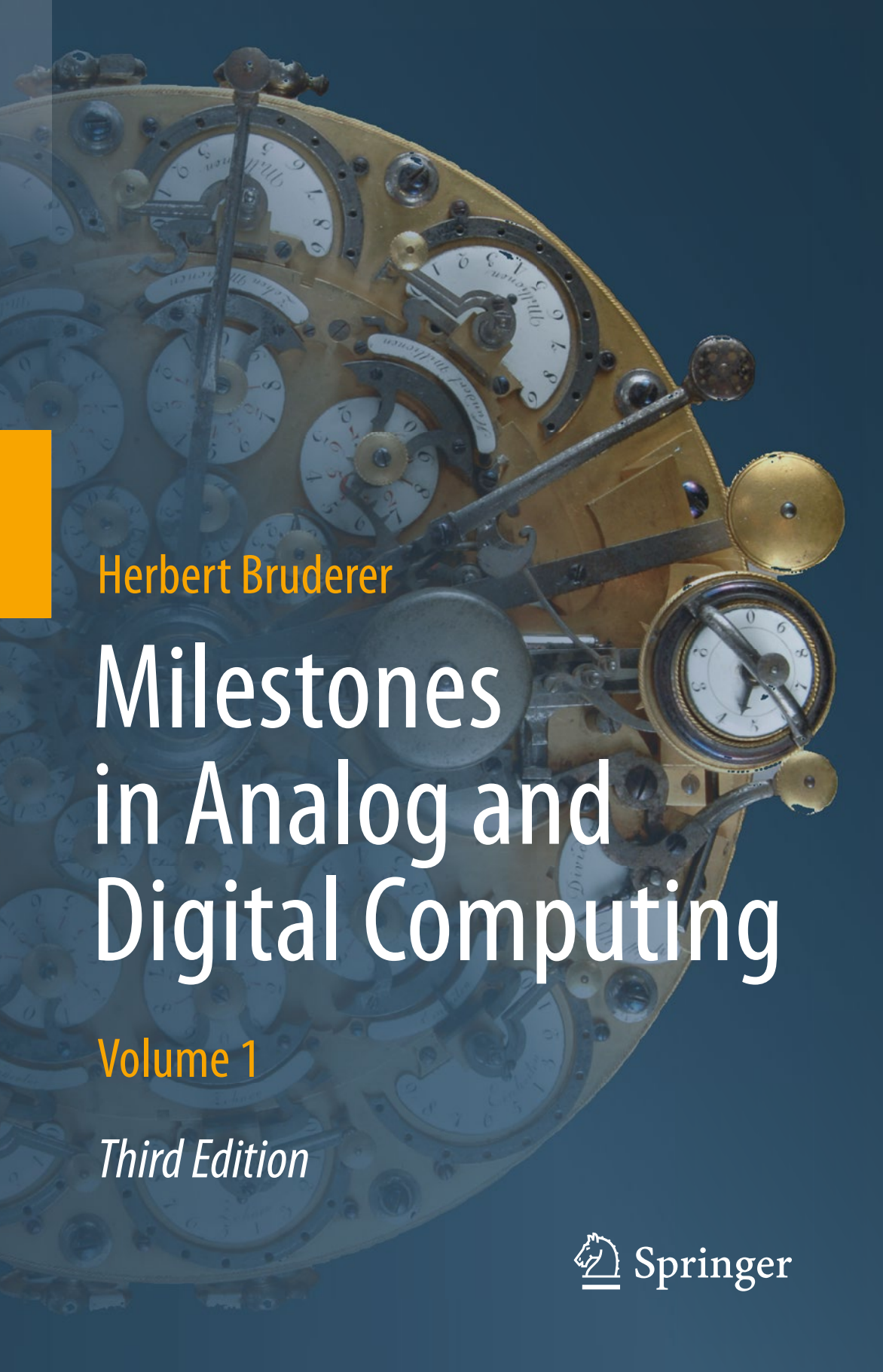

Herbert Bruderer

# Milestones in Analog and Digital Computing

## Volume 1

*Third Edition*

Springer

Milestones in Analog and Digital Computing

Herbert Bruderer

# Milestones in Analog and Digital Computing

Third edition

Translated from the German by John McMinn

Springer

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Rorschach, Switzerland

ISBN 978-3-030-40973-9 ISBN 978-3-030-40974-6 (eBook)
https://doi.org/10.1007/978-3-030-40974-6

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# Preface

As per the title of this book, this work presents selected masterpieces from the field of calculating and computing technology. It also includes related areas, such as historical automatons and scientific instruments (astronomy, land surveying, and time measurement). The book deals with contributions to the history of mathematics, with articles from the history of computer science. The objective is therefore not the complete documentation of historical developments. The focus is primarily on the technical achievements and not on their impact on the economy and society. The work contains no biographies. The history of mathematics and computer science constitutes a cultural-historical travel through time, a journey into the past.

**Two Volumes**
In view of the scope of this work, the book comprises two volumes. Some selected keywords relate to the following content:

*Volume 1*
**Basic Principles, Mechanical Calculating Devices, and Automatons**

- Basic principles (mechanical and electronic calculators, the digital transformation)
- Global overview of early electronic digital computers
- Development of arithmetic
- Mechanical calculating machines
- Classification of calculating aids
- Museums and their collections
- Famous replicas (Babbage, Pascal, Leibniz, Hollerith)
- Slide rules (linear, circular, cylindrical, and pocket watch slide rules)
- Roman hand abacus
- Historical automatons and robots (automaton figures, musical automatons, Leonardo da Vinci's robots)
- Automaton clocks
- Scientific instruments (mathematics, astronomy, surveying, time measurement)
- Chronology
- Technological, economic, social, and cultural history
- Step-by-step instructions

*Volume 2*
**Electronic Computers, Glossaries, and Bibliographies**

- Invention of the computer (Babbage, Turing, Zuse, von Neumann)
- Development in Germany (Zuse, Telefunken, Siemens)

- Development in Great Britain (Enigma, Turing-Welchman Bombe, Colossus, Bletchley Park)
- Development in Switzerland (Zuse Z4, Ermeth)
- Original documents (Zuse Z4 and Ermeth)
- Global development of the computing technology
- German-English glossary of technical terms
- English-German glossary of technical terms
- Worldwide bibliography

There are also hybrid forms between analog and digital calculating devices. The use of mechanical and electronic calculating devices is overlapping. The boundary between the two volumes is consequently somewhat fuzzy. Thus, for example, the chapter "Basic Principles" covers both older and newer calculating machines. The German-English and English-German glossaries and the bibliography include entries covering the entire history of computing technology. The 20 step-by-step instructions (including the Roman hand abacus and the pantograph) refer to both analog and digital calculating devices.

**The Book in Numbers**

The two volumes together encompass around 2000 pages, with more than 150 tables and more than 700 figures. Each of the two German-English and English-German glossaries of technical terms includes more than 5000 entries. The bibliography lists more than 6000 sources.

**What Is New?**

Compared with the award-winning first edition, the second edition has been thoroughly revised and considerably expanded. For the English version, the entire work has been revised and supplemented and errors corrected. Below are the most important changes of the second and third editions:

- New findings: Multiple Curta (world's smallest mechanical parallel calculator), circular slide rule of Weber, and Summus circular adding machine
- Additional step-by-step operating instructions for especially instructive mechanical calculating devices: Millionaire, Madas, Simex, Summus, Brunsviga, and original Odhner
- Significantly expanded global overview of the existing holdings of valuable historical objects in the most important museums
- About 280 new figures (compared to the second edition) of rare analog and digital calculating devices and other scientific instruments (above all from time measurement and astronomy), as well as historically important automaton figures, musical automatons, Roman bead frames, Leonardo's robots, and famous replicas
- More detailed explanation of the finding of the century, the Antikythera mechanism (world's first known astronomical calculating machine), in connection with a survey among internationally leading researchers

- About 50 new tables (compared to the second edition) relating to different subjects
- Comprehensive German-English and English-German glossaries of technical terms dealing with the history of computer science and related fields, each with more than 5000 entries
- Greatly expanded and updated bibliography with more than 6000 entries, including selected publications about arithmetic teachers, history of technology, and history of science, together with history of astronomy, surveying, clocks, automatons, and the digital transformation
- In general, greater consideration of related fields, such as scientific instruments (mathematics, astronomy, surveying, or measurement of time), typewriters, perforated tape controlled looms, and automatons: automaton figures (androids and animal figures), musical automatons (mechanical music instruments), picture clocks, chess automatons, automaton writers, automaton clocks, drawing automatons, and historical robots
- Dealing with the basic questions of the history of science and technology and the preservation of the cultural heritage of technology
- Additional definitions, such as algorithm, logarithm, and numerical and graphical computation (nomography)
- Numerous new definitions relating to mechanical calculating devices, bookkeeping machines and punched card equipment
- Expanded presentation of the differences between analog and digital
- Details about the origin of the binary system before Leibniz
- Overview of current developments, such as digitization, the digital transformation, artificial intelligence, machine learning, industrial revolutions, robotics, drones, social networks, electronic commerce, privacy protection, and data ownership
- Reference to DNA and quantum computers
- Detailed elaboration of controversial issues: Ada Lovelace (reputed to be first woman programmer), Alan Turing (universal computer, stored program, influence on computer design), Thales of Miletus (measurement of the height of the pyramids, intercept theorem), Heron of Alexandria (invention of the pantograph), and onset of artificial intelligence (international computing machinery conference, 1951 in Paris)
- Additional documents from the first Great Exhibition of 1851 in London
- Evaluation of exhibition catalogs (e.g., the Mustermesse Basel and the Bürofachmesse Zurich) and commercial journals
- Determination of the age of Swiss calculating devices with the help of exhibition catalogs and entries in the Swiss Official Gazette of Commerce
- Dating of the world-famous “Millionaire” direct multiplying machine based on the serial number (thanks to newly discovered findings of documents of the manufacturer and global inquiries, for example, with museums, collectors, and surveying offices)

- Considerations for self-built analog devices (pantograph, pair of sector compasses, and proportional dividers)
- Very detailed index of persons, places, and subjects.

**Selected Milestones**
This work presents a number of particularly sensational and surprising findings:

- The world's first (mechanical) astronomical calculating machine
- The world's largest and most accurate commercially available cylindrical slide rules
- The world's first (commercially) successful calculating machine
- The world's oldest known keyboard adding machine
- The world's first (mechanical) "process computer"
- The world's smallest mechanical calculating machine
- The world's smallest mechanical parallel calculating machine.

**Global Surveys**
This work includes numerous global surveys, such as concerning the first (electromechanical) relay and (electronic) vacuum tube computers, the pioneers of computer science and their inventions, and museum holdings. Furthermore, it conveys an overview of the mechanical calculating devices in Switzerland. Together with the extensive index of persons, places, and subjects, the book is therefore suitable as a reference work.

**Step-by-Step Operating Instructions**
Hard-to-find user instructions for historical analog and digital calculating devices are included in order to enhance the user value of this book. These make clear how cumbersome calculating once was.

**Preservation of the Cultural Heritage of Technology**
It is my hope that this book will motivate readers to become interested in the cultural heritage of technology and the preservation of such treasures. Perhaps this publication will wrest some outstanding achievements in computer science from oblivion. It would be gratifying if this book is able to encourage young persons to take up a technical education and thus alleviate the shortage specialists in the next generation. A further important objective is the promotion of the history of technology.

**Digital Transformation**
Groundbreaking inventions, such as the wheel, the steam engine, letterpress, the current generator, the number zero, the computer, the transistor, the World Wide Web, and the robot, have led to a profound reshaping of the world. Many companies have fallen victim to the transition from mechanical systems to electronics. They failed to recognize the signs of the time and were left behind with this development. A similar rapid upheaval is apparent with the

transition from analog technology to digital technology. In this connection, numerous companies have also perished. The upsurge of the global Internet has a far-reaching, many-faceted, and difficult-to-foresee impact on politics, society, economics, science, and technology. The omnipresent informatics penetrates nearly all areas of life. The ongoing digital transformation is often described as the fourth industrial revolution.

Fifty years ago, no one sensed the onset of this fundamental revolution in technology. The inexorable changes overwhelm many persons. Who recalls today how difficult it was to handle the slide rule and tables of logarithms or the typewriter? How will the world look in another 50 years? Will we still be able to read our electronic documents? How long will the lifespan of digital reference works be? Books and newspapers survive for centuries. Let us recall: Albert Einstein derived his groundbreaking insights with paper and pencil, without the help of electronic resources.

**Regarding the Origins of This Book**

The enormous work required to compile this book entailed negative as well as positive experiences.

*Obstacles*

The many years of – exclusively unsalaried – researches were unfortunately complicated by the circumstance that the readiness for the support of these was often meager, in some cases because of narrow-minded jealousy. At times, the work was purposely hindered.

Which historical calculating devices are found at which particular places? The most important museums were asked to check their holding lists for correctness and completeness. Unfortunately, some (repeated) questions remained unanswered. Considerable reluctance was also encountered regarding the willingness to deliver difficultly accessible documents.

Further hurdles arose concerning the entry of the work in Wikipedia.

*Theft of Intellectual Property*

With the discovery of theft or falsification of intellectual property, the victim is often penalized and not the offender. Almost worse than the faulty circumstances themselves is the behavior of the persons involved when this fraudulence comes to light: from resolute silence to intimidation with threatened legal actions. Instead of eliminating plagiarizations and falsifications from the market, these continue to be actively sold.

Works from foreign sources are all too often kept quiet in order to exclude competition.

*Acquisition of Top-Quality Photographic Material*
Acquiring high-resolution photographs of historical calculating devices was enormously time-consuming and in part very expensive. Initially, it was necessary to find the relevant contact partners. In some cases, it was necessary to open an online account with the related illustration database and examine the collections over many hours. Furthermore, the acquisition and use of these photographs required concluding agreements which, in some cases, could be delivered only by letter mail.

Many museums demand exorbitant fees even for works relating to research, which, as experience shows, exist only in limited editions. Apart from one or more specimen copies, it is not at all rare that the cost of a single photograph is more than that of a 1000-page book, even though this provides cost-free transnational advertisement for the institutions in question. For financial reasons, in many cases, it was necessary to do without photographic material. In addition, photos are guarded as though they were state secrets.

For copyright and quality reasons, no photographic material was taken from the Internet. In one particular case, concerning the illustration of the competition between American cyberneticist Norbert Wiener and chess-playing automaton of the Spaniard Leonardo Torres Quevedo (1951), it is not known who is entitled to the copyright. This is evidently a photograph taken from the press. The illustrations were taken from the following countries: Australia, Austria, Belgium, Canada, China, France, Germany, Greece, Italy, Liechtenstein, the Netherlands, Spain, Sweden, Switzerland, the UK, and the USA.

*No Financial Support*
The entire work was financed by the author alone, without any third-party funding. Consequently, there are no obligations and dependencies. The work originated single-handedly.

*Multicolored Mixture*
This work is a practice-oriented mixture of history book, informatics book, textbook, museum guide, instructions for use, glossary, bibliography, and reference work. It presents various outstanding achievements, discusses controversial issues, and defines core themes. Both digital and analog computers are considered, including ornate automatons. Understandably, this structure may be somewhat confusing. It is of course not easy to reconcile such diversity. One can say to the detriment of the book that it is “neither fish nor flesh” and that the common thread is not always immediately recognizable.

*Additions and Improvements*
Wherever possible, the correctness of all assertions was controlled on the basis of the original documents. In spite of great care, however, errors can unfortunately not be excluded. The author is therefore grateful for suggested improvements – calling attention to errors and additional information.

*Search for Objects and Documents*
I would be pleased to receive any information about rare and unknown historical calculating devices – mechanical calculating machines or slide rules of all types – and previously unknown documents.

**English Edition**
The tedious international search for the financial backing of the comprehensive English translation remained unsuccessful. The author himself therefore assumed the costs of the transcription. The search for a qualified native English translator also proved very time-consuming. The search was conducted above all in North America, Great Britain, Germany, and Switzerland. The database of the German Federal Association of Interpreters and Translators was especially helpful here. Ultimately, a good solution was found.

It is not at all self-evident that a publishing house is prepared to publish such a large, four-colored work.

**Environmental Protection**
Although worldwide researches were carried out, not a single flight was necessary for the work. Public transport (train and bus) was used for all domestic and international travel to European museums, libraries, archives, conferences, etc.

**Highlighting**
Certain words and passages deserving particular emphasis are highlighted in italics.

Herbert Bruderer September 2020

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# Acknowledgments

This book owes its origin to a great many persons. Without their very much appreciated help, this work would never have been possible. I would like to express my heartfelt thanks to all those who supported me during roughly 10 years of work. Because of the danger that I could forget to mention some of those who have helped me, with a few exceptions, I will not name these persons.

**Libraries**
First of all, I would like to mention the ETH (Swiss Federal Institute of Technology, Zurich) Library. I am very grateful to the staff of the different sections. Beatrice Ackermann, Ursula Albrecht, Manuela Christen, Aristidis Harissiadis, and Patricia Robertson were able to provide me with numerous, often difficult accessible, domestic and foreign documents.

**Museums and Archives**
Numerous domestic and international technical, scientific, and historical museums were helpful with the researches. Valuable information was obtained from a number of private and public archives.

**Magnificent Fully Functional Androids from the Eighteenth Century**
The three automaton figures of Jaquet Droz, the "Musician", the "Writer", and the "Draftsman", first introduced in 1774, are regarded as the world's finest examples of sophisticated androids. They are part of the holdings of the Musée d'art et d'histoire in Neuchâtel. In connection with a film for the American journal *Communications of the ACM*, Thierry Amstutz demonstrated this mechanical wonder for us.

**Provision of Mechanical Calculating Machines and Cylindrical Slide Rules**
Some collectors supported the investigations by providing analog and digital devices of historical importance: Heiri Hefti, Fritz Menzi, Niklaus Ragaz, and Urs Rüfenacht.

**Scientific Journals and Conference Proceedings**
The results of these time-consuming efforts have found international approval, not in the least thanks to the publications in the flagship magazine of the Association for Computing Machinery (ACM), New York. My special appreciation goes to the editors of the widely circulated Communications of the ACM: Moshe Y. Vardi, Andrew A. Chien, Andrew Rosenbloom, David Roman, Diane Crawford, and Lawrence Fisher. The ACM awards the Turing Prize, generally viewed as the Nobel Prize for informatics.

Other articles (talks given in London and New York) are documented in the conference proceedings of the International Federation for Information Processing (IFIP, Laxenburg, Austria), the global parent organization of the national scientific informatics societies.

Worthy of mention are also the IEEE Annals of the History of Computing (New York), the leading journal for the history of computer science, along with the *Journal of the Oughtred Society* (California), *CBI Newsletter* (Charles Babbage Institute, University of Minnesota, Minneapolis), and *Resurrection*, the newsletter of the British Computer Conservation Society (London).

**Photographs**
To their credit, many institutions made high-resolution black and white and color photographs of history-charged devices, machines, and documents available to me and granted permission to reproduce these. Further information can be found in connection with the respective photographs.

**Award-Winning Book**
The Oughtred Society conferred an award on the first edition of this work in 2016. This USA-based international association is concerned with the history of the slide rule and other mathematical instruments. The Briton William Oughtred was the inventor of the slide rule.

**Book Reviews**
I would like to express my gratitude to Thomas Sonar (Technische Universität Braunschweig), Steven Deckelman (University of Wisconsin-Stout, Menomonie, Wisconsin), Rainer Gebhardt (Adam-Ries-Bund, Annaberg-Buchholz), and Maik Schmidt, as well as Peter Schmitz (Magazin für Computertechnik c't, Hanover) for their outstanding reviews of the first edition. These were published by the Mathematical Association of America and in the Mathematische Semesterberichte (Springer Verlag) and reprinted in the Newsletter of the European Mathematical Society and the Deutsche Mathematiker-Vereinigung.

**English Translation**
The excellent English translation of this difficult and demanding undertaking by the American physicist Dr. John McMinn (Bamberg, Germany), delivered on schedule, deserves a commendation.

**The Publisher**
Finally, I would like to express my particular gratitude to the staff of Springer Nature Switzerland AG, Cham, for their support and realization of this book.

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# Chapter 1
# Introduction

**Abstract** The chapter "Introduction" describes the goal of the book and the period of time covered by the presentations. It conveys an overview of new and exciting findings of objects (above all calculating machines) and documents and provides insight into their origins. The book focuses on the history predating the emergence of analog and digital computer technology and the early history of their development, automaton construction (automaton figures and musical automatons), and selected scientific instruments from the areas of astronomy, surveying, and measurement of time. Special attention is given to the non-English-speaking countries. It is not the intention of the book to present the entire history without interruption. Instead, the emphasis is on the highlights and the most significant achievements. Overviews in the form of tables facilitate the study of the material. Lines of development depict coherent relationships. Instead of a treatment of the most recent era in computer science, the subjects of digital transformation and artificial intelligence are discussed at length. Numerous step-by-step operating instructions for analog and digital calculating devices round out the volume.

**Keywords** Analog technology · Artificial intelligence · Automaton construction · Automaton figures · Calculating technology · Digital technology · Digital transformation · Historical calculating aid findings · Historical robots · Musical automatons · Scientific instruments

## 1.1 Objective

This compilation presents a broad-spectrum of outstanding *masterworks* from the history of computer technology and related fields. The objective is not to present a complete and comprehensive discourse on the development of computer science, but as well as possible to *convey a general understanding of new knowledge*. The milestones should be embedded in a global relationship,

© Springer Nature Switzerland AG 2020

H. Bruderer, *Milestones in Analog and Digital Computing*,
https://doi.org/10.1007/978-3-030-40974-6_1