*Problems Posed by an Expanding Technical Literature**

CHARLES P. BOURNE†, Member, IRE

Summary—A quantitative estimate is made of the magnitude of the world's electronics and electrical engineering journal literature problem. By the use of a number of basic sources of information, a composite picture is established to show total volume, linguistic and national origins, degree of coverage by the abstracting and indexing services, and the availability of special information centers. Some criticism is directed at the electrical engineering professional societies for not taking more positive action on this problem of concern to their entire membership. The paper concludes with suggestions for coping with this general problem.

1. Introduction

In the past several years the entire scientific community has become aware of the fact that it is generating and publishing information at ever-increasing rates. It has become distressingly difficult to keep abreast of the literature or to locate references to works of interest. Information is being published in a great variety of forms—professional journals, conference proceedings, theses and dissertations, patents, house organs, trade publications, and nonperiodical report literature. The flood of literature is due, in large measure, to the increasing number of scientists and engineers actively engaged in new research and development work, as well as to the increasing amounts of support being given to research and development activities in all fields of physical and social science.

The total number of industrial research and development employees increased nearly four-fold in the last 10 years, from 200,000 in 1950 to 780,000 in 1960.[1] Scientists and engineers among these employees grew from 100,000 to 300,000 in that time period. The total amount of support, both by government and industry, for all types of research and development activities was over 12 billion dollars in 1960.[2]

In the field of electronics and electrical engineering, there are about 155,000 engineers and scientists engaged in electronics work.[3] It is estimated that government spending for electronics research, development, testing, and evaluation currently totals about 2 billion dollars per

*Received April 24, 1960.
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[1]Y. Brozen, "Economics of industrial research and development," *Research/Development*, vol. 12, pp. 64-75; August, 1961.
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[2]"Research and Development and the Gross National Product," Nat'l. Science Foundation, Washington, D. C., NSF Rept. 61-9; February, 1961.

[3]*Source:* Electronics Industries Association, "editorial comment," *Instruments and Control Systems*, vol. 34, p. 1350; August, 1961.

year.[4] Most of these projects need the information contained in reports and papers produced by other groups, and most of these projects, in turn, generate a number of reports and papers. In many cases, the only tangible products of the research effort are the reports that are written during the project. In any case, there is clearly a need for the timely and rapid recall of information. The IRE has indicated its awareness of the problem, but to date there has been no indication of any specific actions that would improve the situation for its members.[5] This paper describes the composition of the literature and the nature of the problem that exists for electrical engineers, shows some of the sources of technical information available, and suggests a number of actions that might improve our own communication network.

The growth of the electronics literature is illustrated in Fig. 1 (next page), which shows the tremendous increase in the number of papers published by the IRE in the last 10 years. The volume of AIEE publications and the publications of most other electrical engineering professional societies has also been increasing. An indication of how this volume of literature compares with the volume of literature of workers in other subject fields is graphically portrayed in Fig. 2. This illustration, adapted from an earlier and more general study of the scientific information problem, indicates that the volume of electronics literature is not as great as the volume in several other fields, such as medicine, agriculture, and the biological sciences.[6]

2. The Nature of the Electrical Engineers' Technical Literature Problem

The literature of electronics seems to have a slightly different character than the literature of most other subject fields. For one thing, it represents a very rapidly expanding technology and a number of complex specialty fields (*e.g.*, computers, learning machines, solid-state electronics, new devices, radar astronomy, microelectronics) that generate an intense amount of interest in a relatively short period of time. New disciplines emerge frequently and rapidly, and current information rapidly becomes out-of-date. Electronics has, perhaps, a greater fragmentation of its specialty fields than have other sciences. The electronics literature also seems to include a greater proportion of "house organs," commercial publications, patents, and nonperiodical research reports than do most other fields.

Estimates of the total amount of electronics literature, its linguistic and national origin, and its coverage by the abstracting and indexing services are illustrated in Fig. 3.

It appears that there are about 1000 serial publications or journals of interest to electrical engineers. This is quite liberally interpreted to include workers in many fringe fields (*e.g.*, data processing, solid-state device development, pattern recognition, and queuing theory) as well as in the more traditional fields (*e.g.*, power generation and distribution, communication equipment, and microwave circuits.) This number is based on the total number of different journals covered by 11 abstract services used by electrical engineers.[7] The 11 lists of journals covered by the 11 services add up to a total of about 2000 journals, although only about 1250 different journals are actually represented. Many of these journals did not actually relate to electronics, while many others that did were not listed. These factors probably balance to the extent that an estimate of 1000 relevant journals in the field of electronics would be reasonable.

Several empirical studies have shown that there are 30 to 70 articles per journal per year.[6] Using the estimate of 1000 journals, this would result in a range of 30,000 to 70,000 articles per year in the field of electronics.

The geographical or national origin of the electronics literature was estimated in two different ways, with consistent results. The first estimate was based on the origin of the 1250 different journals covered by the 11 abstract services mentioned previously. The findings of this first examination, listed in Table I and portrayed in Fig. 3, were that the United States, with about one third of the total, is the largest contributor, followed, in order of production, by Great Britain, Germany, USSR, Japan, France, and Italy.

The second estimate of national origins was based on the national origin of 4800 abstracts in eight issues of *Electrical Engineering Abstracts*. The results of this tally, listed in Table II and shown in Fig. 3, were essentially in agreement with the first estimate, except for the transposition in relative rankings of France and Italy. If *Electrical Engineering Abstracts* completely covers the world's electronics literature, then perhaps this tally provides an accurate estimate of the origins of this literature. However, since it seems extremely unlikely that the world's electronic literature is completely covered, these tallies probably describe only the acquisition policies of the particular abstracting services studied. For example, the eight-month sample of *Electronical Engineering Abstracts*, one of the finest services in this subject field, showed fewer than six papers from all of Central and South America combined, fewer than six papers from all of Africa and the Middle East combined, and (with the

[4] "Coordination of Information on Current Federal Research and Development Projects in the Field of Electronics," U. S. Senate Committee on Gov't. Operations and its Subcommittee on Reorganization and Internat'l Organization; September 20, 1961.

[5] F. Hamburger, Jr., "Poles and zeros," Proc. IRE, vol. 48, p. 1693, October, 1960; vol. 49, p. 1261, August, 1961.

[6] C. P. Bourne, "The world's technical journal literature: an estimate of volume, origin, language, field, indexing and abstracting," *Am. Documentation*, vol. 13, pp. 159-168; April, 1962.

[7] Proc. IRE, *Computing Revs., Solid State Abstracts, Physics Abstracts, Elec. Eng. Abstracts, Appl. Science and Technology Index, Nuclear Science Abstracts, Data Processing Digest, Radiofile, J. Acoust. Soc. Am., PGEC-Computer Abstracts.*

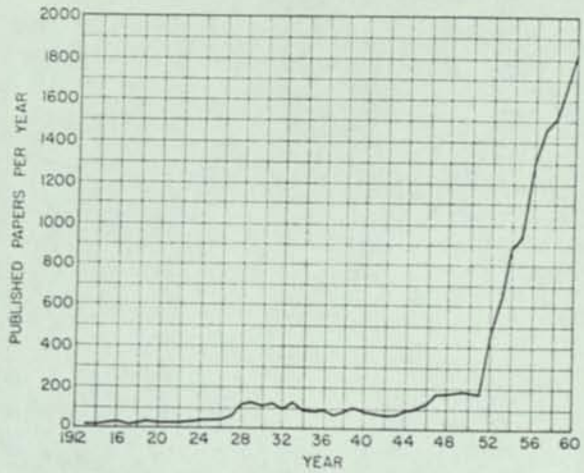

Fig. 1. *Note:* This includes papers in all the IRE technical publications (PROCEEDINGS, TRANSACTIONS, CONVENTION RECORDS, WESCON, WJCC, and EJCC).

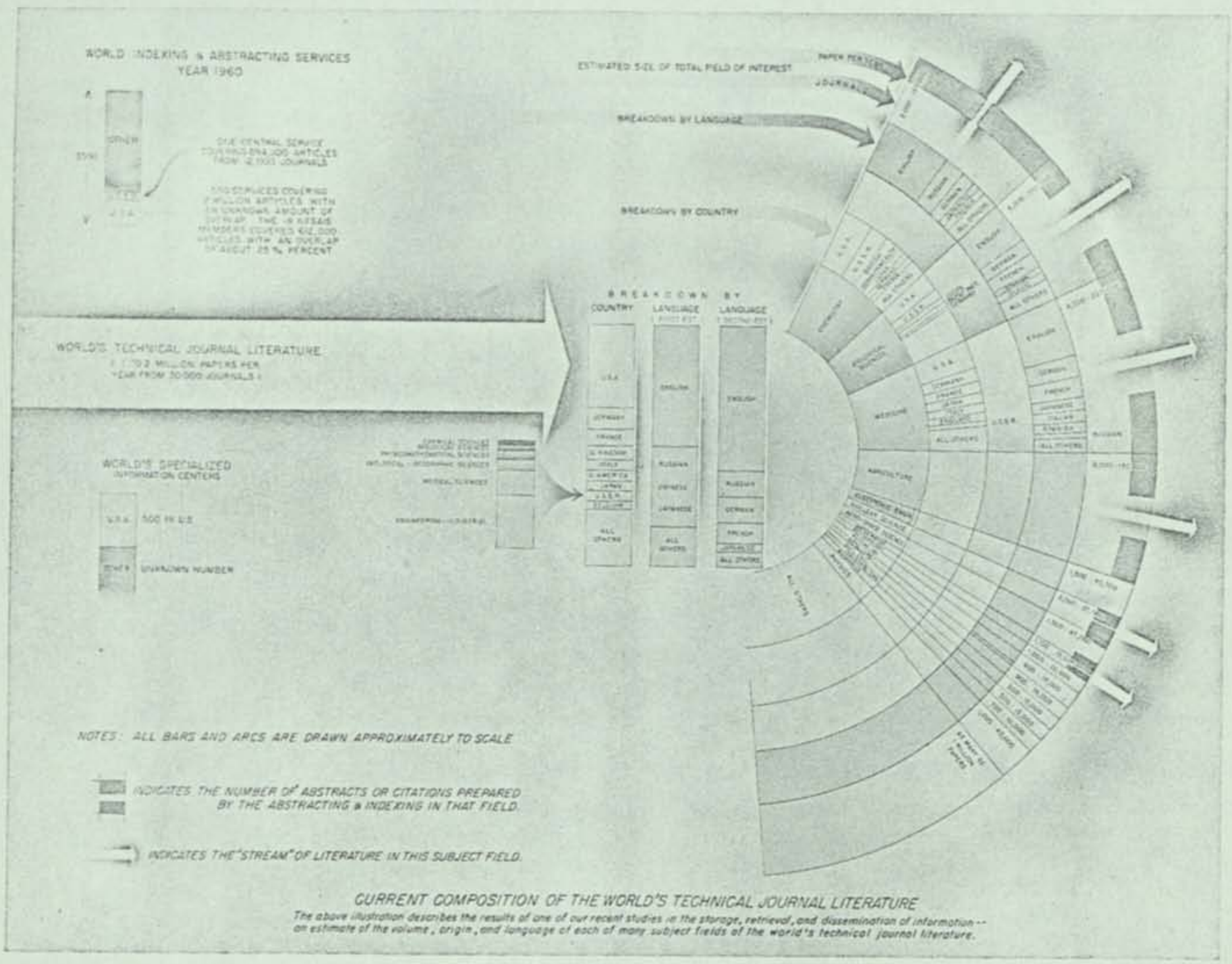

Fig. 2.

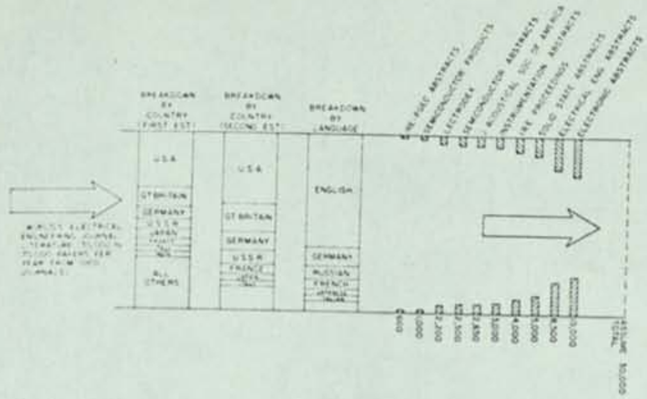

Fig. 3—Current composition of the world's electrical engineering journal literature.

TABLE I

NATIONAL ORIGINS OF THE ELECTRICAL ENGINEERING LITERATURE—FIRST ESTIMATE*

Originating Country	*Per Cent of Total*
USA	31.4
Great Britain	11.0
Germany	7.8
USSR	6.2
Japan	5.4
France	3.5
Italy	2.7
India	2.2
Sweden	2.2
Belgium	2.0
Poland	1.7
Roumania	1.6
Netherlands	1.4
Canada	1.2
Norway	1.2
Switzerland	1.2
Unknown origin	7.7
All others (27)	8.6
	100.00

**Source:* An analysis of the origin of the 1250 different serial publications covered by PROC. IRE, *Computing Revs., Solid State Abstracts, Appl. Science and Technology Index, Nuclear Science Abstracts, Data Processing Digest, Radiofile, J. Acoust. Soc. Am., PGEC-Computer Abstracts, Physics Abstracts, and Elec. Engrg. Abstracts.*

TABLE II

NATIONAL ORIGINS OF THE ELECTRICAL ENGINEERING LITERATURE—SECOND ESTIMATE*

Originating Country	*Per Cent of Total*
USA	40.0
Great Britain	16.2
Germany	10.8
USSR	8.0
France	6.3
Japan	3.8
Italy	2.7
Czechoslovakia	2.0
Netherlands	1.7
Sweden	1.5
Australia	1.3
Switzerland	1.1
Spain	0.9
Poland	0.7
Canada	0.6
Norway	0.5
All others (12)	1.9
	100.0

**Source:* An analysis of the January, 1961, to August, 1961, issues of *Elec. Engrg. Abstracts* (8 months and 4800 abstracts).

TABLE III

LINGUISTIC BREAKDOWN OF THE ELECTRICAL ENGINEERING LITERATURE*

Language	*Per Cent of Total*
English	64.5
German	11.5
Russian	8.2
French	5.2
Japanese	3.0
Italian	2.7
Czechoslovakian	1.7
Swedish	0.8
Dutch	0.6
Norwegian	0.5
Polish	0.4
Spanish	trace
Danish	trace
Slovak	trace
Roumanian	trace
Finnish	trace
Portuguese	trace
	100.0

**Source:* An analysis of the January, 1961, to August, 1961, issues of *Elec. Engrg. Abstracts* (8 months and 4800 abstracts).

exception of Japan) none from Asia or the Far East countries. It does not seem possible that these numbers actually reflect the respective publication figures for these countries. However inaccurate these figures may be, they still provide our best estimate to date.

The linguistic breakdown of the electronics literature was based on the languages of the 4800 abstracts in the eight-month sample of *Electrical Engineering Abstracts.*[8] The results of this examination, listed in Table III and shown in Fig. 3, indicate that English is the predominant language, comprising roughly two-thirds of the literature. English is followed by German, Russian, French, Japanese, and Italian. This should be of interest to those educators who are concerned with students' language requirements.

3. Reference Tools Available to Help With This Literature

Indexing and Abstracting Services

There are at least 60 publications written in English which furnish abstracts or citations of papers and reports that are of potential interest to the electronics workers (see Table IV). Many of these publications are solely abstract or index journals, and some of them are profes-

[8] The language of each of the articles is noted in nearly every one of the abstracts.

TABLE IV

Some Abstracting and Indexing Services of Possible Interest to Electrical Engineers*

ACM Computing Reviews	IRE Transactions on Human Factors: Abstracts Section
Aeronautical Engineering Index	IRE Transactions on Information Theory: Abstracts Section
Applied Mechanics Reviews	IRE Transactions on Medical Electronics: Bibliography
Applied Science and Technology Index (formerly Industrial Arts Index)	Journal of the Acoustical Society of America: Abstracts Section
ASTIA Technical Abstract Bulletin	Journal of the Institute of Navigation
Battelle Technical Review	Kodak Abstracts
Bibliographic Index	Lefax Technical Data Service
Bibliography and Abstracts on Electrical Contacts	Masters Theses in the Pure and Applied Sciences
Biological Abstracts	Mathematical Abstracts
Chemical Abstracts	Mathematical Reviews
Computer Abstracts	Meteorological and Geoastrophysical Abstracts
Corrosion Abstracts	Nuclear Science Abstracts
Data Processing Digest	Philips Technical Review
Dissertation Abstracts	Photographic Abstracts
Electronics Abstracts	Physics Abstracts
Electronics Digest	Prevention of Deterioration Abstracts
Electronics Express	Radiofile (formerly Lectrodex)
Electronic Industries	Review of Metal Literature
Engineering Index	Science Abstracts - A. Physics, B. Electrical Engineering
Geoscience Abstracts	Scientific Information Report
Index Medicus	Semiconductor Abstracts
Instrumentation Abstracts	Semiconductor Products
International Aero/Space Abstracts (formerly Aero/Space Reviews)	Solid State Abstracts (formerly Semiconductor Abstracts)
International Journal of Abstracts—Statistical Theory and Method	Technical Survey
Proceedings of the IRE: Abstracts Section (copied from Electronic Technology)	Technical Translations
IRE Transactions on Circuit Theory: Abstracts Section	Thermoelectricity Abstracts
IRE Transactions on Electronic Computers: Abstracts Section (same as Computer Abstracts On Cards)	U. S. Government Research Reports
	Vacuum Abstracts
	Vertical File Index

Sources:

"A Guide to U. S. Indexing and Abstracting Services in Science and Technology," Nat'l. Fed. of Science Abstracting and Indexing Services, Washington, D. C., June, 1961.

J. T. Milek, "Abstracting and indexing services in electronics and related electrical fields," *Am. Documentation*, vol. 8, pp. 5-21; January, 1957.

sional society journals or publications by other organizations, which include references in addition to their primary content, the technical papers. However, there is no single title announcement or abstract service that provides complete and comprehensive current-awareness reporting of the entire field of electronics. In addition, there is no single index or reference publication that will permit relatively easy retrospective searching of the world's literature in electronics. Some cumulative indexes are available, but these are usually for a restricted amount of material and are seldom very timely. Fig. 3 shows, for example, the extent to which the indexing and abstracting services are covering the electronics field. The publication that provides the greatest number of electronics abstracts is the monthly *Electronics Abstracts*, a commercial service, providing an annual author index, publishing 10,000 abstracts per year from 300 journals, at a cost of 300 dollars per year.[9] Second largest coverage is obtained by *Electrical Engineering Abstracts*, a publication of the British Institution of Electrical Engineers, which published about 8500 abstracts in 1960.

The IRE, the largest electrical engineering professional society, and perhaps the largest technical society in this country with its current membership of about 100,000 members, is not providing the information services that it should. The IRE should provide a comprehensive abstract or title announcement publication and cumulative subject indexes to cover the world's electronics literature. The abstracts currently appearing in the Proceedings of the IRE, as well as their annual subject and author index, are copied and printed one month later from the British publication *Electronic and Radio Engineer*. However, this section covers only about 4000 abstracts per year, which is far from complete coverage of the world's literature.[10] These remarks are not meant to be critical of the compilers of this IRE Abstract and Reference Section. These compilers are selective, make no attempt to be complete in their coverage, and are restricted by monetary considerations as to how many citations per year they can publish. In 1960 the IRE Abstract and Reference Section covered about 25 per cent of the material published by the IRE.[11] The IRE does publish a cumulative author and subject index every five years, covering only papers that appeared in IRE publications. The IRE Professional Groups on Electronic Computers and Medical Electronics, with the publication of abstracts and citations in their respective Transactions, have provided rather comprehensive coverage in limited subject fields, and for this effort their editors should be congratulated.

Special Information Centers

Information centers normally act as the custodians for the original source material, provide reference tools so that users may conduct their own literature searches,

[9] "A Guide to U. S. Indexing and Abstracting Services in Science and Technology," Nat'l Fed. of Science Abstracting and Indexing Services, Washington, D. C., Rept. 101, 79 pp.; June, 1960. See especially p. 52.

[10] For contrast, this 4000 abstracts per year for all of the world's literature could be compared with a forthcoming commercial publication that will provide 3600 abstracts per year for the computer field alone.

[11] E. K. Gannett, Managing Editor, Proc. IRE (private communication).

perform custom literature searches, and sometimes prepare analytical survey reports. Many of these information centers are federally operated, some are commercial ventures, and a few are operated by professional societies and other institutions.

There is presently no single library or information center where an individual can search the major portion of the world's literature in electronics. That is, there is no electronics equivalent of the National Library of Medicine or the Department of Agriculture Library. However, there are already approximately 500 special information centers in the United States, many of which represent subject fields of some interest to electrical engineers. Some special information centers of potential interest to the electronics field are given in Table V. However, many of these special centers, such as ASTIA, restrict their services to government agencies and Department of Defense contractors. The remainder of the centers are not in a position to provide much service to the electronics community in general. It should also be noted that each of the centers represents some narrow specialty field and that they are geographically situated in such a way that essentially all of the centers are east of the Mississippi.

The Chemical Abstracts Service will soon implement a computer searching system to perform literature searching and to help with the index publication for members of the American Chemical Society. Five years ago, the American Society for Metals took the initiative of starting a research project and pilot operation to determine whether the machine searching of metallurgical literature was feasible. It was, and the ASM currently provides a comprehensive literature searching service and current-awareness reporting service for the field of metallurgy, using the computer equipment at Western Reserve University. Starting in 1960, all of the 12,000 abstracts published each year in the ASM *Review of Metal Literature* will be encoded into the machine searching system.[12] Great benefits could be derived from a similar system established by the electrical engineering societies for the world's electronics literature.

The Engineering Societies Library in New York collects and catalogues literature from all fields of engineering.[13] The library facilities are available to the general public, but book loans are restricted to members of the 12 supporting professional societies. The IRE is not an Associate Society and does not contribute to the support of this library—consequently, IRE members are unable to borrow books from this library, although members of the AIEE can.

4. Recommendations

The IRE and the AIEE should initiate and continue a serious study of their own communications practices, and of the information requirements of their own members and other users. Such a study might be supported on a full-time basis in much the same manner as the Documentation Research Project of the American Institute of Physics is being supported by the National Science Foundation. A strong effort should be made to develop better reference tools and search facilities for the entire membership. More active working arrangements should be established with other technical publishers and information services to exchange abstracts and reviews, and to cooperate in the development of special reference tools. The electrical engineering professional societies must participate much more actively in the solution of the technical information problems than they have to date.

[12] M. R. Hyslop, "Metallurgical documentation from research to practice," *J. Franklin Inst.*, vol. 270, pp. 27-33; July, 1960.
[13] R. H. Phelps, "The Engineering Societies Library," *Am. Documentation*, vol. 9, pp. 165-167; July, 1958.

TABLE V

U. S. SCIENCE INFORMATION CENTERS OF POTENTIAL INTEREST TO ELECTRICAL ENGINEERS*

Organization	*Main Subject Field*	*Location*
Acoustical Society of America	acoustics	New York, N. Y.
Advisory Group on Electron Tubes	electron tubes	New York, N. Y.
Advisory Group on Electronic Parts	electron parts and materials other than tubes and transistors	Philadelphia, Pa.
American Ceramic Society, Inc.	ceramics	Columbus, Ohio
American Chemical Society	chemicals	Washington, D. C.
American Electroplaters' Society	electroplating, metal finishing	Newark, N. J.
American Institute of Electrical Engineers	electrical and electronic materials	New York, N. Y.
American Institute of Physics, Inc.	physics	New York, N. Y.
American Physical Society	physics	New York, N. Y.

Table V continued (next page).

TABLE V (*Cont'd.*)

Organization	*Main Subject Field*	*Location*
American Society for Metals, Documentation Service	all aspects of metallurgy	Novelty, Ohio
American Society for Testing Materials	engineering materials and standards	Philadelphia, Pa.
Armed Forces Communication and Electronics Association	communications, photography, electronics	Washington, D. C.
Armed Services Technical Information Agency	all fields of technology	Arlington, Va.
Ballistic Missile Radiation Analysis Center	electromagnetic and acoustical radiation from ICBM's in flight	Ann Arbor, Mich.
Bush, G. F., Association	instrumentation	Princeton, N. J.
Derivation and Tabulation Assoc., Inc.	transistors, microwave tubes, semiconductor diodes and rectifiers	Orange, N. J.
Diamond Ordnance Fuze Laboratory	transducers for ordnance applications	Washington, D. C.
Electrochemical Society, Inc.	electrometallurgy, electrochemicals	New York, N. Y.
Engineering Societies Library	general science and technology	New York, N. Y.
Germanium Information Center	germanium	Kansas City, Mo.
Groth Institute	physical, chemical, and crystal-structural properties	University Park, Pa.
Gould-National Batteries, Inc. Research Center	electrochemical data, batteries and battery components	Minneapolis, Minn.
IGY World Data Center A Rockets and Satellites	all data from IGY rocket and satellite experiments	Washington, D. C.
IGY World Data Center A Aurora Instrumented	aurora data	College, Alaska
IGY World Data Center Aurora Visual	visual observation of aurora borealis	Ithaca, N. Y.
IGY World Data Center A Airglow and Ionosphere	ionosphere, airglow, and physical properties of the upper atmosphere	Boulder, Colo.
Infrared Information and Analysis Center	cryogenics, infrared technology, thermal radiation, spectra	Ann Arbor, Mich.
Instrumentation Abstracts	instrumentation	Evanston, Ill.
Interference Measurement Lab, Inc.	radio interference	Brooklyn, N. Y.
Human Engineering Information and Analysis Service	human engineering	Medford, Mass.
Library of Congress, Science and Technology Division	general science and technology	Washington, D. C.
MIT Engineering Library	general science and technology	Cambridge, Mass.
NBS Instrumentation Information Center	instrumentation	Washington, D. C.
NBS Research Information Center and Advisory Service on Information Processing	information processing, machine translation	Washington, D. C.
Project SETE, New York University	electronic test, checkout, and output equipment	New York, N. Y.
Radiation Effects Information Center	radiation effects	Columbus, Ohio
Radio Corporation of America	aviation electronics survey	Camden, N. J.
Research Triangle Institute	reliability	Dearborn, N. C.
Science Information Exchange	current scientific research projects	Washington, D. C.
Technical Information Corporation	electronic test equipment	New York, N. Y.
Tennessee Valley Authority	generation, transmission and marketing of power	Chattanooga, Tenn.
Thermo-Physical Properties Research Center	thermophysical properties	Lafayette, Ind.
Tungsten Institute	tungsten	New York, N. Y.
U.S. Dept. of Commerce, OTS	reports and translations of general science and technology	Washington, D. C.
U.S. Air Force, Air Info. Div.	aeronautics, electronics, space technology	Washington, D. C.
U.S. Air Force, Office of Science Research, Project ECHO	current research projects sponsored by the Air Force	Washington, D. C.
U.S. Patent Office	all issued U.S. patents and most foreign patents	Washington, D. C.
Welding Research Council	welding	New York, N. Y.
Yardney Electric Corporation	high energy, conversion systems, especially silver-zinc and silver-cadmium batteries	New York, N. Y.

**Sources:*

R. H. Phelps, "The Engineering Societies Library," *Am. Documentation*, vol. 9, pp. 165-167; July, 1958.

M. E. Fields, *et al.*, "Materials Information Centers," Wright Air Dev. Ctr., Wright-Patterson Air Force Base, Ohio, WADC Tech. Note 58-192, ASTIA AD-155 885; September, 1958. This report lists more than 100 information centers.

K. A. Winter and I. Lopatin, "Materials Information Centers," McGraw-Hill Book Co., Inc., New York, N. Y., WADC Tech. Note 60-246, ASTIA AD-259 318; February, 1961. This report lists 86 information centers.

"Interservice data exchange helps avoid test duplication," *Astro News*, vol. 2, p. 3; December 21, 1960.

"Specialized Science Information Services in the United States," Nat'l Science Foundation, location, NSF Rept. 61-68; November, 1961. This report lists 427 information centers.

"Coordination of Information on Current Federal Research and Development Projects in the Field of Electronics," U. S. Senate Committee on Gov't. Operations and its Subcommittee on Reorganization and Internat'l Organization; September 20, 1961.

IRE TRANSACTIONS

ON ENGINEERING WRITING AND SPEECH

VOLUME EWS-5 NUMBER 1 AUGUST, 1962

CONTENTS

IRE PROFESSIONAL GROUP ON ENGINEERING WRITING AND SPEECH

The Professional Group on Engineering Writing and Speech is an organization, within the framework of the IRE, dedicated to helping engineers improve their ability in engineering writing and speaking. All members of the IRE are eligible for membership in the Group and will receive all Group publications upon payment of an annual fee of $3.00.

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Editorial

The Professional Group on Engineering Writing and Speech recently celebrated its fifth birthday in distinguished company, as Dr. Alfred Goldsmith lunched with members of the PGEWS Administrative Committee. Among Dr. Goldsmith's memorable remarks (he is a dean of deipnosophy and prefect of punsters) was the observation that the entire Institute of Radio Engineers is, after all, a professional group on engineering writing and speech, and that PGEWS serves as a focus for these activities.

No IRE member can be unmindful of the huge publishing venture that the IRE represents. The PROCEEDINGS, TRANSACTIONS, section magazines, PG newsletters, and conference records of the IRE contribute mightily to the expanding technical literature discussed in our lead paper. The number of pages published annually by the IRE is said to have increased 10 times in about as many years. Perhaps there is 10 times as much to be said as there was 10 years ago; nevertheless, man does not read 10 times as fast as he did then, nor does he have 10 times as many hours in which to read. His problem is simply 10 times as great, and cries for quick remedy.

The problem belongs to PGEWS, an organization of writers, and it belongs to the IRE, a much larger confraternity of both writers and readers. If we can't find a solution soon, some higher authority may impose an agricultural-type remedy, where writers are paid according to the number of papers they do not publish. The analogy between a warehouse filled with unpublished manuscripts and a silo filled with unused grain is replete with poetic possibility.

Herbert B. Michaelson, who so expertly edited this publication for the past two years, deserves the gratitude of all PGEWS members. Herb was always aware that the first letter of PGEWS stands for Professional, and his journal was just that.

Frederick Van Veen, *Editor*

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1. Introduction

IN THE PAST several years the entire scientific community has become aware of the fact that it is generating and publishing information at ever-increasing rates. It has become distressingly difficult to keep abreast of the literature or to locate references to works of interest. Information is being published in a great variety of forms—professional journals, conference proceedings, theses and dissertations, patents, house organs, trade publications, and nonperiodical report literature. The flood of literature is due, in large measure, to the increasing number of scientists and engineers actively engaged in new research and development work, as well as to the increasing amounts of support being given to research and development activities in all fields of physical and social science.

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The growth of the electronics literature is illustrated in Fig. 1 (next page), which shows the tremendous increase in the number of papers published by the IRE in the last 10 years. The volume of AIEE publications and the publications of most other electrical engineering professional societies has also been increasing. An indication of how this volume of literature compares with the volume of literature of workers in other subject fields is graphically portrayed in Fig. 2. This illustration, adapted from an earlier and more general study of the scientific information problem, indicates that the volume of electronics literature is not as great as the volume in several other fields, such as medicine, agriculture, and the biological sciences.[6]

2. The Nature of the Electrical Engineers' Technical Literature Problem

The literature of electronics seems to have a slightly different character than the literature of most other subject fields. For one thing, it represents a very rapidly expanding technology and a number of complex specialty fields (*e.g.*, computers, learning machines, solid-state electronics, new devices, radar astronomy, microelectronics) that generate an intense amount of interest in a relatively short period of time. New disciplines emerge frequently and rapidly, and current information rapidly becomes out-of-date. Electronics has, perhaps, a greater fragmentation of its specialty fields than have other sciences. The electronics literature also seems to include a greater proportion of "house organs," commercial publications, patents, and nonperiodical research reports than do most other fields.

[4]"Coordination of Information on Current Federal Research and Development Projects in the Field of Electronics," U. S. Senate Committee on Gov't. Operations and its Subcommittee on Reorganization and Internat'l Organization; September 20, 1961.

[5]F. Hamburger, Jr., "Poles and zeros," PROC. IRE, vol. 48, p. 1693, October, 1960; vol. 49, p. 1261, August, 1961.

[6]C. P. Bourne, "The world's technical journal literature: an estimate of volume, origin, language, field, indexing and abstracting," *Am. Documentation*, vol. 13, pp. 159-168; April, 1962.

Estimates of the total amount of electronics literature, its linguistic and national origin, and its coverage by the abstracting and indexing services are illustrated in Fig. 3.

It appears that there are about 1000 serial publications or journals of interest to electrical engineers. This is quite liberally interpreted to include workers in many fringe fields (*e.g.*, data processing, solid-state device development, pattern recognition, and queuing theory) as well as in the more traditional fields (*e.g.*, power generation and distribution, communication equipment, and microwave circuits.) This number is based on the total number of different journals covered by 11 abstract services used by electrical engineers.[7] The 11 lists of journals covered by the 11 services add up to a total of about 2000 journals, although only about 1250 different journals are actually represented. Many of these journals did not actually relate to electronics, while many others that did were not listed. These factors probably balance to the extent that an estimate of 1000 relevant journals in the field of electronics would be reasonable.

Several empirical studies have shown that there are 30 to 70 articles per journal per year.[6] Using the estimate of 1000 journals, this would result in a range of 30,000 to 70,000 articles per year in the field of electronics.

The geographical or national origin of the electronics literature was estimated in two different ways, with consistent results. The first estimate was based on the origin of the 1250 different journals covered by the 11 abstract services mentioned previously. The findings of this first examination, listed in Table I and portrayed in Fig. 3, were that the United States, with about one third of the total, is the largest contributor, followed, in order of production, by Great Britain, Germany, USSR, Japan, France, and Italy.

The second estimate of national origins was based on the national origin of 4800 abstracts in eight issues of *Electrical Engineering Abstracts*. The results of this tally, listed in Table II and shown in Fig. 3, were essentially in agreement with the first estimate, except for the transposition in relative rankings of France and Italy. If *Electrical Engineering Abstracts* completely covers the world's electronics literature, then perhaps this tally provides an accurate estimate of the origins of this literature. However, since it seems extremely unlikely that the world's electronic literature is completely covered, these tallies probably describe only the acquisition policies of the particular abstracting services studied. For example, the eight-month sample of *Electronical Engineering Abstracts*, one of the finest services in this subject field, showed fewer than six papers from all of Central and South America combined, fewer than six papers from all of Africa and the Middle East combined, and (with the

[7]PROC. IRE, *Computing Revs., Solid State Abstracts, Physics Abstracts, Elec. Eng. Abstracts, Appl. Science and Technology Index, Nuclear Science Abstracts, Data Processing Digest, Radiofile, J. Acoust. Soc. Am., PGEC-Computer Abstracts.*

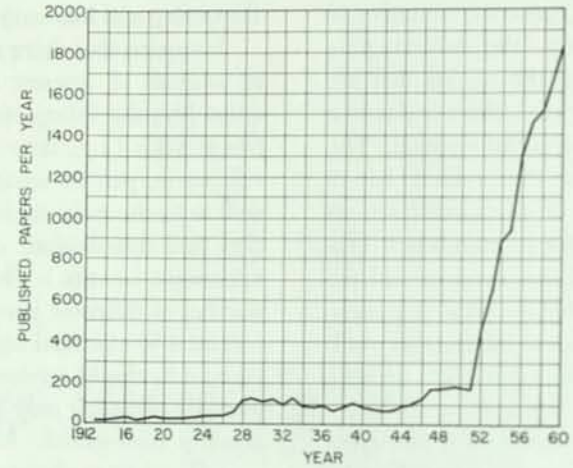

Fig. 1. *Note:* This includes papers in all the IRE technical publications (PROCEEDINGS, TRANSACTIONS, CONVENTION RECORDS, WESCON, WJCC, and EJCC).

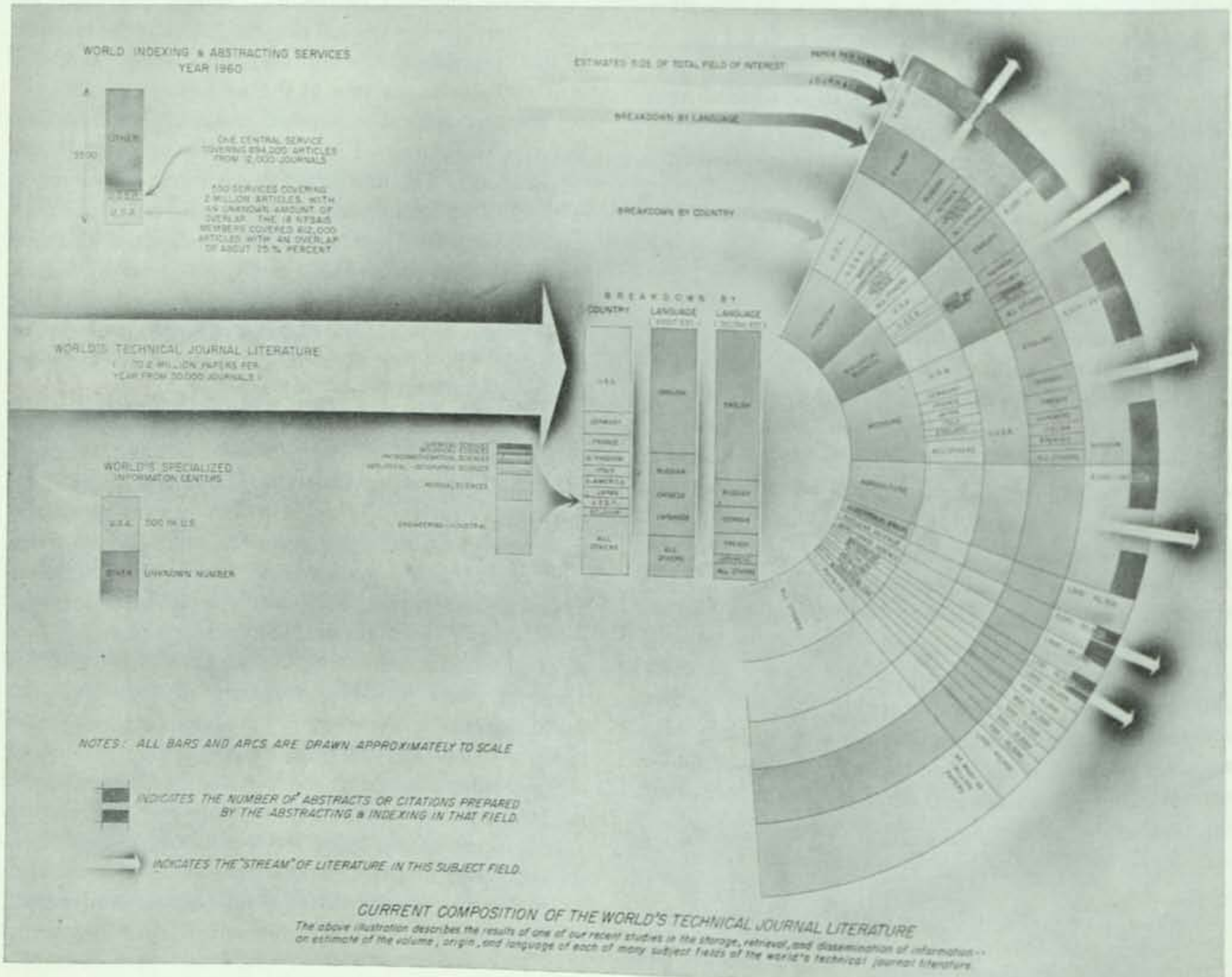

Fig. 2.

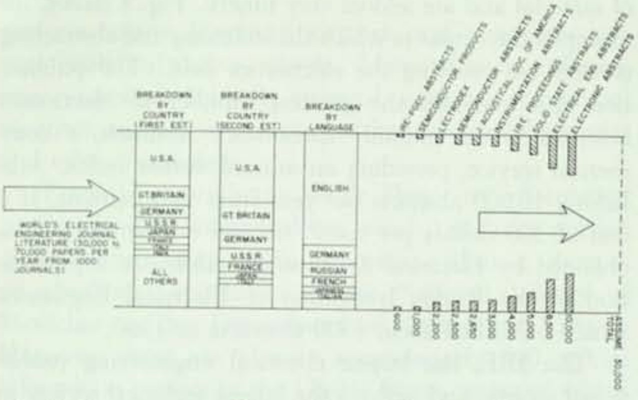

Fig. 3–Current composition of the world's electrical engineering journal literature.

TABLE I

National Origins of the Electrical Engineering Literature–First Estimate*

Originating Country	*Per Cent of Total*
USA	31.4
Great Britain	11.0
Germany	7.8
USSR	6.2
Japan	5.4
France	3.5
Italy	2.7
India	2.2
Sweden	2.2
Belgium	2.0
Poland	1.7
Roumania	1.6
Netherlands	1.4
Canada	1.2
Norway	1.2
Switzerland	1.2
Unknown origin	7.7
All others (27)	8.6
	100.00

**Source:* An analysis of the origin of the 1250 different serial publications covered by Proc. IRE, *Computing Revs., Solid State Abstracts, Appl. Science and Technology Index, Nuclear Science Abstracts, Data Processing Digest, Radiofile, J. Acoust. Soc. Am., PGEC-Computer Abstracts, Physics Abstracts, and Elec. Engrg. Abstracts.*

exception of Japan) none from Asia or the Far East countries. It does not seem possible that these numbers actually reflect the respective publication figures for these countries. However inaccurate these figures may be, they still provide our best estimate to date.

The linguistic breakdown of the electronics literature was based on the languages of the 4800 abstracts in the eight-month sample of *Electrical Engineering Abstracts.*[8] The results of this examination, listed in Table III and shown in Fig. 3, indicate that English is the predominant language, comprising roughly two-thirds of the literature. English is followed by German, Russian, French, Japanese, and Italian. This should be of interest to those educators who are concerned with students' language requirements.

[8]The language of each of the articles is noted in nearly every one of the abstracts.

TABLE II

National Origins of the Electrical Engineering Literature–Second Estimate*

Originating Country	*Per Cent of Total*
USA	40.0
Great Britain	16.2
Germany	10.8
USSR	8.0
France	6.3
Japan	3.8
Italy	2.7
Czechoslovakia	2.0
Netherlands	1.7
Sweden	1.5
Australia	1.3
Switzerland	1.1
Spain	0.9
Poland	0.7
Canada	0.6
Norway	0.5
All others (12)	1.9
	100.0

**Source:* An analysis of the January, 1961, to August, 1961, issues of *Elec. Engrg. Abstracts* (8 months and 4800 abstracts).

TABLE III

Linguistic Breakdown of the Electrical Engineering Literature*

Language	*Per Cent of Total*
English	64.5
German	11.5
Russian	8.2
French	5.2
Japanese	3.0
Italian	2.7
Czechoslovakian	1.7
Swedish	0.8
Dutch	0.6
Norwegian	0.5
Polish	0.4
Spanish	trace
Danish	trace
Slovak	trace
Roumanian	trace
Finnish	trace
Portuguese	trace
	100.0

**Source:* An analysis of the January, 1961, to August, 1961, issues of *Elec. Engrg. Abstracts* (8 months and 4800 abstracts).

3. Reference Tools Available to Help With This Literature

Indexing and Abstracting Services

There are at least 60 publications written in English which furnish abstracts or citations of papers and reports that are of potential interest to the electronics workers (see Table IV). Many of these publications are solely abstract or index journals, and some of them are profes-

TABLE IV

SOME ABSTRACTING AND INDEXING SERVICES OF POSSIBLE INTEREST TO ELECTRICAL ENGINEERS*

- ACM Computing Reviews
- Aeronautical Engineering Index
- Applied Mechanics Reviews
- Applied Science and Technology Index (formerly Industrial Arts Index)
- ASTIA Technical Abstract Bulletin
- Battelle Technical Review
- Bibliographic Index
- Bibliography and Abstracts on Electrical Contacts
- Biological Abstracts
- Chemical Abstracts
- Computer Abstracts
- Corrosion Abstracts
- Data Processing Digest
- Dissertation Abstracts
- Electronics Abstracts
- Electronics Digest
- Electronics Express
- Electronic Industries
- Engineering Index
- Geoscience Abstracts
- Index Medicus
- Instrumentation Abstracts
- International Aero/Space Abstracts (formerly Aero/Space Reviews)
- International Journal of Abstracts—Statistical Theory and Method
- PROCEEDINGS OF THE IRE: Abstracts Section (copied from Electronic Technology)
- IRE TRANSACTIONS ON CIRCUIT THEORY: Abstracts Section
- IRE TRANSACTIONS ON ELECTRONIC COMPUTERS: Abstracts Section (same as Computer Abstracts On Cards)
- IRE TRANSACTIONS ON HUMAN FACTORS: Abstracts Section
- IRE TRANSACTIONS ON INFORMATION THEORY: Abstracts Section
- IRE TRANSACTIONS ON MEDICAL ELECTRONICS: Bibliography
- Journal of the Acoustical Society of America: Abstracts Section
- Journal of the Institute of Navigation
- Kodak Abstracts
- Lefax Technical Data Service
- Masters Theses in the Pure and Applied Sciences
- Mathematical Abstracts
- Mathematical Reviews
- Meteorological and Geoastrophysical Abstracts
- Nuclear Science Abstracts
- Philips Technical Review
- Photographic Abstracts
- Physics Abstracts
- Prevention of Deterioration Abstracts
- Radiofile (formerly Lectrodex)
- Review of Metal Literature
- Science Abstracts - A. Physics, B. Electrical Engineering
- Scientific Information Report
- Semiconductor Abstracts
- Semiconductor Products
- Solid State Abstracts (formerly Semiconductor Abstracts)
- Technical Survey
- Technical Translations
- Thermoelectricity Abstracts
- U. S. Government Research Reports
- Vacuum Abstracts
- Vertical File Index

Sources:

"A Guide to U. S. Indexing and Abstracting Services in Science and Technology," Nat'l. Fed. of Science Abstracting and Indexing Services, Washington, D. C., June, 1961.

J. T. Milek, "Abstracting and indexing services in electronics and related electrical fields," *Am. Documentation*, vol. 8, pp. 5-21; January, 1957.

sional society journals or publications by other organizations, which include references in addition to their primary content, the technical papers. However, there is no single title announcement or abstract service that provides complete and comprehensive current-awareness reporting of the entire field of electronics. In addition, there is no single index or reference publication that will permit relatively easy retrospective searching of the world's literature in electronics. Some cumulative indexes are available, but these are usually for a restricted amount of material and are seldom very timely. Fig. 3 shows, for example, the extent to which the indexing and abstracting services are covering the electronics field. The publication that provides the greatest number of electronics abstracts is the monthly *Electronics Abstracts*, a commercial service, providing an annual author index, publishing 10,000 abstracts per year from 300 journals, at a cost of 300 dollars per year.[9] Second largest coverage is obtained by *Electrical Engineering Abstracts*, a publication of the British Institution of Electrical Engineers, which published about 8500 abstracts in 1960.

The IRE, the largest electrical engineering professional society, and perhaps the largest technical society in this country with its current membership of about 100,000 members, is not providing the information services that it should. The IRE should provide a comprehensive abstract or title announcement publication and cumulative subject indexes to cover the world's electronics literature. The abstracts currently appearing in the PROCEEDINGS OF THE IRE, as well as their annual subject and author index, are copied and printed one month later from the British publication *Electronic and Radio Engineer*. However, this section covers only about 4000 abstracts per year, which is far from complete coverage of the world's literature.[10] These remarks are not meant to be critical of the compilers of this IRE Abstract and Reference Section. These compilers are selective, make no attempt to be complete in their coverage, and are restricted by monetary considerations as to how many citations per year they can publish. In 1960 the IRE Abstract and Reference Section covered about 25 per cent of the material published by the IRE.[11] The IRE does publish a cumulative author and subject index every five years, covering only papers that appeared in IRE publications. The IRE Professional Groups on Electronic Computers and Medical Electronics, with the publication of abstracts and citations in their respective TRANSACTIONS, have provided rather comprehensive coverage in limited subject fields, and for this effort their editors should be congratulated.

Special Information Centers

Information centers normally act as the custodians for the original source material, provide reference tools so that users may conduct their own literature searches,

[9] "A Guide to U. S. Indexing and Abstracting Services in Science and Technology," Nat'l Fed. of Science Abstracting and Indexing Services, Washington, D. C., Rept. 101, 79 pp.; June, 1960. See especially p. 52.

[10] For contrast, this 4000 abstracts per year for all of the world's literature could be compared with a forthcoming commercial publication that will provide 3600 abstracts per year for the computer field alone.

[11] E. K. Gannett, Managing Editor, PROC. IRE (private communication).

perform custom literature searches, and sometimes prepare analytical survey reports. Many of these information centers are federally operated, some are commercial ventures, and a few are operated by professional societies and other institutions.

There is presently no single library or information center where an individual can search the major portion of the world's literature in electronics. That is, there is no electronics equivalent of the National Library of Medicine or the Department of Agriculture Library. However, there are already approximately 500 special information centers in the United States, many of which represent subject fields of some interest to electrical engineers. Some special information centers of potential interest to the electronics field are given in Table V. However, many of these special centers, such as ASTIA, restrict their services to government agencies and Department of Defense contractors. The remainder of the centers are not in a position to provide much service to the electronics community in general. It should also be noted that each of the centers represents some narrow specialty field and that they are geographically situated in such a way that essentially all of the centers are east of the Mississippi.

The Chemical Abstracts Service will soon implement a computer searching system to perform literature searching and to help with the index publication for members of the American Chemical Society. Five years ago, the American Society for Metals took the initiative of starting a research project and pilot operation to determine whether the machine searching of metallurgical literature was feasible. It was, and the ASM currently provides a comprehensive literature searching service and current-awareness reporting service for the field of metallurgy, using the computer equipment at Western Reserve University. Starting in 1960, all of the 12,000 abstracts published each year in the ASM *Review of Metal Literature* will be encoded into the machine searching system.[12] Great benefits could be derived from a similar system established by the electrical engineering societies for the world's electronics literature.

The Engineering Societies Library in New York collects and catalogues literature from all fields of engineering.[13] The library facilities are available to the general public, but book loans are restricted to members of the 12 supporting professional societies. The IRE is not an Associate Society and does not contribute to the support of this library—consequently, IRE members are unable to borrow books from this library, although members of the AIEE can.

4. Recommendations

The IRE and the AIEE should initiate and continue a serious study of their own communications practices, and of the information requirements of their own members and other users. Such a study might be supported on a full-time basis in much the same manner as the Documentation Research Project of the American Institute of Physics is being supported by the National Science Foundation. A strong effort should be made to develop better reference tools and search facilities for the entire membership. More active working arrangements should be established with other technical publishers and information services to exchange abstracts and reviews, and to cooperate in the development of special reference tools. The electrical engineering professional societies must participate much more actively in the solution of the technical information problems than they have to date.

[12] M. R. Hyslop, "Metallurgical documentation from research to practice," *J. Franklin Inst.*, vol. 270, pp. 27-33; July, 1960.
[13] R. H. Phelps, "The Engineering Societies Library," *Am. Documentation*, vol. 9, pp. 165-167; July, 1958.

TABLE V

U. S. Science Information Centers of Potential Interest to Electrical Engineers*

Organization	*Main Subject Field*	*Location*
Acoustical Society of America	acoustics	New York, N. Y.
Advisory Group on Electron Tubes	electron tubes	New York, N. Y.
Advisory Group on Electronic Parts	electron parts and materials other than tubes and transistors	Philadelphia, Pa.
American Ceramic Society, Inc.	ceramics	Columbus, Ohio
American Chemical Society	chemicals	Washington, D. C.
American Electroplaters' Society	electroplating, metal finishing	Newark, N. J.
American Institute of Electrical Engineers	electrical and electronic materials	New York, N. Y.
American Institute of Physics, Inc.	physics	New York, N. Y.
American Physical Society	physics	New York, N. Y.

Table V continued (next page).

TABLE V (*Cont'd.*)

Organization	*Main Subject Field*	*Location*
American Society for Metals, Documentation Service	all aspects of metallurgy	Novelty, Ohio
American Society for Testing Materials	engineering materials and standards	Philadelphia, Pa.
Armed Forces Communication and Electronics Association	communications, photography, electronics	Washington, D. C.
Armed Services Technical Information Agency	all fields of technology	Arlington, Va.
Ballistic Missile Radiation Analysis Center	electromagnetic and acoustical radiation from ICBM's in flight	Ann Arbor, Mich.
Bush, G. F., Association	instrumentation	Princeton, N. J.
Derivation and Tabulation Assoc., Inc.	transistors, microwave tubes, semiconductor diodes and rectifiers	Orange, N. J.
Diamond Ordnance Fuze Laboratory	transducers for ordnance applications	Washington, D. C.
Electrochemical Society, Inc.	electrometallurgy, electrochemicals	New York, N. Y.
Engineering Societies Library	general science and technology	New York, N. Y.
Germanium Information Center	germanium	Kansas City, Mo.
Groth Institute	physical, chemical, and crystal-structural properties	University Park, Pa.
Gould-National Batteries, Inc. Research Center	electrochemical data, batteries and battery components	Minneapolis, Minn.
IGY World Data Center A Rockets and Satellites	all data from IGY rocket and satellite experiments	Washington, D. C.
IGY World Data Center A Aurora Instrumented	aurora data	College, Alaska
IGY World Data Center Aurora Visual	visual observation of aurora borealis	Ithaca, N. Y.
IGY World Data Center A Airglow and Ionosphere	ionosphere, airglow, and physical properties of the upper atmosphere	Boulder, Colo.
Infrared Information and Analysis Center	cryogenics, infrared technology, thermal radiation, spectra	Ann Arbor, Mich.
Instrumentation Abstracts	instrumentation	Evanston, Ill.
Interference Measurement Lab, Inc.	radio interference	Brooklyn, N. Y.
Human Engineering Information and Analysis Service	human engineering	Medford, Mass.
Library of Congress, Science and Technology Division	general science and technology	Washington, D. C.
MIT Engineering Library	general science and technology	Cambridge, Mass.
NBS Instrumentation Information Center	instrumentation	Washington, D. C.
NBS Research Information Center and Advisory Service on Information Processing	information processing, machine translation	Washington, D. C.
Project SETE, New York University	electronic test, checkout, and output equipment	New York, N. Y.
Radiation Effects Information Center	radiation effects	Columbus, Ohio
Radio Corporation of America	aviation electronics survey	Camden, N. J.
Research Triangle Institute	reliability	Dearborn, N. C.
Science Information Exchange	current scientific research projects	Washington, D. C.
Technical Information Corporation	electronic test equipment	New York, N. Y.
Tennessee Valley Authority	generation, transmission and marketing of power	Chattanooga, Tenn.
Thermo-Physical Properties Research Center	thermophysical properties	Lafayette, Ind.
Tungsten Institute	tungsten	New York, N. Y.
U.S. Dept. of Commerce, OTS	reports and translations of general science and technology	Washington, D. C.
U.S. Air Force, Air Info. Div.	aeronautics, electronics, space technology	Washington, D. C.
U.S. Air Force, Office of Science Research, Project ECHO	current research projects sponsored by the Air Force	Washington, D. C.
U.S. Patent Office	all issued U.S. patents and most foreign patents	Washington, D. C.
Welding Research Council	welding	New York, N. Y.
Yardney Electric Corporation	high energy, conversion systems, especially silver-zinc and silver-cadmium batteries	New York, N. Y.

**Sources:*

R. H. Phelps, "The Engineering Societies Library," *Am. Documentation*, vol. 9, pp. 165-167; July, 1958.

M. E. Fields, *et al.*, "Materials Information Centers," Wright Air Dev. Ctr., Wright-Patterson Air Force Base, Ohio, WADC Tech. Note 58-192, ASTIA AD-155 885; September, 1958. This report lists more than 100 information centers.

K. A. Winter and I. Lopatin, "Materials Information Centers," McGraw-Hill Book Co., Inc., New York, N. Y., WADC Tech. Note 60-246, ASTIA AD-259 318; February, 1961. This report lists 86 information centers.

"Interservice data exchange helps avoid test duplication," *Astro News*, vol. 2, p. 3; December 21, 1960.

"Specialized Science Information Services in the United States," Nat'l Science Foundation, location, NSF Rept. 61-68; November, 1961. This report lists 427 information centers.

"Coordination of Information on Current Federal Research and Development Projects in the Field of Electronics," U. S. Senate Committee on Gov't. Operations and its Subcommittee on Reorganization and Internat'l Organization; September 20, 1961.

*The Construction of Statistical Tables**

CHRISTIAN K. ARNOLD†

Summary—This paper outlines, in some detail, accepted rules for constructing statistical tables. Among the topics covered are the criteria for choosing vertical or horizontal presentation of information, use of rules, and table and column captions.

A TABLE is not simply a repository for raw data. It is a specialized form of communication that has distinct advantages over other communicative media for the presentation of certain types of information. Well-constructed tables make it easy for the reader to compare data and to draw conclusions quickly and accurately because they emphasize trends and tendencies. Tables present statistical information in a concise and orderly manner, and eliminate extraneous matter.

Because of the specialized nature of a table, its effectiveness depends largely upon its make-up. A poorly constructed table, like a poorly constructed paragraph, can contribute more to misunderstanding than to understanding, more to confusion than to elucidation. The following rules and suggestions are designed to aid in the preparation of forceful, clear tables.

Strictly speaking, there are few "rules" governing the construction of tables. There are, however, several widely accepted conventions that should be observed. Some of these are based upon limitations imposed by the printer's art, some of them are firmly grounded on sound principles of exposition, others are undoubtedly the result of imitation and prestige or are rooted in mechanical restrictions that no longer exist. These conventions, whatever their origin, are so well established that they should not be violated.

General

The nomenclature and general layout of a table are shown in Table I. The terms "column caption" and "column heading" are used interchangeably. The double-ruled lines separating the column captions from the body of the table and the single line setting off the stub form

*Received June 9, 1961.

†Association of State Universities and Land-Grant Colleges, Washington, D. C.

TABLE I

Nomenclature for the Parts of a Table
(Subtitle in initial cap and lower case)

Stub Heading[a]	Column Caption	Column Caption	
		Subcaption	Subcaption
Line Heading			
Subheading	Tabulated Data (Individual positions in the body are called "cells.")		
Subheading			
Line Heading			
Total			

[a]Table footnotes.

the axes of the table. Data arranged vertically are said to be in columns, those arranged horizontally, in lines or rows.

There are two general "design objectives" that should govern the construction of every table: 1) every table ought to be a self-contained, self-explanatory unit, and 2) every table should be as simple as it is possible to make it.

It is not always possible to achieve the first of these objectives. In many tables, it is impossible to give enough information in the title, subtitle, and column and stub headings to make them completely self-sufficient. However, there are sound reasons for this objective. In the first place, a table cannot always be placed on the same page with the textual material that explains it. To permit this partial dissociation of the table and text, a table must be at least reasonably self-contained. In the second place, a table is often made to do double—or even triple or quadruple—duty. It is, however, expensive and inefficient to repeat the table every time a need to refer to it arises. Consequently, tables are numbered to obviate the repetition of the table, and this further dissociation of table and text increases the need for self-containment.

The need for simplicity is obvious, but this "rule" is often violated, usually because the author fails to consider the position of the reader unfamiliar with the material. A table that is crystal clear to the author who is familiar with the data it contains may easily be confusing to the reader unfamiliar with the data. For this reason, it is often better to present a mass of data in several small, simple tables than to crowd it into one large table. In any event, every table should be made as clear and simple as possible.

Title

Every formal table must be given a number and title and must be referred to in the text. As shown in Table I, the number and title of the table are placed above it, as opposed to the number and title of a figure, which are usually placed below the figure. Tables are numbered consecutively throughout the article, chapter, or report in the order in which they are mentioned. Sometimes the word "Table," followed by the table number, a period, and the title are centered above the table. Sometimes, "TABLE____," in capital letters, is centered above the title, which, in turn, is centered above the table. In either case, the title is punctuated internally but is not followed by a period. If a subtitle, or headnote, is used, it is set apart from the title by smaller type, italics, or parentheses. Again, it is punctuated internally, but is not followed by a period. It is centered below the title.

The title should be a clear, concise, and complete description of the material contained in the table. Because of the importance of the first word in any statement, the *what* of the tabular material should be placed first in the title. The *what* is usually followed by the *where* and *when*, if this information is necessary. Secondary information, that is, information applicable to all material in the table but not necessary for the identification of that material, is placed in the subtitle if its inclusion in the title results in a long or awkward phrase. Information of this sort includes units of measure used throughout the table, general restrictions and limitations, and sources of information. Information contained in the title and subtitle should not be repeated in the column and stub headings, which are the proper places for detailed classifications. The phrase "Table I. Showing . . ." should not be used in the title or subtitle; it may be presumed that the table shows that which is in the table.

Column Captions and Line Headings

The wording and arrangement of the column captions and line headings contribute more than anything else to the effectiveness, or lack of it, of a table. Each column must have a caption that concisely and concretely describes or names the data contained in the column. Similarly, each line (or group of lines) must have a stub entry that concisely and accurately subdivides or classifies the data. A period is not placed after these headings. Grammatical parallelism should be observed throughout the captions and the line headings; this rule is best met if all heads are made to consist of nouns and noun phrases.

Column headings are centered both vertically and horizontally in their boxes. If, because of the length of a column heading, it must be placed sideways on the page, it must be made to read from the bottom, that is, from the body of the table. If one column head in a table must be placed sideways, all column heads in the same table should be written in the same manner. Sideways placement of heads is to be avoided whenever it is possible to do so.

Line headings are aligned on the left within the stub, except for numbers, which are aligned on the right. If a stub entry is used to classify the data of several rows, it is centered vertically within the space occupied by the rows. If there are subentries for the line headings, these subheadings are indented from the margin established by the alignment of the headings. The headings "Total," "Mean," "Average," and the like are also indented the same amount. The stub heading must classify the line headings. It should never be used to introduce the column captions. This rule is often violated.

The single most important principle to be observed in the arrangement of column and stub entries is that figures to be compared should appear in columns and not in rows. There are two sound reasons for this rule: 1) it is far easier to compare figures aligned vertically than those aligned horizontally and 2), because figures to be compared normally have about the same number of digits and are of the same degree of accuracy, the vertical alignment of such figures simplifies the typing problems and results in a neater table than would otherwise be possible.

This rule should always be used in determining which of the classifications are to appear as column captions and which are to be line headings. This selection is often completely automatic; it follows directly from this rule that classifications containing units of measures should always be column captions. In the construction of tables in which none of the classifications of data must be qualified by a unit of measure (for instance, tables in which the same unit of measure is used throughout and is therefore given in the title or subtitle), the author should decide his basic arrangement carefully to emphasize the point he is attempting to make. In Tables II and III, for instance, only one unit of measure is used throughout each table, and the arrangement depends upon the comparison desired. In Table II, the increase in hit probability resulting from the addition of torpedoes in the salvo is emphasized; in Table III, on the other hand, the influence of the lead angle on the hit probability of a salvo is emphasized.

The stub, in other words, should not normally be used to name the data contained in the table but, rather, should be used to name the classifications in which the data appear. *Figures to be compared should always appear in columns!*

Within this broad framework, both the column captions and the line headings should be ordered on the basis of some apparent and logical arrangement. This arrangement may be alphabetical, geographical, temporal, or quantitative, or it may be ordered to demonstrate relations of data within the table. The arrangement should never be haphazard. It is not enough simply to get all classifications accounted for; they should be consistently ordered on the basis of some logical plan. If a temporal ordering is observed, columns should read progressively from left to right, with the latest date on the right. There is no fixed convention for the stub; the latest date may be either at the top or at the bottom. In either case, the ordering must be progressive; data might better be lost outside a table than inside it.

Subcaptions and subheadings should be used whenever it is possible to group classifications of data. This

TABLE II

Influence of the Number of Torpedoes on the Hit Probability of Salvos of Straight Running Torpedoes

(Maximum probability = 1.00)

Number of Torpedoes in Salvos	Lead Angle (deg.)		
	45	90	135
1	0.37	0.55	0.64
2	0.54	0.77	0.66
3	0.64	0.78	0.77
4	0.80	0.96	0.89

TABLE III

Influence of Lead Angle on the Hit Probability of Salvos of Straight Running Torpedoes

(Maximum probability = 1.00)

Lead Angle (deg.)	Number of Torpedoes in Salvo			
	1	2	3	4
45	0.37	0.54	0.64	0.80
90	0.55	0.77	0.78	0.96
135	0.64	0.66	0.77	0.89

practice saves space, improves the appearance of the table and makes it easier to read. Typical column groupings are shown in Tables II and III. Stub groupings may be accomplished in one of two ways: 1) the line heading may be given subheadings, as shown in Table IV, or the line headings may be made to serve several rows of data (Table V).

Abbreviations may be used somewhat more freely in tables than in text. In fact, even the per cent sign and the degree symbol are tolerated in tables when space limitations demand their use. If abbreviations are used, they should be used consistently and uniformly throughout the one table. No abbreviations should be used unless the space saved through their use is actually needed. Units of measure must always be given, either in the title or subtitle or in the column headings. Even though the reason for this rule is obvious, units of measure are often carelessly omitted.

Footnotes are numbered or lettered consecutively beginning with the title, proceeding through the column captions from left to right, and then moving down the line headings. They should be used as seldom as possible. The footnote itself appears directly beneath the table and not at the foot of the page unless the bottom of the table coincides wih the lower margin of the page. No text material should stand between a table and its footnotes. It is often better to use lower-case letters as footnote symbols than to use numbers, because numbers can sometimes be confused with the numerical data in the

TABLE IV

Physical Characteristics of Selected Woods[a]

Type of Wood	Weight (lb/cord)		Heating Value (Btu/lb)	
	Green	Air Dried	Green	Air Dried
Oak				
Red	5800	3900	3379	5564
White	5600	4300	3972	5558
Maple				
Sugar	5000	3900	4080	5590
Red	4700	3200	3745	5969
Pine				
Yellow	3100	2300	7090	9174
White	3300	2200	4226	5864

[a]Based on Data Given in U. S. Dept. of Agriculture Bull. No. 7530.

TABLE V

Change-of-State Characteristics of Selected Substances

Type of Substance	Substance	Boiling Point (deg F)	Latent Heat of Vaporization (Btu/lb)	Melting Point (deg F)	Latent Heat of Fusion (Btu/lb)
Metallic Element	Bismuth	2606.0	–	514.4	22.8
	Mercury	674.6	117.0	−38.2	5.1
	Platinum	7070.0	–	3191.0	49.0
	Silver	3551.0	–	1761.8	37.9
Nonmetallic Element	Argon	−303.0	–	306.4	–
	Bromine	141.8	82.1	18.9	29.2
	Iodine	392.0	42.3	236.3	21.1
	Sulpher	600.8	651.6	239.0	16.9
Organic Compound	Acetic acid	244.4	152.8	62.0	–
	Benzine	176.3	167.2	41.8	–
	Ether (ethyl)	94.3	159.1	−180.4	–
	Toluene	230.5	154.8	−133.6	–

table. Numbers are always written as figures in footnotes to tables, even those standing at the beginning of sentences, except for fractions standing alone at the beginning of a footnote, which are to be spelled out.

Body of the Table

All tabulated material is as nearly centered in each column as the rules for aligning will permit. Whole numbers are aligned on the right, and no decimal point is placed after them unless it is necessary to add zeros to indicate the proper degree of accuracy. Numbers containing decimal fractions are aligned on the decimal points, and zeros are placed before the decimal points or numbers less than unity. A uniform degree of accuracy (that is, the same number of decimal places) should be maintained throughout each column, but only as many significant digits should be used as the precision of the data justifies. If these rules conflict, that is, if it is necessary to use a varying number of decimal places to indicate the proper degree of accuracy in a single column, it is a strong indication that the table needs to be revised.

The numbers in columns of mixed numbers containing common fractions or mixed (common fractions) and whole numbers are aligned on the right of the whole numbers. Decimal indications should be used in tabular work rather than common fractions whenever it is possible to do so.

Double numbers are aligned on the separating symbol: ±, *to*, the dash, or the like. Symbols that precede numbers ±, +, or —) are placed close to the number on the left regardless of their alignment.

Reading columns (columns in which words, phrases, or sentences appear) are aligned on the left, and run-over lines are not indented. Grammatical parallelism must be maintained throughout the entries of a reading column. No initial capital letter or concluding period is used unless the entry makes a complete sentence.

The same unit of measure must be used throughout each column. The reason for this rule is obvious: the reader cannot make an accurate comparison quickly unless it is observed. Yet in many tables, ohms are mated to megohms, feet are placed next to inches, and seconds

TABLE VI

ACCIDENTAL INJURIES BY SEVERITY OF INJURY, 1952[a]

(*Source:* National Safety Council approximations)

Severity of Injury	Total	Motor Vehicle	Public Non-motor Vehicle	Home	Occupational
Deaths	96,000	38,000	16,500	29,000	15,000
Permanent Injuries	350,000	110,000	50,000	110,000	85,000
Temporary	9,250,000	1,250,000	2,000,000	4,200,000	1,900,000
CERTAIN COSTS OF ACCIDENTAL INJURIES					
Wage Loss	$3,000,000,000	$1,200,000,000	$550,000,000	$500,000,000	$850,000,000
Medical Expense	600,000,000	100,000,000	110,000,000	180,000,000	220,000,000
Overhead Cost of Insurance	1,300,000,000	950,000,000	10,000,000	10,000,000	320,000,000

[a]Taken from "The World Almanac," The New York World-Telegram, New York, N. Y., p. 306; 1954.

TABLE VII

ACCIDENTAL INJURIES IN THE UNITED STATES, 1952[a]

(*Source:* National Safety Council approximations)

Type of Injury	Number by Severity of Injury (thousands)			Cost (millions of dollars)		
	Death	Permanent Impairment	Temporary Injury	Wage Loss	Medical Expense	Overhead Cost of Insurance
Motor Vehicle	38.0	110	1250	1200	100	950
Public Nonmotor Vehicle	16.5	50	2000	550	110	10
Home	29.0	110	4200	500	180	10
Occupational	15.0	85	1900	850	220	320
Total[b]	96.0	355	9250	3000	600	1300

[a]Adapted from "The World Almanac," The New York World-Telegram, New York, N. Y., p. 306; 1954.
[b]Figures are rounded and do not necessarily add to totals.

and minutes set up housekeeping together. Convert them to one or the other.

Omitted or missing data are indicated by a dash centered in the cell rather than by a zero, the word "none" or simply a blank cell (Table V). Unnecessary zeroes should be omitted. This practice makes for a neater table and facilitates comparisons.

Table VI contains several serious errors. For one thing, unnecessary zeros are included. The title is not sufficiently broad to include the "Cost" half of the table, nor does it limit the data geographically. In fact, the cost part of the table is not at all integrated with the top half. The faulty title forces repetition of the phrase "Severity of Injury" in the stub of the top half, whereas there is no stub heading for the bottom half. The line headings in the first half are not in parallel construction, mixing an adjective in with two nouns. The unit of measure for the data contained in the top half is at best implied and is nowhere stated. The unit of measure for the entries in the second half, because of faulty integration, is forced from the column captions into the columns themselves. The arrangement forces a comparison of basically dissimilar items. The "Total" column is misplaced, and no explanation is given for the fact that the line entries do not always add up to the sums given in this column. All these errors are corrected in Table VII. Notice the inclusion of zeros in the "Death" column to maintain a uniform number of significant digits throughout the column.

Use of Rules

The use of rules is governed by clarity, appearance, and cost. Undoubtedly clarity and perhaps appearance are best served by the completely ruled, completely boxed table, but cost considerations often force a compromise, especially with letterpress printing processes.

The completely ruled table is framed with a single rule. A double rule is used to separate the body of the table from the stub heading and column captions. All columns and the stub are ruled with a single vertical line.

Ruling in the column captions should be arranged to show clearly the subdivisions of the data. No horizontal rules should be used in the body of the table except when the line headings are made to serve several rows of data. In such an arrangement, horizontal rules are used to set off the groupings, since the groups of rows become, in effect, horizontal columns. In long tables in which this arrangement is not used, the data are grouped arbitrarily (in groups of three, four, or five) as an aid to the reader in aligning the data in rows, but horizontal rules are not used.

A double vertical rule is used in only one situation: when the stub is repeated (that is, when a long, narrow table is "doubled up" to conserve space and to improve the appearance of the table). The second stub is then separated from the last column associated with the first stub by a double vertical rule. A horizontal rule is not used before the "Total" row. Indentation of the line heading and distinctive spacing set it off clearly enough.

Such tables are easy and inexpensive to achieve with photo-offset printing processes, but the expense and difficulty of obtaining the vertical rules usually make them impracticable when letterpress printing is used. A practical compromise is shown in Table V, where the table is enclosed at the top with a double horizontal rule, a single rule separates the stub head and the column captions from the body and encloses the table at the bottom, and all vertical rules are eliminated.

The limitations of this format, however, must be taken into consideration. To be clear, a table constructed without vertical rules must be made relatively simple, and the possibility of employing subcaptions is almost completely eliminated. In addition, data must not be crowded in such a table. A table is not a storehouse; it is a graphic form of communication. If it is not easy to read, a large part of its usefulness has been dissipated.

Informal Tables

The informal table provides a useful form of tabulation midway between the text statement and the formal table. An informal table should be used whenever the tabulation is very simple (consisting of not more than a stub and one column; tabulations consisting of more than one column should be made into formal tables) and is easily incorporated into the sentence structure.

The informal table forms a part of the sentence structure. It is, therefore, incorrect to insert such a table after a sentence completed with a period. Because it is part of the sentence structure, an informal table is not numbered and is not given a title; the information that is normally given in the title is given in the text material introducing the table. Since an informal table is not numbered, this form must not be used for tabulated material that is referred to more than once in the text. An informal table must appear directly below the sentence introducing it.

The stub heading and column caption, including the unit of measure in parentheses, if it is not given in the introductory sentence, are underscored or italicized, but no other rules are used in informal tables. Leaders may be used to aid the eye of the reader. All rules governing centering and aligning are to be observed.

The following illustration shows the correct form for the informal table.

The approximate values of surface tension, based on measurements at ordinary room temperature, for certain selected liquids in contact with air, are as follows:

Liquid	*Surface Tension (dynes per centimeter)*
Benzene	29
Glycerine	63
Mercury	470
Water	75.

Tables and Graphs

Some confusion apparently exists in the use of tables and graphs. At least material is often presented in a graph that should be presented in tabular form. Data not continuously distributed cannot logically and accurately be presented graphically but can be properly presented in tables or bar charts.

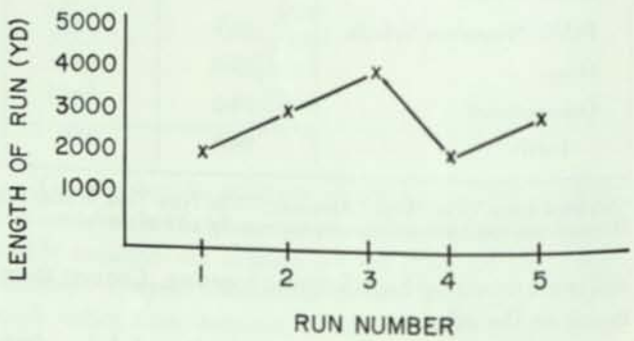

Fig. 1—Lenth of run for torpedo No. 121309.

For example, the graph presented in Fig. 1 is misleading and inaccurate. The continuous line indicates, for instance, that the length of run No. 1½ would have been 2500 yards. This indication, of course, is false. The information could have been presented accurately in a bar chart or a table such as the following:

The length of each run made with torpedo No. 121309 is as follows:

Run Number	*Length of Run (yd)*
1	2000
2	3000
3	3600
4	2000
5	3000.

Technical Writing in Industry: Technique and Morale *

B. C. BROOKES†

Summary—The author draws upon his experiences in teaching report writing in industrial organizations to illustrate some factors, other than the technique of the authors, which can seriously affect the quality of written reports. These factors include unsuitable working conditions, vagueness of specification, slow editing, denial of responsibility, criticism of trivia, and the constant attempt to simplify all things, however complex.

In recent years I have had the opportunity of studying in some detail the writing of technical papers and reports in a number of industrial organizations. My introduction to the organizations has usually been by way of a request to give a course on report writing or some closely allied subject. Before I consent to give such a course I always ask to see a sample of the papers or reports which are alleged to be unsatisfactory and, whenever possible, I meet the senior members of the organization whose complaints about the reports they receive have led to the call for remedial action. On examining the sample of papers I usually find overwhelming evidence that something is wrong. And the senior members of the organization who make the complaints have no doubt whatever that the very real faults of which they complain are wholly the responsibility of those who write the offending documents.

*Reprinted from Group Paper No. D.G.18, presentation of Technical Information Group, London, England.

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But, as my experience of this kind of situation has widened, I have come more and more clearly to realize that the situation in which bad report writing occurs is likely to be more complex than appears at first sight, and the possibility of there being factors other than the incompetence of the authors must be considered. If any other factors emerge from my investigation, then of course the faults that have been complained of cannot be wholly remedied by the giving of a course of report writing to the offending authors. Some additional action will be needed to remove the other causes of the trouble—the giving of a course of report writing alone might even exacerbate the difficulties.

So now, when I am asked to give a course of report writing in some industrial organization, I immediately become what Pope has called "a sly, slow thing with circumspective eyes." Obviously, if I can see that the situation is one which cannot be remedied simply by the giving of a course of report writing, then it would be both dishonest and foolish of me to offer a course with the implication that my treatment should effect a cure.

So I try to discover if there *are* other difficulties and, if so, what they are; I then have to assess whether it lies within my competence—or within my discretion—to suggest how the difficulty may be overcome. Should the evidence suggest, for example, that a complete solution would have to include the resignation of the managing director, then I have to regret that I am much to busy to give an outside course of report writing. Unfortunately, my preliminary studies cannot always be comprehensive and it may happen that it is only during the actual course itself that the full complexities of the situation emerge.

To put it another way, I have been forced to regard complaints about the technical writing within an organization as possibly symptomatic of some deeper malaise and thus to regard the situation pathologically. It is then my task to diagnose the trouble as accurately as I can and either to suggest a remedy or to admit that the case is incurable without drastic surgery. The lesson I have learned is that one cannot cure a spotty disease like measles simply by trying to rub out the spots. But my main difficulty in this work is that everyone else seems to be certain that measles can be cured by rubbing out the spots, and that anyone who cannot cure it that way is just no good at rubbing out spots.

My difficulties are best explained by descriptions of some actual cases. The descriptions will have to be simplified to highlight the particular aspects I want to bring to your attention and, of course, as my information is confidential, I must alter the descriptions so that the organizations cannot be identified—except possibly by those who belong to them. I will give a name to each case to make our discussion easier.

One further point is that the authors I am concerned with are not full-time technical writers, but engineers and scientists of various kinds whose technical and scientific work includes the writing of critical and objective accounts of their activities only from time to time.

I will first outline four illustrative cases and then discuss them in terms of the factors that can be isolated and identified. We shall find that the same factors may enter into more than one of the cases, and that all these factors are ultimately related to morale.

Case No. 1. The Manager Who Got Full Marks

My first doubts about the efficacy of the straightforward report writing course alone arose during a course I gave to senior engineers. The course consisted of lectures and group discussions, exercises and individual tutorials. One member of the course brought along his exercises for critical discussion at the tutorial but offered no point of criticism at all—a situation disturbing to a teacher! And the third time this happened, at only the third tutorial, I had to say that as he had got full marks so far I did not understand why he had bothered to come on the course and do his homework so punctiliously.

He replied that he was gratified to hear the compliment to his skill as a technical writer—he had cultivated the art for many years—but his reason for coming on the course was that he was very anxious to learn how to teach others. His real difficulty was not that he himself could not write tolerably well but that he had to write all the reports that emanated from the department of which he was manager. For years he had tried and failed to teach his juniors, but the young men of his department seemed to know nothing of English—he couldn't imagine what was done in schools nowadays—but what was worse, they did not seem to have the slightest shame in presenting the most illiterate documents for his approval. The result was that he had to spend more and more time, more time than he could afford, correcting their drafts. The department was growing, his responsibilities were increasing, and yet he had to devote himself to chasing details like commas and split infinitives when he should be pursuing the higher things with which senior management concerns itself.

Gently but persistently I elicited further information from him, trying to see what the situation looked like to the younger members of his department. He invited me, of course, to give them a course on report writing.

One can, I think, easily imagine the vicious circle that had become established in his department. A junior member would write a draft and pass it to the manager for approval, but however hard the junior had tried his chief would always be able to find some points to criticise. The drafts were never quite good enough. It is always possible to find fault if one wishes to, and the "manager with full marks" wanted to find fault. It was his way of asserting his authority and maintaining his position.

So he never fully explained to his juniors exactly what he wanted and they were unable to find the answer from experience, by trial and error, because everything they wrote was equally faulted. Gradually the young men had ceased to try to please their chief. As he was bound to alter everything they wrote, he might as well, from their point of view, alter their first draft as their second, their first rough notes as their first draft—and so on. The worse the document presented to him the more he enjoyed himself, angrily complaining and rewriting it, while the junior staff could devote themselves to less strenuous activities than composing reports.

In this group no one had any incentive for breaking out of the situation thus created until the manager himself realized that he could no longer cope with his growing responsibilities.

This case illustrates a situation which is more common in industry than it ought to be—a compulsion to correct, an absurd fussiness about the details of other people's writing, which leads eventually to the utter frustration of those who are supposed to do the writing. No course of report writing, however necessary it may seem to be on looking at the documents produced by the young authors, can by itself correct such a situation.

Case No. 2. The Manager Who Kept the Boys Busy

In this case the work of the department was to provide an investigation and advisory service to customers of the parent company, a company interested in heavy machinery. When a customer asked for technical help, or complained of difficulties arising from his use of the company's products, the manager would send along to the customer one of the members of his staff to investigate the difficulty on the spot. The staff consisted wholly of engineers of various kinds—all of whom I met, and all of whom appeared to be well qualified, practically and academically, for their work.

Their investigation of a complaint might take an hour or two, or it could take days. The investigating engineer would of course report progress by telephone from time to time and would eventually return to the office to make a report—orally if urgent action was needed, but always in writing in due course.

The writing of the full report expected by the manager could be a difficult task. The engineer had to describe how he had come to diagnose the trouble and what remedies he had proposed; he had to discuss any difficulties that remained and to report on any unusual aspects he had observed. Copies of his report would eventually be sent to the technical sales department who wanted to be forewarned of possible new troubles arising from the company's products, to the development department who wanted to learn of any shortcomings in the company's products that indicated a need for improved specification, and to the research department who wanted to hear of any unusual features worthy of laboratory investigation. The report was therefore addressed to technical men demanding detailed and accurate descriptions of the difficulties in precise technical terms. Such reports from the field were considered by the company to be a valuable source of technical and commercial information.

I was called in to this department because the manager complained that the draft reports he received were not as good as they ought to be. He rightly demanded a high standard of presentation with a logical development of the argument, a critical analysis of the problem, and clear assessments of the difficulty accurately expressed in technical terms suitable for the three different readers. The samples of drafts he showed me certainly failed to meet his specification. They were scrappy, casual, and obviously hastily written.

It was only during the report writing course itself that the main source of difficulty became clear. I found that the young engineers on the whole knew how to write, that they knew what they were writing about, and why they were doing it; they were able to correct the specimen drafts we used as exercise material with little help from me. But the difficulty was that in normal working hours they were *allowed no time* in which to do their writing.

The manager, a dynamic personality with many years of experience of this work, could not bear to see the young engineers sitting at their desks in his office and apparently not operating. For him, a man sitting still and not actually writing or telephoning or pushing his slide rule was clearly a man waiting to be sent out on his next assignment—and out on his next assignment he was sent, whether the report on his previous assignment was completed or not.

But even if the young man knew how to look busy and was not sent out immediately again, there was little hope of his being able to write a coherent report in that office, a large open office with engineers, secretaries, technicians and the boss himself milling around amid a clamor of telephone bells, telephone talk, and rattling tea-cups. I soon discovered that a young engineer would only rarely attempt to write his reports in the office. His reports were written as opportunity offered—in trains, in cars, in cafés, in pubs, and often at home after the children had been put to bed and while his wife enjoyed television.

In this case everyone knew what was wanted but the required reports were not written simply because neither time nor place were allowed for their composition. Fortunately the manager was able to appreciate the situation when it was pointed out to him and he agreed to equip a writing room for the authors of reports—a quiet room with the necessary reference books at hand, a sanctuary where they could work without being disturbed by telephones, colleagues or secretaries, and without their pauses for thought being observable by himself.

Since this case I have visited other organizations and have noticed the same kind of difficulty, offices in which technical authors must obviously find it impossible to feel that detachment from the immediate job, or to hope for that freedom from interruption for an hour or two that is strictly necessary for the composing of a report of any technical complexity and informative authority. Ample time and ample facilities are provided for the practical side of the work everywhere, but the time and facilities needed for reporting on it adequately are disregarded or dismissed as unnecessary. Even in University College it sometimes seems that a man with a pneumatic drill and some high quality concrete always has priority over the man who merely wants to read or write.

It becomes increasingly important that we learn individually to concentrate our mental energies while surrounded by distractions and battered by noise and at the same time to write both well and quickly. But meanwhile the lack of adequate time and reasonable facilities for writing seems to be, curiously enough, a cause of the demand for report writing courses.

Case No. 3. The Scientists Who Talked to Themselves

In the third case I visited a department of a large organization—a department again concerned with problems which arise in the field. The young scientists and engineers who did the field work seemed to be well-qualified both practically and theoretically for their work. A single investigation might take several months, but again ample time was allowed for the field visits and for the practical work these visits entailed. Here, further, the manager appreciated the difficulties of composition and the young scientists had fairly good physical conditions in which to work—small separate offices in a new building.

But these scientists too were in trouble with their reports. I asked as usual to see a sample and found that in detail, in texture, the reports were on the whole much better written than most that come my way, though some faults were to be seen. But there were more serious faults. The reports were very long, rather complicated in structure, and very difficult to grasp as a unity. They looked indigestible and they certainly were. Who read them?

Formally the reports were addressed to a senior member of the organization, and usually copies were sent to units in the field where the investigation had been made. But it was difficult to imagine any reader or readers anxiously awaiting the publication of these weighty documents.

I then discovered how the reports came to be written and published. The investigator would prepare a draft. The draft would be submitted to the section head. The section head would normally make some criticisms and send it back. The corrected draft would then be submitted to the group head. The group head would normally make some criticisms and send the draft back down along the line. When the group head had been satisfied, the corrected draft would then be sat on by a committee of three group heads who again would make criticisms and send it back to the wretched author to correct again. Eventually the head of the department would approve the report and it would be published. Elaborate as the procedure may sound, I have in fact simplified it in my description.

As, of course, all the members of the department were out in the field for a large fraction of their working time, this internal editing process could easily take a year to grind through its motions. And so, if the draft report had any coherence and unity as a first draft, it soon lost it as the series of editors suggested the inclusion of this and the exclusion of that, the expansion of one section and the rearrangement of another, and so on. Meanwhile the miserable authors became more and more bored with this long-winded procedure, and more and more reluctant to spend any more care on the report as it became less and less recognizable as the job they set out to do. And during this lengthy process, of course, they had taken on other practical jobs; their memory of the details and background of the work reported in the draft was steadily fading and their interest in it rapidly waning.

But why had this elaborate editing system arisen? In pursuing this question I felt as my colleagues in the Department of Anthropology at University College must feel when they try to trace the origins and interpret the symbolisms of primitive fertility rites. What happened to their reports when they were eventually published? There was, of course, the usual standard distribution to senior members of the organization and to the few units in the field directly concerned with the work. But no one seemed to ask for extra copies and—most important of all—nothing ever came back. No one ever commented on their reports, no one ever thanked them, no one they met ever seemed to have read them, no one ever even told them how awful they were. There was just a cold stony silence—and they felt the silence. It could only mean, they felt, that their reports were not very good after all, that they needed more careful grooming, more correcting, more editing, more rewriting. Slowly the complex editing system was built up. Over the years their reports got steadily bigger and better, more and more divided into subsections, sub-subsections and innumerable appendixes—in short they became more and more unreadable, more and more useless.

My main task here was to persuade them to shorten their reports, to simplify and accelerate their editing system, to forget about the very senior members on the distribution list and to write for the practical men out in the field who could apply their findings directly. Happily, and with the full approval of the head of the department, this they agreed to do.

This case again illustrates a fault observed in other organizations, especially where work of high scientific quality is being done. The final published reports may be more readable than they were in this particular case, but too often in striving to attain an unattainable perfection, the effort of writing and editing and rewriting and re-editing is out of all proportion to the improvement obtained or obtainable. As often as not the extra effort produces a poorer result, an out-of-date forlorn sort of report that slumps to a soggy end, buried in the bottom of the pending trays of those to whom it has been dispatched. Such a system again produces frustration for the authors, a growing distaste for a task of writing which produces only endless and seemingly pointless criticism from within the department and not a whisper of response from outside. It makes of report writing an unfathomable, ineffable mystery of almost theological subtlety.

Case No. 4. The Manager Who Wanted It in a Nutshell

This is the story of a case taken from my current files.

The call for help came from the head of a small research section of a large company which manufactures what may be called electronic devices. The research done by this small section is fundamental and long-term—far removed from the kind of industrial research which is closely tied to the immediate development of the company's products. The company, of course, has a large department for research of this more immediate kind, but we are not here concerned with that work. The members of this special fundamental research group consist mainly of mathematicians, possibly an electrical engineer or two, and—to my surprised delight—a philosopher, an expert in symbolic logic.

So far I have only been able to make a light reconnaissance of the situation. I have studied some reports and have heard some of the complaints made about them. I have met the head of the research group itself—let us call him the manager—and have also met the senior to whom he reports—let us call him the senior manager.

The specimen reports are well written in the sense that their material is well organized, developed and displayed. The only faults noticed at a first reading were relatively trivial faults of texture which could possibly be dismissed as arising from differences in taste. But then, of course, I did not understand what these reports are intended to do. Their contents can be broadly described as involving modern and advanced techniques, mainly mathematical and statistical, and with detailed analysis; for industrial reports they are highly theoretical.

It may not now surprise you to hear that the difficulty about these reports is that no one outside the research group can understand them, and that the *senior* manager responsible for the group finds it difficult to tell *his* superiors what the group is doing. Why can't they just tell him in simple terms—in a nutshell—what it is all about?

Here again is a situation which is more common in industry than it ought to be, especially in research departments. The predicament is this: On the one hand, young men are appointed to do serious specialist scientific work; they are appointed to do this work because they are the best specialists in their particular subject that the company can attract. They accept the appointments believing that they will be able to devote themselves wholeheartedly to their scientific pursuits, that they will be allowed to continue working with that single-mindedness of purpose that enabled them to become the experts the company needed.

On the other hand, the senior manager's task is to interpret the group's work in terms intelligible to his senior colleagues and especially to indicate the commercial implications of their work. Obviously the work of this special research group has a bearing on the company's long-term commercial and financial policy; and the more accurately the company can estimate its long-term policies, the more confidently it can deal with current financial problems. So there is constant pressure on the research group to explain itself in commercial terms.

Unfortunately, the members of the research group are not able to explain themselves in commercial terms; if they could, they would not be the specialists they are and must be to do their research job. Unfortunately, too, the senior men, though some of them may have had some technical training, and though they must all have some technical knowledge of the company's products, cannot understand the reports published by the research group, nor can they hope to.

So here we have, in effect, two groups, highly dependent upon each other, with a communicative gap between them. At present there is goodwill on both sides because the problem is only just beginning to emerge, and to be felt. Obviously, however, a solution must soon be found or there will be another case of frustration. Difficult as this communicative task is, it becomes much more difficult to achieve satisfactorily if the information has to be put in a nutshell.

That case completes my illustrative case-studies. Let me stress again that I have simplified the stories in order to highlight particular difficulties and that no one of them is unique but merely illustrates, in black and white, situations that I find widespread throughout industry in all shades of grey.

Now let me briefly analyze the main faults as I see them, the factors of which, other than the technique of the authors, seriously affect the quality of written reports.

The most obvious one is:

1. Unsuitable Physical Working Conditions

Recently I visited a foundry in which nonferrous metals are cast. My mental image of a foundry, until I visited this one, was of a dark and dusty interior excited by sudden outbursts of molten brilliance as quickly dimmed by clouds of fumes. But this foundry was light and airy, sunlit and clean, and, as the foreman proudly said, one could have eaten one's dinner off the floor. These are the kind of conditions that manual workers are beginning to demand and to get; and there is a phalanx of factory inspectors to see that employers maintain minimum standards. What I would like to see now is equal attention being given to the offices in which young men are expected to write their technical reports; or preferably perhaps I would like to see writing rooms set aside for this purpose, rooms equipped with the necessary reference books and documents and soundproofed against the peremptory clamor of telephone bells. The cost? About the cost of a report writing course. But its effects would be more permanent.

Bad writing conditions are not good for the scientific author's morale.

2. Vagueness of Specification

Often when I have given a course of report writing I realize at the end that all I have done is to have helped the members of the course to discover for themselves *what* they should write and what their purpose in writing is—not *how* to write, for that I find they can usually do.

When the senior members of a firm complain about the quality of the reports they get from their juniors, what they mention are the minor faults of texture that arise from the author's uncertainty of purpose, but what they are really complaining of is that the young men with one, two or a few years of experience, perhaps in a single department, do not understand the whole business of the company, its policies and its personalities, as they, the men of forty years' experience of it do. In effect they expect a three-day course of report writing to give the young men the same insight into the company's affairs as they themselves have. It doesn't.

Often I have to explain patiently to the seniors that their young men can learn to look after the commas and split infinitives themselves but that they would appreciate more guidance on the scope and structure of the papers they are asked to write and the purposes they should try to fulfill. It is often uncertainty of purpose that leads to the uncertainty of punctuation and the other trivial faults the seniors focus on.

Too often the formula seems to be, "Jones, will you write up that work you did on so-an-so?" Such a specification is too vague. It is as practical as going into a hardware shop and saying to the assistant, "I want a spanner." "What sort of a spanner?" "Oh, just a spanner," and then complaining if the ⅞″ Whitworth or whatever you had in mind isn't promptly put in your hand.

Vagueness of purpose is bad for the scientific writer's morale.

3. Slow Editing

My interest in any paper I am writing wanes very rapidly after completing what seems to me to be a satisfactory version. Perhaps I suffer from a one-track mind. But can you expect an author to be enthusiastic about a document that is returned to him for correction of arbitrary details at random intervals over a period of three years? Yet this happens.

This slowness to edit and slowness to publish is bad for the writer's morale.

4. Denial of Responsibility

An editor should remember that every correction he makes or proposes is, beyond a certain limit, merely a means of denying to the author the responsibility for his work. When the process is taken to the extremes I have seen practiced it is not surprising that young authors in effect wash their hands of the whole affair.

I have recently had to recommend to one organization that the name of the young author be put on the front cover of the report along with the name of the organization and department, and the name of its director. Formerly the author's name had been difficult to discover, lurking as it did in small type on an inner page.

Any denial of responsibility for the papers he writes is a denial of the author's status as a scientist and of his scientific right to publish his own work under his own name.

The denial of his responsibility and status is bad for the scientific author's morale.

5. Criticism of Trivia

When a young scientific author has spent some months on a piece of research which has required scientific ingenuity and inventiveness, patience and perseverance, the application of all his technical knowledge and practical skills, when he finally unravels the tangled threads of the problem and laboriously sets down on paper the story of his intellectual adventure, it is chilling for him to receive from a remote senior scientist comments confined to subeditorial details. If he regards his chief as a senior *scientist* he expects to get *scientific* criticism. But, of course, *scientific* criticism, that is, criticism of his scientific techniques, or arguments or conclusions, is hard to get. The report has to be read carefully if its logical faults are to be detected, and such careful reading of scientific papers needs time and concentration.

Too much of our reading is at the subediting level at which we look *at* the words rather than *through* them to what is being said. I am reminded of the Hungarian student who, when asked how he was getting on, replied that he was very well looked after and that the English were very kind. But he had some slight reservation. When pressed to reveal it he said, "You see, my English is not yet good, so when I speak, no Englishman will listen to *what* I say, but only tells me *how* I should have said it. It is very kind of them but very depressing for me." Young scientific authors, too, find criticism confined to trivia bad for their morale.

6. The Nutshell Factor

The belief is widespread that anything, however complex, can be explained to anybody, however dim, in a nutshell. It cannot. Nutshell communication is possible only in the special case when the communicators have much common ground relevant to the subject in question and have a deep common interest in it. Though nutshells are small, they raise big and difficult issues—metaphysical, philosophical, ontological, epistemological—and I do not propose to embark on these now.

I mentioned the nutshell factor because I meet it often. It is particularly distressing for a scientist to be asked to put all his scientific knowledge—perhaps his life's work—into a nutshell for a layman who doesn't propose to make any effort himself towards understanding. The scientist cannot do it, and, as his attempts to reduce his knowledge to nutshell proportions are doomed to almost certain failure, the demand for nutshells is another cause of frustration.

To sum up, I have tried to identify some of the factors which induce a state of poor morale in industrial scientific authors. The authors do not always realize what is wrong—all they feel is that somehow they cannot write the reports expected of them and so they call for a course on how to write reports. In a very high proportion of the cases I have been concerned with, however, it has been one or more of the six factors I have isolated that have needed correction first. Even when a scientific author has an adequate writing skill it cannot be effectively applied unless the six factors all bearing on his morale are first eliminated. Only then can a course of report writing possibly be of benefit.

A Small-Scale Experiment in the Application of Creativity to the Teaching of Technical Communication *

RICHARD L. VENEZKY†

Summary—At Cornell University, a course in technical writing and speaking, required for fifth-year electrical engineers, was redesigned for the summer co-op session to encourage creative thinking, both as an aid to the students in their general engineering work and as a more efficient medium for conveying good technical communicating processes. Students were required to "invent" devices, find answers to imaginary problems, and convey the ideas derived from these projects to other people. Emphasis was also placed on fast, efficient methods for finding information, and coherent explanations of technical problems to many different types of audiences. No attempt has been made to evaluate the long-range effects of this course on the creativity of the individuals concerned. It is felt, however, that the major accomplishments along these lines were the introduction of techniques for ideational fluency and creative problem solving and the constant reinforcement of creative efforts. Included in this paper are the original assignments for the course and a proposal for an ideal, but wholly practical, new course in technical communications based upon the results of this course.

Psychologists, educators, and industrialists have for many years recognized the need for identifying and teaching creativity. The time–dollar–brain-power investment in this search has increased shaply in the past 10 years, and while a definition of creativity acceptable to all "investing" parties has not been found, numerous attempts have been made to distinguish and teach creative thinking. Research efforts from diverse disciplines have been aired semiannually at the University of Utah conferences on the Identification of Creative Scientific Talent (1955, 1957, 1959). Courses in creative thinking have been taught for many years in colleges and private businesses (General Electric, M.I.T., Buffalo, and others). While most of these courses attempt to teach creativity directly, several programs have been designed for applying creativity to the teaching of another topic. At Cornell University a creative art course for children and parents is taught by the education department. Creative design courses are found in numerous mechanical engineering curriculums and studies of creativeness in the public school system have been started in the Portland, Oregon, schools.

Although special courses in creativity have produced promising qualitative results in most cases, the encouragement of creative thinking in existing courses in a curriculum has the following advantages in developing creative talent:

1) Transfer of learning is facilitated. Since teaching creativity involves encouraging special thinking processes which already exist in most individuals, but are rarely used, the direct application of these processes to the everyday concerns of the individual has an obvious advantage over the teaching of creative thinking in isolation.
2) Continual application of creative thinking can be encouraged.
3) The results of most special courses in creative thinking, although encouraging to many, are not definite enough to justify the insertion of a new course in an already overcrowded curriculum.

*Received April 13, 1962.

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In this report the techniques and results of a small-scale experiment in the application of creativity to the teaching of technical communication are described and discussed. Included is a short discussion of recent work in the field of creativity and a proposal for a reorganization of this course.

Creativity

A listing of different approaches to the identification of creative talent suggested by R. L. Mooney[1] provides a convenient outline for discussing current studies of creativity. Mooney's approaches are the following:

1) The product created.
2) The process of creating.
3) The person of the creator.
4) The environment in which creation comes about.

The product approach is employed by Ghiselin[2] in defining two levels of creativity. On one level the universe of meaning is altered by the introduction of some new element of meaning or some new order of significance, and on the other level further development is given to an established body of meaning through the initiation of some advance in its use. In attempting to design ultimate criteria for creativity, Ghiselin claims that the "products immediately relevant for investigation must be things physical or spiritual that have been brought into being by the human agency." A creative product, according to Ghiselin, is unique in the mind of the creator when it appears and the testing of this uniqueness involves an investigation of possible precedents for the idea.

Studies of the process of creative thinking are more common than studies in the other three areas. Guilford,[3] the present-day torch-bearer of factor-analysis, has made factor-analytic studies of the creative process, and Newell, Simon, and Shaw[4] have made introspective investigations of problem solving. Sensitivity to problems, originality, and ideational fluency are the most frequently mentioned creative thinking factors in Guilford's tests. None of these factors, however, appears to be consistently correlated to high creative ability. Newell, Simon, and Shaw, following in the footsteps of Duncker and Bodner and Bloom in applying introspective techniques to problem-solving procedures, define creative activity as "a special class of problem-solving activity characterized by novelty, unconventionality, and difficulty in problem formulation."

The most significant results of these studies are the descriptions of heuristics employed in problem solving. Creativity as an extension of problem solving is also advanced by Vinacke,[5] who claims that "a creative situation (is) one which combines realistic thinking and imagination. It has many of the characteristics of both problem solving and fantasy. It is a kind of problem solving without predetermination of correct solution and with self-expression or externalization as its dominant feature."

In investigations of engineers and scientists by Blatt and Stein[6] and Peck[7] the creative individual is described as "striving," "devoted," "self-sufficient," "sensitive," and "persistent." Peck claims that, "We may reasonably assume . . . that aside from his other qualities, the creative person must be one who is strongly motivated to withstand boredom, fatigue, and all other forms of frustration. He must be a man who can and does exert active, firm self-discipline in his field of interest, even though he fails to manifest this quality in any other aspect of his life."

The environment in which creation comes about has been the subject of recent studies by D. W. Taylor[8] and A. Roe.[9] Considerable interest has also been shown by the research segment of industry in this field—particularly in attempting to create the proper atmosphere for "creative thinking." Whether one investigates schematics, synopses, scientists, or society, the ultimate aim is to learn how to motivate the creative process. From an investigation of the potpourri in the "Creativity Scriptorium" it appears obvious that creativity can be motivated.

Technical Communication Course

At Cornell, the technical communication course (4021) is a required course for fifth-year electrical engineers, and covers both writing and speaking. Major emphasis is generally placed on report writing, although other forms of communication are discussed. During the regular school year, the class meets three times each week for one-hour periods. In every class, writing and speaking abilities normally vary from competent to "how did he get out of high school?" and the instructor, if he is to handle the class as a whole, must choose a middle ground between boring the competent and requiring too much

[1] R. L. Mooney, "A Conceptual Model for Integrating Four Approaches to the Identification of Creative Talent," University of Utah Press, Salt Lake City, Utah; 1957. See especially pp. 170-180.

[2] B. Ghiselin, "Ultimate Criteria for Two Levels of Creativity," University of Utah Press, Salt Lake City, Utah; 1957. See especially pp. 141-155.

[3] J. P. Guilford, N. W. Kettner, and P. R. Christensen, "A Factor-Analytic Study Across the Domain of Reasoning, Creativity, and Evaluation," Psychological Labs., University of South Carolina, Columbia, Rept. No. 16; March, 1956.

[4] Newell, Simon, and Shaw, "The Processes of Creative Thinking," CIP Working Paper No. 13; revised May 26, 1958.

[5] W. E. Vinacke, "The Psychology of Thinking," McGraw-Hill Book Co., Inc., New York, N. Y.; 1952.

[6] Blatt and Stein, "Some personality, value, and cognitive characteristics of the creative person," *Am. J. Pan.*, 1957.

[7] R. F. Peck, "What makes a man creative," *Personnel XXXV*, pp. 18-23; 1958.

[8] D. W. Taylor, "Variables Related to Creativity and Productivity Among Men in Two Research Laboratories," University of Utah Press, Salt Lake City, Utah; 1957. See especially pp. 20-35.

[9] A. Roe, "Early differentiation of interests," in "Second Research Conference on the Identification of Creative Scientific Talent," C. W. Taylor, Ed., University of Utah Press, Salt Lake City, Utah; 1958. See especially pp. 98-108.

of the scribblers. In the summer school session, lasting seven weeks, the course was scheduled for three two-hour meetings per week.

In the design of the summer program, the major guiding principle was the belief that writing and speaking are best learned by writing and speaking, that classroom discussions of technique, style, grammar, and assigned reading of the same, besides being boring, have little teaching value at this level. Considerable thought was also given to motivation . . . to designing techniques that would encourage each student to spend time with his own ideas and his own modes of expression, free from the constraints of the ubiquitous grading process, extraneous fact-finding expeditions, and the anathema of "other-directed" topic material. With these ideas in mind, the course was designed with two two-hour class sessions and one individual conference period each week. The individual conferences, used for discussing each student's work, were directed by Prof. N. Bryant, and the class meetings and most of the assignments were directed by the author of this report.

In pursuance of the goals mentioned above an attempt was made to create a "psychologically free" atmosphere in which the maximum participation from the students could be obtained. By "psychologically free" I mean an atmosphere in which the major emphasis was placed upon individual improvements and not upon class standards, exams, grades, and conformity—an atmosphere that deviated as widely as possible from the conventional classroom sights, sounds, regulations, and assignments.

The creative process was encouraged in a number of different ways. Most of the topic material for writing and speaking assignments had to be "created" by the student himself. Brainstorming sessions were held on a variety of different problems and originality in mode of expression was encouraged. Requiring "imagined" topics for papers and speeches had a twofold advantage: first, it allowed the student the maximum participation in the assignment by allowing the subject of his paper or talk to be his own ideas, and second, it encouraged originality, which is basic to all good communication. Augmenting these advantages was the natural enthusiasm that results from the desire to communicate original ideas.

During the first class period the class discussed what should be taught in a technical communication course and made specific suggestions for both subject matter and teaching processes. On the suggestion of the class, class meetings were thereafter held in the student union building and were conducted on an informal discussion basis.

No textbook was assigned for the course, but the following books were placed on reserve in the engineering library:

G. C. Harwell, "Technical Communication," the MacMillan Co., New York, N. Y.; 1960.
P. Roberts, "Understanding English," Harper and Brothers, New York, N. Y.; 1958.
P. Perrin, "Writer's Guide and Index to English," Scott, Foresman and Co., New York, N. Y.; 1950.
W. Strunk, Jr., and E. B. White, "The Elements of Style," The MacMillan Co., New York, N. Y.; 1959.
B. Hathaway, "Writing Mature Prose," The Ronald Press Co., New York, N. Y.; 1951.
G. Orwell, "Politics and the English language," in "A Collection of Essays," Doubleday and Co., Inc., Garden City, N. Y.; 1957.

In addition to these references, each student was given the "AIEE Author's Guide."

By the fifth year of college every student knows that accepted grammatical forms exist. One purpose of the unconventional atmosphere was to destroy the feeling that these and everything else needed to complete the course successfully could be found in the lecture notes or assigned text. In most assignments the student was required to find not only the correct grammatical style, but also other pertinent information that required the use of different library facilities. Occasional discussions were held on the process of preparing a report or speech. Students were asked to describe in detail everything they did from the time they were given the assignment to the time that they completed it. These were, perhaps, the most valuable discussions held throughout the term.

Brainstorming was introduced as a method for facilitating ideational fluency and several problems were "brainstormed." Groups of six or seven students were used and generally two students served as recorders. Stress was placed on first generating as many ideas as possible and then considering the merits of each idea. Problems used in brainstorming sessions were the following:

1) Find new uses for discarded beer cans.
2) Find new uses for discarded hub caps.
3) Design new methods for teaching the operation of the IBM keypunch.
4) Design new methods for the clinic to use in informing students that they are required by Cornell Health Regulations to take certain shots. (Standard clinic notices were shown to demonstrate the current clinic practice.)

Whether or not these sessions had any long-range value was not determinable. Participation was extremely good, however, and several students remarked that this process seemed to be a useful approach to problem solving.

Finding material that would be both profitable and interesting to the class as a whole was difficult and in many cases class discussions were reduced to one hour or less. Except for the periods used for speeches, class meetings could probably have been dispensed with and the time used more profitably in individual conferences.

Enthusiasm and creativeness appeared to be interdependent. The students who appeared enthusiastic about their own ideas generally produced the most creative work while the unenthusiastic followed the conventional path. In the reverse process, the students who did most of the original thinking appeared more interested in the course work and generally showed more effort than the noncreative group. The students who ranked highest in their engineering class by grade-point average were generally the least creative and had the most difficulty in adjusting to the nonconventional atmosphere, while the students with lower grades and more erratic records adjusted quickly and produced most of the original work.

Written Assignments

1) Write a personal evaluation (one or two typewritten pages) answering the following questions:

a) What things have you enjoyed doing the most in your life?

b) What things have you enjoyed doing the least in your life?

c) What do you expect to be doing 10 years from now?

As an aid to the instructor, this assignment was selected to provide an example of each student's ability to express his own ideas. It was selected with the hope that the introspective analysis would be helpful both to the student and to the instructor. Although most papers written on this topic provided an accurate gauge of writing ability, many were too short to reveal specific problems. In revising this assignment, I would require at least three typewritten pages and would require that the major portion of the paper be written on question c), since this question requires the most personal expression.

2) What do you expect to learn from 4021? (Include any suggestions you have for the course.) One or two pages.

3) (Letter-Writing Assignment) See Appendix I.

All letters employed standard business form, but less than half of the class found Hubbard's editorial or the address of W. H. Brady Co.

4) Describe a technical process to both IRE TRANSACTION readers and *Ladies Home Journal* readers.

5) Write a promotion for the Cornell craftshop, describing how the available tools can be used by engineering students.

Few creative ideas came out of this assignment, although the promotions were generally good.

6) Major Report.

Seven students did individual reports on topics of their own interest. Another group (three students) wrote an orientation booklet for incoming engineers, explaining opportunities at Cornell, the engineering curriculum, and how to study.

The third group (three students) worked on Project Super-Think, a project in which the group was to design transportation, defense, and housing facilities on an imaginary island using only the available materials. The problem situation for this project is explained in Appendix II. At the first group meeting a standard measurement system was adopted and the work necessary for survival on the island was divided among the three students. This was the most successful assignment of the term, both for creativity and technical communication.

7) Select some physical effect not commonly used to design bistable devices and design a new bistable device using this effect.

This assignment worked well—the ideas were good and the papers were generally well written.

Speech Topics

1) Select a real or imaginary problem, design a solution for the problem and prepare a speech convincing your audience that this problem should be solved and that your solution is feasible.

2) Select a field of current technical interest and prepare a talk on current progress in this field, describing primary sources of information for people who want to do further research on this topic.

3) Prepare a short talk on the topic of your major report, outlining the basic ideas that will be incorporated in your report.

4) Describe how your bistable device operates.

Conclusions

There are obvious difficulties and dangers to "concluding" anything definite from a small, qualitative experiment aimed at long-range effects. The most that can be said is that it appears that this experiment was successful. A course that was formerly described as "dull," "dry," and "uninteresting" was, at least for a majority of the students concerned, transformed into a course described as "challenging," "interesting," and "valuable." More actual writing and public speaking was done by each student in this course than was done in the previous course. Each student received considerably more individual help than ever before and was exposed to a greater variety of problems related to technical communication.

The use of so-called "creative processes" served, as a bare minimum, as an effective motivating factor—most people can be expected to attempt to communicate their own ideas better than they attempt to communicate someone else's. Since communication itself is an individual, creative act, emphasis on creativity has a natural advantage in this field. Whether an emphasis on creativity in any other course in the engineering curriculum will be beneficial depends mostly on the nature of the course and the ability of the instructor to use creative processes to achieve the goals of the course.

Whether or not anyone was more creative after this course than before is highly doubtful. The only help in developing creativity appeared to be in the introduction of techniques for ideational fluency and creative problem solving and in the constant reinforcement of original efforts. Without keeping the real purposes of a technical communications course in mind, the type of atmosphere created for this course and the techniques utilized could easily degenerate into gimmicks, stunts, "orange-crate educational devices," and entertaining time-killers. To prevent this from happening and to utilize more fully the techniques tested in this course, the following design is proposed for an "ideal," but wholly practical course in technical writing and speaking.

Proposal

1) The class should be divided into groups of three or four students who will work together as a research team throughout the term. After an initial orientation meeting, each team will be given a problem that requires both group work in planning an approach and gathering information, and individual work in preparing separate reports and speeches. Each team should meet with the instructor once each week to discuss their work and to receive new assignments. Class meetings should be held once each week and should be composed primarily of student speeches that explain the different team projects.

2) A research atmosphere should be followed as closely as possible—an atmosphere based upon the statement, "This is your problem; now go solve it on your own." This requires that grades be de-emphasized and required reading not be given. Special articles should be suggested to those who can profit from them, however, and a standard style guide, such as the "AIEE Author's Guide," should be used.

3) The assignments in the first half of the term should cover a wide variety of communication styles and problems while the second half should be concentrated on a major project, like Project Super-Think. Included in this project could be letters, preliminary designs, speeches, and a major report, all centered on the same topic.

Appendix I

Letter Writing Assignment

1) You are doing experimental design work with printed circuits and need 300 precut, ⅛-inch-diameter circles with a 1/32-inch-diameter hole punched in the center of each. These are normally cut from a material similar to masking tape and are used in preparing the final design for photographing. W. H. Brady Co. makes the circles along with other printed circuit supplies that may be useful to you. Write a letter to this company (this is a real company), ordering the 300 circles and requesting information on other products used in preparing printed circuits.

2) As general manager of a large research laboratory, you receive a letter from a department head suggesting that Hubbard's editorial "A Message To Garcia" be posted on every company bulletin board. Write a reply.

3) You are president of a concern that manufactures expensive waveguides, primarily for the military. At the Flamingo Hotel in Las Vegas you "accidentally" run into the presidents of the other principal manufacturers of waveguides for the military and learn that a basement scientist in Cairo, Illinois, has developed a waveguide out of two coathangers that outperforms all your 500-dollar models. You agree to investigate this problem. Write a letter to the Cairo intruder (Mr. D. H. Lawrence), requesting information and possibly suggesting a meeting to discuss his invention.

Appendix II

Project Super-Think

As a group of advanced-research scientists, you have devised a process for reducing government surpluses to strings of electrons. These electrons are sampled periodically and the information obtained stored on magnetic tape for immediate transmission to any part of the universe. By employing a well-known theorem of Wallace, the data is reassembled at the receiving end into the original surpluses and distributed according to the theorems of Coriolanus.

In the first full-scale test, however, an unpredicted phase shift between transmitter and receiver results from the Swiss electromagnetic bomb tests, and your group of scientists plus the following surpluses are deposited on a strange tropical island:

1 million fraternity paddles
1 million nylon hose
1 million bowling pins
1 million hub caps.

The following is the CIA report on this island:
File No. 5018—Palabra

The isle of Palabra is a rectangular coral reef (15 miles long, 1 mile wide) lying in a temperate zone southeast of the Symplegedes and northwest of Scylla and Charybdis. Temperature in this zone averages 78°F throughout the year, rising to a high of 100°F in the summer and falling to a low of 50°F in the winter. On every day except Friday a heavy mist envelopes the island from 1 to 2 P.M. (Daylight Saving Time). During the remaining hours of sunlight (average day = 17 hours), the sky is cloudless and an 8-mph tropical breeze blows out of the southeast.

Over the coral base of the island a two-foot layer of clean, white sand has been deposited by the breeze blowing past the Symplegedes. Carnivorous plants, averaging 12 ft in height, are the only plants which manage to survive the sandy soil, moist atmosphere, and the swarms of small houseflies which occupy the island.

The southeast end of the island is occupied by a tribe of ferocious pigmy head-shrinkers, the Menningers, and the northeast end is occupied by a colony of Schmoos.[1] A herd of Great White Whales reduce the practicality of sea travel in the vicinity of Palabra by forcing all sailing vessels to pass through the Symplegedes or between Scylla and Charybdis. Air travel is also impossible due to the Van Dyke belt, a six-mile atmospheric layer of ionized, cigar-shaped particles which repel moving objects.

[1]The Schmoos have been studied extensively over the past decade and accurate descriptions of their culture have been published by Bronislaw Malinowski Capp.

Preparation of Commercial Instruction Manuals: a Survey and Some Comments*

EPHRAIM M. MILLER†

Summary—A questionnaire was used to survey the operating practices of commercial instruction-manual groups in the process instrument industry. The results are presented and discussed. Subjects examined include 1) the amount of time the writer must spend on research; 2) areas of responsibility of the instruction department and other departments in the preparation of an instruction manual; 3) relations with customers; and 4) manpower shortage.

THERE ARE very few published facts about the actual practices and problems of industrial instruction-book groups. F. T. Van Veen reported in 1959 the results of his survey of instruction-book preparation in the electronic instrument industry.[1] We thought it would be useful to make a similar survey of the process instrument industry, including some additional questions suggested by Van Veen and others.

In June, 1960, we therefore sent a questionnaire on the preparation of instruction books to 26 manufacturers of instruments used in process measurement and control. Eighteen companies (more than two-thirds) responded; some of them expressed great interest in seeing the results. Here is a summary of what we learned from the survey.

General Characteristics of Instruction Groups

Table I shows the size of the instruction-book groups and the number of people performing different duties. (Respondents were encouraged to give answers in fractions of people, if a worker had other duties besides instructions or if he divided his time between different duties on the list.) The 14 replies fell neatly into two classes—nine companies with small instruction groups (three to seven people), and five companies with large instruction groups (11 to 20 people).

Comparison of the two classes raises an interesting question: Why aren't there more artists and parts listers in the large groups? For parts listers, the answer is that several respondents wrote "Not Applicable," indicating that parts lists are prepared in another department of the company. For artists, two possible explanations are: a) the small groups may not really need a full-time artist, or b) the large groups may avail themselves of draftsmen in other departments of the company for routine jobs, and save their own artists for difficult jobs that require close collaboration between writer and artist.

Where does the instruction-book group fit into the organization chart? Nearly half (8) of the groups are part of Engineering; other groups are part of the Sales Department (4), the Advertising Department (4), both Engineering and Sales (1), and both Engineering and Advertising (1).

Who usually prepares the first draft of an instruction sheet? In six companies, the first draft is prepared by the technical writer; others mentioned "either the design engineer or the technical writer" (5), design engineer (4), sales engineer (2), and service engineer(1).

Instructions are revised frequently in both small and large companies. Over 90 per cent of the respondents to the questionnaire indicated that they reprinted their instruction sheets or manuals about once a year. In the average company, 48 per cent of the reprinted instructions are "exact reprints," 38 per cent are "minor revisions," and 14 per cent are "major revisions." It seems safe to assume that most revisions are made because of instrument design changes. Revisions are also made to include

*Received March 15, 1962.

†Assistant Editor of Instructions, The Foxboro Company, Foxboro, Mass.

[1]F. T. Van Veen, "Electronic instrument industry instruction manual procedures survey," *STWE Rev.*, vol. 6, pp. 18-20; April, 1959.

TABLE I
Number of People on Instruction Manuals Full Time

Duty	Number of People			
	In 9 companies with small instruction group		In 5 companies with large instruction group	
	Range	Average	Range	Average
Writing	0-2	1	4-6	5
Preparing parts lists	0-1	½	0-1	½
Art work	0-1	½	¼-1	¾
Typing and layout	¼-1	¾	1-4	3
Editing and supervising	0-1	½	1-2 ½	1 ½
Other duties	0-3	1	0-12	3 ½
Total people in instruction group	3-7	4 ½	11-20	14

TABLE II
Time Spent by the Instruction Writer on Research and on Writing

Number of companies reporting	Per cent of time spent in gathering facts	Per cent of time spent in writing
2	25-39	61-75
3	40-59	41-60
9	60-80	20-40

new information about the instrument or its application, to correct errors, and to add illustrations or make other improvements in the instruction.

Not many of the companies use outside services for instruction writing or illustration. In answer to a question about per cent of instruction books subcontracted, 14 companies said zero, two companies said 1 to 5 per cent, and one company said 10 per cent. Also, approximately 70 per cent of the instruction-book groups can get line art drawn and photographs taken either within the group or in another department of the company.

What methods of composition and reproduction are used most often? As to composition, typeset was mentioned by 33 per cent of the firms; IBM or Varityped, by 44 per cent; and typewritten, by 56 per cent. For reproduction, 89 per cent of the firms use offset, 17 per cent use letterpress, and 11 per cent use other methods. Percentages add up to more than 100 because some firms checked more than one method.

The Writer's Job

The companies were asked to estimate what per cent of the technical writer's time is spent a) in obtaining and checking the facts he needs for writing an instruction, and b) in writing the text and planning illustrations. As Table II shows, 9 out of 14 companies find that their writers spend 60 to 80 per cent of their time in gathering and checking information.

Is it surprising that research consumes so much of the technical writer's time? It shouldn't be, as the studies at Fordham University on the job of the technical writer point out.[2] In one instrument company, a writing project starts off like this: The writer is given a general description of the new or revised instruction that is required, together with any available reference material (engineering drawings, photographs, related publications, correspondence). He studies this material and, if necessary, asks people in sales, manufacturing, or publications for clarification of details. Frequently it happens that additional research is required. The writer must then determine the best way of getting the necessary information. He may observe, disassemble, or adjust an instrument; he may request the engineering or production department to give him more information on installation, operation, or servicing; he may even go on a trip to observe a customer's instrument installation. In the course of research or in the actual writing, new problems sometimes turn

[2]Staff, "The job of the technical writer," *STWE Rev.*, vol. 5, pp. 7-9; October, 1958. (Summary of a report prepared by J. Child and R. Johnson at The Center for Technical Publications Studies, School of General Studies, Fordham University, June, 1957.)

TABLE III
Relation Between Source of the First Draft of an Instruction and Time Spent by Writer on Research and on Writing

First draft prepared by	Per cent of time spent in gathering facts		Per cent of time spent in writing	Number of companies reporting
	Range	Average	Average	
Instruction writer	25-80	58	42	6
Sales engineer	40-60	50	50	2
Design engineer	50-60	55	45	2
Either instruction writer or design engineer	30-70	58	42	4

up, making it necessary to perform still more research or to reconsider what the scope of the manual should be. Naturally, to do this kind of job, the technical writer must have special knowledge of the technical area in which he is writing. It stands to reason that if companies really want to produce high-quality instruction books, they *should* have this type of writer and he *should* spend a reasonable amount of time on research.

Can the technical writer's research time be cut down by having someone else write the first draft for him? Table III presents the results of Table II rearranged according to who writes the first draft. The admittedly slender data suggests that the answer to our question is "no." This result is reasonable. The typical sales engineer or design engineer doesn't know what facts to select for the manual; he is likely to concentrate on design features that are important to his occupation, and omit installation details or operating procedures which the user needs to know. Also, many engineers do not bother to check thoroughly the information they give the writer; they expect the writer to do the checking. So the writer must spend a lot of time searching the draft for gaps, errors, and lack of consistency with previous publications.

However, it is true that research time isn't always productive. The answers to the next question indicate that some companies do not specify who has the final say on the scope of a manual. This lack of clear-cut responsibility can unnecessarily increase the writer's research time, and thereby decrease the efficiency of the instruction department.

The question was: "Who has final say on questions of instruction content?" The results suggested that this question should have been split into two parts: Who has final say a) on questions of technical accuracy, and b) on questions about the scope of the manual—what topics should be included, how much detail is required, and what the technical level of the instruction should be. Though the question wasn't worded clearly, it was answered by all 18 respondents. The answers were as follows: Sales Department (5), Instruction-Book Group (4), Engineering Department (3), Indeterminate (3), "Engineering Department for technical details and Sales Department for text and layout (must be OK'd by both)" (1), "instruction manuals . . . can include anything that anyone thinks is worth including" (1), "normally Publications Department but in special cases Engineering Department has final say" (1).

Many problems can arise in deciding the scope of an instruction. Consider a hypothetical situation. A writer is assigned an instruction project. He has to interview a sales engineer and a design engineer to gather information. The sales engineer insists that the instruction include detailed information on a rarely sold model of the instrument, because he has received a letter from one of the field engineers requesting that this information be published. The design engineer wants the instruction to cover the new design that (he hopes) will be in production in four months. As for the writer, his boss has asked him not to spend an unreasonable amount of time on the instruction. Sales volume, sales potential, and the pressure of other work may not warrant the hundreds of hours necessary to do the kind of job the writer would like to do. Yet engineers quite naturally assume that *their* instrument always deserves full-dress treatment. Somehow the writer and engineers must reconcile these questions and settle on the scope of the manual. Since many intangibles are involved, it is difficult to make this decision even under ideal circumstances; it is doubly difficult when no department has the authority to resolve ticklish problems.

The question "Who has the final say on questions of instruction format and methods of expression?" brought these responses: sales department (7), advertising department (2), instruction-book group (8), indeterminate (1). Notice that in nine companies the sales and advertising departments have final say on format. (In the same nine

TABLE IV
Availability of Obsolete Instruction Manuals and Parts Lists

Available to Customers?	No. of Companies
No	2
For 2 to 5 years	4
For 10 years	6
For 15 to 40 years	2
Indefinitely or permanently	4

companies, two of the instruction-book groups are part of engineering, one is part of both engineering and sales, and six are part of sales or advertising.) This indicates that people in sales and advertising are aware of the importance of instruction manuals in giving a good impression of the company. As Van Veen points out, what advertisement has the captive audience that an instruction manual has?

The answers to the above question also showed that the instruction-book group has final say on format in 80 per cent (4 out of 5) of the large instruction departments, but in only 44 per cent (4 out of 9) of the small instruction departments. There are two possible reasons for this. First, as the size of the instruction department increases, company management is inclined to give the department more responsibility. Second, when a company produces a large number of interrelated instruction books, decisions on format can best be made by full-time instruction specialists.

Customer Relations

What means are used to obtain customer reaction to instruction manuals? Four firms answered "none," 14 receive comments from salesmen, servicemen, field engineers, and/or application engineers. However, only two of the 14 indicated that they make a deliberate attempt to get customer feedback (one mentioned occasional field trips by instruction writers, and the other said that the service and application engineering departments question the customers). The other 12 answers showed that most, if not all, of these firms simply wait for comments to come in.

Next comes a delicate question: "How many free copies of the instruction book is the customer entitled to when he buys an instrument?" Some customers get huffy if they are told they will be charged for extra copies of an instruction book (even if the charge is so small that it doesn't cover the cost of printing). We found that four firms supply only one free copy; eight firms supply three to six copies; one firm supplies 10 copies; one firm has no limitation on the number of free copies, and four firms evaluate each request individually, taking into consideration the customer volume, intended use (such as training or educational aids), and other factors.

Table IV shows how companies handle the problem of making instruction manuals and parts lists available to customers after the instrument has become obsolete. Two-thirds of the companies keep this material available for at least 10 years. To do this, some firms reprint the manuals and parts lists when the stock gets low; others allow the stock to be exhausted and then make photocopies for each individual request.

Manpower Shortage

Fourteen companies report that they are chronically short-handed for writers; five of these companies are also chronically short-handed for artists or layout experts. Another firm is chronically short for artists but has enough writers, and only three firms have no problems in either category.

The widespread shortage of writers may be due in part to the low status of the instruction department in many companies. An interesting answer in the survey was given by a company that has no full-time instruction writer and is chronically short-handed for writers. To the question, "Who has the final say on instruction content?" this company replied, "There are never any questions. Instruction manuals are inexpensively produced and can include anything that anyone thinks is worth including." Can an organization that operates this way be likely to attract and keep good technical writers?

Conclusion

Two suggestions are offered for further study and experiment:

1) Although many companies are short of writers, there is a question whether the writers they already have are being used effectively. If management takes a close look at the working relationship between the instruction department and other departments, it may discover that a few changes would boost the productivity and also the morale of the instruction writers.

2) Instruction departments should do some "market research." They should try to find out what improvements and changes in instructions are desired by their customers and field engineers. A carefully conducted survey could a) improve customer relations, b) reveal to the instruction department how well it is doing its job, and c) provide a basis for deciding what type of improvements in the instructions are most important.

Abstracts of Recent Articles on Engineering Writing and Speech

PREPARED BY *H. B. MICHAELSON*

Engineering and Research Reports, R. G. Murdick, *Machine Design,* vol. 33, pp. 70-75; August 31, 1961.

Style, format and organization are discussed for the internal memo, the terminal technical report, the project progress report, the development-test report, etc. The functions and organization of a technical report section are also described.

Information Engineering - Reclaiming R/D 'Filings', H. W. Northrup and R. C. Crooks, *Research/Development,* vol. 13, pp. 30-33, 35; February, 1962.

An assembly and classification system is described for filing abstract cards for published technical articles. Duplicates are filed according to subject from keywords which are underscored on the card.

Patterns of Sentence Formation, Frank R. Smith, *STWP Review,* vol. 9, pp. 17-20; April, 1962.

The regular patterns of English sentences are briefly reviewed. Some useful variants that should be applied by technical writers and editors are discussed: front-shifting, back-shifting, inversion, subordination, repetition, and elliptical parallelism.

Rensselaer's Program in Communication and Technical Writing, Jay R. Gould, *The ABWA Bulletin,* vol. 26, pp. 22-25; April, 1962.

The graduate program in Communication Theory and Technical Writing is described briefly. Included is a discussion of the demand for technical writers and of the various sources of these professional people. Some remarks are made about specific courses offered.

Selective Dissemination of New Scientific Information with the Aid of Electronic Processing Equipment, H. P. Luhn, *American Documentation,* vol. 12, pp. 131-138; April, 1961.

A service system is described in which a new document is characterized by a pattern of keywords. This pattern is compared with the "interest profiles" of individuals participating in the service. If the pattern sufficiently matches the profile, an abstract card is sent to the participant.

Tackle a Technical Report as You Would a Circuit Design, J. J. Traynor, *Electronic Design,* vol. 10, pp. 214-215; January 18, 1962.

A method of "mental shorthand" is proposed for writing technical reports. A rough mental schematic is made by following the natural flow of ideas in preparing an outline; the facts are then filled in, with data, calculations and conclusions.

Technical Writing Abroad, W. E. Britton, *STWP Review,* vol. 9, pp. 5-7; April, 1962.

Results are given of fifty interviews in England and on the Continent to determine the available types of courses, training sessions or publications concerned with technical writing. England and Holland are shown to be most active in advancing technical writing. As in the United States, Europeans find that a sound, basic education, without specialized training, does not necessarily produce good technical writers.

Technical Writing is Work, G. F. Shea, *Machine Design,* vol. 34, pp. 148-149; January 18, 1962.

Tips are given on how to economize on the effort that goes into writing a technical manuscript and on how to produce a more polished result.

Writing: Open Channel to Professionalism, W. O. Hadlock, *Electronic Design,* vol. 10, pp. 96-97; May 24, 1962.

The importance of communicating the results of engineering work is discussed. Advice on writing is quoted from successful engineer-authors.

Book Reviews

Communication in Business and Industry, by William M. Schulte and Erwin R. Steinberg.

Holt, Rinehart, and Winston, Inc., New York, N. Y.; 1960.

A well-thumbed copy of "Communication in Business and Industry" will rest on the desk of many a business and professional man who has improved his communications. For this book the range of modern learning about human communication has been filtered through the minds of two sound teachers and is spread out for readers in a pattern ready for direct application.

The authors skillfully touch the needs of readers. As teachers, they understand those needs and as writers they appeal to them, clarify them, and meet them. Little more can be asked of any textbook.

Additionally, this one is pleasant to read and easy to learn from. It is an effective example of its own teachings. The relaxed style is persuasive, so that one has to look twice to detect how his thinking has been altered. At the end of Chapter 1 is a paragraph worth quoting both because it teaches much without ponderosity and because it expresses what this book can and will do for attentive readers:

> As these paragraphs have suggested, to write and speak well requires hard work. The proverbial sayings "Anything worth doing is worth doing well" and "You can't get something for nothing" both apply to the improvement of the communication skills. Catch phrases and magic formulas may inspire a brief flurry of enthusiasm for "doing something" about one's writing and speaking. But unless the individual is willing to follow up good intentions with solid work, the results will be negligible. The reader of this book who works conscientiously over the materials we have provided and thoughtfully studies our discussion of communication problems should be well on his way to becoming a confident, effective craftsman, capable not merely of solving the specific problems covered in this book, but of bringing to the solution of any writing or speaking problem an instrument which he has fully mastered and can use with maximum effect.

Clearly the authors' purpose is to lead readers to act in order to improve themselves, and the organization of the book contributes to that end.

For the critical reader there are unobtrusively thoughtful discussions about language, about the psychology of motivation and of decision making, about human relations, semantics, and logic, as all of these apply to communication. Although translated from learned language into workaday terms, the sound knowledge and close reasoning cogently support the pointed suggestions for communicating effectively. A major point of the book is: "Perhaps the most important cause of failure in business communication is the failure to remember that a human being will receive each communication—and to write accordingly." This warning is followed by concrete examples of letters and reports, critical analyses of how some writers have avoided the failure, and adroitly interwoven explanations of the psychology of readers.

Examples, of course, are the stock in trade of teachers. But even more with this book, a reader will feel that he is examining the communications within a large firm and learning from the successes and mistakes of the people who have handled actual situations. Contrasts between effective and ineffective treatments of communication situations point up the meaning of particular suggestions. For instance, the story of "A Costly Letter" intrigues us into accepting sensible advice about considering readers and leads us to examine situations in order to meet them effectively.

None of the usual communication problems of men in business and industry is neglected, and clear directions are provided where direction is possible. In the chapter on "Preparation of Materials," for instance, "With this illustration in mind, let us formulate a useful procedure for preparing any communication" introduces a list and full explanations of seven steps of preparation. Other chapters deal with such topics as "Wasteful Prose," "Sentence Structure," "Ideas and Language," "Punctuation," and "Writing to Persuade." Materials for revision provide adequate drill to prepare one for applying his learning to his own communications.

A special attraction of the book is the illusion it creates. The reader seems to be participating in the actions, the thoughts, and the feelings of people at work. Well-told anecdotes draw one into a situation and intrigue him to think attentively with the authors while they develop principles and techniques for achieving effective communication. While one is reading, he is also practicing, a way of learning that is as effective and sensible as any yet devised.

THOMAS FARRELL

Proposal and Inquiry Writing—Analysis, Techniques, Practice, by Siegfried Mandel and David L. Caldwell.

The Macmillan Company, New York, N. Y.; 1962. 246 pp. $7.50.

At long last another relatively new and lustily growing American industry is beginning to have its folklore committed to writing and published in hard-cover form. The newcomer, one that accounts for an important percentage of the serious effort devoted today to scientific and engineering endeavor, is the "technical-proposal generation" industry. This early contribution to its permanent literature, offered by the authors as "a reference guide and handbook," is both well-conceived and artfully executed.

Presented in textbook rather than handbook form, the exposition is complete, lucid, and thoroughly indexed. The prose style is straightforward and easily followed, and the emphasis throughout is on the "bread-and-butter" approach most useful to the actual practicing engineer/writer facing the immediate task of preparing a "selling" technical proposal. The book is heavily larded with illustrative examples of every proposal element discussed; and one complete chapter is a miniature proposal in which the sample and the accompanying explanatory text are displayed on facing pages, for the utmost in clarity.

As to the comprehensiveness of the book, it is safe to say that the interest of any group routinely involved in proposal preparation has not been slighted. Not only is there a complete treatment for the technical man (whose duty it is to prepare the bulk of the proposal), but adequate justice is done the management representative, the accountant, and finally the legal adviser who negotiates the contract for the proposal that actually sells. If this were not enough, the authors open their discussion with a chapter on techniques of preparing a workable inquiry or request for bids.

In keeping with the scheme of making the most use of the illustrative example, there are three supplements provided which offer working models of an inquiry letter, a checklist for project engineers, and a second sample proposal, this time in abbreviated form.

By way of a bonus, two additional topics are covered. One, a chapter entitled "Proposal Production," is a masterfully concise treatise on the graphics involved in reproducing the proposal, in which a strong case is made for the use of multilith. The other is a very useful supplement on PERT/PEP techniques, to which no proposal writer with any pretensions to sophistication could fail to pay obeisance.

As indicated earlier, this is a work concerned solely with technique and practical application, and it deals only sparingly with theory and conjecture. As such, it offers few controversial openings with which the workaday reviewer can take issue.

One nettlesome point is the insistence that the table of contents, merely by the fact that it finds itself at the front of a proposal, is thereby simply and completely transformed into an "index." A second point concerning the front end of the proposal, with which issue might be taken by many, is the stand that the summary is best omitted.

A shortcoming of perhaps greater concern is the brevity accorded the chapter on organizing the efforts of the several disciplines brought to bear in the preparation of a proposal. To be sure, there can be no argument with the cogency of the concepts or the clarity with which they are covered, but rather with the shallow depth to which the discussion probes.

A detailed method for efficient organization, particularly of the engineering effort on a technical proposal for a major military system, is something for which there is a sore need. Yet, this is a topic covered only superficially here. In fairness, though, the authors could not have undertaken it without throwing the book completely out of balance. Perhaps this would be a worthwhile subject for a sequel to this work, and, if undertaken with the same thoroughness and clarity of exposition, it too should merit serious attention from all those who consider themselves journeymen "proposal generators."

William E. Collins

The Engineering Secretary's Complete Handbook, by Eleanor Schremser Laird.

Prentice-Hall, Inc., Englewood Cliffs, N. J.; 1962. 245 pp. $5.95.

It may seem odd that a book review on the Engineering Secretary is directed to engineers. However, as the preface states, the busy engineer will not have time to train his secretary in the many duties of her position. This book will help do this. Mrs. Laird tersely sets forth the requirements and expectation of engineering for the Engineering Secretary. She is general in her approach when activities are tailored to local situations. She is specific in areas where there is little doubt about what is required. Chapters on special typing problems, abbreviations and symbols, reproduction methods, simple drafting, technical dictation, specifications and standards, security and patents contain information that could be gained only through years of experience. The normal content of Secretarial Handbooks is included too. However, the focus is always engineering. Chapters on accounting responsibilities, filing, and secretarial techniques are intended to integrate the secretary into the creative engineering team. The Engineering Secretary's Complete Handbook will provide orientation that will make your secretary an effective extension of your project.

LaVern G. Lee

A Guide to Technical Literature Production, by Emerson Clarke.

TW Publishers, River Forest, Ill.; 1961. 192 pp.

This paperback is crammed with the type of really useful information often promised but rarely delivered in our literature. A "must" book for the publications manager, this, and especially for someone new at it. There are organization charts and job descriptions aplenty, and any administrator concerned with setting up a publications department will find down-to-earth suggestions on work-area layout, organization of writing and production groups, personnel training, scheduling, filing systems, and cost-estimating.

If the publications manager is the book's best audience, the technical writer is its star. The author discusses methods of recruiting, interviewing, evaluating, encouraging, organizing, criticizing, and rewarding the technical writer. The book falters in the "Evaluating the Writer" chapter, which includes a suggested test of the writing skill of a prospective technical writer. This test asks the "engineering writer" to find the errors in such sentences as:

The apperatus was schedualed for delivery.
Changeing the gear ratio releived the torque.
All the labratory personell moved accross the hall.
Its a perfect device.
Being fabricated from magnesium, I achieved a remarkable lightness in case design.

If the above looks like a high-school entrance exam, it in fact constitutes "class-proven" material from "an engineering writing course sponsored by the Chicago Engineering Societies." The author considers 40 to 60 per cent in this writing test suitable for an apprentice technical writer. If, as he says earlier in the book, "the future of the technical writing profession depends upon . . . the apprentices," the profession had better watch out.

However, there is more than enough paydirt in this handbook to please anyone in the publications business.

Frederick Van Veen

*Letter to the Editor**

I've heard a number of complaints recently about the poor quality of some of the papers presented at technical meetings. A large part of the trouble is undoubtedly being caused by the difficulty of evaluating a paper from an abstract or a summary. I have a suggestion that I hope will help.

The central problem in the evaluation of papers is that the papers are not usually written until after they are accepted for presentation. One way to solve the problem would be to require that the complete paper be submitted for review. This is an undesirable solution from two standpoints: first, it would undoubtedly have adverse effects on the timeliness of the paper; second, it would put a great load on the paper review committees.

The other solution is the one that is being used now: review of a short form of the paper. But, do the abstract and summary represent the best short form for the purpose? I don't think so. The abstract, which is really not an abstract, but a theme paragraph, is little more than an expanded form of the title. The reviewer can tell what the paper is about, but he can learn very little of the depth of treatment and organization of the paper. The summary is a bit better merely because it is larger than the abstract and can contain more information. But writing a summary (which is really a short form of the paper) requires quite a bit of work on the part of the author, and the end result is still not the easiest thing for a reviewer to wade through.

I believe that the best short form, from the standpoint of both reviewer and author, is the outline. The author, if he is to organize his paper well, must sooner or later prepare an outline. Hence, requiring one for evaluation of the paper does not place an unnecessary load on the author. From the standpoint of the reviewer, it should certainly be faster to go through an outline than to read a summary. A quick look at the main topics will tell what the subject matter is and how it is organized. If the subject matter is not suitable, the reviewer can stop right there. If the subject matter is O.K., the reviewer can go further into the outline to determine the depth of treatment and suitability of approach. If subject matter is marginal, the reviewer can make his decision on the basis of organization. He can thus eliminate papers that are likely to be both marginal in subject matter and poorly organized.

I do not propose that we eliminate the abstract; it is needed to publicize the paper. But let's call it what it really is, a theme paragraph or, still better, let's use book-industry jargon and call it a blurb. What I do suggest is that the use of outlines for evaluation would simplify the review committee's task without putting an unnecessary load on the author or affecting the timeliness of the paper.

Harry Baum
Publications Coordinator
Radio Corporation of America
Harrison, N. J.

*Received December 18, 1961.

INFORMATION FOR AUTHORS

Manuscripts and correspondence for IRE TRANSACTIONS ON ENGINEERING WRITING AND SPEECH should be sent to the Editor, Frederick Van Veen, General Radio Company, West Concord, Mass. Manuscripts are reviewed within one month.

MANUSCRIPTS: Three copies of the manuscript should be submitted. It should be typewritten double-spaced on one side of the sheet. References should appear as footnotes, numbered consecutively, and included in the following order: the author's name (including initials), title of paper, journal name, volume, initial and final page numbers, and date of publication. Footnotes should be listed on a separate sheet and not inserted in the text. Each paper must be accompanied by an abstract not more than 200 words in length. The abstract should *clearly* indicate the purpose and content of the paper.

ILLUSTRATIONS: Only original illustrations should be submitted. Photostatic copies of originals are not acceptable, except where they are exceptionally clear, with sharp black-and-white contrasts. All line drawings (graphs, charts, diagrams, etc.) should be prepared on drafting cloth or white drawing paper in India ink. It is preferable that only the main coordinate lines show in graphs. All lettering must be large enough to be legible when reduced 50 to 75 per cent in size. Photographs should be glossy prints and must not be marred by paper clips. Figure numbers should be indicated on the back of each illustration. Figure numbers and captions should be listed on a separate sheet accompanying manuscript. All drawings, photographs, and other manuscript material should not be larger than 8½ by 11 inches for ease in handling.

NEWSLETTER: Material for the PGEWS NEWSLETTER should be sent to T. T. Patterson, Jr., Radio Corporation of America, Camden, N. J.

THE INSTITUTE OF RADIO ENGINEERS
INCORPORATED

PROFESSIONAL GROUP CORRESPONDENCE

29 August 1962

PLEASE ADDRESS REPLY TO

General Radio Company
West Concord, Mass.

Mr. Charles P. Bourne
Stanford Research Institute
Menlo Park, California

Dear Mr. Bourne:

I am sending you herewith two copies of the August, 1962 issue of the IRE Transactions on Engineering Writing and Speech, in which your paper, "Problems Posed by an Expanding Technical Literature," appears.

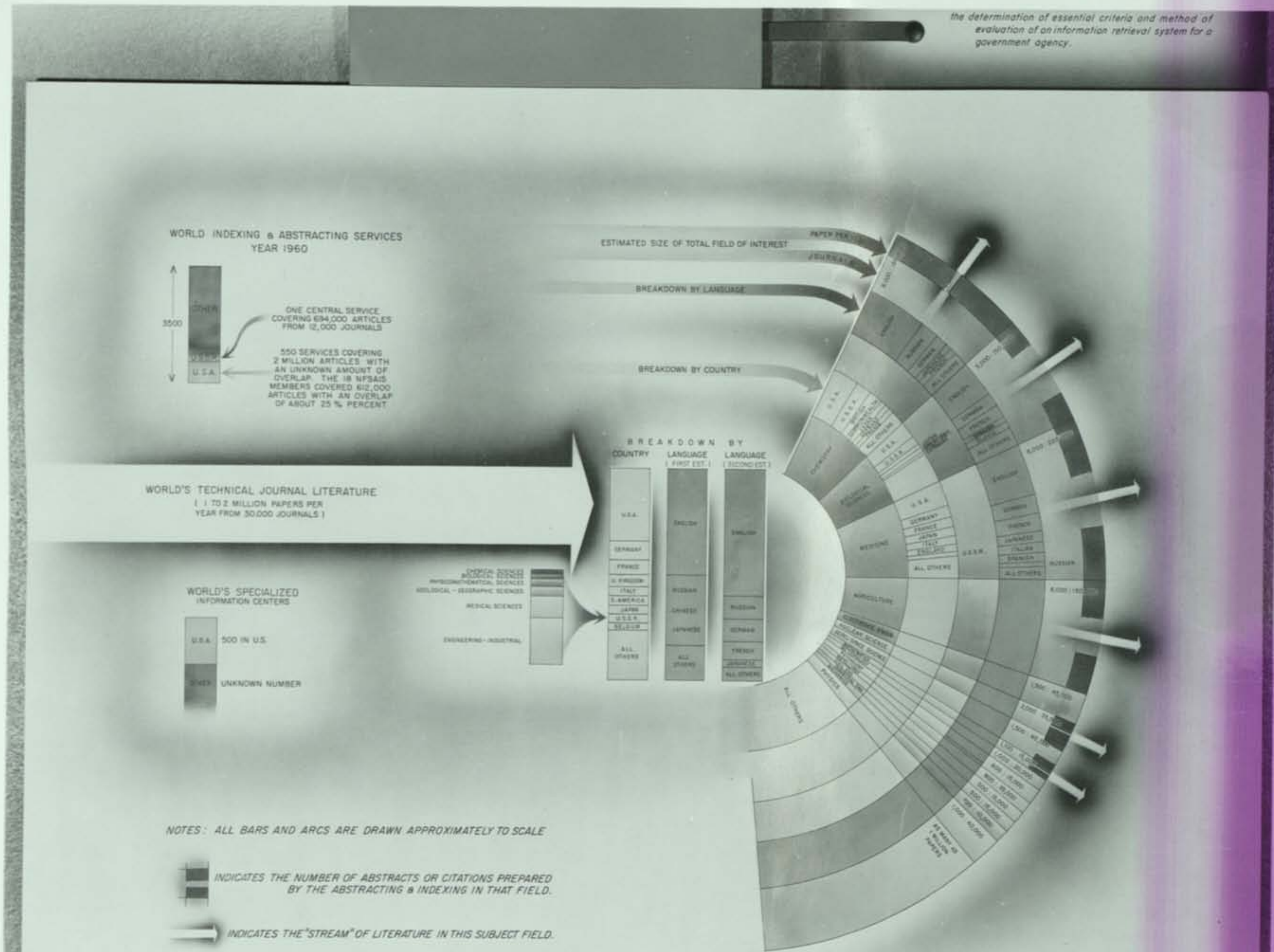
I am sure that Transactions readers enjoyed your paper, and I would like to express my personal thanks for such an excellent contribution.

Very truly yours,

Frederick Van Veen

Enclosure
FTVV:ama

Frederick Van Veen
Vice-Chairman, PGEWS



CURRENT COMPOSITION OF THE WORLD'S TECHNICAL JOURNAL LITERATURE

The above illustration describes the results of one of our recent studies in the storage, retrieval, and dissemination of information -- an estimate of the volume, origin, and language of each of many subject fields of the world's technical journal literature.

May 1960 San Francisco

8th Western

THE HISTORICAL DEVELOPMENT, AND PREDICTED STATE-OF-THE-ART OF THE GENERAL-PURPOSE DIGITAL COMPUTER

By Charles P. Bourne and Donald F. Ford
Computer Techniques Laboratory
Stanford Research Institute
Menlo Park, California

Summary

Some of the important characteristics of all the general-purpose digital computers that have ever been built, or are in the process of being built, have been collected together in order to show the changes in performance and characteristics during the passage of time. These collected data, as well as information regarding recent development work, have been used to extrapolate the characteristics and performance figures into the 1960-1965 era. The report considers such characteristics as add and multiply times, memory characteristics, pulse repetition rates, and internal system parameters.

The collected data seems to suggest that the majority of the computers developed between now and 1965 will show very little change in performance from that which was obtained during the last five years. However, a few research machines will definitely advance the technology, possibly as much as one order of magnitude for some of the characteristics. In appendix B there is a listing of approximately 300 different computers, in an attempt to provide an initial directory of the world's computers.

Introduction

This paper presents the results of a study that was conducted to answer the question, "What can be learned from a historical study of the development of general-purpose digital computers?" It was of interest to re-trace, in summary fashion, the development of the digital computer. It was also of interest to see if the development of any of the machine characteristics followed a pattern which would allow an extrapolation into the future. The study was restricted to the characteristics which describe the memory and central processor or arithmetic units, and did not consider input-output features.

The characteristics were examined from the viewpoint of a machine user, and not a machine designer or component specialist. That is, an attempt was made to describe the operational performance which the computer system provides the user, instead of concentrating on the details of the manner in which the logic is accomplished. For example, a comparison of typical execution times was studied, instead of looking at the switching times for the individual circuits. In a few instances, a study was made of some of the more hardware-oriented characteristics such as the pulse repetition rate or "clock" rate, and the type of high-speed memory component used.

The machine characteristics were obtained from several summary publications[1,2], as well as numerous journal articles and the literature of manufacturers. The data for approximately 180 of the machines was checked by letters of verification from the equipment designers or manufacturers.

The machine characteristics which were examined are listed below. The definitions for these characteristics are included in Appendix A.

- Number of addresses per instruction
- Number of index registers
- Number of decimal digits per instruction
- Number of decimal digits per data word
- Number of binary bits per instruction
- Number of binary bits per data word
- Internal clock rate
- Fixed point add time
- Fixed point multiply time
- Floating point add time
- Floating point multiply time
- Number of memory speed levels
- Types of high speed memory
- High speed memory size
- High speed memory access time
- Total internal memory size

Summary Comparisons of Computers to Date

Each of the machine characteristics was plotted against a horizontal calendar scale in order to observe the changes and rates of change for the parameters. A single point was plotted for each different machine type to show the earliest date that the system performed with the described characteristics. Points were plotted for all the available data, however, in many cases, various parameters were not described in the literature. For this reason, all the plots do not contain the same number of points.

The actual growth curve to show the rate at which new computer models have been developed is shown in Fig. 1. Fig. 2 shows the cumulative number of different computers which have been developed. In addition to the computers which are shown on Fig. 1 and 2, approximately 65 machines were not plotted, since an accurate operational date could not be determined. It can be seen that new computer models are being developed in continually increasing numbers, and that this trend will probably continue into the future. The increasing number of new computer models is due to several factors, but it would appear that the major reasons are those which are listed below:

1. Parallel efforts by commercial organizations acting in the spirit of free enterprise, with each organization competing for a share of the market with its own particular model. This is fostered by the increasing market for computers.

2. Continued marketing pressures to improve the performance characteristics of a particular computer model, or to produce more competitive equipment.

3. Efforts by universities and some industrial concerns to build their own computers in order to develop a technical competence in this field, or to obtain an inexpensive computing facility.

4. The emergence of a computer industry in areas which were late in starting in this field. For example, Japan built no digital computers before 1953; since that time however, she has developed 29 different computers, and shows every indication of developing more. The European countries are also developing rapidly as computer manufacturers.

Internal Characteristics

There has been very little uniformity or indication of trends for such internal characteristics as the number of addresses per instruction and the number of characters per data word or instruction. There have been some slight trends noticed in the number of index registers and the internal clock rate.

1. Number of Addresses per Instruction - Figure 3 shows that the single-address instruction is used more than any other type, although a large number of systems have used two-and-three-address systems. The four-address systems are definitely a minority; however, there is one instance of a five-address system. Future computers will probably follow the same pattern, with predominantly single-address format.

2. Number of Index Registers - Figure 4 shows that there is a definite trend toward providing index registers (or "B-boxes") in increasing numbers for each computer. The use of a single index register is first noted in 1951. The first system with multiple index registers is noted in 1954. From that time on, systems became available with a greater number of registers, and in some cases this went as high as 64, 99, and 1024 index registers per machine. A large percentage of the future computers will probably have at least one index register. Index registers have proven to be effective for applications in both business and scientific computations, and will probably appear more frequently on both types of systems.

3. Decimal Digits per Instruction - Figure 5 shows the data for the non-binary machines, to indicate the number of characters (decimal, octal, or alphabetic) per instruction. There does not appear to be any significant degree of uniformity, although more systems use 10 digits than any other number. Future computers will probably show the same large variety and lack of uniformity.

4. Decimal Digits per Data Word - Figure 6 shows a large spread of values running from 4 to 24 digits. However, data words with 10, 11, or 12 digits appear to be the predominant choice. In 1953 the concept of a variable-length data word was introduced, and several systems utilized this feature after that. Future computers will probably continue to show a variety of values, but may use the 10, 11, or 12 digits more often than any other choice. There will probably be an increasing number of machines with variable-length data words.

5. Binary Bits per Instruction - Figure 7 shows the binary bits per instruction ranging from 4 to 68. There is a decided lack of uniformity, and no strong tendency toward a particular value. Future computers will undoubtedly follow the same large variety and lack of uniformity.

6. Binary Bits per Data Word - Figure 8 shows the binary bits per data word ranging from 4 to 72. However, the majority of the systems have ranged between 30 and 50 bits per data word. Future computers will probably follow the same large variety and lack of uniformity.

7. Internal Clock Rate - Figure 9 shows the internal clock rate or pulse repetition rate. This is not a very good measure of the speed or power of a particular computer. This is because the great variety of ways in which the logic can be implemented (serial, parallel, and various combinations of serial-parallel) can provide a large range of effective operating speeds. There are several examples of machines with nearly equal arithmetic speeds in spite of the fact that one of the machines has a clock rate which is five times slower than the clock rate of the other machine. Conversely, it might be noted that all of the IBM-700 series machines from 1953-1957 used a 1.0 Mc clock, even though there were marked differences in execution times. The clock rate data was included here to give an indication of the speeds of operation of the internal circuits. The fastest clock rate (10.0 Mc) is currently credited to the IBM-STRETCH, or Los Alamos computer, although hardware has been developed[3,4] which operates at speeds up to 500 Mc. The data shows, among other things, that people like round numbers, as indicated by the large number of 100 Kc and 1 Mc systems. The clock rates ranged from 200 cycles per minute to 10.0 Mc.

There are a moderate number of asynchronous systems (at least 28) which date back to the earliest machines. Because the asynchronous systems offer an inherent speed advantage over the clocked systems, they will probably find increasing use as better design techniques become available. There will be an increasing number of systems which use clock rates of 1 Mc or higher. There are already at least 47 systems which operate with pulse rates of 1 Mc or higher. These internal speeds can now be achieved fairly easily with current transistor and diode circuitry. However, because of the variety of possible applications, there will continue to be a large number of new systems with moderate internal speeds (100 - 500 Kc).

Arithmetic Speeds

As defined in the Appendix, the execution times for the add and multiply operations are the effective operating times which a programmer would use in estimating the running time of a particular program. It can be seen from the pertinent figures (Fig. 10, 11, 12, 13) that there continues to be a wide range of execution times for all computers. This wide range of machine speeds, and characteristics, does not solely reflect the state-of-the-art or its trends. This range of values more accurately reflects the policy decisions and compromises which were made by each computer builder in his attempt to aim for a particular part of the commercial market, or produce (at minimum cost) a technical staff or computing facility. It is probably reasonable to state that not every builder tried to advance the state-of-the-art. Because of the fact that the collected data represented a heterogenous collection of intents and compromises, it was felt that it would be misleading to represent this data in some mathematical notation such as a yearly average or polynomial approximation.

The computers which have served to extend the state-of-the-art were primarily research and development machines, and were not designed primarily for commercial exploitation. The distinction in performance between systems which were built for research and systems which were built for commercial exploitation is shown in Fig. 14. This figure shows the fixed point multiply times for the machines in these two categories, and indicates that the state-of-the-art improvements were furnished entirely by the research machines. However, the commercial machines usually caught up with the fastest research machines in a matter of approximately five years.

Many builders have claimed the title of "world's most powerful computer" for their particular machine. It is impossible at this date to define accurately and unambiguously "computer-power". However, in an attempt to find out how long a machine could expect to retain this title, it was assumed that "computer-power" was proportional to the multiply time. With this assumption, it was a simple matter to determine the ten most powerful computers in each year from 1944 to the present. It was indeed an interesting observation to note that, on the average, a computer did not remain in the "top-ten" for more than three years.

For many reasons, there will be a continued effort to develop computers with faster execution speeds. However, it appears that faster speeds will not be achieved by extensions of the current hardware practices and techniques. It appears that new components and approaches must be developed if these speeds are to be attained. Meagher[5] sums this up very nicely in the following paragraph.

> "Let us first examine the need for new techniques which has resulted from our desire for higher speed. The existing circuits, with separate resistors, diodes, capacitors, and transistors, have a physical size which requires at least one cubic inch for a logical element. One such circuit has within itself a loop which constitutes an inductance with a shunt capacitance in the switching element. This LC circuit exhibits resonance. If the loop is about one-half inch in diameter, the inductance would be about 0.06 microhenry, and further, if the capacitance is 5 micro-micro-farad (both reasonable minimum values), the resulting resonant frequency would be about 300 Mc. Clearly it would be difficult to operate this circuit at an information frequency of more than about one-fifth the resonant frequency, or in other words, 60 Mc. We are already close to this frequency in some present computer circuits. Thus, faster circuits require either smaller size for "lumped-constant" techniques, or, alternatively, "distributed-constant" techniques. Low temperature circuit elements offer one possibility for extremely small size. Micro-wave techniques, the subject for the Symposium, offer the possibility of the distributed-constant approach."

To date, all of the circuits for storage and logic in the operating computers have employed a frequency band for pulse rates which starts at or near zero and extends to some upper limit. The upper limit for this base-band type of system appears to be about 50 Mc (see reference[8]). It would appear that some new techniques would have to be devised to achieve information pulse rates of greater than 50 or 100 Mc.

Microwave circuits for storage and logic functions have been demonstrated by Sterzer[15] which operate at pulse rates of 100 Mc and a carrier frequency of 2,000 Mc; and by Ortel[4] which operate with pulse rates of 500 Mc and a carrier frequency of 11,000 Mc. Ortel demonstrated a serial multiplier operating at a clock frequency of 160 Mc which multiplied two 8-digit binary numbers to form a 16-digit product in 1.6 microseconds. It was stated that it would be feasible to use the same microwave circuit with a clock frequency of 640 Mc to obtain a multiplication time of 0.4 microseconds.

Billing[6] and Rudiger have stated that the use of the nonlinear capacitance of semiconductor diodes in parametron circuits also appear promising for high frequency operation. Experimental work has been conducted at frequencies up to 450 Mc, and theoretical studies seem to indicate that frequencies in the neighborhood of 30 Kmc should be possible.

Aside from economic problems, one of the major technical problems in achieving very high circuit speeds is that the time allocated to switch a signal through the circuit approaches the propagation time for any electrical wave. This is stated very well by Leas[7] in the following paragraphs.

> "To improve substantially upon the present computing speeds, manipulative elements for the basic functions of gating and storing binary signals are required which have extremely fast physical response, reckoned in nanoseconds (10^{-9}) rather than microseconds (10^{-6}). Furthermore, because large numbers of such elements must be used in systems sufficiently comprehensive to make significant use of their speed, these elements must be physically small in order that the machine itself be small enough not to cause prohibitive delays due to the finite propogation velocity of electrical signals.
>
> "For example, during one nanosecond electrical signals in free space travel one foot (30 cm), and in most solid materials only 6 to 8 inches (15 to 20 cm). This means that two circuits must be only fractions of an inch apart if the delay between them is to be negligible. Furthermore, the whole computer size is limited since the performance of an instruction requires information to reach and be returned from all parts of the computer. To obtain memory cycles of 10 milli-microseconds, the computer can not be more than 18 to 24 inches (45 to 60 cm) in diameter."

In addition to the problem of physical size, Leas also mentions the problem of power consumption of the individual logic elements.

> "This limitation in size also sets limitations on the power consumption of individual elements. For a computer of minimum size, at least 5000 logical elements and 10,000 memory elements will be required, implying power consumptions below 500 mw for each logic element, and 50 mw for each memory element, if normal forced air cooling is used. It is highly desirable that these figures be reduced to increase the capability of the computer. Satisfactory values would be 15,000 logic elements, each taking 150 mw, and 2.5 x 10^5 memory elements, each taking 2 mw."

One additional drawback to improving the execution times is the lack of a very high speed random access storage. Unless some "look-ahead" or sophisticated control techniques are used, the lack of a high speed memory will prevent the effective execution speeds from being achieved. Temporary solutions may be obtained by using a small amount of very fast memory in a multi-level memory. Further impediments to widespread use of high speed operation are the lack of inexpensive instrumentation equipment, the scarcity of technical and professional manpower with training in this area, and the lack of production and testing experience.

1. <u>Fixed Point Add Times</u> - The fastest fixed point add time (0.57 microsec) is currently credited to the University of Illinois ILLIAC-2. It might also be noted that after 1950 all of the computers that claimed the title of "world's fastest adder" were binary machines. A computer with an add time of less than 0.1 microseconds will probably not be built before 1965, even though the hardware techniques are already available to build adders to operate at even faster speeds. Logic circuits and adders have been operated at clock rates of 50 Mc, and even up to 500 Mc using radio frequency carrier techniques[9], but the components and circuitry are currently so expensive and bulky that they will probably not be used as part of a complete computer system.

2. <u>Fixed Point Multiply Times</u> - The fastest multiply time (1.4 microseconds) is credited to the IBM-STRETCH, or Los Alamos machine. As with the add times, the fastest machines are predominantly binary machines. A computer with a multiply time of less than 0.5 microseconds will probably not be built before 1965. Prototype multipliers have operated at 50 and 160 Mc clock rates[8,4], but these devices will probably not be incorporated into a complete computer system for some time.

3. <u>Floating Point Add Times</u> - Figures 11 and 13 illustrate the systems which are known to utilize floating point hardware (binary or BCD). After 1958, more and more systems incorporated floating point arithmetic circuitry, and the execution speeds increased in the same manner as for the fixed point operations. The fastest floating point add time (0.8 microsec) is currently credited to the IBM-STRETCH machine. Floating point arithmetic has proven to be a useful feature both for scientific and business computers. There will be an increasing need for floating point hardware in business computers as more users employ mathematical tools and operations research techniques for business applications. The instances where a single machine is used for both business and

scientific computations will also press the need for floating point hardware in any general-purpose machine at least as an optional feature. For future computers, it is expected that a greater percentage will incorporate floating point hardware and the speeds will generally increase, but a computer with a floating point add time of less than 0.1 microseconds will probably not be built before 1965.

4. Floating Point Multiply Times - Figure 13 shows the comparative floating point multiply speeds. The wide pattern with some increasing speeds is generally the same as for all the other execution speeds. The fastest floating point multiply time (1.4 microsec) is credited to the IBM-STRETCH machine. A computer with a floating point multiply time of less than 0.5 microseconds will probably not be built before 1965.

Internal Memory

1. Number of Memory Speed Levels - In many computers the internal working memory consists of a combination of different types of memory devices with different speeds of access. For example, there are machine designs in which a small amount of core storage is backed up by additional drum storage, or a few high speed drum bands are backed up by a large number of slower bands. In many cases, the slower storage media is not directly addressable, and provisions are made to transfer data to and from the high speed storage in some modular quantity such as 20 or 100-word blocks. A homogenous, directly-addressable memory is desirable from a programmer's viewpoint, since the programs which use multi-level storage are necessarily more complex and less efficient than programs which utilize single-level storage. However, for large memories, the multi-level storage does provide a reasonable compromise between the expense and performance of high-speed and low-speed systems. Figure 15 illustrates the number of systems which have used 1-, 2-, 3-, or 4-level memories. Single level systems are more numerous than any other type. For future machines, it is expected that the single level machines will continue to dominate the scene, but there will still be many multi-level systems.

2. Types of High Speed Memory - Figure 16 describes the types of devices which have been used for the high speed memory. A definite pattern of emergence and de-emphasis can be noted for most of the devices. The various types of high speed memory--relay, vacuum tube, delay line, drum, cathode ray tube, magnetic core, disk, and diode-capacitor--made their operational appearance in that order.

It would appear that the relay, vacuum tube, delay line, and cathode ray tube memories are on the way out. From now until 1965, the drum and core memories will be the devices which will appear most frequently as the high speed memory devices. There will be an increased application of thin magnetic films[10] for memory applications in the immediate future and some systems with large (1000-5000 words) thin film memories should be operating before 1965. A small section (32 words) of film memory has already been used with the Lincoln Lab TX-2 computer[11, 12, 13], but it has been used as part of the control circuitry and not as part of the addressable memory.

3. High Speed Memory Size - In order to examine and compare the memory sizes of the single-level along with the multi-level memory systems, it was decided to look at the size of the highest speed memory as well as the size of the largest possible total internal memory size. Figures 17 and 18 illustrate the size of the high speed memory, which is always less than or equal to the total internal memory size. Figure 17 distinguishes between binary and non-binary memories, and Figure 18 distinguishes between the types of device used as the memory element. The maximum or extreme size of high speed memory is generally increasing. However, if the top and bottom extreme points are removed from either of these figures, the range of values actually shows very little change over the last decade. Another feature which is changing (see Fig. 18) is the type of device used for the high speed memory. This is in agreement with the data from the preceding section on types of high speed memory. Future computers will probably fall in the same range described in the figure, but there may be an occasional system which will show a larger high speed memory size, perhaps to 20 million bits. This figure is a little misleading since this size of memory could almost be achieved by a single magnetic drum. However, there will be an increasing number of systems with large, directly-addressable high speed memories.

4. High Speed Memory Access Time - Figure 19 shows the high speed memory access times, and distinguishes between the types of devices used as the memory element. This figure shows that with a few exceptions, the state-of-the-art of memory access time has not shown as rapid a development as some of the other operating speeds. Access times on the order of 10 microseconds have been achieved with computers since 1950. The credit for the fastest memory access time currently belongs to the University of Illinois ILLIAC-2, which achieves a 0.2 microsecond access time with a small section of high speed transistor flip-flop buffer memory. Most of the fast access times have been achieved with magnetic cores. The probable limit[12] to core switching speeds is 0.1 microseconds, and although the probably limit to thin film switching speeds is 0.01 microseconds, future computer systems

will probably not achieve an access time of less than 0.05 microseconds before 1965. The higher memory speeds in the immediate future will probably be obtained with thin magnetic films, transistor flip-flops, and diode-capacitor memories. Tunnel diodes have also been mentioned[14] as devices for high speed access (10^{-8} to 10^{-7} sec), but they will probably not be available in an operational computer before 1965.

5. Total Memory Size - Figure 20 shows the total amount of internal memory which is available for each computer. There is a large spread of values, and a general increase in the maximum sizes, but the average size of the memory has remained about the same for the last ten years. Future systems will probably fall in the same range described by the figure. There will be an increasing use of large, random-access devices such as the disk files or drum files. A computer system which utilizes photoscopic storage for high density permanent storage (such as the glass disk memory developed for the Air Force machine translation projects) will probably be demonstrated before 1965.

Discussion

An examination of many of the computer characteristics failed to disclose any significant trends. The number of bits or digits per instruction or data word is an example of this lack of definite trend. For many characteristics, it appears that the majority of machines have utilized approximately the same state-of-the-art, or have copied each other to a large extent, and that a relatively small group of machines have provided the significant technical advances. It is also interesting to note that very few of the machines which were developed for commercial exploitation really provided any major advances in the characteristics studied in this paper. It would appear that if there is an interest only in predicting the extensions of the state-of-the-art, then this can probably be accomplished primarily by looking at the small number of developmental and feasibility machines in addition to studying the progress which is being reported on circuit and component development.

The collected data seems to suggest that the majority of the computers developed between now and 1965 will show very little change in performance from that which was obtained during the last five years. However, a few research machines will definitely advance the technology, possibly as much as one order of magnitude for some of the characteristics, such as multiply times, memory sizes and memory access times.

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Appendix A

Definitions

Computer

This is the name of the computer model being described. If significant changes have been made in the original model, then the new computer configuration is described as an additional entry (e.g., IBM 705 Mod. 1, IBM 705 Mod. 2, IBM 705 Mod. 3). Whenever possible, the manufacturer's or builder's name precedes the computer's common name.

Operational Date

This is the date on which the computer model was operating as a complete system. This may not be a clearly defined date, but represents an approximation to the date at which a system with the described parameters was shown to be an actuality.

Number of Addresses per Instruction

This indicates the number of addresses which are included in a single instruction. This includes addresses of the next instruction, as well as addresses for the data being operated upon, and in some cases the addresses of addressable registers.

Binary (decimal) Digits Per Instruction (data word)

This indicates the number of functional digits per instruction and/or data word. The sign digit is included in this count, but not parity digit. If the data word can have 2 or 3 different sizes, the maximum size is considered.

Number of Index Registers

This is the number of special ("B-box") registers which can perform automatic address modification to the command which is currently being interpreted and executed.

Clock Rate

This is the internal pulse repetition rate or clock rate of the computer.

Add Time

This is the time required to execute an add command under optimum programming conditions. The time required for memory accesses are included in this number. Ten-digit operands were chosen for those machines which used a variable-length data word. If a range of speeds was given with no other explanation, an arithmetic mean of the range was chosen as the add time. It was assumed that no indirect addressing or address modification occurred at the time that the command was being executed.

Multiply Time

This is the time required to execute a multiply command under optimum programming conditions. The time required for memory accesses are included in this number. Ten-digit operands were chosen for those machines which used a variable-length data word. A word of "fives" was chosen for those cases where the execution time was a function of the value of the operand digits. If a range of speeds was given with no other explanation, an arithmetic mean of the range was chosen as the multiply time. It was assumed that no indirect addressing or address modification occurred at the time that the command was being executed.

Floating Point Add (Multiply) Time

This is the time required to execute a floating point command with floating point hardware. The execution times are not included for the machines which have to perform floating point arithmetic by subroutine. The general assumptions listed for the add and multiply times are also applicable here. If the floating point times are the same as the fixed point times, it is probably because the machine is basically a floating point machine and an entry was made in both the fixed and floating columns.

Number of Speed Levels of Memory

This is the number of different speeds of internal memory which are present in a computer. This number does not include auxiliary storage (magnetic tapes, drums, etc.) which is not essential to the operation of the basic machine. The amount and access time of the highest speed memory of each machine are described in separate tabulations.

High Speed Access Time

This is the time required to read a word (10 BCD characters if not otherwise specified) from the highest speed memory of the machine under optimum programming conditions. If a range of access times is quoted with no further explanation, then an arithmetic mean of the access time was used.

Type of High Speed Memory

This is the type of the highest speed memory used for each machine.

Total Memory

This is the total amount of available memory (bits for binary machines, characters for BCD, bi-quinary, or alpha-numeric machines) for all levels of directly-addressable memory, exclusive of auxiliary storage (magnetic tapes, drums, etc.)

Size of High Speed Memory

This is the total amount of available memory with the fastest access time.

General-Purpose, Stored-Program Computer

This is a machine which has a stored program (by plugboard, pinboard, or internal memory), and can perform program iterations and modify its own stored commands. (A few machines which do not completely satisfy this requirement are included in this report because of their historical or technological significance.)

APPENDIX B

AIL, INC., MODAC 5014
AIL, INC., MODAC 404
AIL, INC., MODAC 410
AIL, INC., MODAC 414
AIR FORCE CAMBRIDGE ABC
ALWAC 800
ALWAC 3-E
ARB. ELEK. RECH. PERM
ARGONNE LAB. AVIDAC
ARGONNE LAB. GEORGE
ATOM. EN. RES. EST. HARWELL
AUTONETICS RECOMP 1
AUTONETICS RECOMP 2
AUTONETICS VERDAN
BELGIAN BELL IRSIA-FNRS
BELGIAN BELL TEL. BELL
BELL TEL. MARK-22 *MOD-4*
BELL TEL. MODEL-6
BELL TEL. MODEL-5
BELL TEL. LEPRECHAUN
BENDIX G-15
BENDIX G-20
BIRBECK COLLEGE ARC
BIRBECK COLLEGE SEC
BIRBECK COLLEGE APERC
BIRBECK COLLEGE APEXC
BRITISH TAB. HEC-1
BRITISH TAB. HEC-2
BRITISH TAB. HEC-2M
BRITISH TAB. HEC-4 *1201*
BRITISH TAB. 555
BRITISH TAB. HEC 1202
BRITISH TAB. 1400
BROOKHAVEN MERLIN
BRUSH ELECT. ENG. CO., LTD.
BULL GAMMA-3
BULL GAMMA 60
BURROUGHS E101
BURROUGHS 205
BURROUGHS 220
BURROUGHS LAB COMPUTER
BURROUGHS UDEC-2
BURROUGHS UDEC-1
CAL INST. TECHNOL. MINAC
CAMBRIDGE UNIV. EDSAC-1
CAMBRIDGE UNIV. EDSAC-2
CLARY DE-60
COMP. RES. CORP. CADAC-102A
COMP. RES. CORP. CRC-107
COMP. RES. CORP. CADAC-102
CONSOL. ENG. CORP. 36-101
CONTROL DATA CORP. 1604
CONTROL DATA CORP. 160
CORBIN CORP. CORBIN
C.S.I.R.O. MARK-1
DANISH BOARD DASK
DARMSTADT DERA
DIG. EQUIP. CORP. PDP
REF. RES. TEL. EST. COMPUTER
EIDGEN. TECHN. HOCH. R4S
ELEC. LAB. TOKYO MARK-1
ELEC. LAB. TOKYO MARK-2
ELEC. LAB. TOKYO MARK-3
ELEC. LAB. TOKYO MARK-4
ELEC. LAB. TOKYO MUSASINO-1
ELEC. LAB. TOKYO SENAC-1
ELEC. LAB. TOKYO MARK-4A
ELEC. LAB. TOKYO MARK-5
ELLIOTT BROS. NICHOLAS
ELLIOTT BROS. 403
ELLIOTT BROS. 404
ELLIOTT BROS. 402E, F
ELLIOTT BROS. 402
ELLIOTT NRDC 401 MARK-1
E.M.I. ELECT. EMIDEC-1100
E.M.I. ELECT. EMIDEC-2400
ENG. ELEC. CO. DEUCE MK-1
ENG. ELEC. CO. DEUCE MK-2
ENG. ELEC. CO. DEUCE MK-2A
ENG. ELEC. CO. KDP-10
ERA LOGISTICS
FACIT INC. EDB
FERRANTI ARGUS
FERRANTI ATLAS
FERRANTI MANCHESTER MARK-1
FERRANTI MARK 1*
FERRANTI MERCURY (MARK 2)
FERRANTI ORION
FERRANTI PEGASUS-1
FERRANTI PEGASUS-2
FERRANTI SIRIUS
FERRANTI PERSEUS
FLAC
FORD INST. DATAKEEPER-1000
FUJI PHOTO FILM CO. FUJIC
FUJI COMMUN. FACOM-138
FUJI COMMUN. FACOM-1288
FUJI COMMUN. PC-2
FUJI COMMUN. FACOM-212
FUJI COMMUN. FACOM-222
GENERAL ELECTRIC 150
GENERAL ELECTRIC 210
GENERAL ELECTRIC 312
GENERAL ELECTRIC 100
GENERAL ELECTRIC OMIBAC
GENERAL ELECTRIC OARAC
GOETTINGEN G-3
GOETTINGEN G-1
GOETTINGEN G-2
GOETTINGEN G-2
HARVARD MK 2 *DAHLGREEN*
HARVARD MARK-3 *ADEC*
HARVARD MARK-4
HASLER ERMETH
HITACHI LTD. HIPAC-1
HITACHI LTD. HITAC-102
HITACHI LTD. HIPAC-101
HITACHI LTD. HITAC-301
HITACHI LTD. HITAC-1
HOGAN LABS CIRCLE COMP.
HOKUSHIN ELECT. H-1
HONEYWELL 800
HONEYWELL DATAMATIC 1000
HUGHES DIGITAC *AIRB*
HUGHES DIGITAIR *AIRB*
IBM 604
IBM 607
IBM 608
IBM 305 RAMAC
IBM 650 MOD. 1

IBM 650 MOD. 2
IBM 650 MOD. 4
IBM 701 *CRT MEMORY*
IBM 701 *MC MEMORY*
IBM 702 MOD. 1
IBM 702 MOD. 2
IBM 704
IBM 705 MOD. 1
IBM 705 MOD. 2
IBM 705 MOD. 3
IBM 709
IBM 7080
IBM 7070
IBM 7090
IBM 1401
IBM 1620
IBM STRETCH *LOS ALAMOS*
IBM AN/FSQ-7 *SAGE*
IBM AN/FSQ 7A *SAGE*
IBM NORC
IBM DINABOC *AIRBORNE*
IBM COMAR-1 610 PROT
IBM ASEC *HARVARD MK.1*
IBM DATA COORD/RETRIEVER
INFO. SYSTEMS 609
IN. P.M. RECHENAUTOMAT-IPM
JACOBS INSTR. JAINCOMP-A
JACOBS INSTR. JAINCOMP-B
JACOBS INSTR. JAINCOMP-C
JAPAN TEL. & TEL. M-1
KIDRICH INST. COMPUTER
LEEDS & NORTHRUP LN-3000
LEO COMPUTERS LTD. LEO-1
LEO COMPUTERS LTD. LEO-2
LEO COMPUTERS LTD. LEO-2C
LFE DIANA
LIBRASCOPE ASN-24 *AIRB*
LIBRASCOPE LGP-30
LIBRASCOPE LIBRATROL-500
LIBRASCOPE LIBRATROL-1000
LIBRASCOPE RPC-4010
LIBRASCOPE FAA-ARTC COMP.
LIBRASCOPE ASROC COMP.
LIBRASCOPE CP-209
LINCOLN LAB TX-0
LINCOLN LAB MEMORY TEST
LINCOLN LAB TX-2
LINCOLN LAB CG-24
LINCOLN LAB TX-3
LOS ALAMOS MANIAC-1
LOS ALAMOS MANIAC-2
MAGNAVOX MAC-3
MARCHANT MINIAC C,2
MATH CENTRUM ARMAC
MATH CENTRUM ARRA
MATSUSHITA COMM. DM-8001A
MELLON INST. COMPUTER
METR. VICK. METROVICK-950
METR. VICK. A.E.I. 1010
M.I.T. WHIRLWIND-1
MINISTRY OF SUPPLY MOSAIC
MIT WHIRLWIND-1 *MC MOD.*
MONROE MONROBOT-3
MONROE MONROBOT-5
MONROE MONROBOT-6
MONROE MONROBOT-MU
MOORE SCHOOL EDVAC
MOORE SCHOOL ENIAC
MOORE SCHOOL MSAC
NAREC
NATIONAL-ELLIOTT 802
NATIONAL-ELLIOTT 405M
NATIONAL-ELLIOTT 405
NAT. PHYS. LAB. PILOT ACE-1
NAT. PHYS. LAB. PILOT ACE-2
NAT. PHYS. LAB. ACE
NAVAL RES. LAB NAREC
NBS SWAC
NBS SEAC *DL MEMORY*
NBS SEAC *DL & CRT*
NBS DYSEAC
NBS PILOT *PRIMARY COMP.*
NBS PILOT *SECOND. COMP.*
NCR 102D
NCR 304
NCR 102A
NEPA/USAF FAIRCHILD COMP.
NIPPON ELECT. NEAC-1101
NIPPON ELECT. NEAC-1103
NIPPON ELECT. NEAC-2201
NIPPON ELECT. NEAC-1102
NIPPON ELECT. NEAC-2203
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OKI ELECT. OPC-1
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ONR RELAY COMPUTER
PACKARD BELL PROCESS CONTROL COMP. 3/60
PENN ST. UNIV. PENNSIAC
PHILCO COMPAC
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PHILCO C-1102
PHILCO S-1000 *SOLO*
PHILCO S-2000
POWERS-SAMAS PCC
PRAGUE SAPO
PRINCETON INST. AD. ST. IAS
PTT PTERA
RAND CORP. JOHNNIAC
RAYTHEON RAYCOM
RAYTHEON RAYDAC
RCA 110 *PROCESS CONTROL*
RCA 502
RCA 503
RCA BIZMAC 2
RCA 501
RCA BIZMAC 1
RCA 504
REA CO. READIX
REM-RAND UNIVAC 1102
REM-RAND UNIVAC-1
REM-RAND UNIVAC 1101
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REM-RAND UNIVAC-3
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REM-RAND ATHENA
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REM-RAND AFCRC MAG. COMP.
REM-RAND X-308 *BOGART*
REM-RAND LARC
REM-RAND M-460 *COUNTESS* 5/58
RICE INSTITUTE COMPUTER
RPC-4000
RW-40 *AN/FSQ-27*
RW-300
RW-400
RW-30 *AIRBORNE*
SAAB CO. SARA
SHIBAURA ELECT. TAC
SHIBAURA ELECT. TOSBAC-3
SIEMENS 2002
SOC. DELECT. AUTO. CAB-500
SOC. DELECT. CAB-2000
SOC. NOUV. DELECT. KL-901
SOC. DELECT. CUBA
SOC. DELECT. AUT. CAB-3000
SOC. DELECT. AUT. CAB-3030
STAND. TEL. STANTEC ZEBRA
STANDARD ELECTRIC STANLEC
STAND. ELEK. LORENZ ER -56
SWEDISH BOARD BARK
SWEDISH BOARD BESK
SYLVANIA MOBIDIC
SYLVANIA UDOFT
TBA-1
TECHNITROL 180
TEL. RES. EST. TRE COMPUTER
TELEFUNKEN TR-4
TOKYO SHIBAURA CO. TAC
TOKYO UNIV. PC-1
TOKYO UNIV. MUSASINO-1
UNDERWOOD ELECOM 100
UNDERWOOD ELECOM 120
UNDERWOOD ELECOM 125
UNDERWOOD ELECOM 200
UNIV. OF CALIF. CALDIC
UNIV. OF LUND SMIL
UNIV. OF TORONTO UTEC
UNIV. OF ILL. ORDVAC
UNIV. OF ILL. ILLIAC-1
UNIV. OF ILL. ILLIAC-2
UNIV. OF MICH. MIDAC
UNIV. OF WISC. WISC
UNIV. OF MICH. MIDSAC
USSR ARAGATZ
USSR EREVAN
USSR M-3
USSR VOLGA
USSR MESM
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USSR STRELA *ARROW*
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USSR URAL
USSR BESM-2
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VIENNA TECH URRI
VIENNA TECH. MAILUFTERL
WEGEMATIC 1000
WEIZMAN INST. WEIZAC
WESTINGHOUSE NORDIC-2
WHARF ENG. LAB. MAC
WARF ENG. LAB. M-2
WILLOW RUN RES. CEN. MIDAC
ZEISS RELAY COMP. OPREMA
ZEISS ZRA-1
ZUSE CO. Z-4
ZUSE CO. Z-11
ZUSE CO. Z-5
ZUSE CO. Z-22

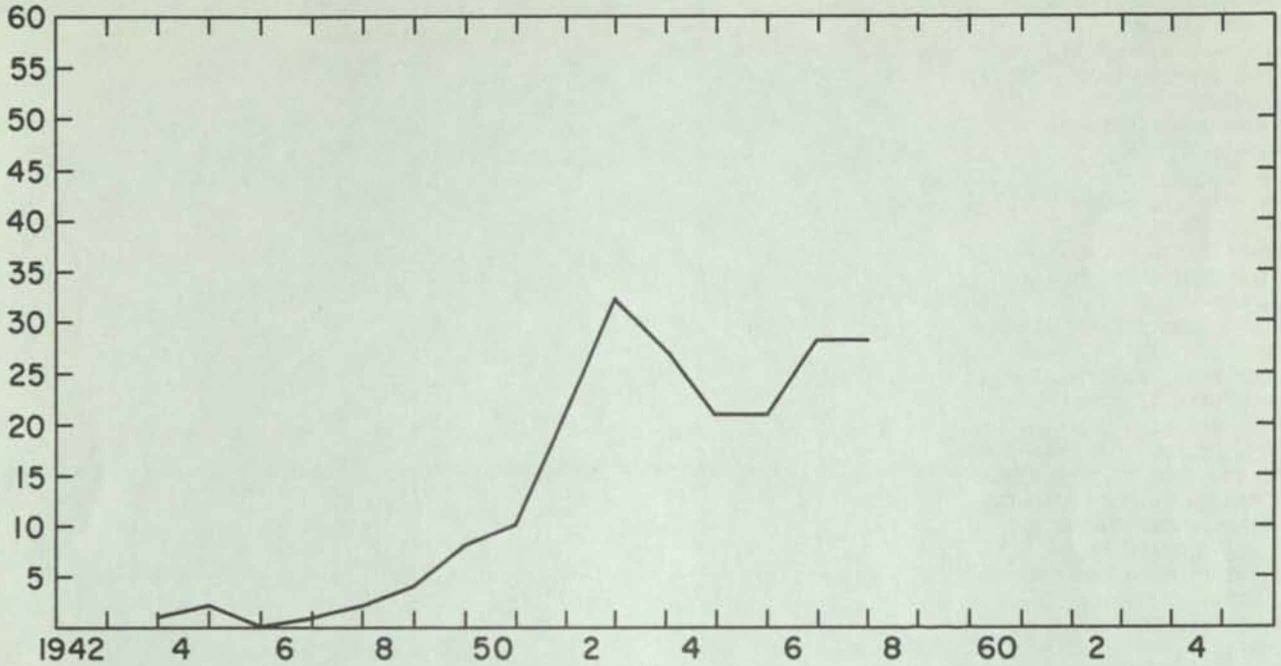

FIG. 1 NUMBER OF DIFFERENT TYPES OF COMPUTERS BUILT PER YEAR

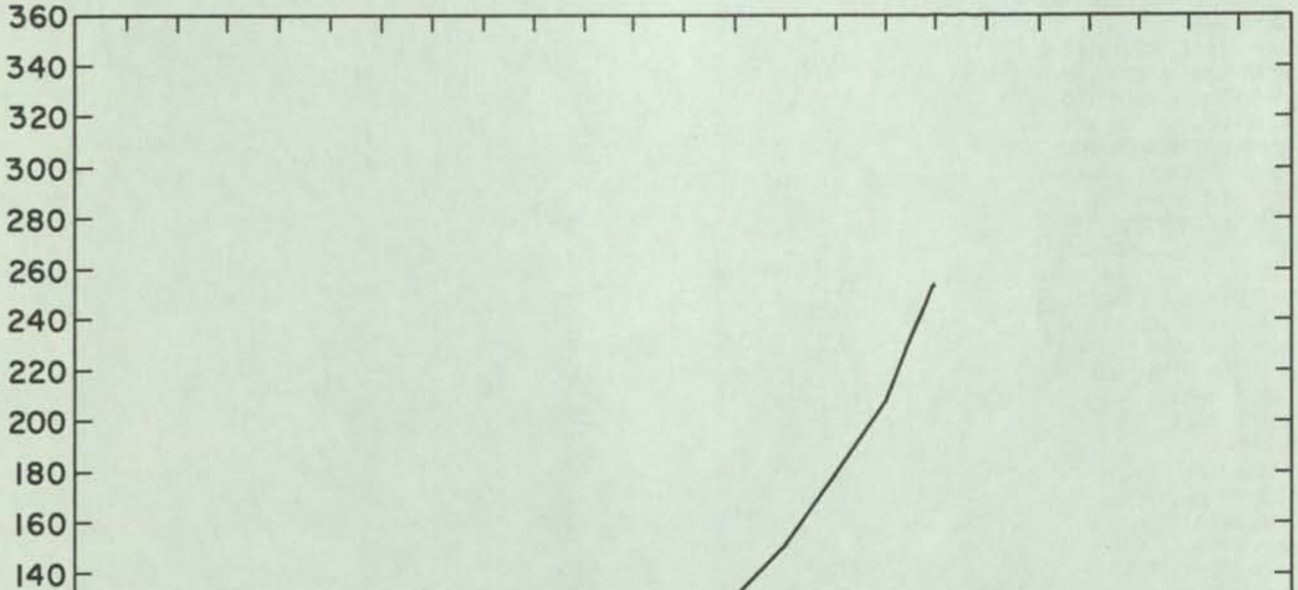

FIG. 2 TOTAL NUMBER OF DIFFERENT TYPES OF COMPUTERS DEVELOPED TO DATE

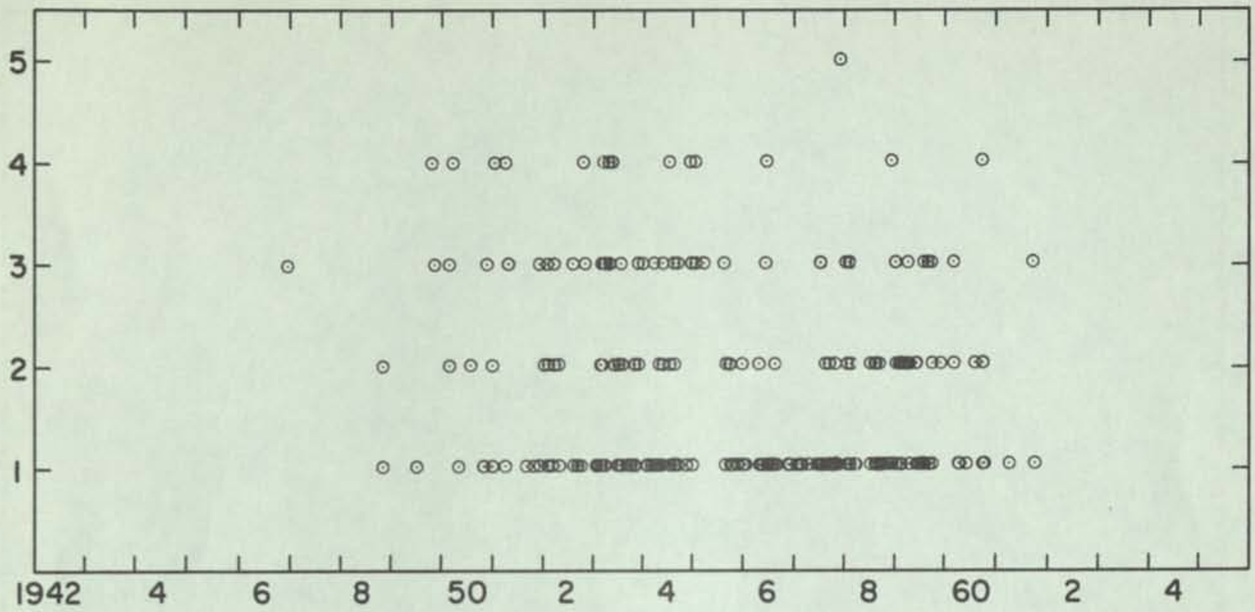

FIG. 3 NUMBER OF ADDRESSES PER INSTRUCTION

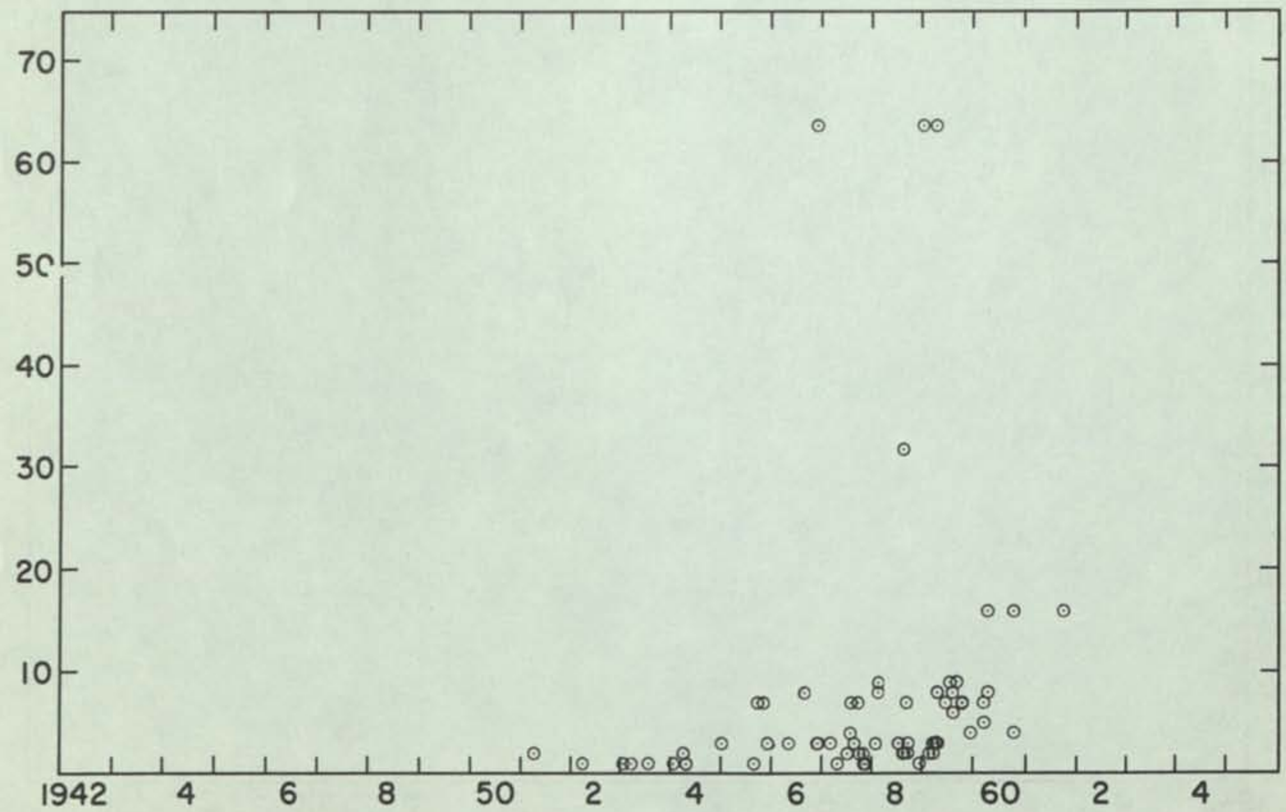

FIG. 4 NUMBER OF INDEX REGISTERS PER MACHINE

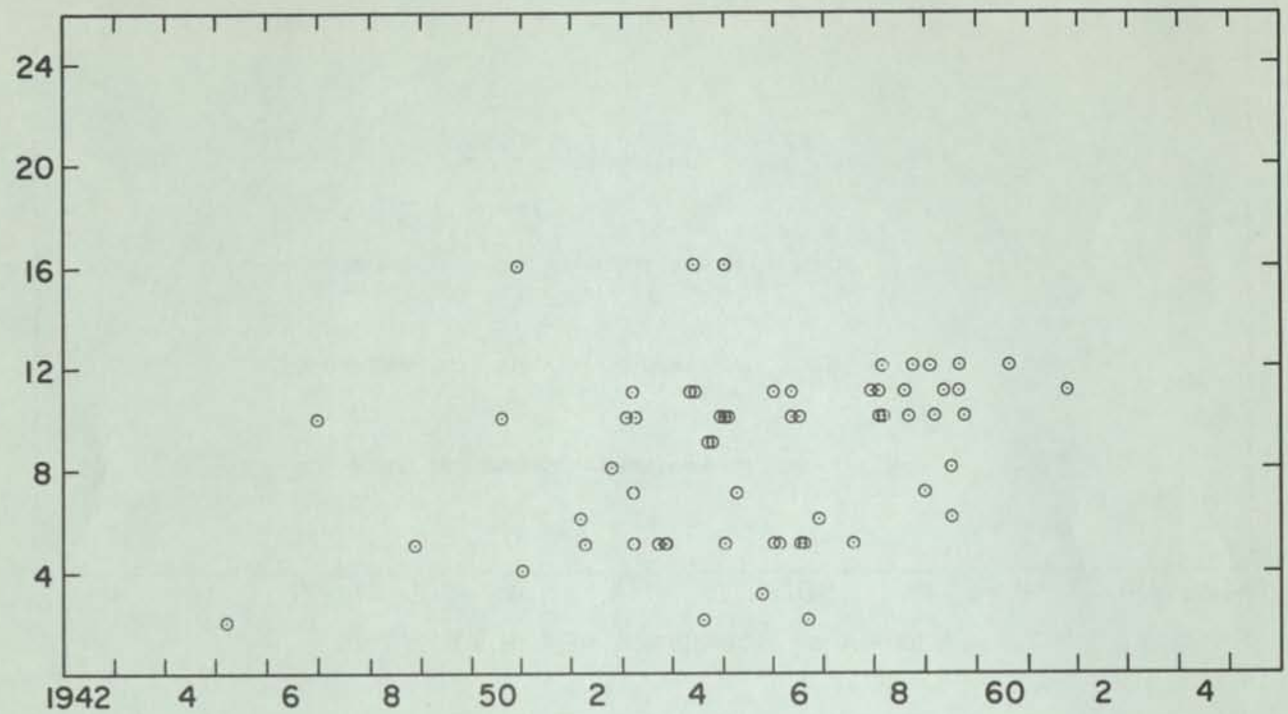

FIG. 5 NUMBER OF DIGITS PER INSTRUCTION

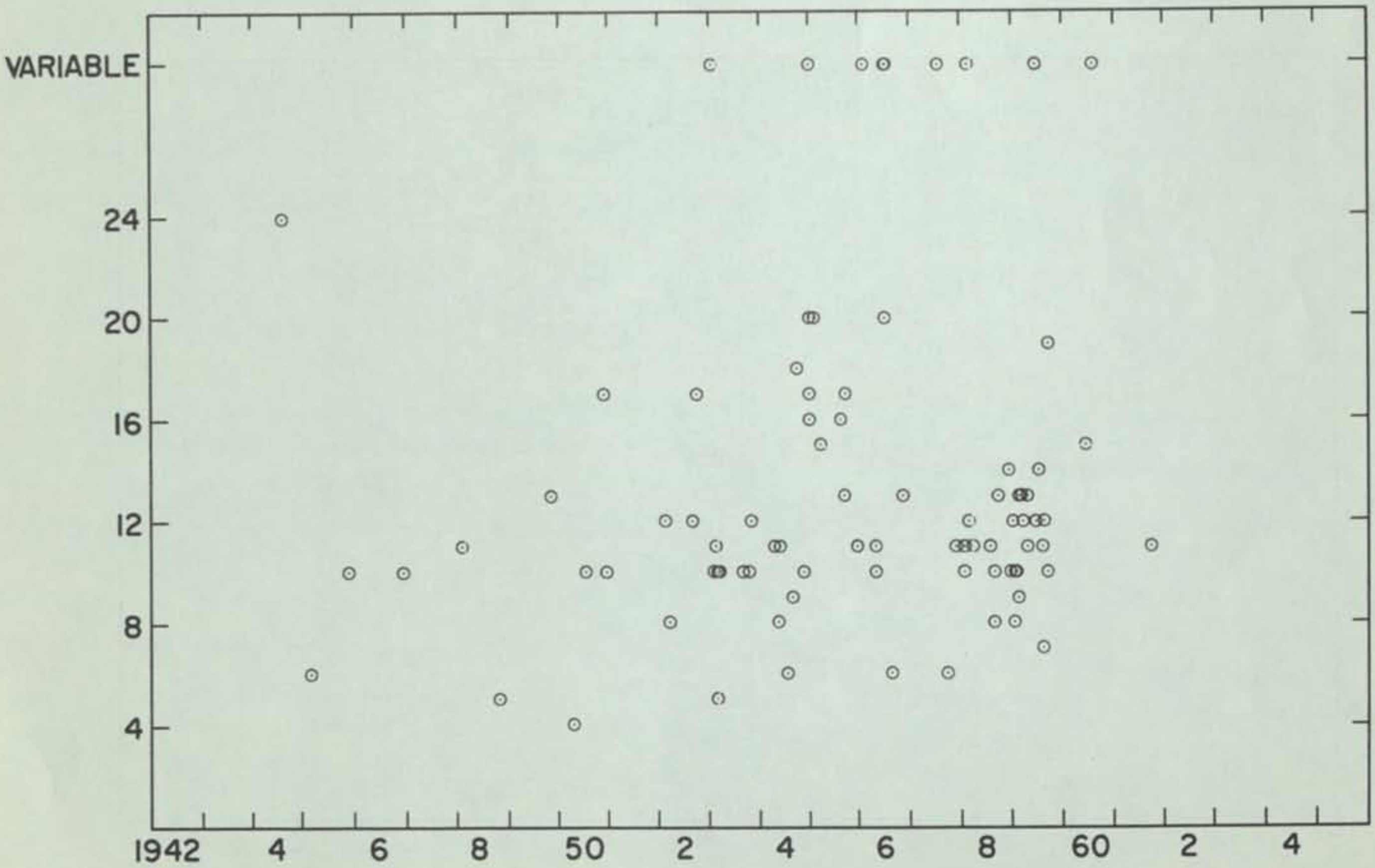

FIG. 6 NUMBER OF DIGITS PER DATA WORD

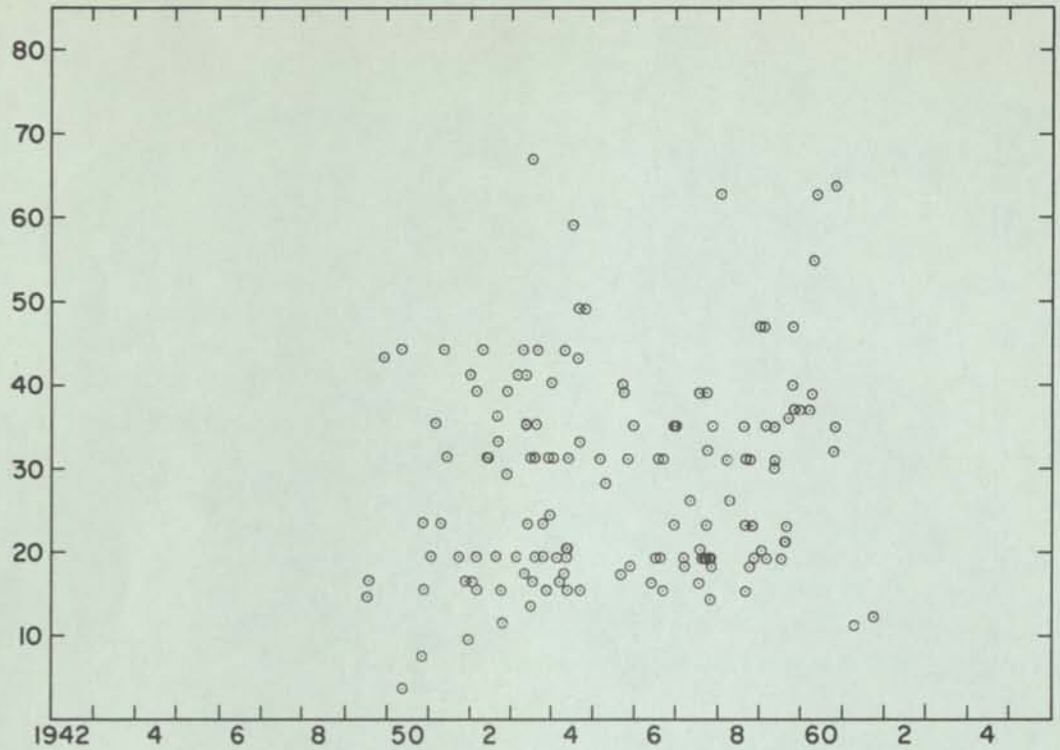

FIG. 7 NUMBER OF BINARY BITS PER INSTRUCTION

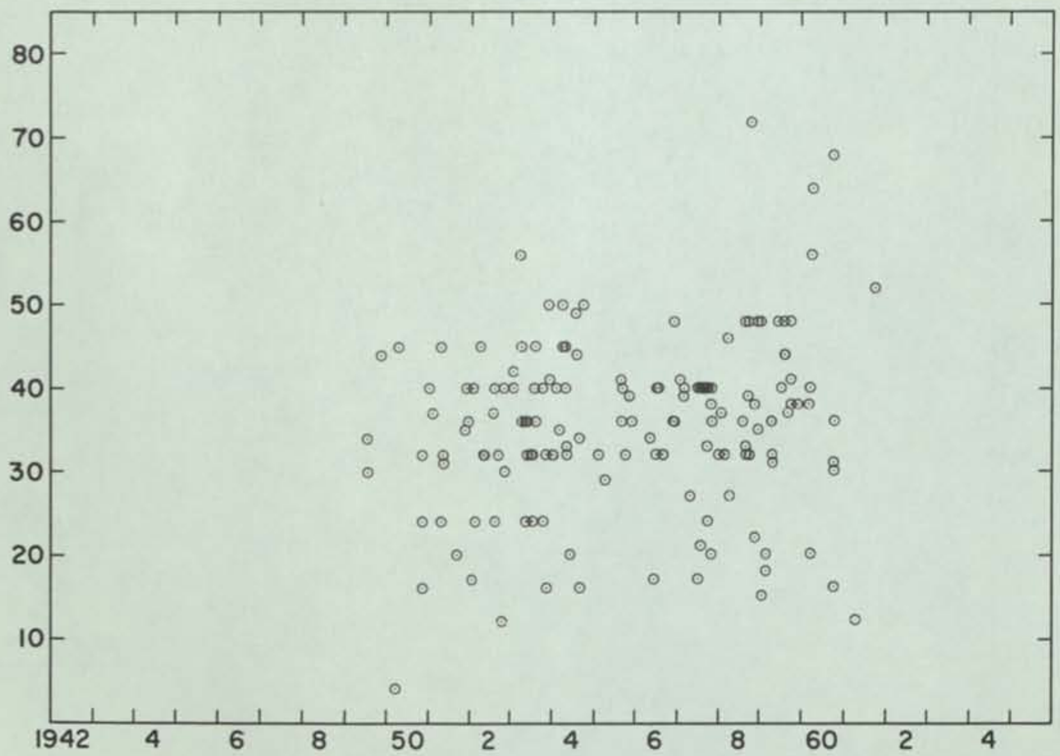

FIG. 8 NUMBER OF BINARY BITS PER DATA WORD

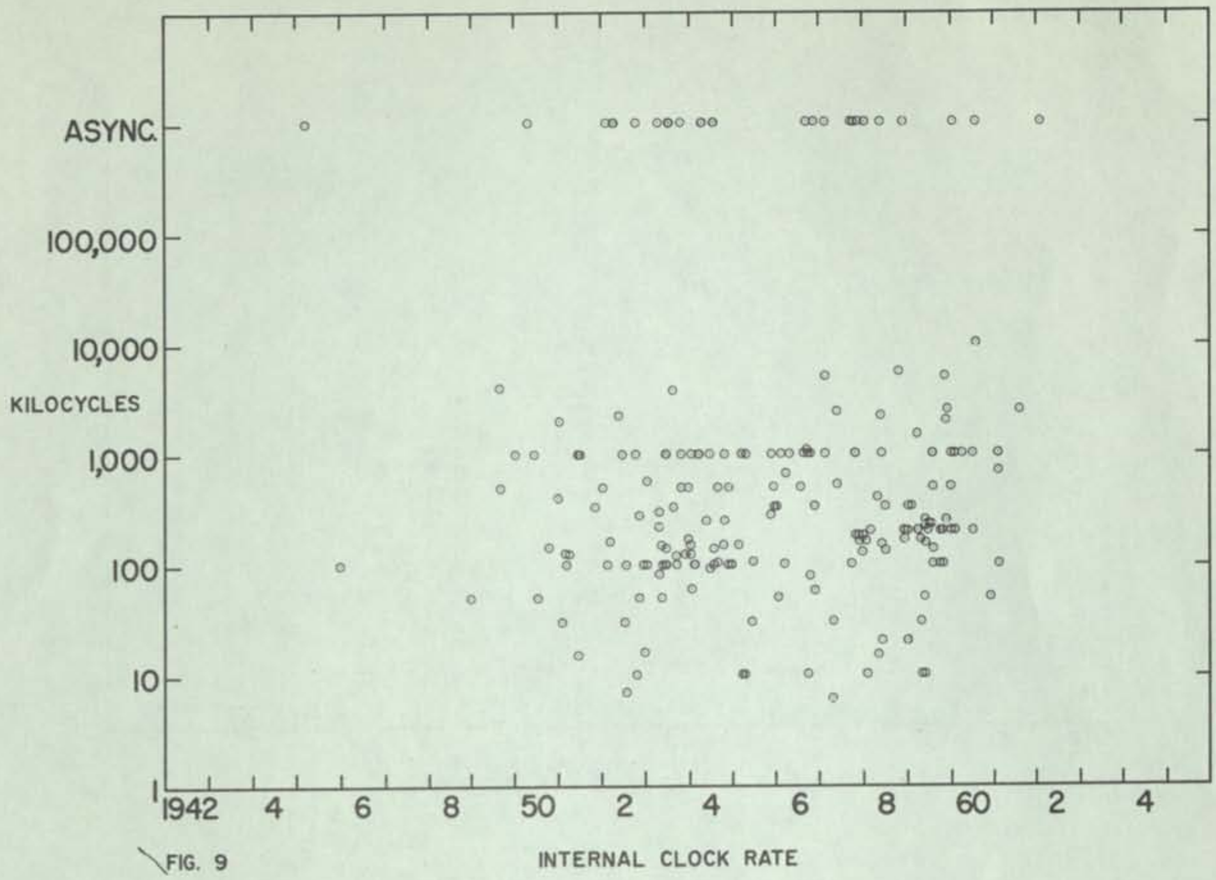
ASYNC.
100,000
10,000
KILOCYCLES
1,000
100
10
1
1942
4
6
8
50
2
4
6
8
60
2
4
INTERNAL CLOCK RATE

FIG. 9

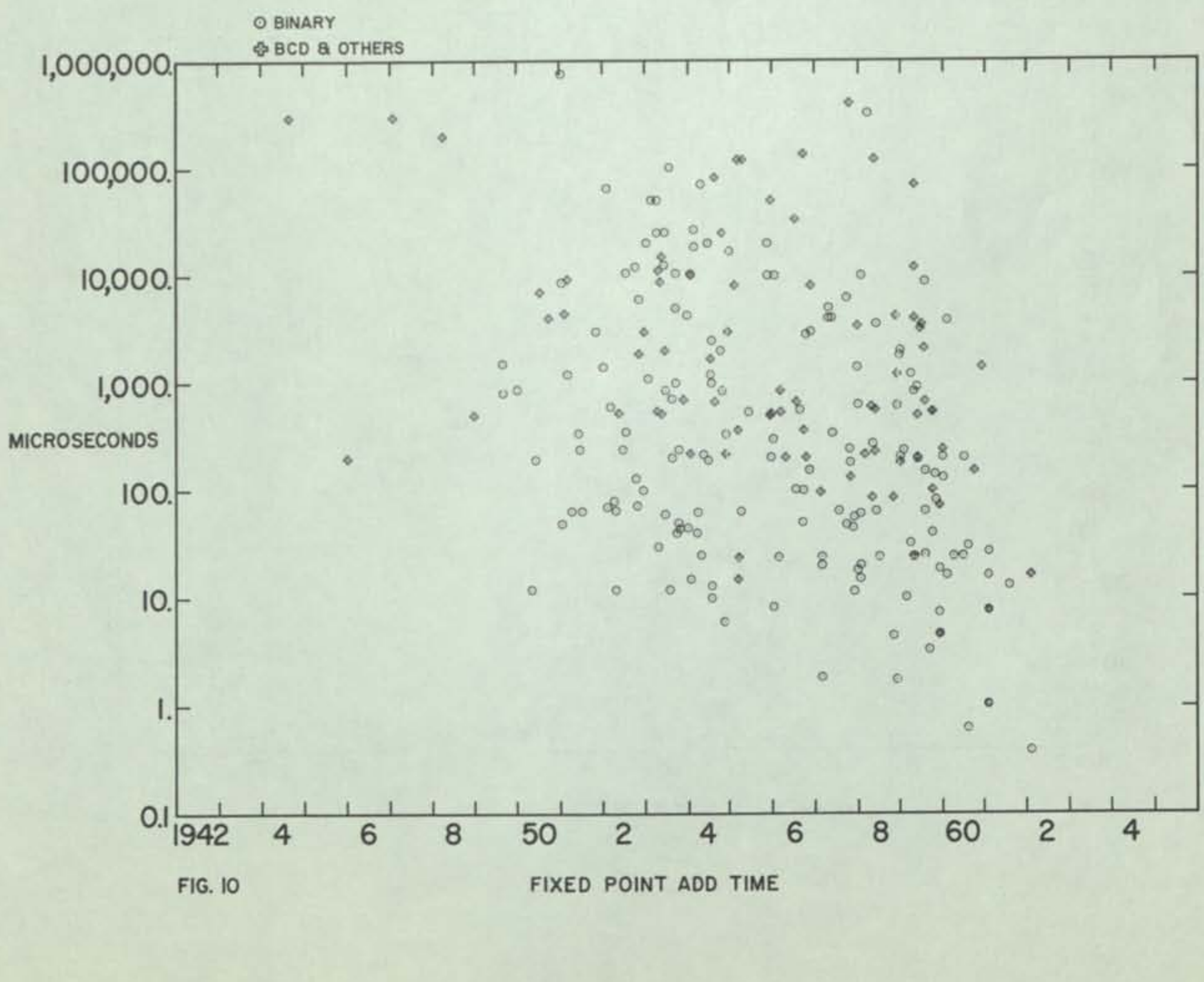
O BINARY
BCD & OTHERS
1,000,000.
100,000.
10,000.
1,000.
MICROSECONDS
100.
10.
1.
0.1
1942
4
6
8
50
2
4
6
8
60
2
4
FIXED POINT ADD TIME

FIG. 10

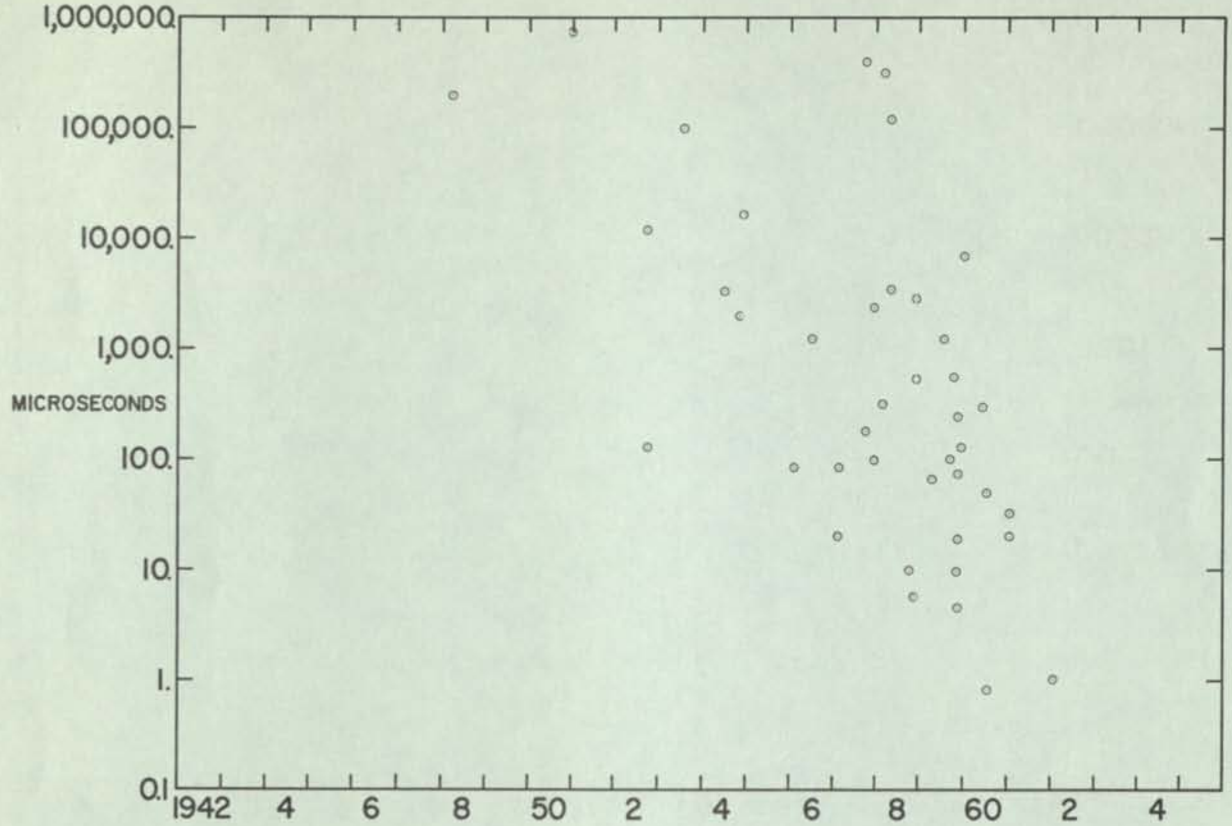

FIG. 11 FLOATING POINT ADD TIME

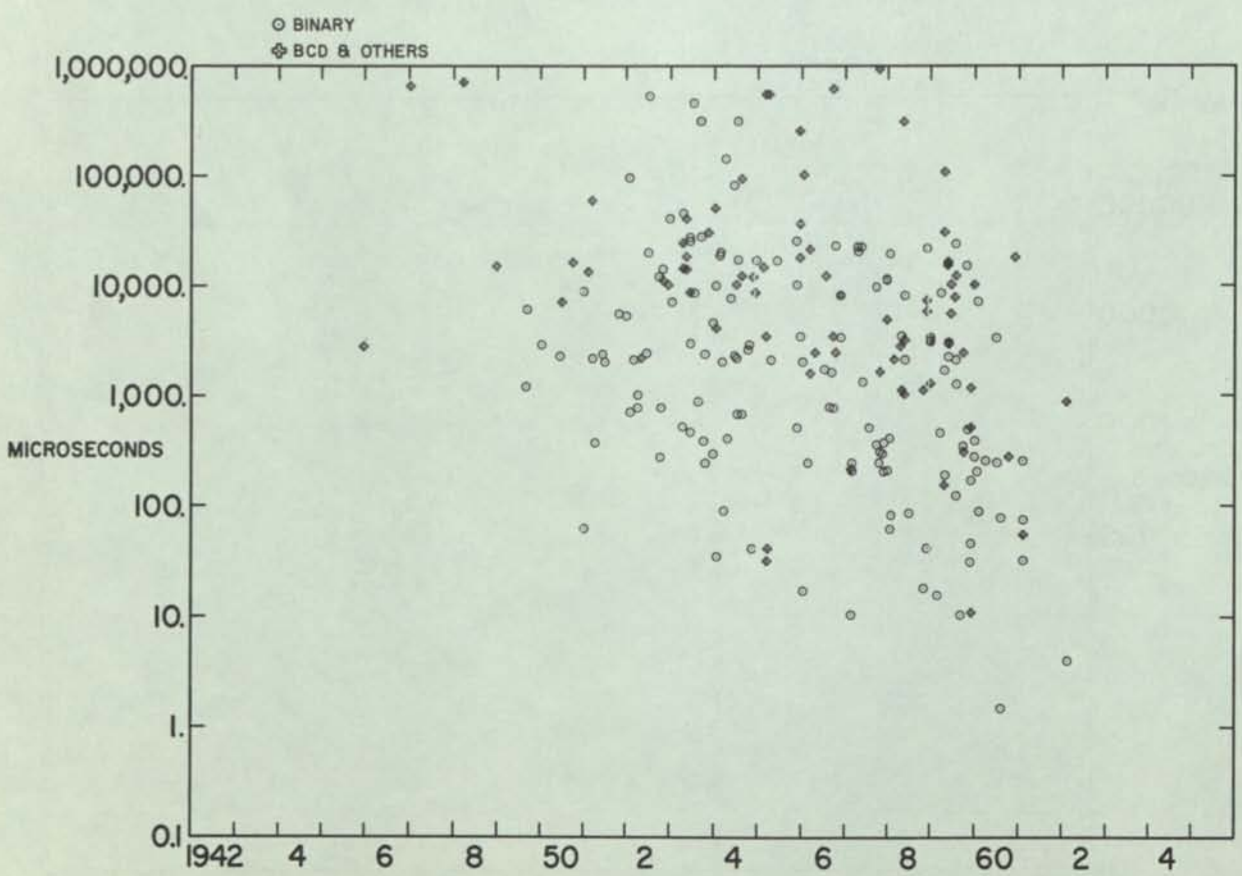

FIG. 12 FIXED POINT MULTIPLY TIME

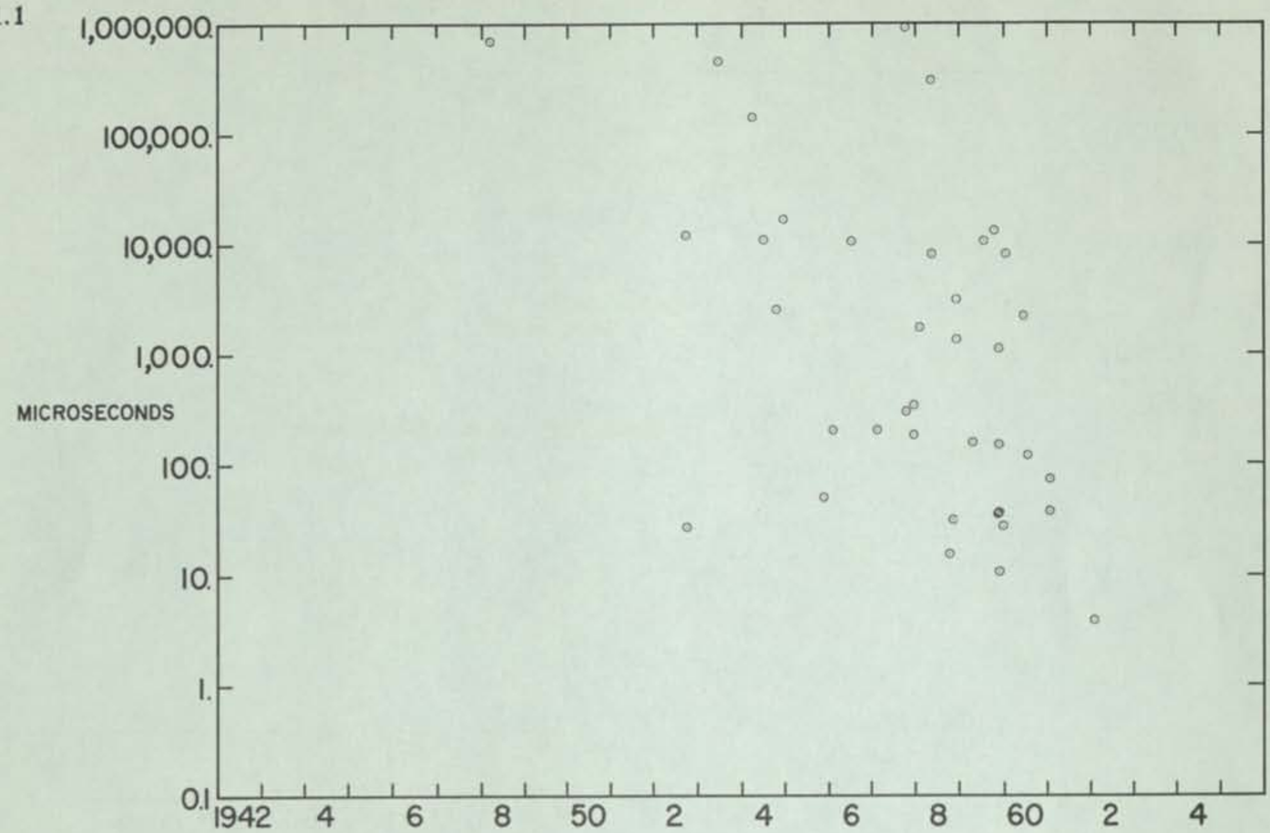

FIG. 13 FLOATING POINT MULTIPLY TIME

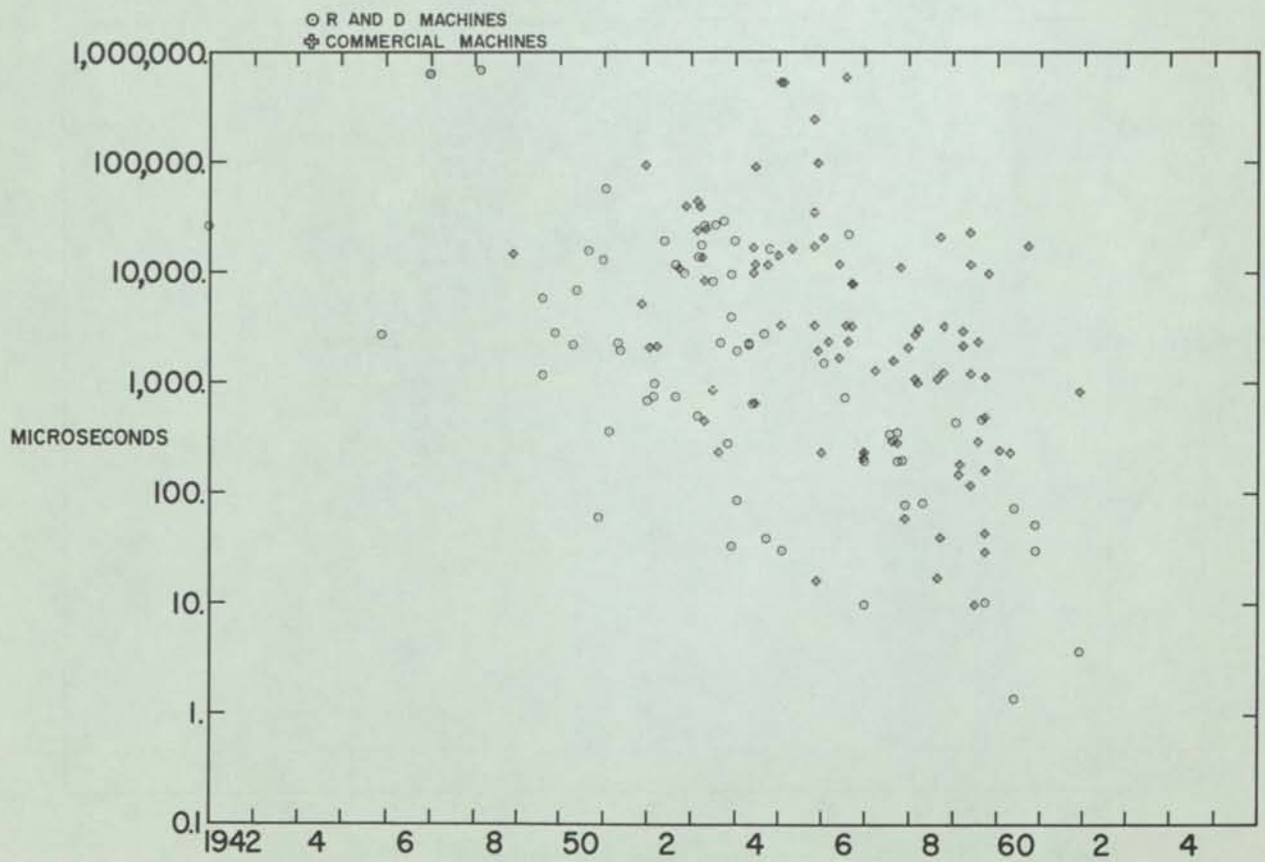

FIG. 14 FIXED POINT MULTIPLY TIME - BY COMPUTER TYPE

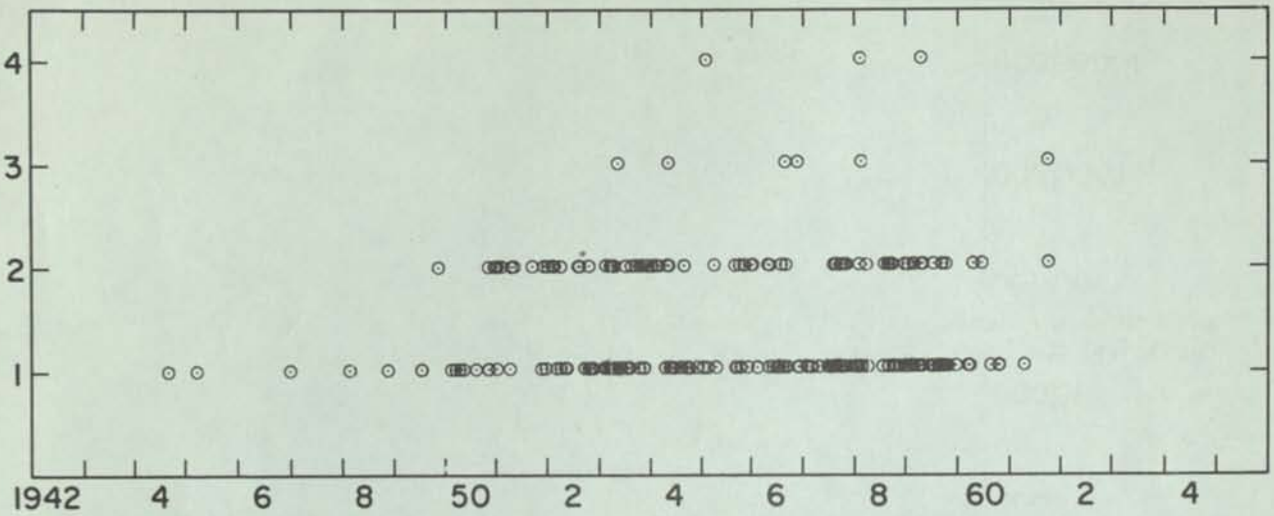

FIG. 15 NUMBER OF MEMORY SPEED LEVELS

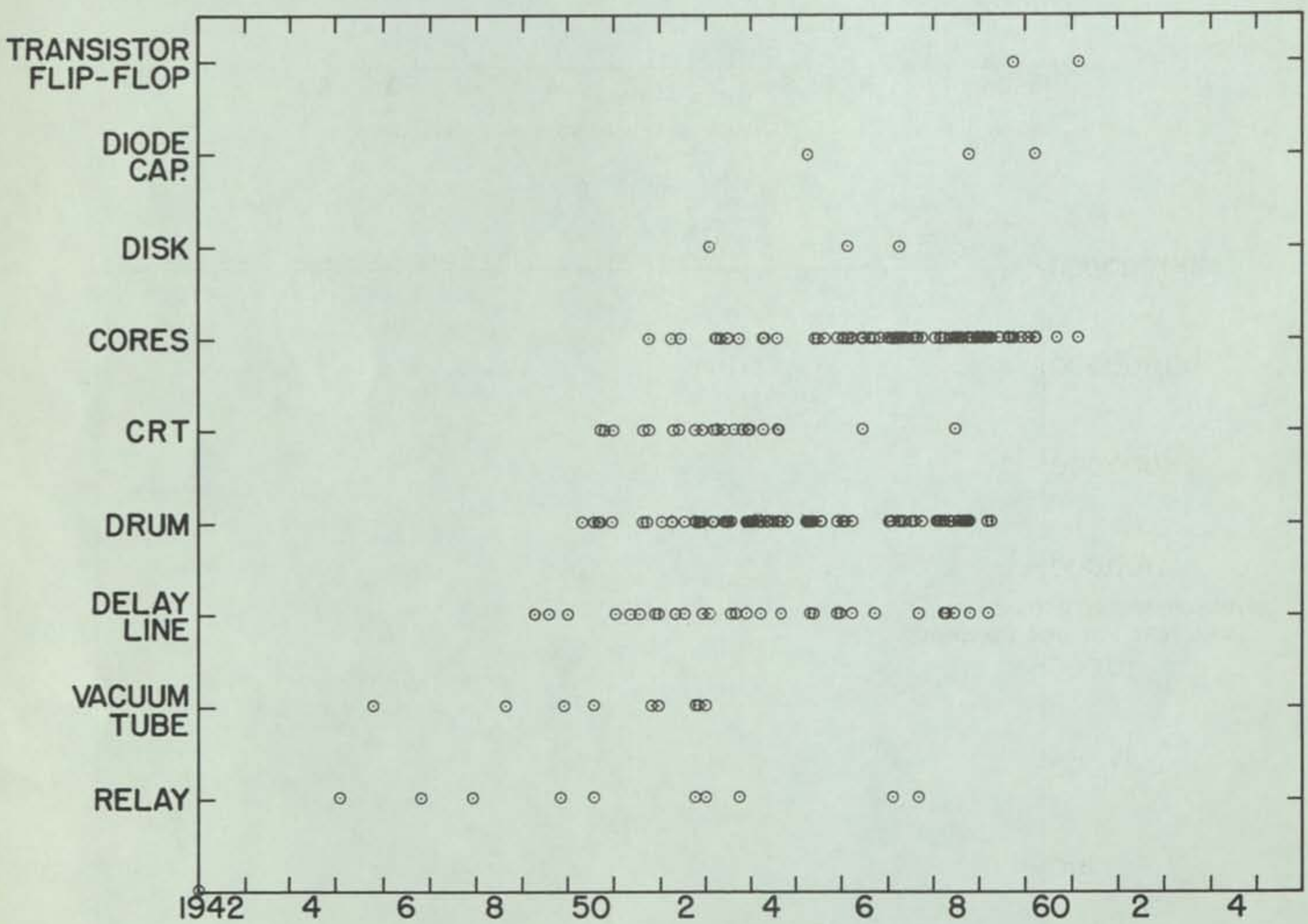

FIG. 16 TYPES OF HIGH SPEED MEMORY

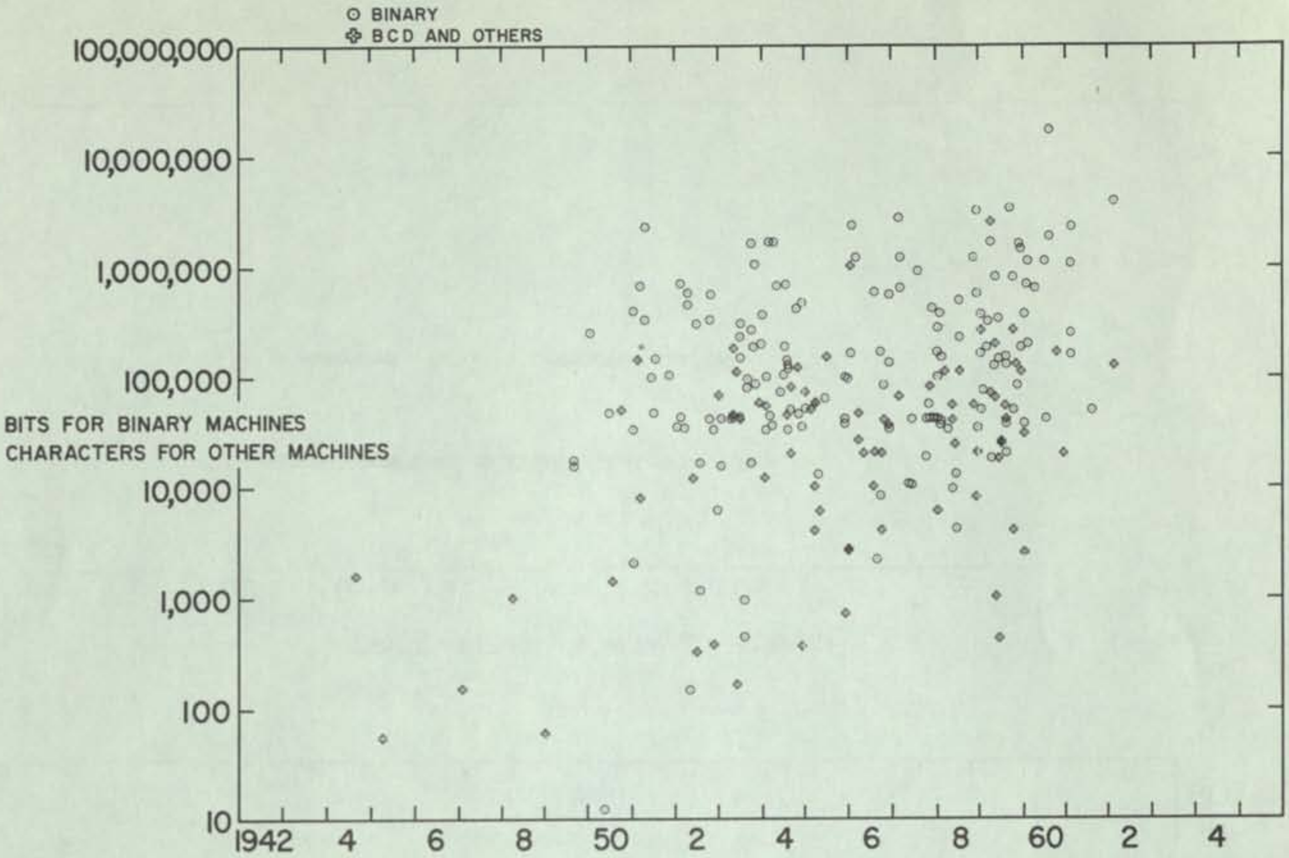

FIG. 17 HIGH SPEED MEMORY SIZE - BY CODE

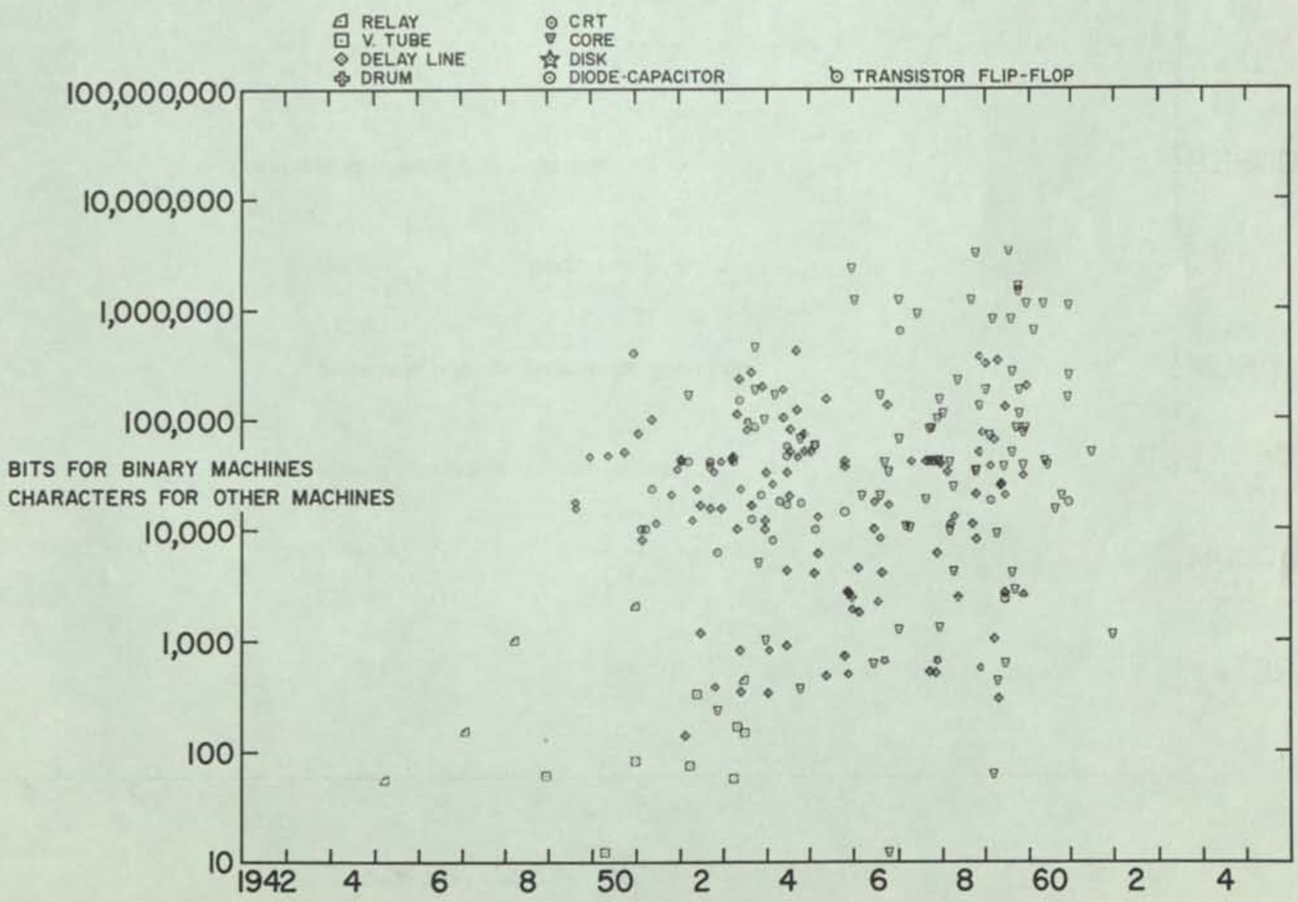

FIG. 18 HIGH SPEED MEMORY SIZE - BY TYPE

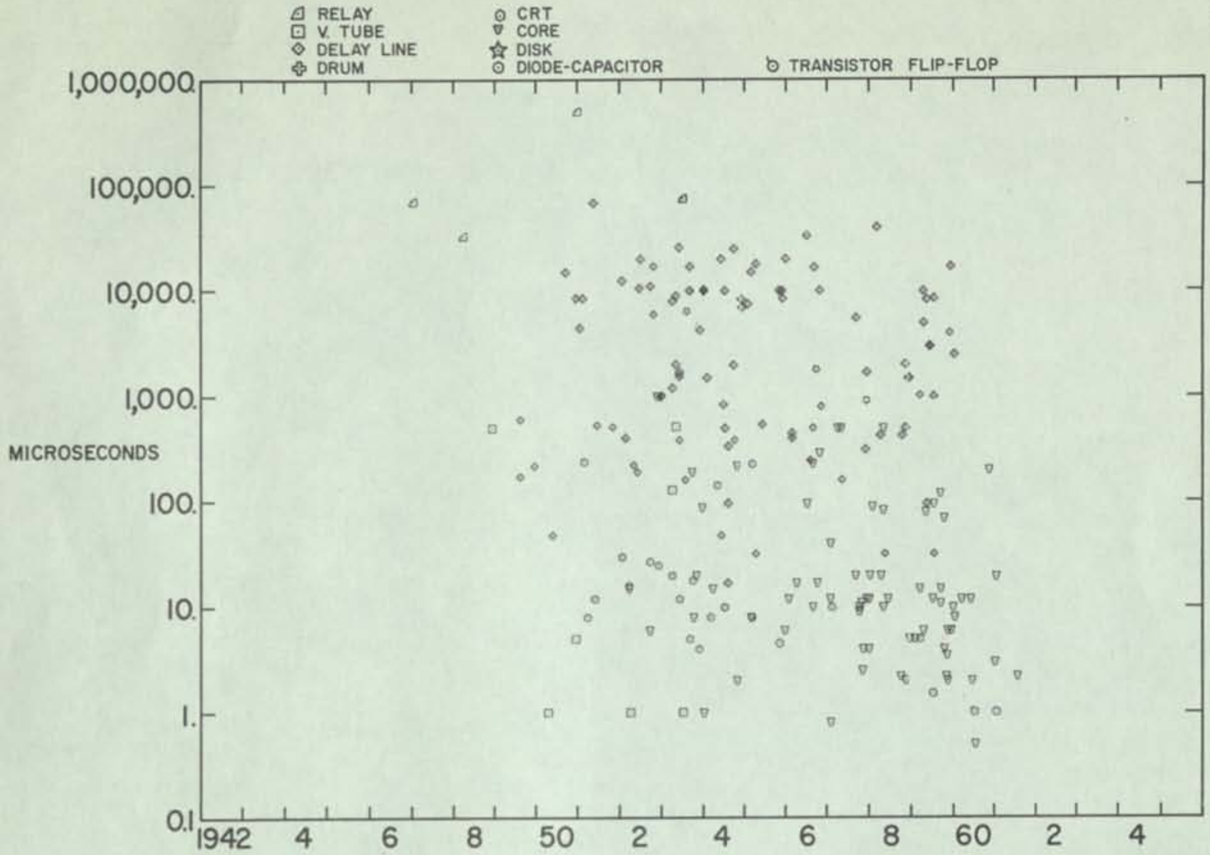

FIG. 19 HIGH SPEED MEMORY ACCESS TIME

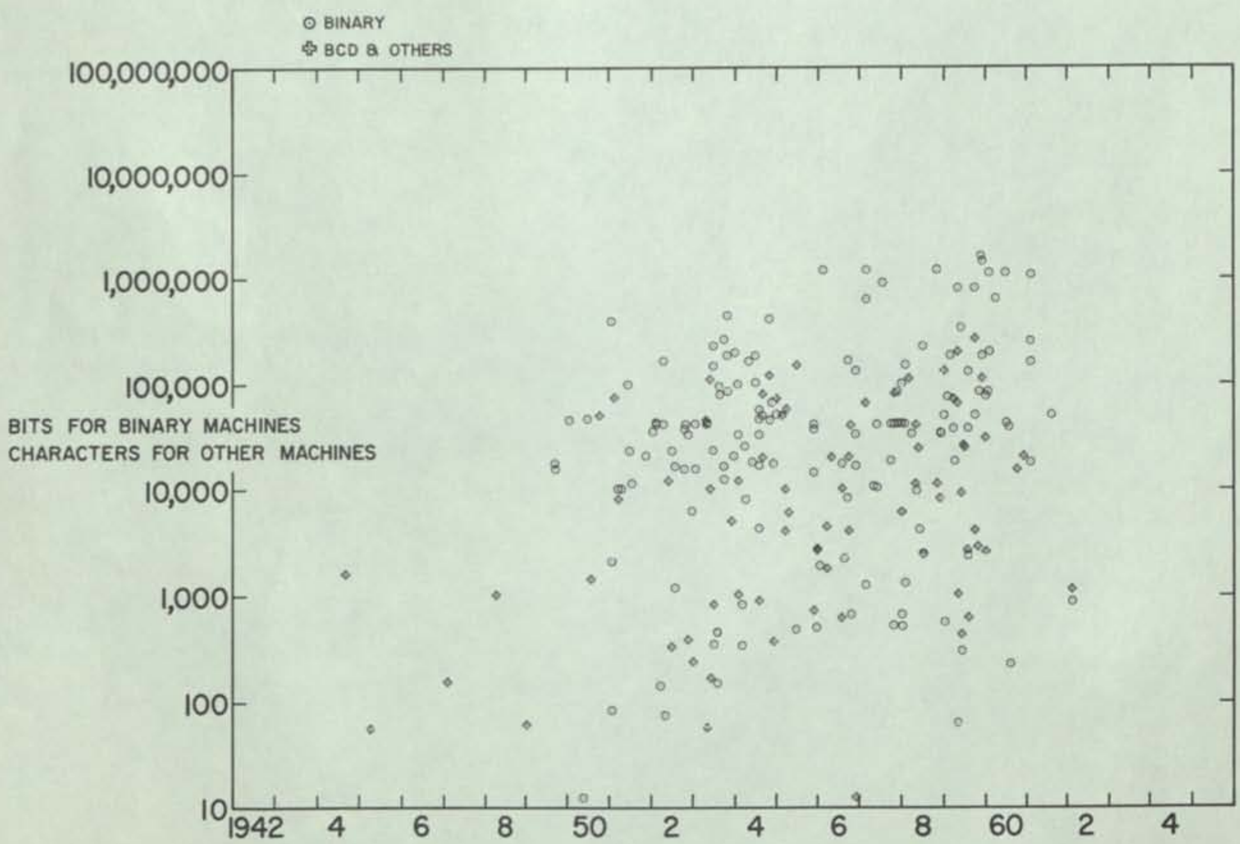

FIG. 20 TOTAL MEMORY SIZE

LIST OF JOINT COMPUTER CONFERENCES

1. 1951 Joint AIEE-IRE Computer Conference, Philadelphia, December 1951
2. 1952 Joint AIEE-IRE-ACM Computer Conference, New York, December 1952
3. 1953 Western Computer Conference, Los Angeles, February 1953
4. 1953 Eastern Joint Computer Conference, Washington, December 1953
5. 1954 Western Computer Conference, Los Angeles, February 1954
6. 1954 Eastern Joint Computer Conference, Philadelphia, December 1954
7. 1955 Western Joint Computer Conference, Los Angeles, March 1955
8. 1955 Eastern Joint Computer Conference, Boston, November 1955
9. 1956 Western Joint Computer Conference, San Francisco, February 1956
10. 1956 Eastern Joint Computer Conference, New York, December 1956
11. 1957 Western Joint Computer Conference, Los Angeles, February 1957
12. 1957 Eastern Joint Computer Conference, Washington, December 1957
13. 1958 Western Joint Computer Conference, Los Angeles, May 1958
14. 1958 Eastern Joint Computer Conference, Philadelphia, December 1958
15. 1959 Western Joint Computer Conference, San Francisco, March 1959
16. 1959 Eastern Joint Computer Conference, Boston, December 1959
17. 1960 Western Joint Computer Conference, San Francisco, May 1960
18. 1960 Eastern Joint Computer Conference, New York, December 1960
19. 1961 Western Joint Computer Conference, Los Angeles, May 1961
20. 1961 Eastern Joint Computer Conference. Washington, December 1961
21. 1962 Spring Joint Computer Conference, San Francisco, May 1962
22. 1962 Fall Joint Computer Conference, Philadelphia, December 1962
23. 1963 Spring Joint Computer Conference, Detroit, May 1963
24. 1963 Fall Joint Computer Conference, Las Vegas, November 1963
25. 1964 Spring Joint Computer Conference, Washington, April 1964

Conferences 1 to 19 were sponsored by the National Joint Computer Committee, predecessor of AFIPS. Back copies of the proceedings of these conferences may be obtained, if available, from:

- Association for Computing Machinery, 14 E. 69th St., New York 21, N. Y.
- American Institute of Electrical Engineers, 345 E. 47th St., New York 17, N. Y.
- Institute of Radio Engineers, 1 E. 79th St., New York 21, N. Y.

Conferences 20 and up are sponsored by AFIPS. Copies of AFIPS Conference Proceedings may be ordered from the publishers as available at the prices indicated below. Members of societies affiliated with AFIPS may obtain copies at the special "Member Price" shown.

Volume	*List Price*	*Member Price*	*Publisher*
20	$12.00	$7.00	Macmillan Co., 60 Fifth Ave., New York 11, N. Y.
21	6.00	6.00	National Press, 850 Hansen Way, Palo Alto, Calif.
22	8.00	4.00	Sparatan Books, Inc., 301 N. Charles St., Baltimore 1, Md.
23	10 00	5.00	Sparatan Books, Inc.
24	16.50	8.25	Sparatan Books, Inc.
25			Sparatan Books, Inc.

NOTICE TO LIBRARIANS

This volume (25) continues the Joint Computer Conference Proceedings (LC55-44701) as indicated in the above table. It is suggested that the series be filed under AFIPS and cross referenced as necessary to the Eastern, Western, Spring, and Fall Joint Computer Conferences.

2

FETCH - ENG

```
 Search request: F PE IEEE TRANSACTIONS HUMAN FACTORS
Search result:  4 records found in the PERIODICALS database

Type EXPLAIN LOCATE PE for library locations; HELP for more detail.
Type SHOW SEARCH to see other results available for DISPLAY.

1. IEEE transactions on human factors in electronics.
     New York, N.Y. : Institute of Electrical and Electronics Engineers,
   c1964-c1967.
     RELATED TITLES:
       Continues: IRE transactions on human factors in electronics.
       Continued by: IEEE transactions on man-machine systems.
       LLNL  Main lib  no call number         1-8  1960-67
       UCB   Engin     TA166.A1 I15           Bound 1(Mar 1960)-7(1966)//
       UCB   Engin     MICROFILM 32436        1(Mar 1960)-8(1967)
       UCSB  Main Lib  TA166 .I2 Sci-Eng      v.HFE-4 (1963)-v.HFE-8 (1967).  Not
                       currently received.
       UCSD  S & E     TK 1 I126              4-8 (1964-1967)
       NRLF            TK5700 I31             HFE. 1-8, 1960-67 VOLUMES RELOCATED
                       TO NRLF. INQUIRE AT PSL LOAN DESK; Type EXP NRLF for loan
                       details.
                                         (Record 1 continues on the next screen.)
Press RETURN to see the next screen.
CAT->
 Search request: F PE PROCEEDINGS AFIPS
Search result:  9 records found in the PERIODICALS database

Type EXPLAIN LOCATE PE for library locations; HELP for more detail.
Type SHOW SEARCH to see other results available for DISPLAY.

1. Joint Computer Conference.
     Joint Computer Conference.
     Montvale, N.J. [etc.] AFIPS Press [etc.]
     RELATED TITLES:
       Continues: Joint Computer Conference Proceedings.
       Continued by: National Computer Conference National Computer Conference
         and exposition 1973.
       UCB   Astr/Math QA76.A1 J6             Holdings not reported.
       UCB   Engin     QA76.A1 J6             BOUND fall
                       1962(22)-1972(41)//CUMULATIVE INDEXES: 1962(21)-1970(37)
       UCB   Main      QA76.A1 J6             CUMULATIVE INDEXES:
                       1962(21)-1970(37)
       UCD   Phys Sci  TK7885.A1J6            v.22-41,1962-1972.
       UCI   Main Lib  TK 7885 A1 J6          B22-41(1962-72).  Not currently
                       received.
                                         (Record 1 continues on the next screen.)
Press RETURN to see the next screen.
CAT->
 Search request: F personal author CAUTIN, H# AND TW EASY ENGLISH
Search result:  1 record at all libraries

Type SHOW SEARCH to see other results available for DISPLAY.

1. Caution, Harvey.
```

1

QA 76
A1 J6

try AFIPS for 1959

There are no more records to display. Type PS to see previous screen.
CAT->
Search request: F PE WESTERN JOINT COMPUTER CONFERENCE
Search result: 4 records found in the PERIODICALS database

Type D PE SHORT followed by record number to display call number and holdings.
Type EXPLAIN LOCATE PE for library locations; HELP for more detail.

1. JOINT COMPUTER CONFERENCE.
Proceedings. <UCSB>
no UCB.
2. JOINT COMPUTER CONFERENCE.
Proceedings of the ... Joint Computer Conference. <UCD,UCI,UCSC>
3. WESTERN JOINT COMPUTER CONFERENCE.
Proceedings. <UCLA>
4. Western Joint Computer Conference. los Angeles. Proceedings of the...
<USC>

CAT->
Search request: F XPE SPECIAL LIBRARIES #
Search result: 43 records found in the PERIODICALS database

Type EXPLAIN LOCATE PE for library locations; HELP for more detail.

10. (continued)
Other entries: Special Libraries Association.
Special libraries. Annual directory issue.

Subjects: Special libraries -- Periodicals.

Call numbers:

UCB	Bancroft	Z671 .S6	BOUND 38(1947)-39(1948) ; Library lacks: 38:1(Jan 1948)
UCB	Main	Z671 .S7	BOUND 1(1910)-86(1995); later issues unboundCUMULATIVE INDEXES: 1(1910)-17(1926); 1971-1986 Unbound issues in Periodical Room
UCB	Main	Z671 .S7 set 2	BOUND 71(1980)-83(1992)CUMULATIVE INDEXES: 1981-1986
UCD	Shields	Z671 S6 Stacks	v.72,19??- Unbound in SHIELDS Current Periodicals

(Record 10 continues on the next screen.)
Press RETURN to see next screen. Type PS to see previous screen.
CAT->

1 FETCH - ENG

Search request: F PE AFIPS CONFERENCE PROCEEDINGS
Search result: 9 records found in the PERIODICALS database

Type D PE SHORT followed by record number to display call number and holdings.
Type EXPLAIN LOCATE PE for library locations; HELP for more detail.

1. JOINT COMPUTER CONFERENCE.
   Joint Computer Conference. <UCB,UCD,UCSB,UCI,UCSC,CSL>
2. Joint Computer Conference. Afips Conference Proceedings. Sponsored by...
   <USC>
3. NATIONAL COMPUTER CONFERENCE.
   AFIPS conference proceedings. <UCLA>
4. NATIONAL COMPUTER CONFERENCE.
   Conference proceedings - National Computer Conference. <STAN>
5. NATIONAL COMPUTER CONFERENCE.
   National Computer Conference. <UCB,UCD,UCSB,UCI,UCSC,STAN,CSU,CSL>
6. NATIONAL COMPUTER CONFERENCE.
   National Computer Conference and exposition. <UCB,UCD,UCSB,UCI,UCSC>
7. National Computer Conference. Afips Conference Proceedings/American...
   <USC>
8. NATIONAL COMPUTER CONFERENCE AND EXPOSITION.
   Proceedings. <STAN>

Press RETURN to see the next screen.
CAT->
Search request: F PE AFIPS CONFERENCE PROCEEDINGS
Search result: 9 records found in the PERIODICALS database

Type EXPLAIN LOCATE PE for library locations; HELP for more detail.

5. National Computer Conference.
   National Computer Conference.
   Montvale, N.J., AFIPS Press.
   RELATED TITLES: want 1959
   Continues: National Computer Conference National Computer Conference and exposition.

UCB	Astr/Math	QA76.A1 J6 stacks	BOUND 1975(44)-1986(55) Monograph
UCB	Engin	QA76.A1 J6	BOUND 1975(44)-1987(56)//
UCD	Phys Sci	TK7885.A1J6	v.44-56,1975-1987.
UCI	Sci Lib	TK 7885 A1 J6 Bar	B42-56(1975-87). Not currently received.
UCSB	Main Lib	TK7885.A1 J6 Sci-Eng	v.44 (1975)-v.56 (1987). Not currently received.
UCSC	Science	TK7885.A1J6	44-56(1975-1987). Not currently received.

For Non-UC holdings type D SHORT 5 ALL.

CAT->
Search request: F PA LINCOLN, C# AND TW FOURTH FETCH
Search result: 1 record at all libraries

Type SHOW SEARCH to see other results available for DISPLAY.

Date of Conf.? for Hillman article chapt 4

1.
Author: International Association of Technological University Libraries.
Title: Educating the library user: proceedings of the fourth triennial meeting, 1970, edited by C. M. Lincoln. Loughborough (Leics.), Loughborough University of Technology (Library), 1970.
Description: [135] p. 1 illus., forms. 30 cm.

UCB Main Z711.2 I57

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The Institute of Radio Engineers (IRE)

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Bibliographical History
of the
Proceedings of the Eastern and Western Joint Computer Conferences
1951-1962

The first two conferences were held in the east. Since then there have been two a year, a spring one in the west and a late fall meeting in the east. A Joint Computer Committee to sponsor these conferences was organized by the Association for Computing Machinery, the Professional Group on Electronic Computers of the Institute of Radio Engineers, and the Committee on Computing Devices of the American Institute of Electrical Engineers.

In May 1961, the three parent societies created the American Federation of Information Processing Societies (AFIPS) to take over the sponsorship of the conferences from the National Joint Computer Committee. The AFIPS is set up so that other interested organizations can join. For further information on the history and objectives of these conferences see the Forword to the Proceedings of the Eastern Joint Computer Conference, held in Washington, D.C., December 12-14, 1961.

In 1962 these conferences combined to form the Joint Computer Conference, with the spring meeting held in the west and fall meeting held in the east.

The National Joint Computer Committee began assigning volume numbers to the proceedings beginning with volume 18. Retroactive volume numbers were assigned to the previous conferences proceedings. The chart below will make this sequence clear. The volume numbering is being continued with the Joint Computer Conference Proceedings.

Vol. Number	Conference	Location	Date
1	(1st) Eastern	Philadelphia	Dec. 10-12, 1951
2	(2nd) Eastern	New York City	Dec. 10-12, 1952
3	(1st) Western	Los Angeles	Feb. 4-6, 1953
4	(3rd) Eastern	Washington	Dec. 8-10, 1953
5	(2nd) Western	Los Angeles	Feb. 11-12, 1954
6	(4th) Eastern	Philadelphia	Dec. 8-10, 1954
7	(3rd) Western	Los Angeles	Mar. 1-3, 1955
8	(5th) Eastern	Boston	Nov. 7-9, 1955
9	(4th) Western	San Francisco	Feb. 7-9, 1956
10	(6th) Eastern	New York City	Dec. 10-12, 1956
11	(5th) Western	Los Angeles	Feb. 26-28, 1957
12	(7th) Eastern	Washington	Dec. 9-13, 1957
13	(6th) Western	Los Angeles	May 6-8, 1958
14	(8th) Eastern	Philadelphia	Dec. 3-5, 1958
15	(7th) Western	San Francisco	Mar. 3-5, 1959
16	(9th) Eastern	Boston	Dec. 1-3, 1959
17	(8th) Western	San Francisco	May 3-5, 1960
18	(10th) Eastern	New York City	Dec. 13-15, 1960
19	(9th) Western	Los Angeles	May 9-11, 1961
20	(11th) Eastern	Washington	Dec. 12-14, 1961
21	1962 Spring	San Francisco	May 1-3, 1962
22	1962 Fall	Philadelphia	December 1962

EASTERN JOINT COMPUTER CONFERENCE

1st, Philadelphia, December 10 - 12, 1951.
Review of electronic digital computers; Joint AIEE-IRE Computer Conference. Papers and discussions presented at the Joint AIEE-IRE Computer Conference.
New York, American Institute of Electrical Engineers, 1952.
(Its publication S-44)

2nd, New York, December 10 - 12, 1952.
Review of input and output equipment used in computing systems. Joint AIEE-IRE-ACM Computer Conference. Papers and discussions presented at the Joint AIEE-IRE-ACM Computer Conference.
New York, American Institute of Electrical Engineers, 1953.
(Its publication S-53)

3rd, Washington, December 8 - 10, 1953.
Proceedings. Theme: Information processing systems -- reliability and requirements. Papers and discussions presented at the Joint IRE-AIEE-ACM Computer Committee.
New York, Institute of Radio Engineers, 195[illegible].

4th, Philadelphia, December 8 - 10, 1954.
Proceedings. Theme: Design and application of small digital computers. Papers and discussions presented at the Joint ACM-AIEE-IRE Computer Conference.
New York, American Institute of Electrical Engineers, 1955.
(Its publication T-70)

5th, Boston, November 7 - 9, 1955.
Proceedings. Papers and discussions presented at the Joint ACM-AIEE-IRE Computer Conference. Theme: Computers in business and industrial syste[ms]
New York, Institute of Radio Engineers, 1956.

6th, New York, December 10 - 12, 1956.
Proceedings. Papers and discussions presented at the Joint Computer Conference. Theme: New developments in computers.
New York, American Institute of Electrical Engineers, 1957.
(Its publication T-92)

7th, Washington, December 9 - 13, 1957.
Proceedings. Papers and discussions presented at the Joint IRE-ACM-AI[EE]
Computer Conference. Theme: Computers with deadlines to meet.
New York, Institute of Radio Engineers, 1958.

8th, Philadelphia, December 3 - 5, 1958.
Proceedings. Papers and discussions presented at the Joint Computer Conference. Theme: Modern computers: objectives, designs, applicatio[ns]
New York, American Institute of Electrical Engineers, 1959.
(Its publication T-114)

9th, Boston, December 1 -
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10th, New York, December 1
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11th, Washington, December
Computers -- key to to
New York, Macmillan,
Processing Societies

WESTERN JOINT COMPUTER CONFER

1st, Los Angeles, Februar
Proceedings of the Wes
IRE-AIEE-ACM Computer
New York, Institute

2nd, Los Angeles, Februar
Trends in computers:
Proceedings of the Wes
New York, American I
(Its publication S-5

3rd, Los Angeles, March 1
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New York, American I
(Its publication T-8

5th, Los Angeles, Februar
Proceedings. Papers p
Conference.

6th, Los Angeles, May 6 -
Proceedings. Contra
New York, America
(Its publication

9th, Boston, December 1 - 3, 1959.
Proceedings. Papers presented at the Joint IRE-AIEE-ACM Computer Conference.
n.p., Published by the 1959 Eastern Joint Computer Conference for the National Joint Computer Committee, 1959. (Copies available from sponsoring organizations)

10th, New York, December 13 - 15, 1960.
Proceedings. Papers presented at the Joint IRE-AIEE-ACM Computer Conference.
n.p., Eastern Joint Computer Conference, 1960.
(Copies available from sponsoring organizations)

11th, Washington, December 12 -14, 1961.
Computers -- key to total systems control. Proceedings.
New York, Macmillan, 1961. (American Federation of Information Processing Societies Publication, vol. 20)

WESTERN JOINT COMPUTER CONFERENCE

1st, Los Angeles, February 4 - 6, 1953.
Proceedings of the Western Computer Conference held by the Joint IRE-AIEE-ACM Computer Conference Committee.
New York, Institute of Radio Engineers, 1953.

2nd, Los Angeles, February 11 - 12, 1954.
Trends in computers: automatic control and data processing: Proceedings of the Western Computer Conference.
New York, American Institute of Electrical Engineers, 1954.
(Its publication S-59)

3rd, Los Angeles, March 1 - 3, 1955.
Proceedings.
New York, Institute of Radio Engineers, 1955.

4th, San Francisco, February 7 - 9, 1956.
Proceedings. Papers presented at the Joint ACM-AIEE-IRE Computer Conference.
New York, American Institute of Electrical Engineers.
(Its publication T-85)

5th, Los Angeles, February 26 - 28, 1957.
Proceedings. Papers presented at the Joint IRE-AIEE-ACM Computer Conference.

6th, Los Angeles, May 6 - 8, 1958.
Proceedings. Contrasts in computers.
New York, American Institute of Electrical Engineers, 1959.
(Its publication T-107)

7th, San Francisco, March 3 - 5, 1959.
Proceedings. Papers presented at the Joint IRE-AIEE-ACM Computer Conference.
New York, Institute of Radio Engineers, 1959.

8th, San Francisco, May 3-5, 1960.
Proceedings. Papers presented at the Joint IRE-AIEE-ACM Computer Conference.
n.p., Western Joint Computer Conference, 1960. (Copies available from sponsoring organizations)

9th, Los Angeles, May 9 - 11, 1961.
Proceedings. Papers presented at the Joint IRE-AIEE-ACM Computer Conference.
n.p., Western Joint Computer Conference, 1961. (Copies available from sponsoring organizations)

JOINT COMPUTER CONFERENCE

San Francisco, May 1 - 3 , 1962.
Proceedings, 1962 Spring Joint Computer Conference.
Palo Alto, Calif., National Press, 1962. (AFIPS, vol 21)

Philadelphia, December 1962. (exact days of meeting not indicated)
AFIPS Conference proceedings: 1962 fall Joint Computer Conference.
Washington, D.C. Spartan Books, 1962. (AFIPS, vol. 22)
(Theme: Computers in the space age)

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SUPPLEMENT A TO QUARTERLY REPORT 2 CONTRACT AF 30(602)-2142

THE ORGANIZATION OF A MEMORY SYSTEM FOR INFORMATION RETRIEVAL APPLICATIONS

By: *Charles P. Bourne*

Prepared for:

1960

ROME AIR DEVELOPMENT CENTER
GRIFFISS AIR FORCE BASE

AIR RESEARCH AND DEVELOPMENT COMMAND
ROME, NEW YORK

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

SRI

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

June 1960

Supplement A to Quarterly Report 2

SRI Project EU-3101

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ROME AIR DEVELOPMENT CENTER
Air Research and Development Command
United States Air Force
Griffiss Air Force Base
New York

Contract AF 30(602)-2142

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ABSTRACT

This is a supplement to Quarterly Progress Report 2, and as such represents special technical observations on the design of a multiple instantaneous response file (MIRF). The MIRF, as compared to other mechanized files, is unique in that all file items in the proposed system are interrogated simultaneously instead of sequentially. This report describes several possible ways of encoding and organizing the data stored in such a file. The ways described were designed to correspond to conventional documentation systems and utilize standard documentation concepts such as coordinate indexing and superimposed codes. An estimate of the total memory capacity requirement was obtained for each of these systems. From the standpoint of total memory elements required, the use of a coordinate indexing system with superimposed coding seems to be the most promising approach. It appears that 70 million to 200 million bits will be required to implement a file which acts as an index to one million technical documents.

Some empirical data from operating documentation systems is also presented to provide some preliminary estimates of system design parameters.

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ILLUSTRATIONS

TABLES

THE ORGANIZATION OF A MEMORY SYSTEM FOR INFORMATION RETRIEVAL APPLICATIONS

I INTRODUCTION

As a special technical supplement to Quarterly Progress Report 2 on the MIRF project, this report describes the considerations and preliminary approaches to the system organization. It does not describe any of the hardware developments. It is mainly concerned with how the memory should be organized to exploit the characteristics of a simultaneous interrogation. There are many ways in which this file can be organized internally. This report describes some general organizations which are useful for this type of file and have not previously been described in the literature. The actual cost and complexity of the physical realization of this file will depend to a large extent upon the total amount of memory that is desired. For this reason an estimate of the total memory requirement was obtained for each of the proposed systems.

Some empirical data was obtained from several operational documentation systems in order to provide some preliminary estimates of design parameters. Illustrations are given to show the distributions of the number of descriptors per document, the number of characters per descriptor, and the number of descriptor characters per document.

II OBJECTIVES

The research effort established by the Air Force* for this multiple instantaneous response file (MIRF) was to determine the most feasible technique for designing a MIRF with the following characteristics:

(1) Size and Nature of the File

(a) Size--maximum of two million items of information.

(b) Nature--a single record for each item. This record shall consist of an identification number, an abstract, and appropriate logical specification. A working file once established should be subject to the addition of new items and the elimination of obsolete items with a minimum of alteration of the existing file complex.

(2) Search and Response Criteria

(a) Instantaneous querying of the entire file.

(b) The system should handle relations of "equality," "less than," or "greater than" alone and in combination, plus up to two levels of logical phraseology.

(c) The total response time for all queries including the first-item output time shall approach zero. The response shall consist of item identification number or index data in the form of an abstract.

(3) Economic Considerations

The costs of establishing the maintaining the file must be justifiable and in line with the quality of the output characteristics, scope of the material than can be included in the file, and size of the "hardware."

In the MIRF specifications further discussions elaborated on the requirements, and defined a file item as a single record or reference (to a record), with an identification number and all the pertinent descriptors.

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* Purchase Request Continuation Sheet, "Multiple Instantaneous Response File," PR No. 03121, 3 August 1959.

There are a great many applications possibilities for MIRF. Each one of them would probably require a different system organization. However, this study concentrates on the documentation problem, and it considers MIRF to be the index to a file of 1 to 2 million technical documents. When considered as a document index, the required response would then consist of an item identification number, or item abstract, or the item itself.

The twin goals of a rapid response time (with memory action perhaps in the fractional second range) and of a potentially high volume storage capacity (50 million to 500 million bits) require the development of special techniques and components. These special devices will be reported upon in subsequent reports. It might be noted that in addition to requiring techniques for simultaneous interrogation of the entire file contents, MIRF also requires an amount of memory comparable to the largest available mass memory systems. These are listed in Table I.

Table I

MAXIMUM STORAGE CAPABILITIES OF MODULAR MEMORY SYSTEMS

Unit	Maximum Storage Capacity (Millions of Bits)
IBM Direct Access Photomemory	7,000
Magnavox Magnacard File Block (105 trays)	1,575
Aeronutronic HI-RAC Disc	525
Potter Instrument Co. RAM	500
Proposed "MIRF" Store	50-500
Hydel Inc. Photomemory	400
Time Inc. Memory	314
IBM STRETCH Disc	288
Burroughs 220 Tape Bin, Model 556	215
Magnetic Tape Transports from Various Manufacturers	150
IBM Glass Disc Photomemory, Mark 2	100
Bryant Computer Products Div. Disc	75
IBM RAMAC Disc, Model 7300-2	60
Remington Rand RANDEX Drum	42
International Telemeter Corp. Glass Disc Photomemory, Mark I	30
IBM RAMAC Disc, Model 7300-1	30
IBM STRETCH Core Memory	18
Laboratory for Electronics Inc. HD File Drum Unit	15
Remington Rand LARC Drum	15

III METHODS OF MEMORY ORGANIZATION FOR MIRF

A. GENERAL

MIRF will require a memory organization which is different from those commonly used for computers. As background information, it might be noted that the memory in nearly all computers is organized in such a way that the program or control circuitry, at any time, operates in one of the two following ways:

(1) A single word is read (or written) from a specified address or location in memory. That is, the memory can be visualized as a large number of pigeon-holes or boxes, with a unique address on each box.

(2) A continuous block of words is read (or written), starting from a specified address in memory. This is essentially the same as (1) except that references are made to continuous strings of addresses--perhaps 10 to 20.

It might also be noted that computers usually work with a fixed-length word size, normally in the range of 6- to 72-binary digits (bits)--or 6- to 24-decimal or alphanumeric characters. Circumstances indicate that MIRF may also use a fixed length word format of 50 to 500 bits in length, depending upon the particular format and the indexing requirements.

Organization of data by words may or may not be appropriate for a MIRF, but it is unlikely that location of data in the memory will be significant. There are several ways in which MIRF can be organized. The final choice will depend to a certain extent upon the characteristics of the devices which eventually will be proposed for the hardware implementation. The system has a range of alternatives between storing the entire document in memory (in digital or graphic form) and storing only the necessary indexing information to locate pertinent documents. The actual organization of the indexing information in memory will probably be the same regardless of whether the system operates with the indexing data or with the indexing data plus text material. However, the cost of the memory elements will probably restrict the system to the storage of the indexing data only. Several of the possible organizations are described in the following parts of this section.

B. A COMPLETELY UNORGANIZED FILE

Conceptually, this file consists of a large hopper or bin, into which all the file input data is dumped when received. No attempt is made to index or classify the data before it goes into the file. The material goes into the hopper in no definite or prescribed sequence. That is, the input system receives the information in much the same manner as does the in-basket on a busy desk. For searching purposes, each inquirer goes to the hopper with a template or screen corresponding to the particular file system or organization that is wanted.

This particular screen selectively acts on the unorganized file to produce a response to the inquirer's template; moreover, this response is framed in the pattern and context of interest to the inquirer. In other words, we could imagine this process in terms of a flotation or precipitation operation wherein each seeker provides the particular--or unique--catalyst that separates out the information wanted. Operationally, this type of organization offers tremendous advantages--primarily, the reduction of the indexing/classification of the file input. Unfortunately, the development of this system poses so many theoretical and practical problems that it may not be possible, or practical, to realize it.

A more restricted version of this concept is the idea of indexing or classifying each item by 2, 3, or 4 different indexing techniques before putting it into the hopper. This modified scheme would be a great deal easier to implement.

C. AN AUXILIARY FILE WHICH IS ARRANGED BY LOCATION ADDRESSES

This conventional system cannot satisfy the simultaneous action required of the MIRF. However, it could be employed in an auxiliary serially-ordered file. This arrangement would allow a method of operation wherein the results of the simultaneous MIRF search could be used as addresses to the auxiliary file locations. Furthermore, using an auxiliary memory to store expanded descriptions of the selected file items (e.g., document title, author, corporate author, date, etc.) would provide a more complete response to the inquirer; in addition, the auxiliary memory could be implemented with conventional memory techniques such as several large magnetic drums or disks.

D. A FILE WHICH CORRESPONDS TO CONVENTIONAL DOCUMENTATION SYSTEMS

It is possible to arrange the file in such a manner as to provide an automatic system which is completely analogous to conventional documentation systems such as hierarchical or coordinate indexing. Some of these equivalent systems are described below.

1. Hierarchical Structure

A collection of information which can be easily and accurately described by any hierarchical classification scheme does not need a MIRF type of device. With an accurate classification system, it should be possible to assemble all the items or references to items in well defined groups so that there is no need for a simultaneous file interrogation. However, a special memory organization (not necessarily simultaneous) could be used for hierarchical schemes if desired. A description of various modes of operation is included in Sec. III-D-1 as supplementary information and is not directly concerned with the utilization of devices of the MIRF type.

In a manner similar to conventional location addressing for digital computers, it should be a rather straightforward job to organize a memory with a conventional hierarchical structure such as the Universal Decimal Classification or the Library of Congress Classification. This would permit users to communicate with the machine in a language familiar to them. It would also subject the memory system to arguments, pro and con, common to all hirarchical systems. As a side note, ease of file maintenance and the possible capability of automatically handling the "see also" references are two advantages of using the MIRF type of device for a hierarchical file.

The operation of the system would require that each incoming item be catalogued and assigned a decimal (or mixed alphanumeric) classification number. Each item for the memory would then take the following general configuration:

Classification Number	Item Description	Control Bits

The "Classification Number" acts in a manner similar to indirect addressing. That is, the classification number in the word describes the address where this item is to be stored. Since there may be a number of items having the same classification number, arrangements must be made to handle duplicate entries and responses.

"Item Description" contains data describing the file item--that is, document number, title, author, abstract or complete text, etc. A designation, "Control Bits," is required for control purposes to indicate, for example, interfaces between some sections of the file or to suggest alternate references.

A possible operational approach would use a table to give the starting point of the major file sections so that a serial search technique could be used for locating the specific items. With a content-addressed memory--a memory in which specific words are selected on the basis of information stored in them and not on the basis of where the word is located in the memory--all the classification numbers could be interrogated simultaneously. Consequently, a scanning technique would not be necessary. A content-addressed memory would also allow new information to be inserted in the memory in an arbitrary or a random sequence, instead of requiring a more controlled file input operation.

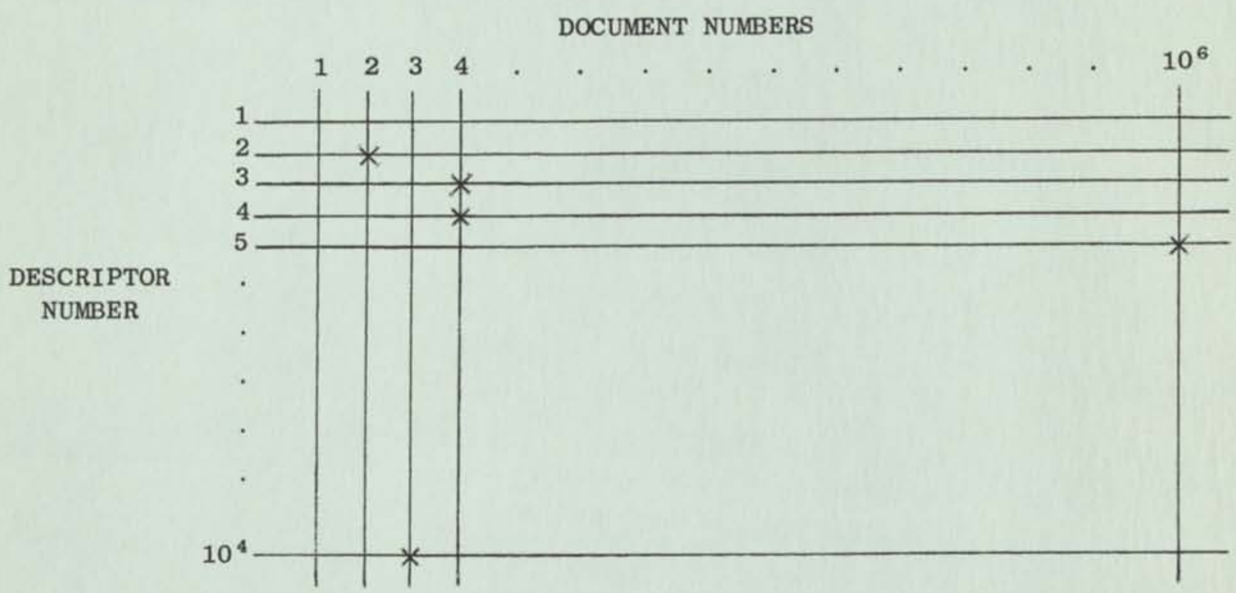
No special problems appear to complicate implementing a hierarchical structure having a content-addressed memory; however, there is a need to devise "see also" references and there will certainly be a number of file items required that have the identical address (i.e., a multiple response). The use of a MIRF to implement a hierarchical structure would permit inserting new items, which belong in an existing logical sequence to be inserted in arbitrary physical locations. This greatly simplifies the file maintenance problems.

2. Coordinate Indexing

A memory configuration can be arranged which represents the equivalent of a conventional coordinate indexing or Uniterm system. It represents a system in which no descriptor is subordinate to another, and in which any number of descriptors may be selected for a given description or inquiry. For simultaneous searching (instead of scanning or collating) this might be physically accomplished by a variety of methods--although each method seems to have a rectangular matrix as a basic part of the system. Several of these general approaches are given below:

a. Use of General and Explicit Matrix So That There is a Memory Position Available for Every Combination of Descriptor and Document Number

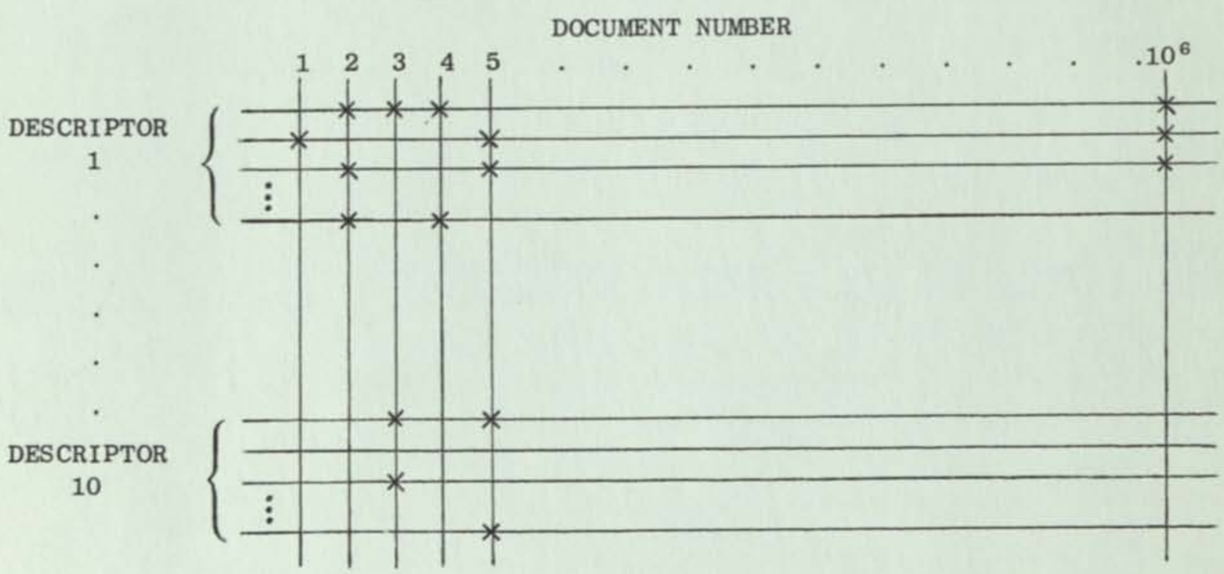
This is illustrated by the following diagram:



In an electrical realization, the search operation could be implemented by using a single sense wire (horizontal lines) for each descriptor in the dictionary, and threading it through all of the document number positions (vertical lines). This general matrix need not contain the entire document description, but it could be used to furnish a control signal for the selection from a slower file. The search logic could also be performed on these control signals. This general matrix would require as many as [(10,000 descriptor possibilities) x (1 million documents)] 10^{10} memory positions. This is an extremely wasteful use of the memory and reflects the cost of having an entirely general system, e.g., one in which any number of descriptors may be specified. Since the assignment of descriptors to a document is a semi-permanent arrangement, it might be possible to furnish physical storage or switching elements only for the memory positions which are actually used. This approach would probably be very difficult to achieve in practice, but if it could be accomplished there would be a requirement for [(average of 10 uniterms per document) x (1 million documents)] 10 million memory positions. This is a reduction by a factor of 1000 over the generalized matrix.

b. <u>Explicit and Restricted Matrix with Binary Coding</u>

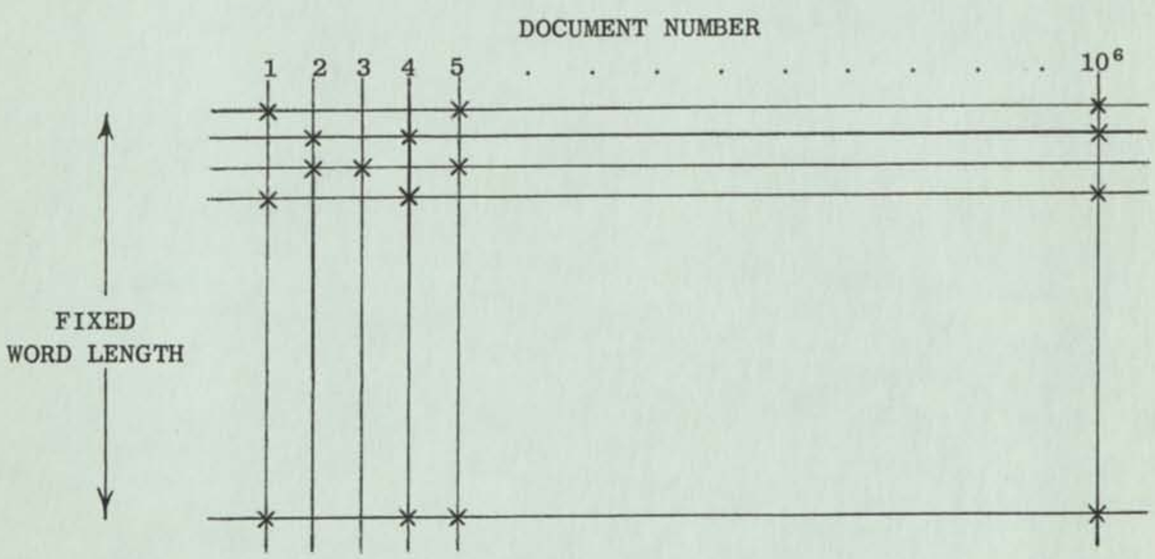
If a restriction can be placed on the maximum number of descriptors, used to describe each document, then the system can be implemented with less hardware than is required for the general matrix. A description of this form is shown below:



This example shows a system limited to 10 descriptors per document. Assuming the dictionary would contain less than 16,384 descriptors, each descriptor could be uniquely represented by 14 bits (i.e., $2^{14} = 16{,}384$). For a completely general situation with a dictionary of up to 16,384 terms, the matrix would require [(14 bits per descriptor) x (N descriptors per document) x (1 million documents)] 14 N million bits. For the situation in which 10 descriptors per document are allowed, a total of 140 million memory positions is required. This is much less than the 10^{10} memory positions required for the general and explicit matrix. It may also be possible to implement these systems with number systems other than binary, i.e., ternary or octal.

c. <u>Fixed-Length Words with Content-Addressed Memory</u>

Another possible approach is the use of specially encoded individual memory words to describe each of the file items, i.e., to concentrate our attention on the group of bits which are used to describe each particular file item. This approach is the following form:



The word length will depend upon the type and degree of indexing which is required for the system. The detailed examination of various word formats has disclosed that some systems are possible which can operate with as few as 70 bits per word. This number is lower than the requirements of the previously mentioned organizations, and thus has received the most consideration and study. The various word formats are described in more detail in the next sections.

IV DETAILED EXAMINATION OF FIXED LENGTH WORDS WITH A CONTENT-ADDRESSED MEMORY

A. GENERAL

A consideration of the possible general methods of file organization and of the stated objectives of this study project indicates that a system which corresponds to a conventional documentation system may satisfy some of the requirements for this system. In particular, it appears that a system of coordinate indexing would be the easiest and most straightforward to implement. A detailed study of the number of memory elements required to implement several different word formats for a coordinate indexing scheme is described in the following sections. Curves for each format are given in Fig. 1 to show the total memory requirement as a function of the maximum number of descriptors allowed per document.

B. NUMBER OF BITS REQUIRED FOR DOCUMENT IDENTIFICATION

The document collection ranges from 1 to 2 million items. Each one of the items will require at least a document number. The number may be represented either explicitly as part of the file data or implicitly by the position of the data in the file. For pure binary notation (2^{21} = 2,097,152) <u>21</u> bits will allow document numbers to be counted up to 2,097,152 which is adequate for the present MIRF configuration. For BCD (binary coded decimal) notation, 7 BCD characters or <u>28</u> bits will allow document numbers to be counted up to 9,999,999 which is more than adequate.

To summarize, the following number of bits may be required in each word, as an identification number (ID#):

(1) 21 bits for a pure binary ID#

(2) 28 bits for a binary-coded-decimal (BCD) ID#.

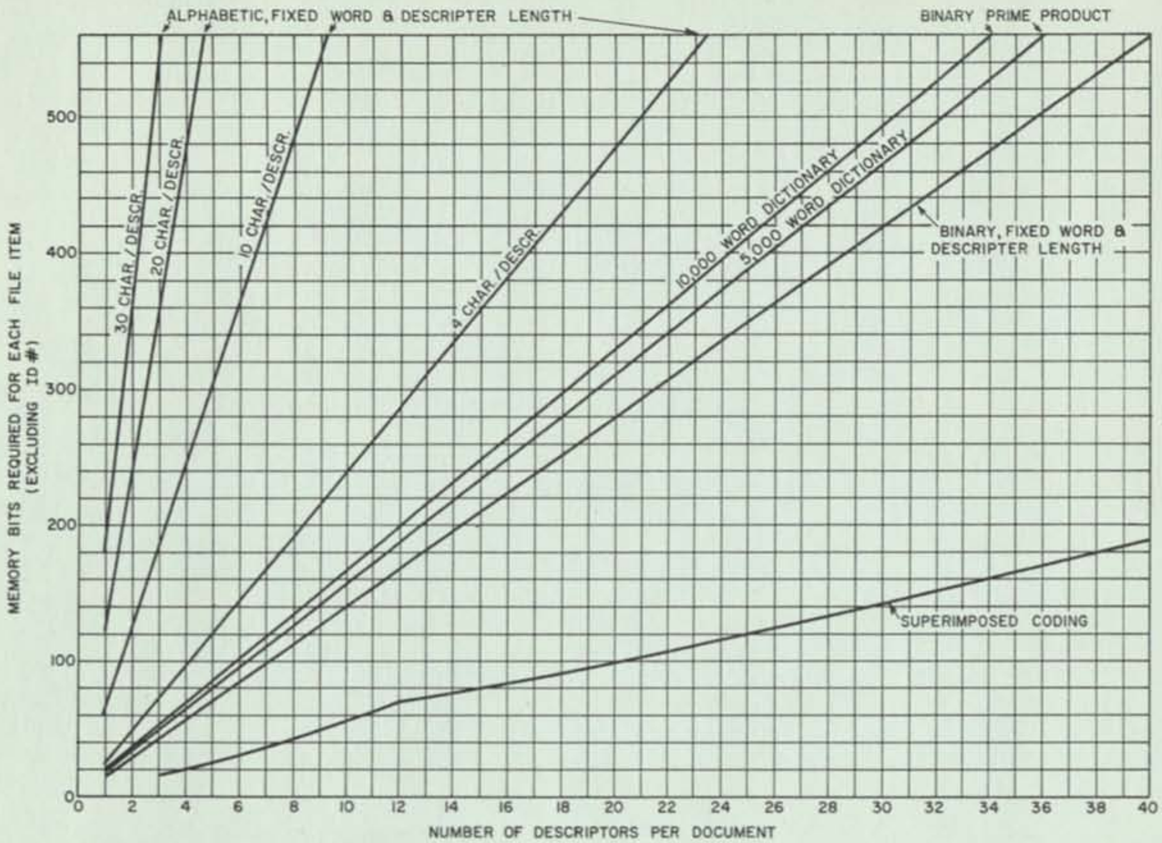


FIG. 1

MEMORY REQUIREMENTS AS A FUNCTION OF THE WORD FORMAT AND THE NUMBER OF DESCRIPTORS PER DOCUMENT

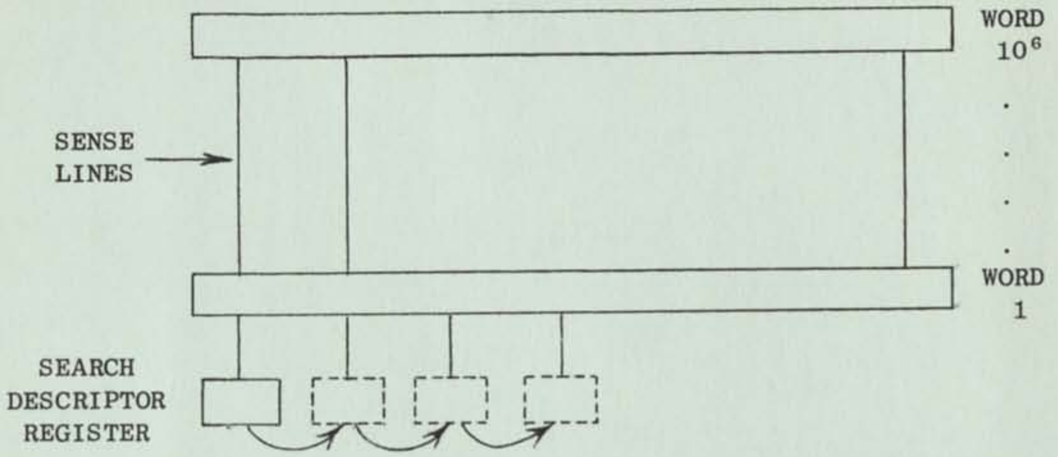
C. WORDS WITH FIXED FIELDS

1. Organization for Interrogation

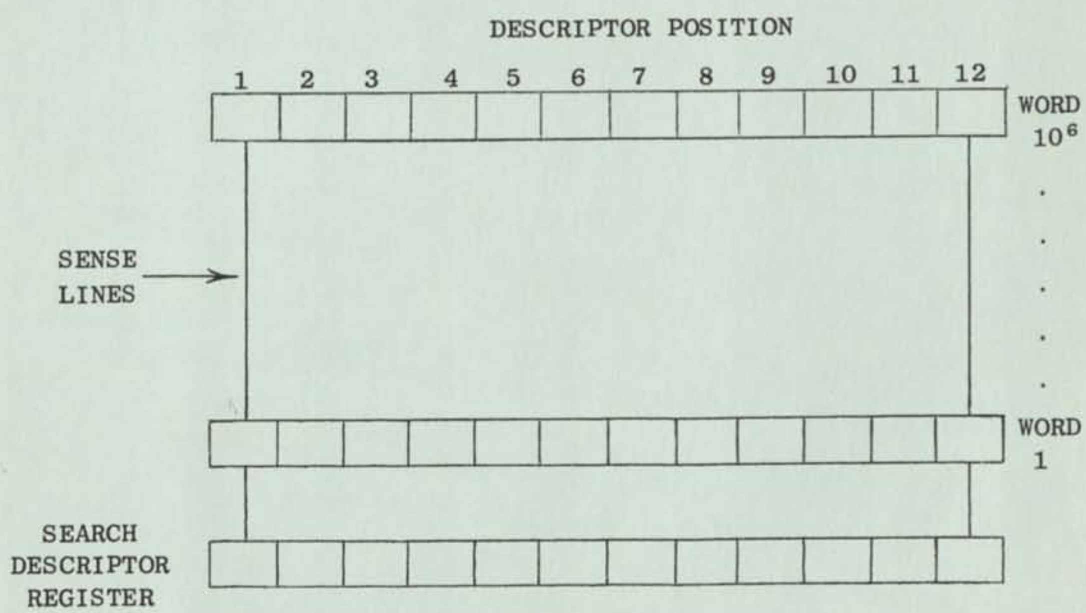
The fixed-field word structure might take the following form:

ID#	Descriptor #1	Descriptor #2	…	Descriptor #N

That is, each of the one or two million words in the memory would have the general structure given above. The search could be performed by taking each of the search descriptors (one at a time) and comparing them (sequentially) against all of the descriptor positions. The intermediate responses might be accumulated in some control memory in order to be available for the logic tests of the complete search. This search procedure is illustrated by the following diagram.

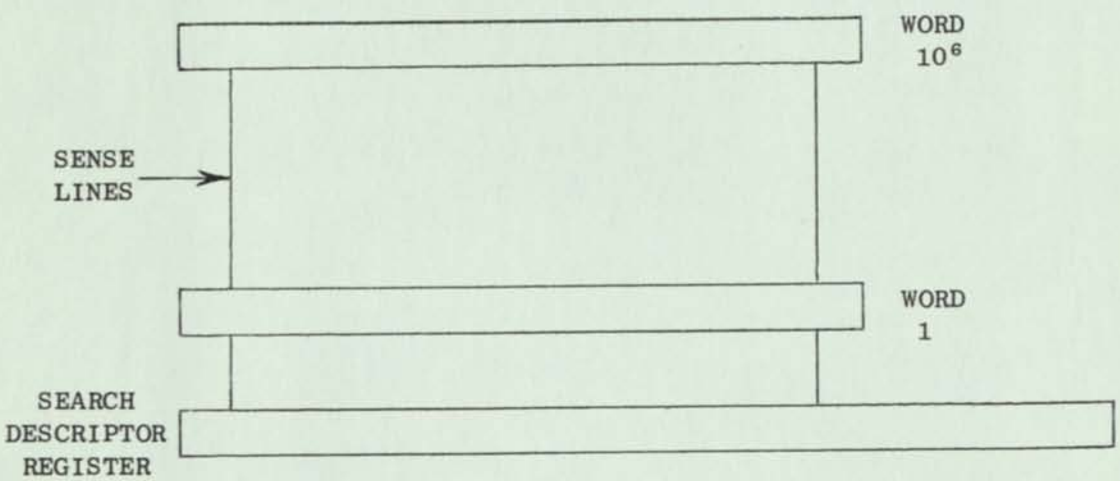


Instead of scanning each of the descriptors one at a time against the file, the search might also be conducted by simultaneously comparing all the search descriptors with their corresponding word positions. This method is illustrated by the following diagram:



All the fixed field methods have the serious disadvantage of being unable to conveniently handle the "alignment problem"--that is, situations in which the matching descriptors are present, but not in the corresponding positions of the file word and search word. For example, simple comparison circuitry would not handle the situation in which the search descriptor in position 1 (of the Search Descriptor Register) actually occurs in one or more words, but not in position 1 (of the Memory Words).

One way to alleviate this problem is to shift the search register, while interrogating, so that each search descriptor has an opportunity to match against every position of every word. Additional logic and memory would have to be provided to remember the intermediate results and make the logic tests for the complete search. This is illustrated by the following diagram:



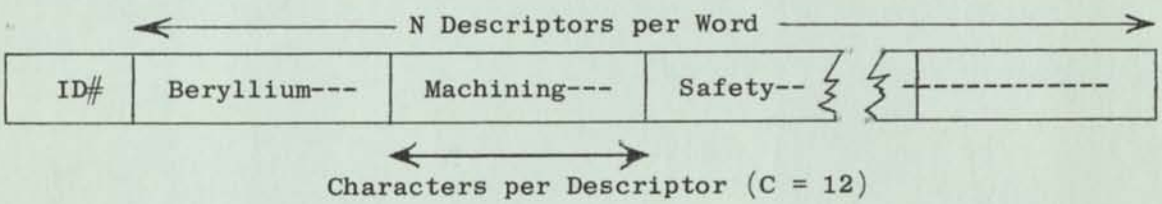
If there is a requirement to perform a search with more descriptors than there are descriptor positions, within a word, the shifting technique will allow the system to do this.

It would not be meaningful to talk of search requirements which have more AND functions than descriptor positions because none of the words in the file could ever satisfy the search criteria. However, it is meaningful to talk of search requirements which have more OR functions than descriptor functions because it would be possible to frame a question in the manner indicated. The latter type of situation might also arise if the MIRF were being used as an "automatic press clipping service" or message tagging device, in which each file word corresponded to a word of interest to be matched for, and the search words actually consisted of a large amount or continuous stream of data to be monitored.

2. Various Word Formats

a. Alphabetic Spelling of the Descriptors with Fixed Descriptor Length and a Fixed Word Length

Consider the following format for each file item:



In this format, a fixed number of characters (12 in the above figure) is assigned to describe each descriptor. Some empirical data (see Fig. 2) seems to indicate that for full spelling, 90-95% of the descriptors can be represented by 12 to 13 characters. The empirical data also indicates (see Figs. 3 and 4) that for some documentation systems, 90 to 95% of the documents can be represented by 12 to 15 descriptors. For all of the estimates in the report, it was assumed that an alphabetic character would be represented by 6 bits.

To summarize, the total bits required per item (exclusive of the ID#) are as follows:

Descriptors per Document	Alphabetic Characters per Descriptor			
	10	20	30	40
6	360	720	1080	1320
10	600	1200	1800	2400
20	1200	2400	3600	4800
40	2400	4800	7200	9600

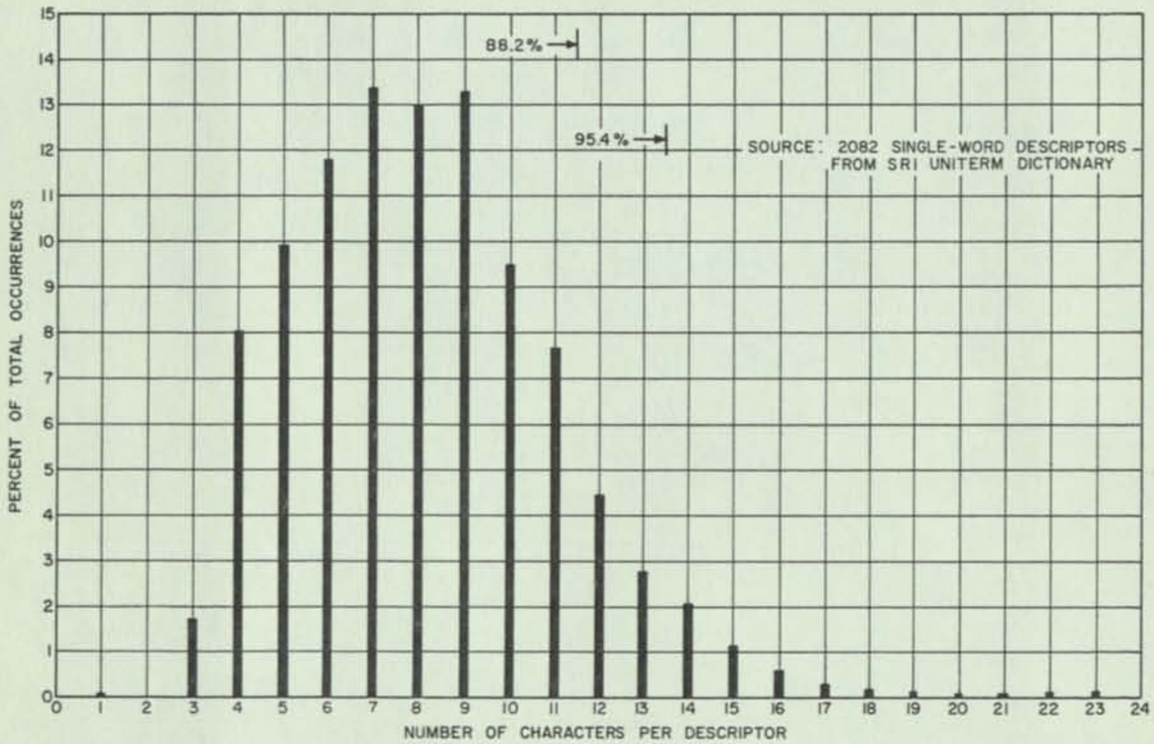


FIG. 2

SAMPLE DISTRIBUTION OF THE NUMBER OF CHARACTERS PER DESCRIPTOR

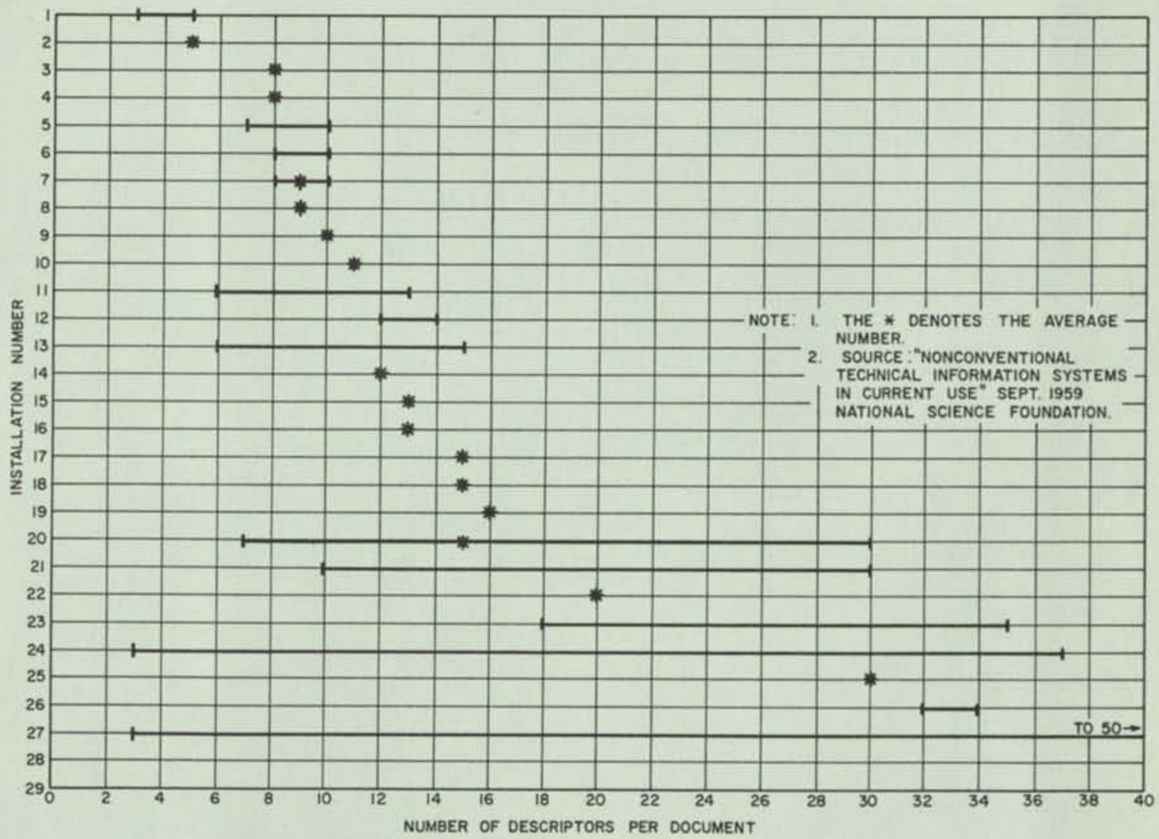
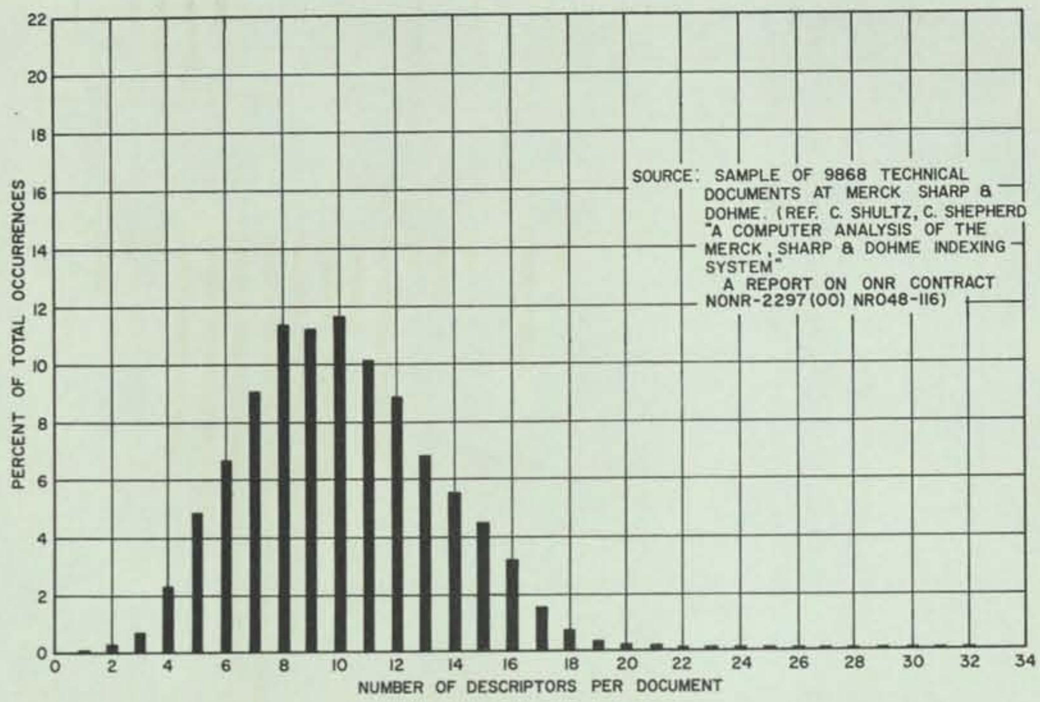
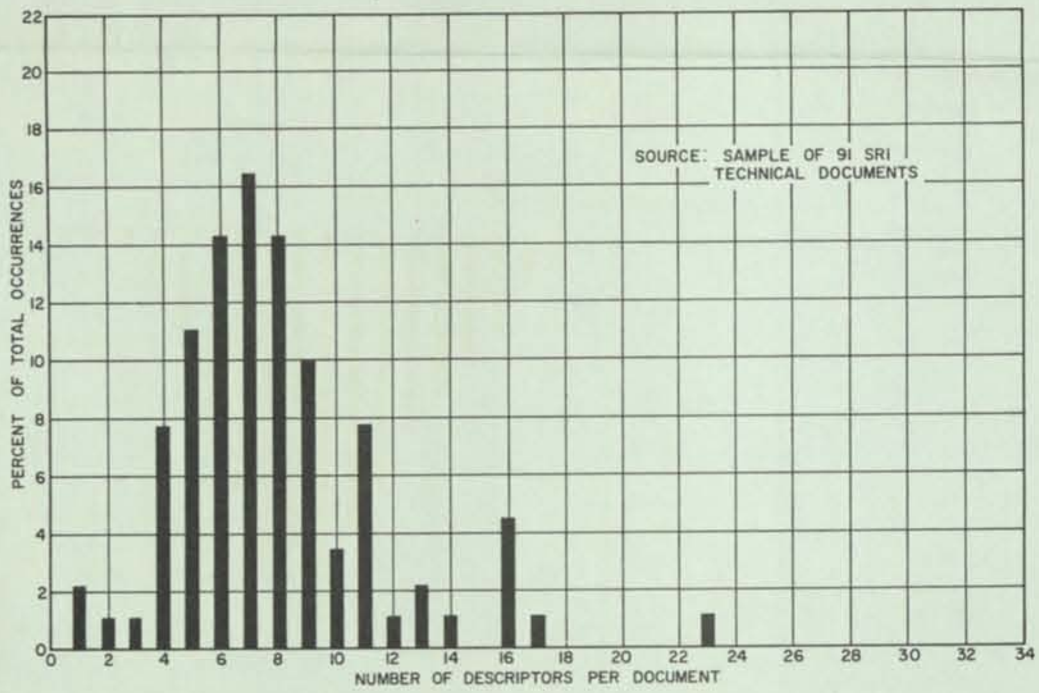


FIG. 3

RANGE OF SYSTEM REQUIREMENTS FOR THE NUMBER OF DESCRIPTORS PER DOCUMENT





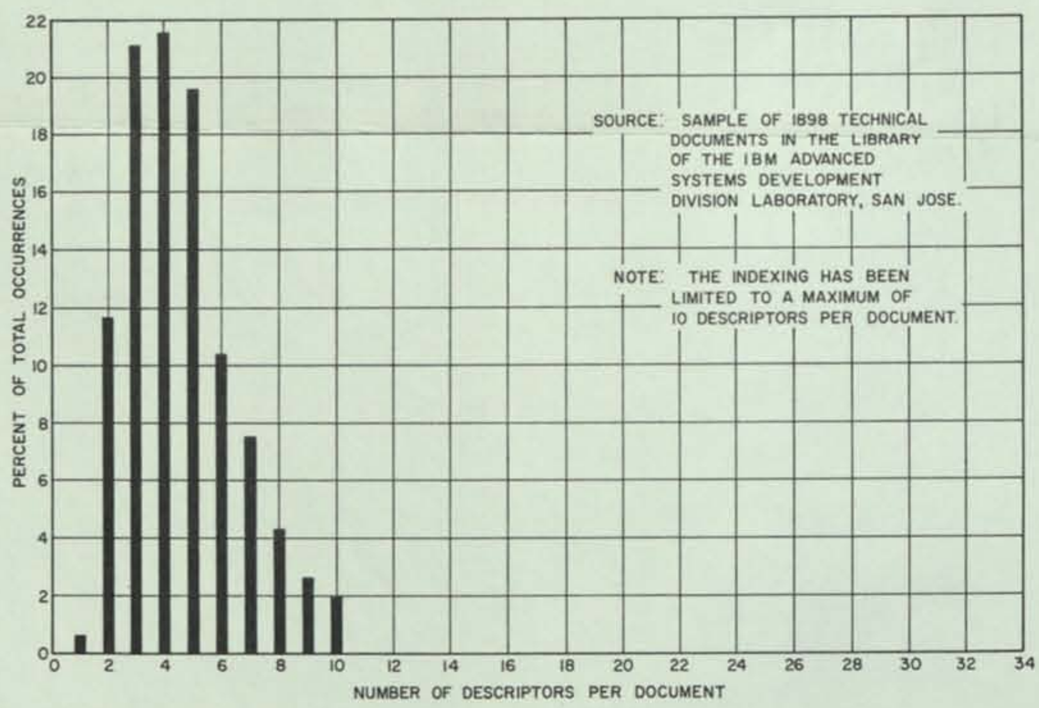


FIG. 4

SAMPLE DISTRIBUTION OF THE NUMBER OF DESCRIPTORS PER DOCUMENT

However, the total word length is fixed so that for the majority of file items (say 90-95%) there is enough space for all the descriptors to be completely spelled out. Some empirical data seems to indicate (see Fig. 5) that for some documentation systems, 90-95% of the documents can be represented by 130-150 characters.

To summarize, total bits required per item (exclusive of the ID#) are as follows:

K	Total Bits
20	120
100	600
200	1200

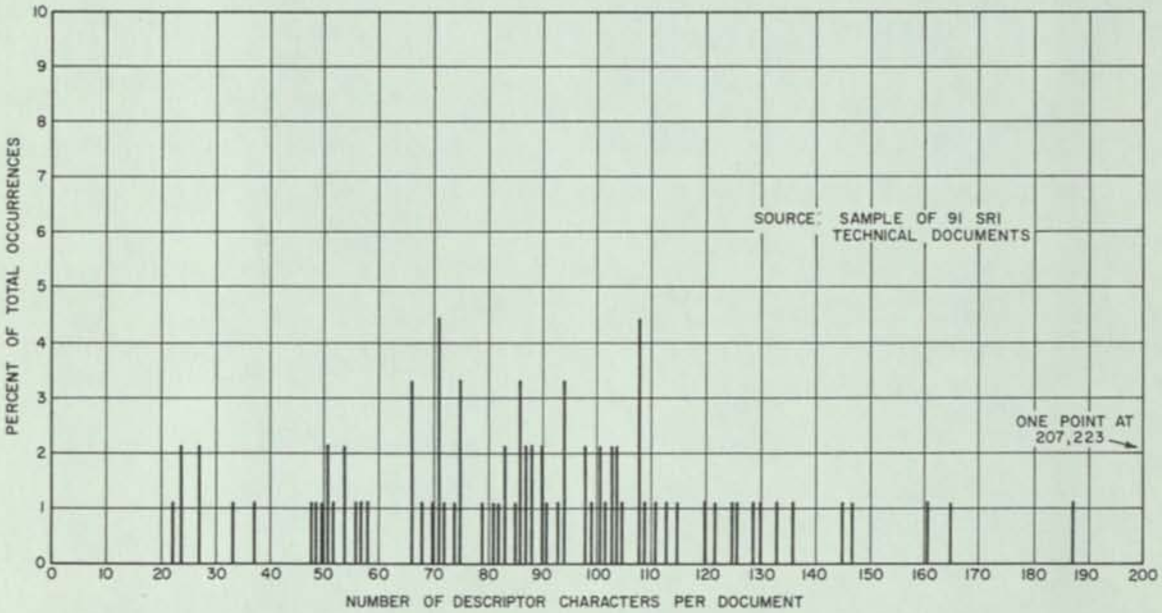


FIG. 5

SAMPLE DISTRIBUTION OF THE NUMBER OF DESCRIPTOR CHARACTERS PER DOCUMENT

d. Binary Descriptor Spelling with Fixed Descriptor Lengths and Fixed Word Lengths

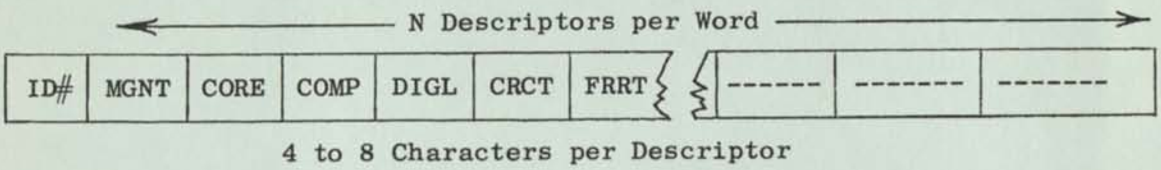
Consider the following format for each file item:

← N Descriptors per Word →

ID#	01011010110100	00110000010000	01110010100001	000 ⟩	⟨01001	11001101001000

b. Condensed Alphabetic Spelling of the Descriptor with a Fixed Descriptor Length and a Fixed Word Length

Consider the following format for each file item:



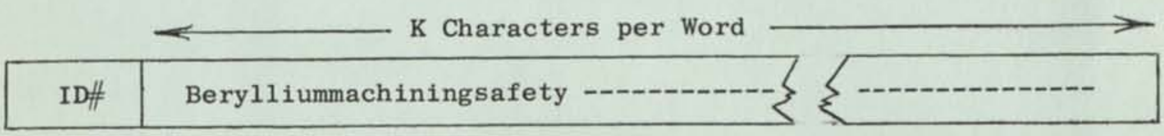
In this scheme, essentially a condensation of the previous scheme, each descriptor is abbreviated as much as possible in order to conserve space. A reduction to something between 4 and 8 characters might still provide adequate discrimination between descriptor terms. There would be a fixed descriptor length, and a fixed word length.

To summarize, total bits required per item (exclusive of the ID#) are as follows:

Descriptors per Document	Alphabetic Characters per Descriptor				
	4	5	6	7	8
6	144	180	216	252	288
10	240	300	360	420	480
20	480	600	720	840	960
40	960	1200	1440	1680	1920

c. Alphabetic Spelling of the Descriptor with Variable Descriptor Lengths in a Fixed Word Length

Consider the following format for each file item:



Each descriptor is completely spelled out and positioned immediately adjacent to a neighboring descriptor. For each descriptor, and for the total number of descriptors, the number of bits required is variable.

In this scheme, represent each descriptor by its dictionary catalog number in a fixed length binary notation (2^{12} = 4096, 2^{13} = 8192, 2^{14} = 16,384). In this manner, each descriptor can probably be represented by 14 binary digits, or less.

To summarize, total binary digits required per item (exclusive of the ID#) are as follows:

N	Total Bits
1	14
10	140
20	280
40	560

e. Indexing by Assigning Prime Numbers to Each Descriptor

Consider a system in which each descriptor is represented by a unique prime number; and in which a document, or a search statement, is represented by the product of all the pertinent descriptors. In order to search the memory, each memory word is divided by the search word. The search criteria is satisfied if there is no remainder after division. This would be an extremely difficult and expensive system to implement since it requires some form of division equipment for each word in the memory. An example of the coding of a memory word is given below:

Descriptors for Document A	Individual Descriptors Are Represented by This Number	Document A Is Represented by This Number
Magnetic	1	1x2x3x5x7 = 210
Core	2	
Memory	3	
Digital Circuits	5	
Computers	7	

The memory word has the following form:

ID#	Product of the Prime Numbers

The number of bits which must be allocated for the product of primes will depend on the largest number which can be generated. This will depend upon the number of descriptors used, and the size of the vocabulary. If a 5000 or 10,000 word vocabulary is required, and prime numbers are assigned in ascending order (1, 2, 3, 5, ...), then the last items in the vocabulary will be numbered rather high. The following numbers are pertinent:*

The 5,000th prime number is 48,593
The 10,000th prime number is 104,723
The 15,000th prime number is 163,819
The 20,000th prime number is 224,729 .

As an indication of the size of the coding field, for a dictionary of 10,000 descriptors a document with 12 descriptors would require a coding field sufficiently large to hold the number $(104{,}723)^{12}$. The magnitude of this number is approximately 1.8×10^{60}, which can be represented by 61 decimal digits or 200 binary digits. A few more examples are given below.

For a dictionary of 5,000 descriptors, and excluding the ID#:

Descriptors per Document	Largest Prime Product	Total Decimal Digits Required	Total Binary Bits Required
4	5.57×10^{18}	19	63
6	1.32×10^{28}	29	95
10	7.38×10^{46}	47	156
12	1.74×10^{56}	57	187
20	5.44×10^{93}	94	312

* Derrick Norman Lehmer, List of Prime Numbers from 1 to 10,006,721, Publication No. 165, Carnegie Institute of Washington, D.C. (1914).

For a dictionary of 10,000 descriptors, excluding the ID#:

Descriptors per Document	Largest Prime Product	Total Decimal Digits Required	Total Binary Bits Required
4	1.21×10^{20}	21	67
6	1.33×10^{30}	31	101
10	1.61×10^{50}	51	167
12	1.80×10^{60}	61	200
20	2.59×10^{100}	101	330

D. WORDS WITH SUPERIMPOSED CODING

1. General

Instead of using a memory organization with data words or file entries following a rigid format, it is possible to exploit schemes in which several items of indexing data are superimposed in the same memory location. The use of superimposed coding offers a significant saving in memory size requirements. The saving is made by reducing the size of the field necessary to describe the indexing data.

Consider a system in which each of the descriptors is represented by a particular bit pattern, such as:

Descriptor	Corresponding Bit Pattern
#1	101100010011000100
#2	100010000100001000
#3	001000000011101100 .

These patterns, for a particular file item, could be superimposed in a logic sum to form a single pattern (101110010111101100, for the above example). In this case, the memory word format would assume the following pattern:

ID#	Superimposed Descriptor Patterns

It can be seen that there is a possibility for significant reductions in word length.

The search operation would consist of comparing the pattern of a search descriptor (or the pattern of several superimposed search descriptors) against the superimposed pattern in each of the memory words. If there is an "agreement," then there is a good possibility that the search descriptor was used to form the superimposed pattern. The "agreement" does not consist of an equality comparison. It consists of an "inclusion," in which every "one" in the search pattern must be matched by a "one" in the corresponding position of the memory word. The digit values of the other positions are not considered. With the superimposed coding, there will always be an agreement if the same descriptor was used for coding and searching.

However, there will also be an agreement when the pattern from two or more indexing descriptors combines to form a new pattern which happens to include the search descriptor's pattern. In other words, the searcher always gets the pertinent responses, plus a little bit more. This extra and irrelevant response is often called "false drop" or "noise." It is a characteristic of most superimposed coding schemes. However, it has been stated that this noise contribution can be made as small as desired by the applications of proper design techniques.* In order to derive any specific estimates as to how much memory space can be saved by using this technique, assumptions must be made regarding the permissible noise and the maximum numbers of descriptors likely to be used in searching and indexing. In any case, it should be possible to design a word format which requires a modest amount of memory.

Some of the search logic is inherent in the superimposed pattern. For example, a search criteria of the logical product of three descriptors (i.e., A, B, and C must be present) can be handled by superimposing the bit pattern of each of the question elements and comparing that single pattern against the file. A search criteria which consists of the logical sum of three descriptors (A or B or C) can be handled by breaking the search into three separate questions. For each case, it is assumed that the search process is actually a simultaneous search of the entire file contents. The implementation of file searching, with mixed logical

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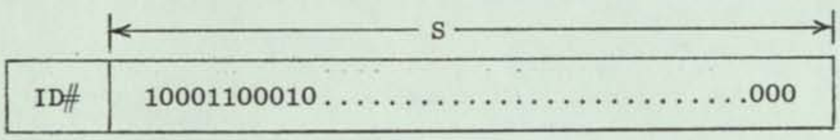
* See Bibliography at end of report.

expressions and inequalities, poses some problems. In addition, it does not appear to be possible to perform conveniently the negation (NOT) function with superimposed coding, regardless of the practical implications of using it. Inequalities (greater than, less than) can be implemented, but they appear to be awkward functions to handle practically. Searching fixed alphabetic and numerical data (such as names, dates, organizations, etc.) for inequalities or exact comparisons, can be handled by separating the word format into a superimposed code field and a fixed data code field.

2. Various Word Formats

a. Superimposed Coding with Unique Binary Numbers for Each Descriptor

Consider the following format for each file item:



The word consists of an ID# and a single fixed length field (S) for the superimposed code. Each descriptor is represented by S binary digits. The final indexing code consists of the superposition of the codes of all the pertinent descriptors. The pertinent parameters for the design of a particular code* are:

- C - The number of items in the total collection
- L - The anticipated lower bound of the number of descriptors normally used for searching
- M - The anticipated upper bound of the number of descriptors normally used for indexing
- R - The tolerable noise ratio = E_{max}/C
- E_{max} - The maximum number of false drops with L search descriptors.

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* Mooers, C., "The Application of Simple Pattern Inclusion Selection to Large-Scale Information Retrieval Systems," April 1959. Zator Tech. Bull. No. 131, AD-215 434.

In terms of these parameters, each descriptor code pattern should contain N "marks" (or binary "ones"), where

$$N = \left\langle \left(\frac{1}{L}\right) (-\log_2 R) \right\rangle = \left\langle \left(\frac{1}{L}\right) (3.31) (-\log_{10} R) \right\rangle .$$

Where the symbols < > mean that the nearest integral value is to be taken. The least number of sites (S) that must be used to contain N descriptors (see Fig. 6) is

$$S = \langle 1.445\ N\ M \rangle .$$

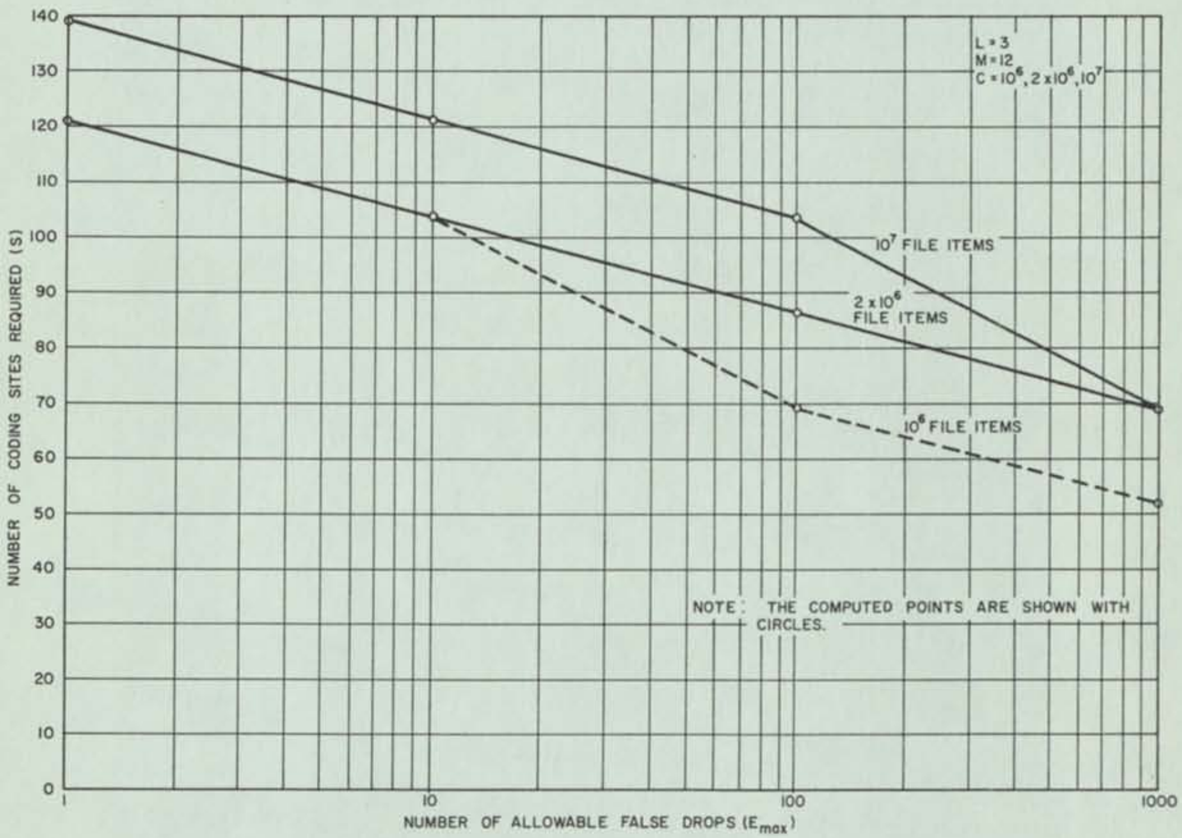

FIG. 6

SUPERIMPOSED CODING: MEMORY REQUIREMENTS AS A FUNCTION OF THE NUMBER OF ALLOWABLE FALSE DROPS

For a sample calculation, assume the following parameters:

$$C = 10^6$$

$$L = 3$$

$$M = 12$$

$$E_{max} = 100$$

$$R = \left(\frac{E_{max}}{C}\right) = \frac{100}{10^6} = 10^{-4}$$

$$N = <\left(\frac{1}{L}\right) (3.31) (-\log_{10} 10^{-4})>$$

$$= \frac{3.31}{3} (-1) (\log_{10} 10^{-4})>$$

$$= <\frac{3.31}{3} (-1) (-4)> = <4.41>$$

$$= 4$$

and

$$S = <1.445(4)(12)> = <69.36>$$

$$= 69 \ .$$

To summarize, for a collection of 10^6 items, an allowable false drop of 100, and a least number of descriptors equal to 3 (i.e., $C = 10^6$, $E_{max} = 100$, $L = 3$) the following figures apply:

M	N	S (excluding the ID#)
3	4	14
6	4	29
12	4	69
20	4	96
40	4	191 .

The number of bits required for each file item also varies with the size of the file. This slight variation is shown in Fig. 6.

b. Superimposed Coding with Several Fixed Fields for Abbreviated Descriptor Spelling

Consider this format and example in which a separate field is used for each letter position of an abbreviated descriptor word. The descriptor might be abbreviated in the manner suggested, directly below, with the "letter positions" (ABCDE ... Z, etc.) placed as indicated in the diagram for the pattern which follows the list of descriptors.

Abbreviated Descriptors	Descriptors
ARCS	ARCS
AZMH	AZIMUTH
COMP	COMPUTER
DGTL	DIGITAL .

The memory word format would assume the patterns:

	A A C D	R Z O G	C M M T	S H P L
ID#	10110....0	0000..........1	0010.........0	0000..........0
	ABCDE....Z	ABCD..........Z	ABCD.........Z	ABCD..........Z

The degree to which a list of descriptors can be abbreviated, and still maintain their discrimination, has not been determined. However, it should be noted that 4 alphabetic characters have the inherent possibility of forming $26^4 = 456,976$ different combinations. As a first approximation, while still maintaining 10,000 unique entries in the dictionary, it might be suggested that each of the descriptors in a 10,000 word dictionary could be reduced to 6 or 8 characters. It should also be possible to take advantage of the frequency distributions of the letters* in order to use fewer than 26 positions (e.g., 20) of the word for each letter. It should also be possible to use a more general superimposed code for each of the alphabetic letters. These techniques have not been given a detailed analysis, although it does appear that they would require slightly more memory positions than the single field superimposed code.

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* H. Ohlman, "Subject-Word Letter Frequencies with Applications to Superimposed Coding," Preprints of the International Conference on Scientific Information, Washington, D.C. (November 1958).

V EMPIRICAL DATA TO GUIDE THE SYSTEM DESIGN

Figures 2, 3, 4, and 5 describe the data which was collected from several existing files in order to obtain some preliminary design parameters. The name of the source file is shown on each figure. If a decision is made at a future date to design the MIRF for a specific application, then additional data will probably have to be collected to optimize the hardware for that particular task. For it to be applicable to a large number of specific problems--after the design parameters had been determined--the previous portion of this report was deliberately written in a general manner.

The physical size of the file, and the actual number of required memory elements will depend upon the particular application which is proposed, since the number of descriptors required for each document greatly influences the total memory requirement. Figure 3 shows the large variation in system requirements of descriptors per document. Figure 4 illustrates the distributions of the number of descriptors required for each document for several operating systems. Statistics were also obtained to describe (see Fig. 5) the number of descriptor characters per document, and the number of characters per descriptor (see Fig. 2). Data for the number of characters per descriptor was based on a sample of single words, only. That is, no multiple words (e.g., aerodynamic heating), or groups of common root words (e.g., compute, computer, computing) or "see-also" references were included in the sample.

The empirical data did indicate the general form of the distributions that these file parameters might take, and also indicated some general magnitude bounds. It should be emphasized that a detailed investigation of any proposed operational environment would be desirable in order to achieve economies in memory utilization and logic requirements.

VI SUMMARY

For a very large memory system, such as the proposed MIRF, the efficiency of utilization of memory becomes a very important item because the total cost of the device will depend to a large extent upon the amount of memory required. For that reason, this particular report has considered memory capacity requirements to be the criteria for selection of the internal organization of a filing system. Device and logic considerations will be presented in subsequent reports. File organization, based on coordinate indexing, appears to provide both the logical capabilities and the depth of indexing required for this device. A MIRF could be used for a hierarchical file structure, simplifying the file maintenance problem; however, such a file would not provide all the logical facilities required by the specifications of this project.

In regard to memory capacity requirements, the word-organized and content-addressed memory is the most favorable approach for the implementation of the coordinate indexing schemes. With a word-organized memory, many word formats are possible. The techniques of superimposed coding are attractive because they require the least amount of storage elements; in addition, the superimposed coding scheme is free of the alignment problem that was described in Section IV. That is, no shifting, partial-field comparison, or intermediate control and memory are required. Possibly, there may be other logical considerations, such as the problems of negation and inequalities, which make the superimposed codes less attractive. The actual number of bits per word for the superimposed codes depends upon the file parameters, such as the amount of false drops which can be tolerated, and the number of indexing terms per document. A relaxation of some of these parameters would provide a reduction in the amount of memory which is required.

A comparison of the memory requirements of the various word-organized schemes is given in Table II. This particular table describes the memory requirements for systems with the assumed requirements of 12 to 15 descriptors per document, or 130 to 150 descriptor characters per document, and 25 to 30 alphabetic characters per descriptor. A more general summary, for various number of descriptors per document, is given in Fig. 1.

Table II

SUMMARY OF MEMORY REQUIREMENTS

Method	Approximate Total Number of Bits per Item
Superimposed Coding--single field	70-200
Superimposed Coding--multiple fields and abbreviated spelling	140-180
Prime Products	180-220
Binary--fixed field and word length	190-230
Abbreviated Alphabetic Spelling	240-570
Alphabetic Spelling--variable descriptor length	800-900
Alphabetic Spelling--fixed field and word length	1750-2700

To summarize, from the standpoint of total memory capacity requirements it appears that the coordinate indexing system, with a word structure which uses single field superimposed coding, is the most favorable approach. The superimposed coding with multiple fields and abbreviated spelling also appears attractive as an alternative. For a file of one million documents, there will be a minimum requirement of approximately 70 million to 200 million bits of storage if the MIRF is to operate as an index to the file.

Both of the superimposed coding techniques, single field and abbreviated spelling, should be examined in more detail for verification and improvement of the memory estimates, as well as for improvement or development of new techniques.

Study of actual devices may suggest other coding methods which offer particular advantages in physical construction.

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REPORT NO. Sp. Tech. Report COPY NO. 19, 20

CLIENT U.S. Dept. of Defense. Defense Atomic Support Agency

CONTRACT NO. DA-49-146-XZ-042

TITLE A STUDY OF THE DISPLAY SYSTEM REQUIREMENTS FOR THE DEPARTMENT OF DEFENSE-DAMAGE ASSESSMENT CENTER (DOD-DAC)

AUTHOR J. J. Bialik, C. P. Bourne, R. A. Heintz

DATE ISSUED 7/60

CLASSIFICATION S

LAB NOTEBOOK NO.
(FO-0-224)
D-0-479 -- D-0-559

SRI PROJECT NO. EU 3192 (647) ACC. NO. 6294

SRI PROJECT NO. Eu 3270 656 ACC. NO. 7021

REPORT NO. Appendices to Technical Report 1 COPY NO. 24, 25

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US Army San Francisco Procurement District

CONTRACT NO. DA-04-200-ORD-1072

TITLE AN EVALUATION OF A PROPOSED ACQUISITION RADAR FOR NIKE-ZEUS
(Oral Presentation to Personnel of ARGMA at Redstone Arsenal, November 9, 1960)

AUTHOR R. C. Honey, J. F. Cline, W. F. Gabriel, C. P. Bourne, L. Feinstein, C. B. Clark, R. N. Emmick, S. Dairiki

DATE ISSUED 2/61

CLASSIFICATION S

LAB NOTEBOOK NO.
√(EO-1-98)
√ D-1-277

SRI PROJECT NO. EU-3166-2 (orig. 641) ACC. NO. 7029

REPORT NO. Sp. Tech Report COPY NO. 19, 20

CLIENT U.S. Dept. of Defense. Defense Atomic Support Agency

CONTRACT NO. DA-49-146-XZ-042

TITLE A STUDY OF THE DISPLAY SYSTEM REQUIREMENTS FOR THE DEPARTMENT OF DEFENSE-DAMAGE ASSESSMENT CENTER (DOD-DAC)

AUTHOR J. J. Bialik, C. P. Bourne, R. A. Heintz

DATE ISSUED 7/60

CLASSIFICATION S

LAB NOTEBOOK NO.

(FO-O-124)

D-O-479 — D-O-559

SRI PROJECT NO. EU 3192 (647) ACC. NO. 6294

SRI PROJECT NO. EU-3166-2 (org. 641) ACC. NO. 7029

REPORT NO. Sp. Tech. Report COPY NO. 19, 20

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DATE ISSUED 7/60

CLASSIFICATION S

LAB NOTEBOOK NO.

(FO-O-224)

D-O-479 -- D-O-559

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LAB NOTEBOOK NO.
(FO-O-224)
D-O-479 -- D-O-559

SRI PROJECT NO. EU 3192 (647) ACC. NO. 6294

SRI CONFIDENTIAL

Chas Bourne

Final Report

DEC. 1960

OPPORTUNITIES FOR BELL & HOWELL IN THE INFORMATION RETRIEVAL MARKET

By: Charles P. Bourne and Richard H. Randall

Prepared for:
BELL & HOWELL RESEARCH CENTER PASADENA, CALIFORNIA

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

SRI

SRI CONFIDENTIAL

SRI PROJECT NO. IE I-3434 (org 224)

ACC. NO. 6888

REPORT NO. Final

COPY NO. 47, 48

CLIENT Bell & Howell Research Center

CONTRACT NO.

TITLE OPPORTUNITIES FOR BELL & HOWELL IN THE INFORMATION RETRIEVAL MARKET

AUTHOR C. P. Bourne, R. E. Randall

DATE ISSUED 12/60

CLASSIFICATION SRI Confidential

LAB NOTEBOOK NO. 34p.

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

December 1960

Final Report

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By: Charles P. Bourne and Richard H. Randall

SRI Project I-3434

Prepared for:

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I INTRODUCTION

The merger between Bell & Howell Company and Consolidated Electro-Dynamics Corporation produced an organization with technical skills and manufacturing facilities for a large array of products. The Bell & Howell Research Center has asked SRI to make this study of the market for information-retrieval equipment to assist the company in determining which of these skills and products might be used to take advantage of the opportunities in the market.

Since at the beginning of the project it was agreed that special attention would not be devoted to any particular segment of the information-retrieval market, detailed statistics have not been compiled for each segment of the market nor has the analysis and interpretation of the data collected been concentrated on any individual segment. Additional information should be gathered in those parts of the market that appear to be the most promising prior to Bell & Howell's undertaking any major effort to penetrate the market.

The information-retrieval industry is not well defined, and even the words "information retrieval" have many different meanings. In the broadest sense, almost all human activities are concerned with information retrieval; however, for the purpose of the study, the information-retrieval industry is described as being composed of those companies that supply equipment, materials, and services for the filing of information and for its subsequent retrieval. The information-retrieval market is generated by those organizations that have the need for such facilities. The study was not directed towards an analysis of the market for equipment that is used for data processing except when such equipment is used exclusively for the filing and subsequent retrieval of information.

During the course of the research, all of the major divisions of the Bell & Howell organization were visited to develop information on Bell & Howell's capabilities. Meetings were held with managerial, operational, and research personnel to discuss the product line, manufacturing capabilities, laboratory facilities, personnel interests, and marketing organization of each of the divisions.

Specifically, the objectives of this research have been:

(1) To describe the market for information retrieval equipment.

(2) To identify those segments of the market that appear to offer the most opportunities for Bell & Howell.

(3) To assist Bell & Howell in matching the company's present and potential skills to the market requirements.

The study was undertaken as a joint project between the Institute's Divisions of Engineering and Economics. Charles Bourne, a member of the General Systems Department in the Division of Engineering, served as project leader, and Richard Randall of the Economics Division participated as the market analyst on the project. The project was under the general supervision of Allan Lee, Manager of Electronic Industries Economic Research in the Institute's Division of Economics.

II SUMMARY AND CONCLUSIONS

Current annual national expenditures for information-retrieval equipment are estimated to be approximately $100 million and are expected to double by 1965. Over one-half of the present sales are for manual filing equipment, and expenditures for this type of equipment are expected to remain larger than those for any other kind of information-retrieval equipment during the coming five-year period.

The sale of punched tabulating-card equipment, and photocopy and micro-image equipment for information-retrieval applications is expected to show the most rapid growth rate. Currently the sale of photocopy and micro-image equipment for information-retrieval applications is estimated to be $10 to $15 million annually and is projected to increase to $40 to $60 million annually by 1965.

Other types of equipment that are expected to find increasing use in the field of retrieval are data-processing computers, special-purpose magnetic-media storage equipment, and edge and interior punch card systems. Character-recognition equipment, both optical and magnetic, are not expected to find many information-retrieval applications.

The foregoing estimates of sales reflect only a slight penetration of the potential market for information-retrieval equipment. Much of the equipment that is being used for information retrieval and that is expected to be used within the next five years has been designed originally for other purposes. The rate of growth of information retrieval equipment sales will be determined by how rapidly device development, equipment designs, and studies of information theory can yield systems that will suit the requirements of the many and varied potential applications for mechanized equipment. It is estimated that at present between $15 and $30 million is being spent on research and development activities and that 80 percent of it is being spent on equipment design and device development. Thus, approximately 25 percent of the total revenue from equipment sales is being reinvested in research and development.

No Bell & Howell products currently exist which could be immediately applied to the information-retrieval market. However, there appear to be several types of equipment which should be considered seriously for commercial development by Bell & Howell. The product area which looks especially attractive for Bell & Howell is that part which is concerned with the storage and retrieval of images. The micro-xerographic equipment looks particularly interesting and may be the area of greatest potential of all the equipment mentioned in this report. The factors which make micro-xerography so attractive are: (1) it is the one area in which the Bell & Howell corporation has a unique development, (2) prototype equipment is already under development, with a relatively large amount of outside support, (3) there appear to be no major obstacles to prevent the realization of a commercial product, (4) the personnel at Bell & Howell who have the most knowledge and interest in information retrieval problems are also those whose experience has been primarily with photographic and micro-image equipment, (5) a rapid growth rate is expected in the market for this type of equipment.

Some specific types of photographic and micro-image equipment that have a large potential market and should receive consideration by Bell & Howell are: roll microfilm viewer-searchers, selective copying equipment, and photocomposing devices. Secondarily, it is believed that some opportunity might exist in the production of combination digital and image equipment. In addition, a limited market for certain specialized equipment exists that might take advantage of some of the custom design facilities at Bell & Howell; among these are: special-purpose magnetic media storage equipment, random-access image devices, special-purpose image systems, and unit-record image systems.

The production and engineering groups within the existing Bell & Howell organization that could contribute the most to participation in the information retrieval equipment market are the Bell & Howell organization in Chicago, the Datalab Division and the Bell & Howell Research Center. The groups that would probably have supporting roles are the Datatape Division and the Rochester film plant. Those groups that would probably be virtually unaffected are the Phillipsburg Plant, the A&C Division, the Systems Corporation, CVC, the Transducer Division and EMI.

If Bell & Howell is to make a successful penetration of the market for information-retrieval equipment, the organization appears to require strengthening in many areas. In particular, it would appear that:

(1) Additional personnel will be required for the investigation of users' problems and specific application areas.

(2) Groups will have to be organized with the responsibility for the design of storage and retrieval systems.

(3) A program should be initiated to identify Bell & Howell with the information-retrieval field.

(4) Distribution channels will have to be selected.

(5) A sales force will have to be staffed.

(6) Systems engineers to install information-retrieval equipment and to instruct customers in its use will have to be hired.

(7) Equipment maintenance facilities will have to be provided.

III THE INFORMATION-RETRIEVAL MARKET

A. THE TOTAL MARKET

Present annual national sales of information-retrieval equipment are estimated to be approximately $100 million and are expected to double by 1965. Table I divides the estimated sales among the several types of equipment that are used for information storage and retrieval. The sales values shown in the table are for equipment used solely for information-retrieval functions and thus the sales value indicated is only a fraction of the total sales of each type of equipment. It can be seen from the table that the most rapid annual growth rates are expected in the sales of tabulating-card equipment and of photocopy and micro-image equipment.

The table also lists the estimated value of annual supplies sold for use with each type of equipment. The value of equipment sales is the annual expenditures by users of equipment for information-retrieval functions, and the value of supplies is the annual expenditure for materials used with the equipment. Thus, in Table I, a 1-to-1 ratio would mean that equal annual expenditures are made for supplies and for equipment.

It should be noted that the total population of information-retrieval equipment is composed of many types of equipment the primary use of which is not necessarily the storage and subsequent retrieval of information. Much of the equipment now used for information-retrieval functions, such as punched-card and computer equipment, was initially designed for processes such as scientific computations or payroll calculations that contained few information-retrieval functions.

TABLE I

MARKET FOR INFORMATION-RETRIEVAL EQUIPMENT AND SUPPLIES

(Millions of Dollars)

Type of Equipment	Estimated Annual Sales I.R. Equipment* 1960	Estimated Annual Sales I.R. Equipment* 1965	Annual Growth Rate	Ratio of Supply $ to Equipment $
Tabulating-Card Equipment	$ 2-3	$10-15	40%	1:1
Photocopy and Micro-Image	10-15**	40-60	32	2:1
Data-Processing Computers	15-20	30-50	17	---
Magnetic-Tape Computer Peripheral Equipment	2-4	4-6	14	1:10
Special-Purpose I.R. Magnetic Media	1-2	2-4	14	1:10
Special-Purpose I.R. Digital Systems	negl.	4-6	--	---
Edge- and Interior-Punch Card+	2-5	5-10	15	6:1
Character-Recognition Equipment	negl.	1-2	--	---
Manual Filing Equipment	40-60++	50-75	4	3:1
TOTAL MARKET	$72-109	$146-228	15%	

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* The estimated sales values are for equipment used for I.R. functions, and the sales value indicated is only a fraction of the total equipment sales of each type of equipment.

** The sales value indicated is the estimated value of equipment sold for I.R. functions and excludes the sales value of copying equipment whose function is the duplication of information for distribution purposes only.

+ Interior-punch card excludes tabulating cards.

++ Excludes equipment sold for dead-storage filing.

The growth rates projected for the various types of equipment now being offered for sale in the information-retrieval market reflect only a small penetration into the ultimate market potential. Some indication of the magnitude of the potential market can be gained by considering a few statistics on activities that are associated with information retrieval--for example: (1) the Federal Government produces 25 billion pieces of paper per year and has accumulated enough records to fill 7.5 Pentagons, (2) the cost to create and maintain Federal Government records is about 4 billion dollars per year.

In 1900, one out of 50 persons employed in the United States was a part of the clerical labor force; today, one out of 6 jobs is clerical and requires a labor force of 8 million people whose salaries total 70 billion dollars per year. If only a small proportion of these expenditures were available for information-retrieval equipment, extremely large equipment expenditures could be made each year.

Since much of the information-retrieval function is presently being performed with manual filing equipment, it is interesting to note that the cost to maintain a four-drawer file is estimated to be $225 to $250 per year. This includes the cost of the file drawer, the expense of the associated supplies, and the clerical time required to maintain the file.

A more important justification for the development of information-retrieval equipment than the huge sums being spent to perform the function today, is the non-availability of information from present-day filing systems. Technical literature is but one example of an area in which such a vast amount of information is generated that systematic retrieval with present methods is an almost impossible task. There are between 50,000 and 100,000 technical journals throughout the world publishing approximately 3 million articles each year. The rate of annual growth of technical publication is estimated to be between 10 and 15 percent. In addition, there are 75,000 technical books published each year throughout the world, and their number is growing at a similar rate.

For any part of this vast amount of technical information to be of use to the engineers and scientists for whom it is written, it must be catalogued, filed and later identified and retrieved. Of the 12.5 billion dollars spent each year in the United States on research, it is estimated that about 90 percent is for applied research. It is possible that improvements in information-retrieval capabilities will permit a significant improvement in the use of these funds by preventing duplication of developmental efforts, and by making pertinent information more readily available. Today, only a fraction of the information potentially available is ever used because in many cases no adequate information-retrieval system is available to locate it.

Table II lists some general application areas in which a relatively large potential market for information-retrieval systems exists. The numerical values associated with each of the application areas in the table are listed to indicate the magnitude of the potential market, but are not intended to imply that information-retrieval equipment could easily be designed to satisfy the requirements of each application area. Some of these application areas and the specific equipment that has been successfully used in each will be discussed later in this section of the report.

Another indication of the magnitude of the potential market for information-retrieval equipment can be obtained by examining the research expenditures that are being made in the field of information retrieval. Table III estimates these expenditures to be between 15 and 30 million dollars annually, and divides these estimated annual expenditures among the principal types of organizations sponsoring such research efforts. It is worthwhile noting that the expenditures for research approximate 25 percent of the estimated annual equipment sales. Such a high ratio between research expenditures and revenue suggests the anticipation of a very large potential market if these developmental efforts are successful. The ratio also suggests the very early stage of development of information-retrieval equipment, systems, and theory.

TABLE II

AREAS OF MAJOR POTENTIAL APPLICATION OF INFORMATION RETRIEVAL

Organization or Activity	Approximate Number of Units in U.S.	Reference No. *
Government hospitals (Patient records)	1,650	1
Non-Government hospitals (Patient records)	3,500	1
Physicians and surgeons (Patient records)	155,000	1
Opticians (prescriptions)	3,000 dispensing offices	2
Optometrists (prescriptions)	22,000	3
County recorders (legal records)	3,047 counties	4
Title insurance companies (legal briefs)	2,500	5
County assessor (property and tax records)	3,047 counties	4
Tax return specialists (statutes)	13,000 public accountants	6
Lawyers and legal services (legal literature)	53,300	7
Realtors (property description and histories)	109,000	7
Security and Commodity Brokers (general business records)	5,800	7
Insurance agents (policy briefs)	42,300	7
Life insurance companies (251 million policy briefs)	1,400	8
Fire and casualty insurance companies (policy briefs)	350	9
Credit reporting agencies (credit ratings)	3,300	10
Credit agencies (other than banks)	22,700	7

*All references are listed at the end of the report.

TABLE II (Continued)

Organization or Activity	Approximate Number of Units in U.S.	Reference No.
Banks (client accounts)	16,200	7
Manufacturers (general business records)	2,000 with over 1,000 employees	11
Newspaper and magazine publishers (morgues of past issues)	20,000 publications	12
Special libraries (technical information)	2,500	13
Public libraries	11,000	14
Industrial research labs	5,000	15
Organizations which generate and store engineering drawings	10,000	10
Engineering and architectural services (drawings)	15,400	7
General Contractors--building (drawings)	86,000	7
General Contractors--other than building (drawings)	21,000	7
Special trade contractors (drawings)	185,800	7
Local police files	20,000 municipalities	4
Elementary schools, high schools, colleges (transcripts)	141,000	16
Employment agencies (personnel records and requirements)	4,000	17
Advertising agencies (copy and art work)	8,000	17

TABLE III

INFORMATION RETRIEVAL RESEARCH EFFORT

	Annual Expenditures (Millions of Dollars)
Council on Library Resources	$ 1 - 2
National Science Foundation	1 - 2
Private Corporations (internally sponsored)	5 - 10
Military Agencies (USAF, Dept. of Navy, Dept. of Army)	5 - 10
Other Government Agencies (CIA, NSA, Library of Congress, Bureau of Standards, etc.)	3 - 6
TOTAL	$15 - 30

Table IV estimates the division of research expenditures among the various types of research that are being conducted in the information-retrieval field. By far the largest expenditure is being made for the development of equipment for storage and retrieval systems and for improvements in the associated devices and techniques. A rather significant proportion of the total research effort is being devoted to paper studies of the theory of information retrieval; such studies include mathematical models, techniques for indexing and classification, methods of automatic indexing and abstracting, and studies to define users' requirements of information-retrieval systems.

B. TABULATING-CARD EQUIPMENT

During the next 5 years, sales of tabulating-card equipment are expected to show the most rapid growth rate of any of the kinds of equipment used for information-retrieval purposes. Table I shows that present sales of tabulating-card equipment for information-retrieval purposes are estimated to be in the order of 2 to 3 million dollars annually, and that these sales are expected to increase to 10 to 15 million dollars annually by 1965. Such an increase reflects an annual growth rate of 40 percent. In addition to these expenditures for equipment, an equal expenditure is expected for the purchase of the tabulating cards that will be used with the equipment.

TABLE IV

AREAS OF RESEARCH

Relative Magnitude of Effort

50%: Equipment development for storage and retrieval systems.

30%: Device and technique development.

10%: Language translation.

10%: Theoretical studies (such as mathematical models, indexing and classification techniques, automatic abstracting, and user requirements).

The major manufacturers supplying equipment for use with punched tabulating cards are IBM and Remington Rand. These two companies, in addition to producing a complete line of tabulating-card equipment such as collators, sorters, readers, and card punches, also manufacture some specialized tabulating-card equipment for the information-retrieval market.

A great many individuals and organizations use punched tabulating cards and electronic accounting machines for storage and retrieval applications, and other related tasks such as reproduction and dissemination. In most instances, the applications are implemented with tabulating-card equipment which is already available within an organization, but which is being used primarily for some other purpose such as general accounting. Only a few organizations are able to justify the acquisition of this equipment solely for storage and retrieval applications.

Although all of the card systems reportedly use general-purpose tabulating-card equipment to good advantage, several new pieces of tabulating-card equipment have been marketed within the last few years specifically for documentation applications. These units, all developed by IBM, are:

IBM-9900 Special Index Analyzer (a commercial modification of the COMAC, which was developed by Documentation Incorporated under Air Force sponsorship).

IBM-9310 Universal Card Scanner.

IBM-101 with row-by-row scanning attachment (a modification to the existing IBM 101 Statistical Sorter).

Primarily because of the high cost of such equipment very little use has been made of these special systems, and under the present circumstances it is unlikely that these particular units will receive any substantial utilization in the immediate future. However, the use of the standard tabulating-card equipment will continue to rise, particularly in some of the newer applications.

The standard punched-card equipment has been used in a variety of situations, many of which can be generalized into the following classes of application:

(1) Situations where the production of a printed list is the major objective (i.e., composing a page for reproduction or distribution where the quality of the printing is not a major factor)--Examples of this application are generation of business telephone directories, personnel rosters, library catalogs, parts lists or catalogs, and literature indexes).

(2) Situations where the organization and correlation of information is the main objective--Examples of this application are the analysis of statistics, facility scheduling, and the maintenance of student's transcripts.

(3) Situations when the search of a permanent file is the major objective--This is the main information-retrieval application area, and is characterized most commonly by searches of engineering drawings, chemical structures and properties, patents, personnel records, and indexes to technical reports.

C. PHOTOCOPY AND MICRO-IMAGE EQUIPMENT

The sales value of photocopy and micro-image equipment used for information-retrieval purposes is expected to increase from annual sales of 10 to 15 million dollars in 1960, to 40 to 60 million dollars by 1965. By 1965, it is expected that this type of equipment will constitute the largest value of sales of mechanized equipment for information-retrieval purposes. The expected increase in sales represents an annual growth rate of 32 percent during the coming 5-year period. In addition to the expenditures for the equipment, it is expected that approximately twice this amount will be spent for supplies necessary to operate the equipment.

It should be noted that the estimates of expenditures for photocopy and micro-image equipment and supplies, are for those units used for information-retrieval functions, and exclude the sales value of copying equipment whose only function is a duplication of information for distribution purposes.

Table V tabulates the major equipment manufacturers now producing photographic and micro-image systems for use in the information-retrieval applications. Today, the Filmorex and Minicard equipment are the only systems which can be considered to be completely operational. With the exception of a single Minicard test system at Eastman Kodak, all of this image equipment currently operating in the United States is being used by government installations. A single Filmorex system and four Minicard systems have been installed. Most of the other systems and system components listed in Table V are still under development or have been developed but are not actually used for documentation activities.

TABLE V

MAJOR MANUFACTURERS OF IMAGE STORAGE AND RETRIEVAL EQUIPMENT

Major Equipment Manufacturers	Representative Equipment Manufactured
IBM	Project "Walnut"
Rabinow Engineering Company	Film Searcher
AVCO, Inc.	Verac 903
Benson-Lehner Company	FLIP
Itek, Inc.	Itek Card
Magnavox	MEDIA System and Film Searcher
General Precision Laboratory, Inc.	Telecard System
Ferranti-Packard	Rapid Access Look-up
Samain Company	Filmorex
Eastman Kodak	Minicard
FMA, Inc.	File Search System
General Electric Co.	Thermoplastic Recording

D. DATA-PROCESSING COMPUTERS

A certain amount of data-processing computer time is being used for processes that are concerned primarily with the storage and retrieval of information. Although the use of this equipment solely for information-retrieval functions is expected to increase during the coming 5-year period, its rate of increase is not expected to be as rapid as the increase in use of tabulating-card equipment or of photocopy and micro-image equipment.

The major manufacturers of data-processing computers are well known; some of the principal ones are IBM, RCA, Remington Rand, and Burroughs, each manufacturing several units of digital computers and associated peripheral equipment.

As computer equipment becomes more readily available, more and more organizations and individuals are expected to program them for storage and retrieval applications. With a very few exceptions, the information-retrieval programs have represented only a very small fraction of the total workload of the installations, and do not represent the task for which the computer was initially acquired. Some variation of a retrieval program, usually for a collection of technical reports and documents, has been demonstrated on nearly every type of computer in operation today.

In addition to file searching, the computers have also been used for the generation of conventional catalogs and indexes to be used in manual systems, the automatic routing or dissemination of material to potentially interested parties, the preparation of abstracts from straight textual material, the generation of lists of key-index words, and the generation of permutation or key-word-in-context indexes. Despite the arguments that have been advanced questioning the advisability of using computers for information-retrieval applications, their use is expected to increase.

Essentially all of the original work with computers for information-retrieval applications has been done by the government and commercial organizations, who are themselves technical information users and distributors, rather than by the universities and library schools. To some degree this may be due to the general unavailability and perhaps cost of computer equipment, although it must be noted that there are more than 100 computer systems currently operating in the U.S. universities and colleges.

E. MAGNETIC-MEDIA PERIPHERAL EQUIPMENT

In conjunction with the use of data-processing computers for information-retrieval purposes, a significant amount of magnetic-tape peripheral equipment, designed primarily for data-processing applications, is also used for information-retrieval functions. The use of this magnetic-media peripheral equipment for information-retrieval purposes is expected to show the same relative increase in usage as was shown for data-processing computers. The major manufacturers of peripheral magnetic-media systems for computers, other than the manufacturers of computers, are Potter and Ampex.

F. SPECIAL-PURPOSE MAGNETIC-MEDIA AND DIGITAL SYSTEMS FOR INFORMATION RETRIEVAL

The sale of special-purpose magnetic-media systems designed specifically for information-retrieval purposes is currently estimated to represent expenditures of 1 to 2 million dollars annually and is expected to increase to 2 to 4 million dollars annually by 1965. Table VI lists the manufacturers of several magnetic-tape and card systems that have been developed specifically for file-searching applications. Only 1 or 2 of each of the above units have been produced to date and none of them is yet completely operational in a documentation system. There has been some development, but no major marketing of special-purpose digital systems for information retrieval.

It should be noted that the functions of a tape-searching device may also be performed just as well on a computer system, and the recent commercial availability of several moderately priced data-processing computer systems has offered severe economic competition to these expensive special-purpose magnetic-media systems that have been designed specifically for information-retrieval purposes. Many of the special-purpose systems cost upwards of $100,000 each. With the exception of a very few special applications, it is unlikely that very many of these expensive special-purpose tape searchers will be used in the next few years. However, the relatively inexpensive systems, such as the Herner-Heatwole tape searcher, costing approximately $10,000, should find a more receptive market. The more complex and expensive tape-searching equipment will probably be used primarily by special-information centers such as the operational Western Reserve University-American Society for Metals Information Center. A few organizations with very large and special file problems may also purchase the more expensive systems.

TABLE VI

MAJOR MANUFACTURERS OF SPECIAL-PURPOSE MAGNETIC-MEDIA EQUIPMENT FOR INFORMATION RETRIEVAL

Major Equipment Manufacturers	Representative Equipment Manufactured
Computer Control Company	Index Searcher
Remington Rand	Univac Searchwriter
Reese Engineering Company	Findafact
General Electric	GE 250
Magnavox	Magnacard
Herner-Heatwole	Tape Searcher
Aeronutronics	Logic Processor

G. EDGE- AND INTERIOR-PUNCHED* CARDS AND EQUIPMENT

Sales of edge- and interior-punched card equipment for information-retrieval applications are estimated to represent an annual expenditure of approximately 2 to 5 million dollars, and are expected to increase to an annual sales value of 5 to 10 million dollars within the coming 5-year period. The sales of the cards themselves are expected to represent 6 times the amount of the expenditures made for the equipment. The type of equipment referred to in this category uses cards that (1) are perforated on the edges and sorted by means of spindles and other manual means, or (2) contain interior perforations that are sensed manually or by equipment not conventionally used to sort punched tabulating cards. One common type of interior-punched card is often referred to as a "peek-a-boo" card because of the nature of the search method, which consists of holding a group of cards up to the light and then looking through them to find coincident holes.

The major manufacturers of edge- and interior-punched cards and equipment are shown on Table VII. The table also lists the type of card marketed by each manufacturer.

There has been a large increase in the use of edge-punched cards during the last 10 years. However, the applications which are closely related to the classical documentation problems form a small portion of the commercial market for these cards. Other uses of these cards, by individual customers who use upwards of 1/4 to 1/2 million cards per year, are for such applications as production control systems and hospital charge tickets, and have steered the card manufacturers' attention away from the more poorly defined documentation problems. As a result, the development of edge-punched card systems for information retrieval has come primarily from a large number of individual users

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*This group of interior-punched cards and equipment excludes the conventional IBM and Remington Rand type of tabulating card and equipment.

and not from the manufacturers. There now exists a relatively large pool of relevant information and case studies about edge-punched card systems. However, nothing exists today that could properly be called an integrated and effective edge-punched card system. The Zator card is the only edge-punched card that was designed and used specifically for documentation purposes. It is expected that there will be further developmental work on edge-punched cards and equipment, although there have not been any basically new developments for several years.

TABLE VII

MAJOR MANUFACTURERS OF EDGE-PUNCHED AND INTERIOR-PUNCHED CARDS AND EQUIPMENT

Major Equipment Manufacturers	Representative Equipment Manufactured
Royal-McBee	McBee Edge Punch Cards
Jonkers Business Machines	Termatrex Interior Punch Cards
E-Z Sort Co.	E-Z Sort Edge Punch Cards
Zator Co.	Zator Card
Visirecord, Inc.	Brisch-Vistem Interior Punch Cards
William K. Walthus, Inc.	Findex Interior Punch Cards
Howard Benson Company	Omnidex Interior Punch Cards
Superior Business Machines, Inc.	Flexisort Interior Punch Cards

The current card systems have been used in a variety of applications, most of which can be broken down into the following general classes:

(1) Systems for reporting and/or charging (e.g., time cards, charge tickets, requisition forms)

(2) Systems for storing technical data (e.g., files of transistor or tube characteristics, performance or test data, material composition or characteristics, and parts descriptions or specifications)

(3) Systems for scheduling (e.g., classroom scheduling, production scheduling)

(4) Personnel records

(5) Bibliographies

(6) Commercial business records (mailing lists, ledger cards).

H. CHARACTER-RECOGNITION EQUIPMENT

The current sales of character-recognition equipment for information-retrieval purposes are negligible. However, it is expected that during the coming 5-year period some use will be made of such equipment for information-retrieval applications. Table VIII lists the major manufacturers of character-sensing equipment and divides these manufacturers into those making the equipment based upon optical techniques and those producing equipment based upon the use of magnetic techniques.

Character and page-reading equipment have been developed to such a point that there are presently at least 150 machines in operation for reading characters one line at a time for such applications as the mechanized handling of bank checks, retail charge slips, and oil company sales slips. Several units are in operation for reading entire pages of typewritten English text for input-to-data-processing or communication systems. In its present form, character-sensing equipment will not be applicable to documentation problems for several years to come. Likewise, page-reading equipment will be severely limited in its use. The restricted use of character-sensing equipment for documentation applications is primarily due to (1) the restrictions of the techniques, such as the rather strict requirements on type font, printing quality, and format of the printing, and (2) the relatively small need for this type of capability and equipment for general documentation systems. However, there are a number of special information-processing operations such as direct text scanning or searching, automatic preparation of indexes, and the collation and organization of text material, that could profitably use page-reading equipment.

TABLE VIII

MAJOR MANUFACTURERS OF CHARACTER-SENSING EQUIPMENT

Optical Equipment	Magnetic Equipment
IBM	IBM
National Data Processing Corp.	National Cash Register
Baird-Atomic, Inc.	National Data Processing Corp.
Rabinow Engineering Co., Inc.	Burroughs Corp.
Philco Corp.	General Electric Co.
Farrington Mfg. Co.	Compagnie des Machines Bull
Briggs Associates, Inc.	
E.M.I. Electronics, Ltd.	
Solartron	

I. MANUAL FILING EQUIPMENT

As can be seen from Table I, the major expenditures for equipment and supplies for information-retrieval functions are for manual filing equipment. The development of mechanized information-retrieval equipment is not expected to significantly affect the demand for manual filing equipment and supplies within the next five years. The development of mechanized equipment is in its infancy, and the use of manual filing equipment is expected to remain the largest segment of the information-retrieval equipment market.

IV THE ROLE OF BELL & HOWELL IN THE INFORMATION-RETRIEVAL MARKET

A. BELL & HOWELL EQUIPMENT OPPORTUNITIES

1. General

No Bell & Howell products currently exist which could be immediately applied to the information-retrieval market. However, there appear to be several types of equipment which should be considered seriously for commercial development by Bell & Howell. A functional description of this equipment is given in the following sections. The criteria that were used to judge whether equipment might be suitable for Bell & Howell to manufacture and market were: (1) that the product is compatible with the skills, interests, and capabilities of the Bell & Howell organization, and (2) that there appears to be a good market potential for this equipment. Products which did not satisfy these criteria were not considered further. In most cases, the equipment described below in Secs. IV-A-2 and 3 is of such a nature that it can be manufactured and marketed as a standard product on a relatively large-volume basis. There is also some more specialized type of equipment that might be appropriate for Bell & Howell to manufacture. These special products are more suited to development and marketing on a project or job-shop basis, and are described in more detail in Sec. IV-A-4, below.

2. Image Equipment

The application area that looks especially attractive for Bell & Howell is the one that might use equipment to process, reduce, store, search, and duplicate images. There appear to be four major areas that show promise for manufacturing and marketing standard products. These four are listed below and are ranked by their probable degree of opportunity for Bell & Howell.

(1) Micro-xerographic recording

(2) Roll microfilm viewer-searchers

(3) Photo-composing equipment

(4) Selective Copying Equipment

a. Micro-Xerographic Recording

The micro-xerographic recording techniques look particularly interesting and may have the greatest potential of all the equipment mentioned in this report. The factors which make micro-xerography so attractive are:

(1) It is the one area in which Bell & Howell has a unique development. That is, any of the other suggested equipments could be developed and marketed by a number of other organizations, but there does not appear to be any strong competition to the micro-xerographic recording.

(2) Prototype equipment is already under development by Bell & Howell, with a relatively strong outside sponsorship. Financial support might not be readily available for the development of other types of equipment.

(3) Preliminary results seem to indicate that the equipment will operate as planned, and there appear to be no major technical obstacles to prevent the realization of a commercial product.

(4) A staff has already been trained in the fundamentals and techniques of micro-xerography and there is a great deal of enthusiasm among the staff for this product. Such a situation contributes to a productive developmental effort for this particular product.

(5) Micro-xerography appears to have some very interesting and attractive market possibilities.

There appear to be two general categories of applications for micro-xerographic printing: (1) those applications that need, or could use the add-an-image capability, and (2) those applications such as publication and duplication in which there is no need for the add-an-image feature. The add-an-image feature should be studied in more detail to provide some accurate guide lines for the product planning and marketing effort. Further studies of application areas and user requirements will also be required for product-planning purposes--for example, the degree of automatic feeding required, the degree of automatic positioning needed for image posting, and the speed and paper-handling requirements.

In addition, further investigation should be made of user requirements and preferences for the various image-reduction ratios. Preliminary indications suggest that a large number of potential users would require reduction ratios of 3:1 or 5:1, rather than the more severe reductions of 12:1 or more. The division of the potential market by the various reduction ratios is important because Bell & Howell is currently licensed (with individual case exceptions) to work only on reductions of 12:1 or more.

b. Microfilm Viewer-Searchers

The roll-microfilm viewing-searching equipment is suggested for applications where a large amount of searching is required for information on rolls of microfilm.

Consider for example a system in which each film frame has some indexing data physically located with the image, and represented digitally by magnetic or optical storage. A keyboard could be used to enter the search criteria and to initiate an automatic search sequence that would result in the display of the selected film frame(s). Equipment options might include the provision for hard-copy printout of desired images.

It might be advantageous to market such equipment jointly with one or more publishing companies so that the equipment and the file of information could be sold as a package. An example of this approach is given by the Rogers Publishing Co. in their marketing and servicing of microfilm catalog files. Rogers has cooperated with Recordak to provide a microfilm catalog system for the missile and aircraft manufacturing industry. Rogers obtains and indexes thousands of pages of specification and data sheets annually, puts these in microfilm magazine form, and sells this catalogue system to the users. For compatibility reasons, Recordak motorized viewers are required with the installations. The first installations were made in early 1960, and within 8 months, 40 installations were made. It should also be noted that these installations were only for catalogues for the missile and aircraft manufacturing industry. Separate microfilm catalogue systems are also proposed for the following fields: automotive, communications and electronics, industrial machinery, electrical power and distribution equipment, instruments and appliances. In addition to catalogue reference systems, the equipment could also be developed and marketed in conjunction with the organizations such as the New York Times, Wall Street Journal, the material from which is regularly published in microfilm form, and in conjunction with organizations such as Chemical Abstracts, Patent Office Gazette, material from which is regularly published in paper form.

Co-marketing of equipment with publishers could result in a universal or standard machine design and indexing rules, so that the equipment could be installed in almost any library as a standard reference device for searching the microfilm literature of a variety of publishers. Standardization might be accomplished in a manner similar to the way in which check coding was standardized by the American Bankers Association, and could serve to increase the utility and applicability of the equipment. The elimination of the need for the user to maintain special equipment to generate his own film file with special coding, could result in a more attractive sales package.

c. Photo-Composing Equipment

Several models of equipment are available, notably the Kodak Listomatic and Vari-Typer Foto-List equipment, that transfer information at high speeds from individual cards to successive positions on a microfilm strip to compose lists and tables for subsequent printing operations. Such equipment typically reads one, two, or three lines of typed information from the top of an IBM card to compose the final image. The equipment allows catalogues and directories to be maintained easily and revised manually, and subsequently to be run periodically through the photocomposing machine to generate masters for printing. Typically, some telephone directories, parts catalogues, and indexes are prepared in this manner. There are at least 70 of these units already in use, and there appears to be a potential market for many more. The present equipment is rather limited in its features and capabilities, and an improved design would probably find a receptive market. One improvement in particular would be an increase in the editing capability of the machine so that it could take variable amounts of information from the card, and possibly from selected portions of the card.

d. Selective-Copying Equipment

The selective-copying equipment is suggested for applications in which a full-sized copy, or slightly reduced copy, is required of a particular portion of a full page. This type of equipment might easily use some of the xerographic printing techniques. The aim would be to provide a mechanism by which selected segments of a page, such as the title, a reference, a figure or a table might be copied onto selected portions of another medium such as another page, an IBM card, an edge-punched card, a 3-by-5 note card or catalog card, without requiring any cutting, pasting, or other special procedures. There does not appear to be any equipment in existence that meets this particular need.

3. Combination Image and Business Machine Systems

In addition to the image equipment, another application area that has a potential for a standard product line is that area which might use equipment combining the features of imagery and standard business machines. No equipment currently exists that can easily store and manipulate images and associated alphanumeric data. However, there are a number of applications which could use this capability. Two examples of this type of equipment and some suggested applications for it are given below:

(1) A modified bookkeeping machine that could post a micro-image of a bill or receipt at the same time, and on the same page, post the dollar amount. Such equipment would provide a complete audit and security record. It would also allow more complete information to accompany the record where the original documents are not available, such as when multiple distribution is required.

(2) A family of equipment, similar to conventional IBM punched-card equipment, that could process image data in addition to punched alphanumeric data. Such equipment should be able to do the conventional punched-card tasks as well as some extra tasks, such as the reproduction of a deck of cards, including the images, and the listing or tabulating of the information, including the images, on the same listing. The equipment might be used for such tasks as the generation of multiple copies or joint lists of mixed graphic and alphanumeric data, such as: (1) people's names and associated portraits, (2) part numbers with their associated pictures, (3) property descriptions for tax or real estate purposes with associated pictures of the property, (4) physical inventory records with pictures of the inventory items, (5) vehicle registration cards with pictures of the vehicles.

4. Special Products for Individual Users

a. General

There appears to be a small market for a variety of non-standard equipment that would probably be developed on a project or individual customer basis, to satisfy the needs of a particular user. Examples of such equipment are: (1) magnetic-media systems, (2) random-access image storage and retrieval systems, and (3) image-input systems for data processing. This equipment is described in more detail in the following sections. Although there is some market for this type of equipment, there is no indication that Bell & Howell has any significantly unique equipment or techniques that might put it in a strong market position. This special equipment could be made by a number of other organizations, many of which have already produced some equipment of this type. Some specific suggestions for equipment opportunities are described in the following sections.

b. Magnetic-Media Systems

Potential users of information-retrieval equipment will continue to show interest in magnetic tape and magnetic card searching systems, although there seems to be only a small demand for complex and expensive systems. Perhaps a very modest and inexpensive system with limited capabilities might find a more receptive market. Search speeds and logical complexity could be sacrificed to reduce the equipment cost. It would probably be advantageous to make the tape compatible with the computer tape of one of the IBM computer systems, so that it would be possible to generate and maintain the search tapes by computer equipment already in wide use. This would provide a means by which large organizations such as the Department of Defense, Armed Services Technical Information Agency, and large businesses, could generate the tapes at a central location and then distribute them to the various field locations for local searching. Such equipment would also permit some degree of standardization so that information agencies such as special abstract services, and the compilers of manufacturers' catalogues, could furnish tapes on a subscription basis to their customers. The Datalab and Datatape Division of Bell & Howell have a good capability for this type of product development.

c. Random-Access Image-Storage-and-Retrieval Systems

There are a large number of systems under development for the random-access storage of images, and there appears to be some market for these systems. However, except for the work that was proposed for General Electric Co., there do not seem to be any actual hardware developments within Bell & Howell that could provide a starting point for a product development.

d. Image Input Systems for Data Processing

There are a variety of applications where it would be convenient to read information from roll microfilm for input to data-processing equipment. The National Bureau of Standards, for example, has developed a system (FOSDIC-II) for reading microfilm images of punched cards as a computer-input device. An extension of this technique (FOSDIC-III) permitted the direct machine reading of microfilm copies of the original 1960 census forms which were filled out by the field interviewers. Consequently, the information on the original form could be used directly for input to the census data processing computers.

Some other commercial applications of microfilm-input devices for computers are:

(1) Handling of questionaires and mail survey responses

(2) Ballot counting

(3) Inventory control from manual checklists

(4) Convenient and relatively inexpensive storage for large volumes of permanent data files such as weather data, test results, or general

business files that might otherwise be stored on punched cards or magnetic tape

(5) Convenient and relatively inexpensive means for transmitting large volumes of data over large distances (e.g., by mail rather than by other communication links).

However, there do not appear to be any hardware developments within Bell & Howell that might provide a strong point of departure for a developmental effort in this area.

e. Unit-Record Image Systems

There is also a potential market for image systems using individual film chips as the basic file item, and incorporating both the image and the pertinent indexing information on the same chip. Bell & Howell has the capabilities to develop such equipment, but does not have any actual developments in this product area. In addition, there is strong competition in the market from organizations that have already demonstrated this type of equipment--for example, Eastman Kodak's Minicard, Samain's Filmorex, Itek's Itek-card, and Magnavox Magnacard with film or video image.

B. EFFECT ON THE BELL & HOWELL ORGANIZATION

1. Systems Approach for Sales

There are several different types of sales method within the Bell & Howell organization. Some Bell & Howell products are marketed by outside companies--for example, microfilm equipment and supplies by Burroughs. Some products are sold directly to retail outlets--for example, home movie equipment. Some products are sold directly to the ultimate users by the interested divisions, such as is done at Phillipsburg, Datatape, and CVC. No sales organization currently exists within Bell & Howell that is suited to the marketing of equipment for the information-retrieval market. The primary limitations of the present Bell & Howell marketing organizations for the sale of information-retrieval equipment are:

(1) The lack of sales personnel with the background, interest, knowledge and appreciation of the potential applications of information-retrieval equipment.

(2) Only a moderate amount of contact has been had with the organizations and activities that constitute the information-retrieval market.

(3) Most of the organizations are oriented toward component sales efforts rather than the systems sales efforts that will be required in the information-retrieval market.

The information-retrieval market, like the data-processing market, will probably have to be handled with a systems sales approach rather than a component sales approach. That is, the salesman, or sales team, will have to work with a prospective customer to help describe and define a problem, synthesize a complex of equipment and procedures to solve the problem, and then write a proposal for a method of solution. If such a proposal is accepted, the sales organization must then provide staff assistance to the customer to help with the physical installation of the equipment, to train the customer's personnel, and to integrate and convert from the present system to the newly developed one. Continued maintenance and service facilities will also probably be required. To accomplish such a program, personnel specializing in systems studies, maintenance, and service publications must complement the regular sales force. Thus, a more expensive sales effort, with a different approach than that currently used by most of the Bell & Howell sales organizations, is required.

2. <u>Systems Approach for Engineering Development</u>

With a few exceptions, Bell & Howell's engineering has been directed toward the development and manufacture of high-quality precision equipment. Engineering emphasis has not usually been on systems design. Most of the developmental effort and staff experience with information-retrieval equipment has been equipment-oriented, and has been concerned primarily with the device technology. Moreover, with the exception of the experience of perhaps three or four people within the entire Bell & Howell organization, there is little knowledge of users' requirements that could be incorporated into equipment design. There has not been enough application- or user-oriented personnel available to work with the equipment-oriented people to develop systems that reflect the needs and interests of the market.

3. Public Identification of Bell & Howell with the Information-Retrieval Field

Potential users of information-retrieval equipment are generally unaware that Bell & Howell is working on equipment and solutions for their problems. Some direct commercial advertising may help, but indirect publicity is also needed, such as the publication of technical papers in professional journals, the active participation by Bell & Howell personnel in conferences, seminars, and in the activities of associations or societies concerned with information retrieval. A continuing display of the company's interest and competence by such indirect means would provide a great deal of support to the sales organization. This indirect method of publicity has been used very effectively by IBM and other companies to inform potential customers of their developmental efforts, equipment designs, and service organizations. Indirect publicity becomes more important with systems sales than with component sales, and should be fostered if entry is to be made into the information-retrieval market. Outside of the company's own organization there is little knowledge of Bell & Howell's activities in the field of information retrieval.

ACKNOWLEDGMENT

The success of this study effort has been due in large part to the splendid cooperation and support provided by the many members of the Bell & Howell organization who were contacted by the SRI team during this project. Particular thanks go to Dr. Charles F. Robinson, Mr. John G. Heiland, Mr. Milt C. Lauenstein, Mr. Malcom G. Townsley, Mr. Art R. Spalding, Mr. Joe Quateman, Mr. Lou Smitzer, and Mr. Bill Bixby.

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