quotations from testimony and exhibits.

6. Plaintiff's list of exhibits related to the particular event statement with (usually) brief indication of contents of each exhibit, together with extensive cross-referencing to relevant pages of the transcript wherever the exhibit was offered in evidence, objected to, discussed, etc.

7. Plaintiff's summary of supporting testimony, cross-referenced, together with any other relevant testimony, to appropriate transcript page numbers.

This formidable, highly structured, but readable document naturally concentrates on the various points at issue in the trial, so does not attempt to summarize or analyze all of the information contained in the testimony or exhibits. Other simple forms of index go some way to performing this function. These include a 7,500-page master KWIC index to Plaintiff's summaries of source documents, together with much smaller subsidiary KWIC indexes to summaries of testimony and to the subject matter description of each trial exhibit. There are also other indexes consisting of straightforward alphabetized listings of exhibits, organized in various ways.

It is in all an impressive demonstration of the power of computer techniques to facilitate use of what could otherwise be an absolutely overwhelming mass of information. The computerized lists enable one to obtain a good idea of the contents of the trial exhibits. Thus these lists, and the trial transcript, which together occupy almost 200 microfiche cards, are an extremely valuable source
of historical information. Apparently the exhibits themselves are in the main still in custody in Minneapolis where they can be inspected, but some have been returned to their owners. However copies of the documentary exhibits and of the testimony are also available at the Moore School of Electrical Engineering, University of Pennsylvania.
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I.A.S. Computer
  Booth 1975, Burks et al 1946, Butler 1968, Goldstine 1972,
  Goldstine and von Neumann 1947, 1948a, 1948b, 1963, Knuth and
  Pardo 1976.
I.B.M.
  Belden and Belden 1962, Brennan 1971, Connolly 1967, Engelbourg
I.B.M.: Automatic Sequence Controlled Calculator
  (See Harvard Mark I.)
I.B.M.: Card Programmed Calculator
I.B.M.: Relay Calculator
  Eckert (W.J.) 1946a, Hoffleit 1949, Lotkin 1951.
I.B.M.: Selective Sequence Electronic Calculator
  Eckert (W.J.) 1948b, Phelps 1974, Rodgers 1969, Anon 1948a,
  1949c.
I.B.M.: Watson Laboratory
I.B.M.: 603-605 Computer
  Eckert (W.J.) 1948c, Woodbury 1949.
I.B.M.: 610 Autopoint Computer
  Brennan 1971.
Institut Blaise Pascal Computer
Institut für Praktische Mathematik, Darmstadt
  (See also Darmstadt Machine)
  de Beauclair 1968.
Jacquard Embroidery Frame
  Scheyer 1921.
Jacquard Loom
  Adam 1973, Ballot 1923, Barlow 1878, Eymard 1863, Kreindl 1935,
  Poncelet 1857, Porter (?) 1831, Posselt 1877, Scheyer 1921, 1922,
  1902b.
Jakobson: calculator
Jarvis (Babbage's draughtsman)
  Babbage (H.P.) 1910b.
Jo, K.
  Okazaki 1971.
Keen, B.
Kilburn, T.
Kinautograph Cloth-Cutting Machine
Scheyer 1922.
Lake, C.D.
Latin Hexameter Machine
(See Eureka.)
Lehmer, D.H.
Rohrbach 1948a.
Leibniz, G.W.
Leibniz: calculating machine
Apokin and Malostrov 1974, Flad 1963, Kormes 1929, Leibniz 1679,
Lentz, J.
Brennan 1971.
LEO
Williams (R.) 1976.
Leupold: calculating machine
Locking Frame
(See Railway Signal Interlocking Machines.)
Logabax: book-keeping machine
(See Campos: book-keeping machine.)
Logical Expression Evaluation
Couffignal 1938a, Gardner (M.) 1952, 1958, Hilton 1963, Jevons
1870, Mays 1953, Patterson 1960.
Lohmeyer
Work 1946.
Lorant, F.
Connolly 1967.
Los Alamos
Feynman 1976.
Lovelace, Augusta Ada, Countess of
Bowden 1960, Briguglio and Bulferetti 1971, Crosse 1890, 1891, de
Ponblanche 1974, de Morgan 1882, Eckert (J.P.) 1970, Hammersley
1974, Hollingdale 1966, Kean 1973, Mayne 1929, McLaughlin 1977,
Moore 1977, Porter (?) 1831, Quetelet 1872.
Ludgate, P.E.
Randell 1971.
Ludgate: analytical engine
1951a, Williams (M.R.) 1976.
Luebbert, W.F.
Campagne 1974.
Macadie and Ratcliff: sorting machine
Anon 1938.
Machine 13
Anon 1971a.
MacNider: adding machine
Anon 1885b.
Madame X: cryptanalytic machine
Campagne 1974.
Magnetic Calculating Machine
Magnetic Drum Store
Booth 1975, Lehmann 1953, Crawford 1942, Snyder 1977, Zuse 1970b,
Anon 1973a.

Maillardet

Manchester Computer
Wilkinson 1949, Williams (F.C.) 1975, Williams and Kilburn 1948,
Anon 1949d.

MANIAC
Metropolis and Worlton 1972, Anon 1978a.

Marquand Machine
Patterson 1960.

Mauchly, J.W.
Fegley 1967, Goldstine 1972, Johnson (L.R.) 1970, Knuth 1970,

Mechanical Automata
Ibn al-Razzazz al-Jazzari 1974, Bedini 1964, Buchner 1950,
Chapuis and Droz 1949, 1958, Cohen 1966, Cooke 1893, Diderot
1748, d'Ocagne 1937, Droz 1962, Foucaud 1848, Goldscheider and
Zemanek 1971, Penniman 1978, Price 1964, Scheuer 1921, 1922,
Supplee 1913, Timbs 1863, Vaucanson 1738, 1742, Walther 1973,

Mechanical Programmer
(See Calculation Control Switch.)

Menabrea, L.F.
Briguglio and Bulferetti 1971, Bulferetti 1967, Goddard 1906,
Anon 1843.

MESM
Åpokin and Maistrov 1974.

Metropolis, N.
Anon 1978.

Michie, D.
Evans (n.d.).

M.I.T.
Radford 1939, Redmond and Smith 1975, Smith (T.M.) 1975, Wilde
(n.d.).

Monotype Machine
Schefer 1921.

Moore School Lectures
Curtiss 1946, Eckert (J.P.) 1946, Stibitz 1946, Travis 1946,

Morland, Sir Samuel

Morland: calculating machine
Boys 1886.

Morse Code
Schellen 1870.

MOSIAC
Lavington 1978.

Muller: difference engine

Mumma, R.E.

Museum of the History of Science, Oxford
Collier 1970.
Musina: calculating machine
Barnard 1869.
M-9 Gun Director
Cesareo 1946.
Napier, J.
Archibald 1948.
Napier's Rods
National Accounting Machine
Comrie 1932b, 1936, de Beauclair 1968, Todd 1974.
Nautical Almanac Office
Comrie 1928a, 1932a, Todd 1974.
N.C.R.
N.E.C. Statistical Relay Computer
Anon 1955b.
Newman, M.H.A.
No. 5 Crossbar Dial System
Holbrook 1975.
Norfolk, G.L.
Northrop
Klaas 1953, Stern 1979, Anon 1949e.
N.P.L.
N.S.A.
Odinner-Wheel Calculators
Apokin and Maistrov 1974, Church 1951, Comrie 1927, 1932, Horsburgh 1920, Locke 1924.
ORDVAC
Kempf 1961.
Osaka University
Jo et al 1972.
Overbeck, W.P.
Bush 1940, Wildes (n.d.).
Overhoff, G.
Work 1946.
Palmer, R.
Phelps 1974.
Paper Tape
(See also Harvard Mark I, Harvard Mark II, Darmstadt Machine, and Perforated Records.)
Paris Exposition (1867)
Barnard 1869.
Pascal, B.
Pascal: calculating machine
Pegged Cylinder
(See also Mechanical Automata)
Pereire: calculating machine
Wolf 1938.
Perforated Records
Scheyer 1921, 1922, Suplee 1913.
Petherick, E.J.
Millington (n.d.).
Phillips, E.W.
Phillips: binary multiplier
Pierce, J.R.
Pierce: automatic accounting machines
Anon 1910b.
Pinkerton, J.
Evans (n.d.).
Piolaine (clockmaker)
d'Ocagne 1935.
Planfertigungsgerät
Zuse 1976b.
Plankalkül
Polanco, G.T.-Q.
Anon 1977.
Poleni: calculating machine
Horsburgh 1920.
Post Office Research Station
Powers, J.L.
Powers: tabulating system
Powers-Samas Co.
Prandi, F.
Prudential Assurance Co.
Anon 1954.
Puchberger, G.
Fack 1946.
Punched Card Machinery
(See also F. Bull, J. K. Gore, Hollerith: tabulating system,
MacAdie and Ratcliffe: sorting machine, J. K. Pierce, and
Powers: tabulating system.)
Punched Card Machinery: interconnection
Berger 1928, Brenman 1971, Bush 1936, Couffignal 1930, 1933, de
Beauclair 1968, Dreyer and Walther 1946a, Eckert (W.J.) 1940,
Punched Card Machinery: later developments
Arkis 1935, Beika 1975, Berger 1928, Comrie 1933b, Connolly 1967,
Deveaux 1926, Feindler 1929, Fisher 1913, Fleck 1973, Johns 1926,

**Punched Card Machinery: origins**

**Punched Card Machinery: usage**

Quetelet, A.
- Dodge 1873.

Radford, W.H.
- Wildes (n.d.).

**Railway Signal Interlocking Machines**

**Rapid Analytical Machines**
- Campagne 1974.

**Rapid Arithmetical Machine**

**Rapid Selector Project**

R.C.A.

**Read-Only Memory**
- Rajchman 1963, Schellen 1870.

Regnier, J.
- Barnard 1869, Poncelet 1857.

**Relay Structure Factor Calculator**
- Booth 1975.

**Remington Rand: Type 309**
- de Beauplair 1968.

Renwick, W.
- Worsley 1949.

Rice, R.
- Klaas 1953.

**Rockefeller Electronic Computer Project**
- Wildes (n.d.).

**Roth: calculating machine**
- Horsburgh 1920.

Rotula
- Bryden 1972.

**Royal Signals Museum**
- Dickson 1978.

**Royal Society**

Runcorn, S.K.
- Cunningham and Hynd 1946, Millington (n.d.).
Rutishauser, H.
Bauer 1976.

Saxby and Farmer: interlocking machine
Edwards (W.E.) 1911, Thompson 1965.

Schäffler, O.
Adam 1973, Cheysson 1892, Connolly 1967, de Beauclair 1968,

Schueutz, P.G. and E.

Schueutz: difference engine
Anderson 1932, 1933, Babbage (C.) 1855, Babbage (H.P.) 1910b,
Comrie 1932b, Felt 1893, Haga 1963, Losano 1974, Manby 1856,
Verry 1940, Williams (F.J.) 1866, Williams (M.R.) 1976, Anon
1855a, 1856, 1857a, 1866, 1870.

Schickard, W.
Hammer 1958, von Freytag Loringhoff 1957, 1964, 1973a, 1973b,
Anon 1935.

Schickard: calculator
Adam 1973, Apokin and Maistrov 1974, Czapla 1961, de Beauclair

Schreyer, H.

Science Museum, London
Babbage (B.H.) 1872, Baxandall 1926, Collier 1970, Pugh 1975,
Wittenberg 1970.

Scientific Computing Service
Anon 1946e.

S.E.C.
Booth 1975, Kitz 1951.

Seeber, R.
Phelps 1974.

Sellers: automatic multiple punch
Scheeyer 1921.

Sequence-Control Mechanisms
(See also Calculation Control Switch, Mechanical Automata,
Perforated Records)

Shadrach
Sharpless, T.K.

Shire, E.S.
Cunningham and Hynd 1946, Millington (n.d.).
Siemens und Halske AG
Connolly 1967.

Sill, J.S.
Aiken 1964.

Smithsonian Institution
Redmond and Smith 1975.

Société d'Encouragement pour l'Industrie Nationale

S.S.E.C.
(See I.B.M.: Selective Sequence Electronic Calculator.)

Stanhope: calculating machine
Boys 1886, Verry 1940, Wolf 1938.
Station X
Calvocoressi 1974.
Stibitz, G.
Stucken, H.
Work 1946.
Stuivenberg, J.
Connolly 1967.
Sumador Chino
Rogers 1960.
Tabulating Systems
(See Punched Card Machinery.)
TAC
Anon 1955b.
Tate: calculating machine
Boys 1886.
Tauschek, G.
Tchebichev: calculator
Apokin and Maistrov 1974, Church 1951.
Ten Thousand Register Machine
(See Campos: book-keeping machine.)
Thomas de Colmar
doCagne 1935.
Thomas: arithmometer
Thompson: difference engine
Tokyo University: relay computers
Anon 1955a, 1955b.
Tomkins, C.B.
Anon 1971a.
Torres y Quevedo, L.
Torres y Quevedo: arithmometer
Torres y Quevedo: other machines
Totalisators
Travis, I.
Brainerd 1976.
TREAC
Lavington 1978.
Trinks-Brumsviga-Museum
Anon 1936b.
Turing, A.M.

Ulam, S.
Evans (n.d.).

UNIVAC
Sten 1979.

U.S. Bureau of the Census
Billings 1891, Durand 1913, Merriam 1903, Newcomb 1913, Truesdell 1965, Anon 1902c, 1910a.

U.S. Office of Naval Research
Stifler 1950, Anon 1955b.

Valtat, R.L.A.
d'Ocagne 1938.

Vaucanson, J.

Verea: calculating machine
Locke 1926.

Vicenza
Barlow 1878.

Vienna Museum of Industry and Technology
Chroust 1974.

Vitruvius: hodometer
Beck 1900.

von Gersten: calculating machine
Brauner 1926.

von Knaus

von Neumann, J.

Wanderer Werke
Connolly 1967, de Beauclair 1968.

Watson, T.J.

Watson Laboratory
(See I.B.M.: Watson Laboratory.)

Weiner, B.
Kliir 1963.

Whirlwind
Redmond and Smith 1975, Smith (T.M.) 1975, Wildes (n.d.).

Wiberg, M.
Archibald 1947b.

Wiberg: difference engine
Anderson 1933, Comrie 1932b, Deauay 1863, Jacob 1911.

Wilkes, M.V.

Wilkinson, J.H.

Williams, F.C.
Williams: storage tube memory
Williams, S.B. Campaigne 1974.
Womersley, J.
Woodger, M.
Evans (n.d.).
Wynn-Williams, C.E.
Zuse, K.
(See also Plankalkül)

Zuse: computers

Zuse Apparatebau
Work 1946.