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FINAL REPORT
ON COMPUTER SET
AN/GSQ-16 (XW-1)

VOL I
THE PHOTOSCOPIC MEMORY SYSTEM

PREPARED FOR

INTELLIGENCE LABORATORY

ROME AIR DEVELOPMENT CENTER (ARDC)

GRIFFISS AIR FORCE BASE, NEW YORK

CONTRACT AF30 (602) -1823

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IBM Research Center, Yorktown Heights, New York

FOREWORD

This report is intended to document the state of development of Computer Set AN/GSQ-16 (The Photoscopic Memory) and its associated information handling methods at the termination of the first phase of Contract AF30 (602)-1823. The primary objective of the work in this phase was to evaluate the Memory and get it running reliably. At a technical review conducted jointly by IBM and the Intelligence Laboratory in March, 1959, the Memory was demonstrated as capable of automatically looking up words in a Russian text and printing out English equivalents in comparable format. The demonstration was made possible not only by the improvements effected in the system mechanics and circuitry, but also by improved methods devised for ordering and loading the dictionary information and the cooperation of the Rome Air Development Center in making a Russian- English word list available. The word-list was compiled at the University of Washington, also under a contract with the Intelligence Laboratory.

Volume I describes the Photoscopic Memory as it forms a part of an automatic language translation system and reviews all the work performed in the contract period to enable the memory to carry out its function in this system reliably. Effectively, Volume I is a final project summary. Volumes II through VI describe the principles upon which the various components of the system depend, the physical characteristics of these components, their operation and, to the degree required by engineering personnel, their maintenance. Inasmuch as they provide complete records of the equipment, these volumes extend the earlier reports prepared under Contract AF 30(602)-1566.

The work at IBM Research was carried out under the direction of Dr. Gilbert W. King. Appendix A is a list of the project personnel.

ABSTRACT: An initial working system for translating Russian to English utilizes a large capacity photoscopic memory with fast access time as the primary tool. This report discusses the requirements for "real-time" translation of Russian technical literature and indicates the degree to which the present, or Mark I, system is capable of meeting these. It then describes the over-all operation of this system, stressing the logic of the search procedure and other design features of the memory which make the system workable. Since the translating power of the memory depends upon the dictionary information stored within it, the techniques and devices for preparing this information and loading it onto the storage disc are also described. Lastly, a summary is given of the work performed during the contract period to bring the equipment to its present operational level.

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Section I-Background

The automatic translation of language has become desirable in the last few years because of the increasing quantity of important scientific papers in foreign languages. Our scientists managed in the past to keep up with the French and German output, but now writings in Japanese and Russian are also of major importance and about 25 other languages contribute literature of smaller, though not negligible, quantities. While the translation of these languages can be performed by humans, the magnitude of the task indicates the extreme value of automatic methods.

A basic requirement of a machine upon which such methods can be based is clearly a large, rapid random access memory. There are 10^5 stems in a language with roughly 10 inflexional forms for each in Indo- European languages, and it is estimated that 10^3 bits of lexical information will be required per word on the average. The capacity requirement is then 10^9, which accords well with another point of view: that it is necessary to box a linguist in the machine. It is estimated that the capacity of an expert' s brain is 10^9 bits of professional material.

The rate of production in the Soviet Union of printed material which at least one person in the United States should read is 100 words per second. We may assume the addressing can be designed to supply the necessary lexical information in one look-up, so the random access should be 10 milliseconds to 10^9 bits, in 10^3 computer word lengths.

It is fallacy to suppose that the basic units in communication by words are words themselves. The information necessary for translation concerns words, word groups (e.g., prepositional phrases) and also parts of words. Thus the concept of the unit record of numerical machines must be abandoned, and replaced by an addressing capability of searching for the longest sequence in the remainder of the sentence.

The length of the address (the sequence of characters in the source language word) will vary from six to over a hundred bits; and the information retrieved will vary from a few to several thousand bits. Perfect matches will not always be made (for example, with internally inflected phrases or typographical errors) and, indeed, will not be absolutely necessary.

The system utilizing Computer Set AN/GSQ-16 (the Photoscopic Memory) is based on these principles. Its capacity is $3x10^7$ bits as compared to the 10^9 bits mentioned above for an ultimate system and its access time is 35 milliseconds as compared to the 10-millisecond figure quoted. The higher figures, however, do not exceed the limitations of the basic techniques involved and should be obtainable through straightforward development work.

The present system, designated the USAF Mark I Translator, consists of two separate sets of equipment, one which loads the dictionary onto the storage medium (the photo disc) and the other which performs the actual translation function. The speed and flexibility of the loading system is compatible with the language translation requirement. The translation system is capable of deriving adequate English equivalents for a high percentage of Russian inputs. The English, moreover, appears with proper format in upper and lower case Roman letters and is complete with punctuation. Future effort will be directed toward increasing the input and output speed, which currently lag the Memory. Greater logical powers, particularly for sentence analysis, will also be investigated to improve the yield of satisfactory translations.

A simplified pictorial block diagram of the translating system is shown in Figure 1. The heart of this system is the glass disc on which are recorded coded Russian idioms, phrases, and words paired with English meanings. The disc thus acts as an automatic dictionary which is read by means of a cathode-ray tube light source, a moving lens, a photo multiplier tube, and some electronic circuitry (the digit detector). In addition to the disc equipment, key portions of the system include the input Flexowriter which is used for typing the input Russian text, the input register which holds input text until the disc is searched for the proper dictionary entry, and the output Flexowriter which prints the translation.

Continuing to examine Figure 1, we can explain the operation of the translation system by tracing the events which flow from right to left as a result of some input text which has been typed on the input Flexowriter. The input Russian characters are each coded in the form of holes in an input tape. After the tape passes through the tape reader the information becomes coded into "ones" and "zeros", six per character, and is placed in the input register. These characters are then compared with the information being read out of the dictionary in order to determine the proper direction to move the lens and cathode-ray tube beam. This is analogous to a human looking into a printed dictionary at what - ever page is open and then flipping pages in the proper direction as a result of reading the first entry. Instead of pages in a printed dictionary we have tracks on the disc dictionary. The light beam continues to step across tracks, reading a small portion of each, until the comparator indicates that it has gone too far. The light beam is then brought to rest and the disc rotation (1400 r.p.m.) allows the reading of every entry on a particular track. This corresponds approximately with our reading the entries on a page of a printed dictionary from the bottom in order to get the longest possible match (for example, "time constant" before "time"). When a proper match to a Russian semantic unit has been found, the corresponding English meaning is read out through the high speed register to the output Flexowriter. At the same time, logical circuitry indicated by the "distributor" has kept an account of the number of input characters for which a a match has been found. This allows the input characters which have just been translated to be discarded and fresh input characters to be shifted into the input register.

The output buffer in Figure 1 is a gathering place for all output

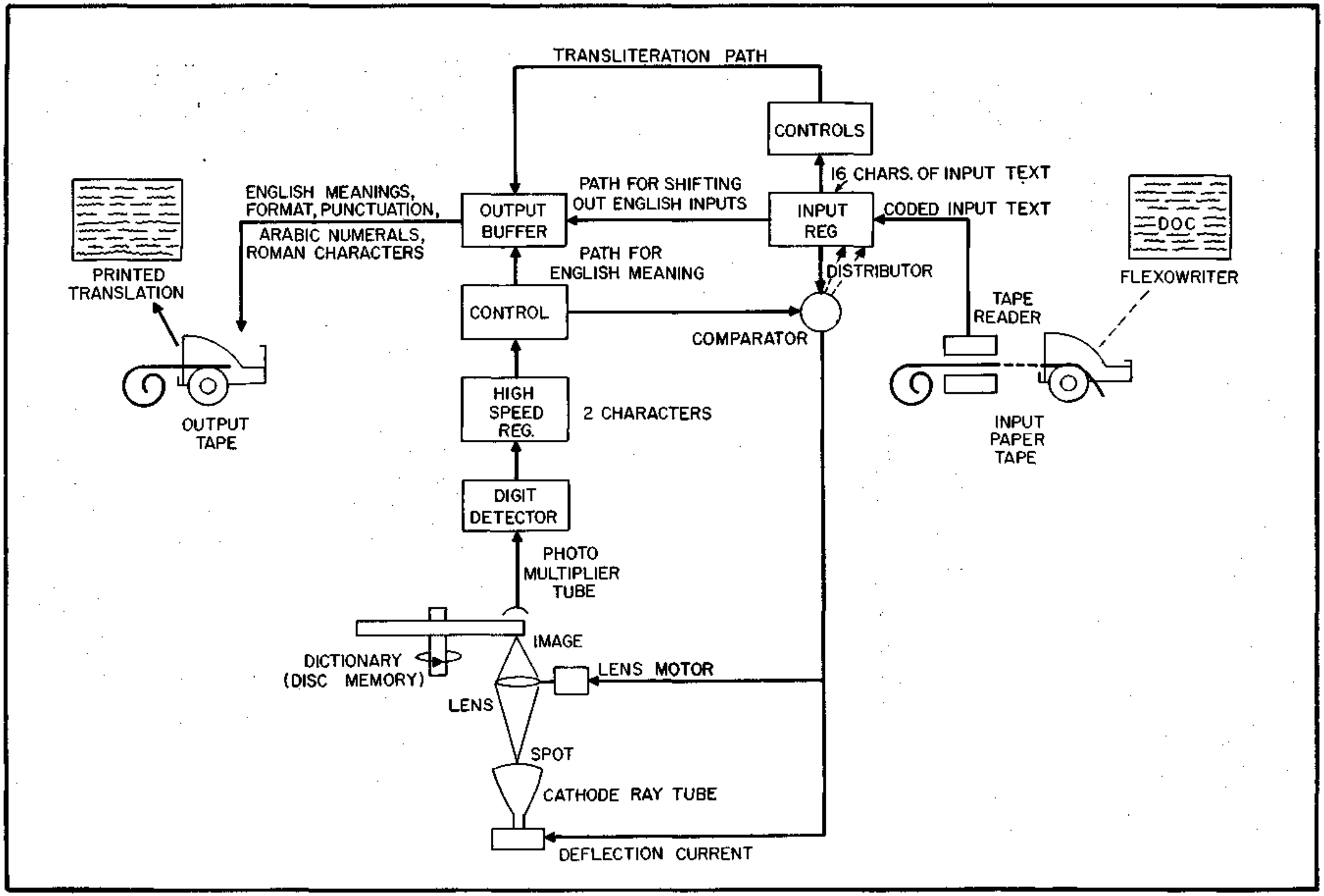


Figure I - Translation System

characters prior to printing out. It holds one character at a time, receiving it from various sources depending upon the nature of the contents. When no translation whatsoever is required, such as for Roman characters, punctuation, and numerals, the characters come directly from the input register. In the case of Russian word inputs, English meanings come to the output buffer from the disc memory equipment. In the case of input Russian which must be transliterated into Roman characters, such as proper names, the direct transfer from the input register is blocked so that control circuits can allow the transliteration stuffing equipment to make the proper changes. When an input Russian word should be translated but cannot be found in the automatic dictionary, it is also transliterated. In both cases of transliteration, the output typewriter ribbon color is shifted to red. This feature allows the user to notice at a glance what additions are required in the next edition of the dictionary.

The cathode-ray tube shown in Figure 1 is used as a light source because an electron beam can be moved faster than any other source. When it is necessary to move the light from one disc track to another, the change is made extremely rapidly by means of the deflection current. The lens motor, with its higher inertia, moves more slowly and allows the cathode-ray tube electron beam to return to the center of the tube face. Thus the cathode-ray tube beam makes possible the low access time (35 milliseconds average) while the lens motor prevents the electron beam from going too far toward the side of the tube.

The speed of this translating system is sufficient to translate Russian technical literature at an average rate approximately equal to the rate at which it is produced (30 words per second at present). Only the relatively slow speed of the input and output Flexowriters limits the speed of the system to a substantially lower rate. In the future it is expected that the input speed limitation will be removed by the use of automatic page scanners and character sensing. The output speed limitation can be eliminated by means of high speed printers and by multiplexing several output units as illustrated in Figure 2.

Some details on the layout of coded information in the disc memory are shown in Figure 3. A ten-inch glass disc contains 30 million bits of information on 700 tracks in an annulus 0. 36 inches wide. The width of the annulus is kept as small as possible for the sake of rapid access. The coded lexicon entries are represented by

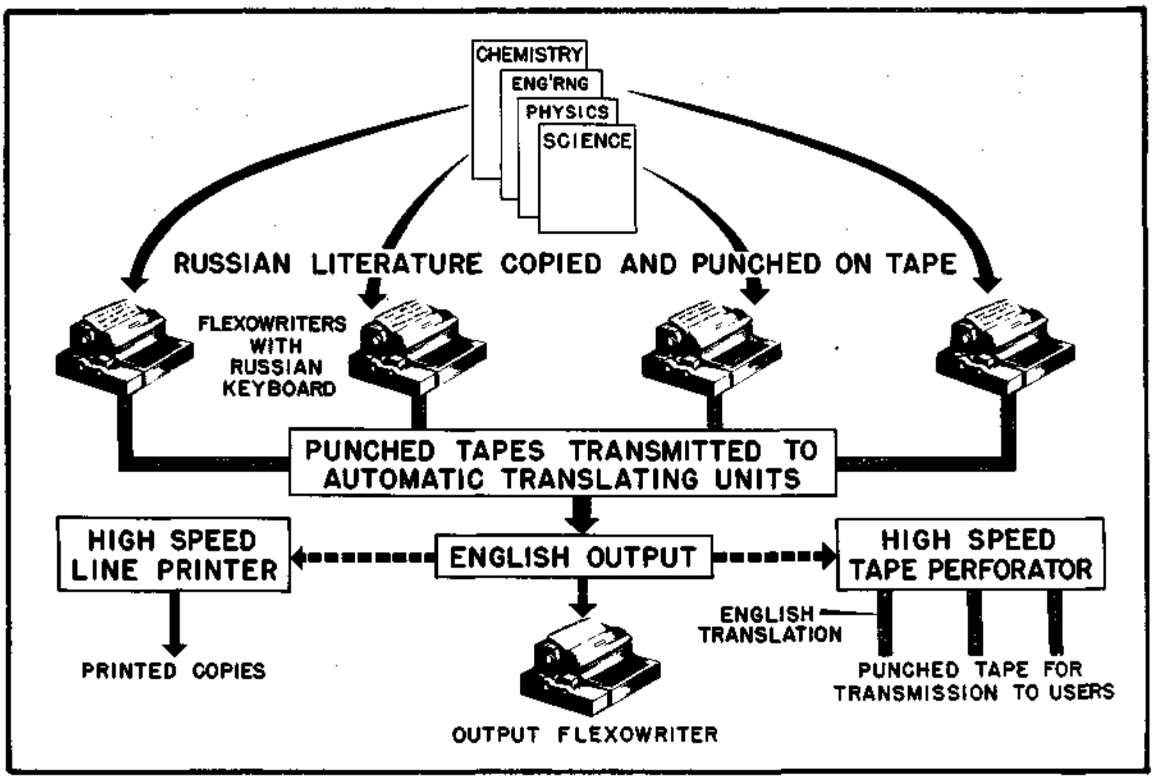


Figure 2 - High-Speed Output System

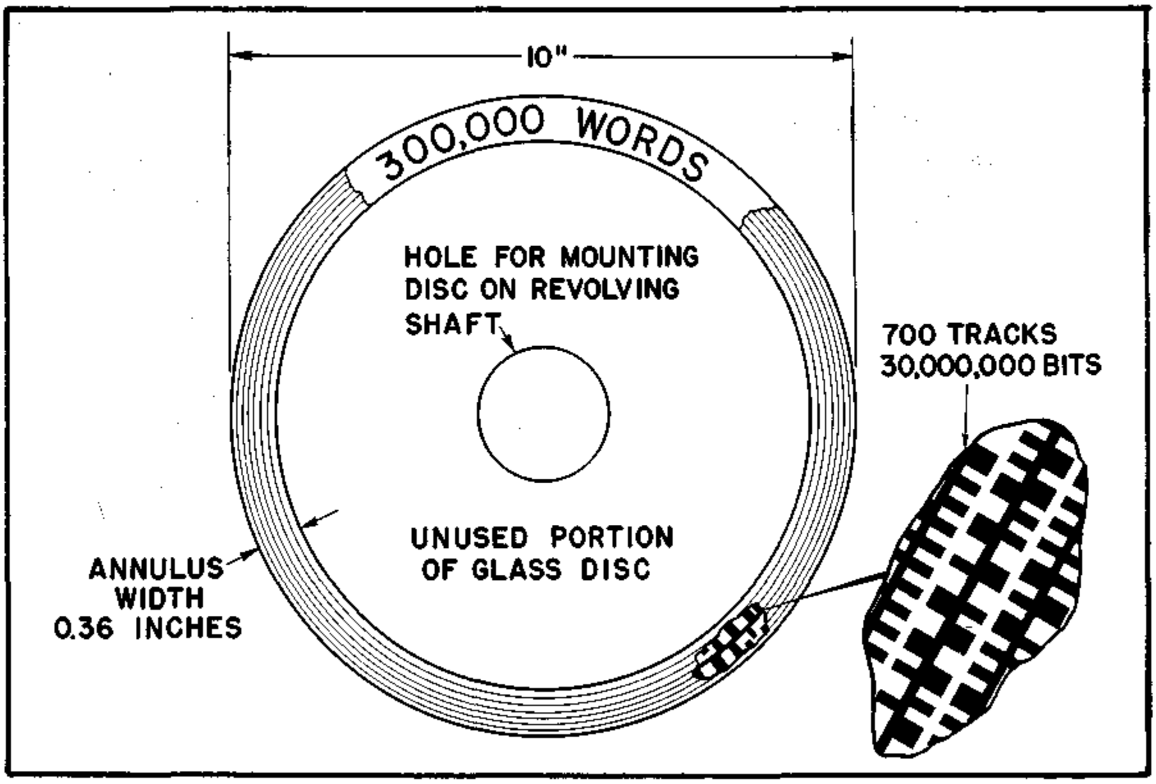


Figure 3 - The Photoscopic Memory

clear and black squares approximately one-third of a mil (0. 00033 inches) on a side. These marks interrupt the light beam. from the cathode-ray tube on its path to the photomultiplier and, therefore, differentiate a zero from a one. Since these marks have been kept small for the sake of access time, the light source on the face of the cathode-ray tube has also been kept small. It is, however, quite intense (1600 candles). In order to prevent the electron beam from burning the phosphor on the face of the tube, as will happen in any cathode-ray tube when its beam is kept in the neighborhood of a single spot, the beam, in addition to the motion required for stepping from track to track, is made to trace a circle about two inches in diameter. This motion is compensated by a vibration in the lens so that positioning on the tracks of the disc is not affected.

Figure 4 illustrates the manner in which zeros and ones are recorded on the disc. In either case a light square as well as a dark square is required. Only the order (i.e., whether or not the dark precedes the light) is changed to differentiate between the two types of bits. On the bottom of the figure are shown portions of three typical tracks. The corridors between the tracks are alternately colored black and clear. This allows the average light intensity of the photomultiplier tube to provide a signal for tracking. When the beam is correctly positioned, a "grey" level of light is transmitted to the photomultiplier. When the beam is too far to one side the incident light intensity increases, creating an error signal which allows a servo-mechanism to move the electron beam and lens so that the light beam will return to the center of the track. When the beam drifts toward the other side, the light intensity decreases, creating an error signal of the opposite polarity which moves the light beam again back to the center. Thus very accurate tracking by the light beam is assured.

Lexicon entries on the disc are laid out in such a way that the Russian words and idioms themselves make up the address of the entry. Each character in the Russian word has a certain binary code which can be interpreted as a weight. Cyrillic "e" has the lowest weight and Cyrillic "B" the highest. Each coded Russian word, therefore, looks like a long binary number. The layout on the disc is in numerical order, which is different from alphabetical order but has a certain similarity to alphabetical order. When the disc is being scanned track by track, each bit (one or zero) in the Russian word is compared with the corresponding bit in the input register (which here is acting like a memory address register).

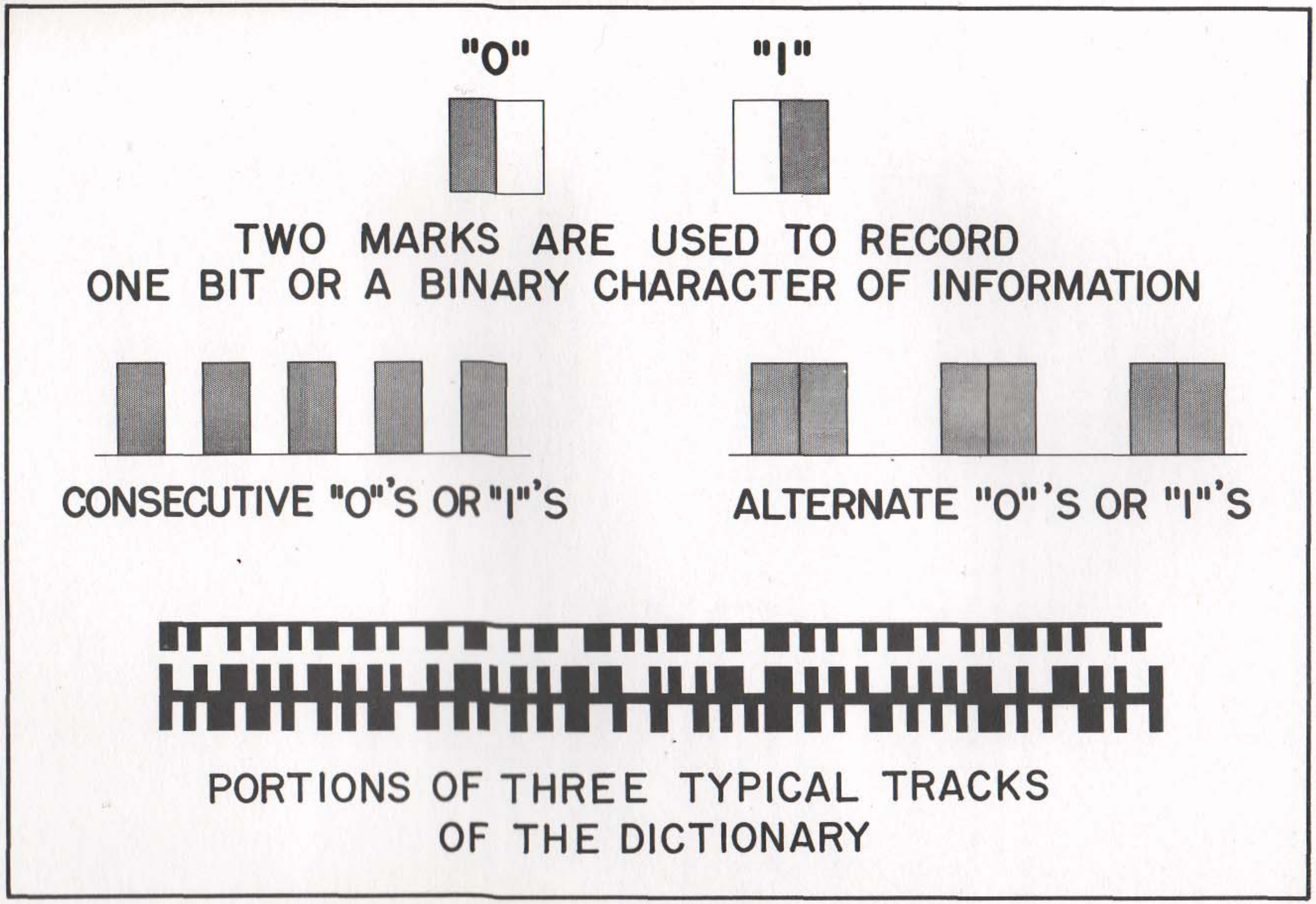


Figure 4 - Basic Disc Code

This comparison is continued until disagreement is found. At this time, a "zero" on the disc and a "one" in the input register means "go ahead" to the next track. The inverse combination means "go back". Only when the correct entry has been passed is a particular track scanned exhaustively at a rate of one megacycle per bit. The exact match has been found when each one and each zero in the Russian dictionary word matches up exactly with each one and zero in the input register until the symbol signifying the end of the Russian word in the dictionary entry is reached. Figure 5 shows a typical lexicon entry on the disc, with P representing a character in the Russian word and E representing a character in the English word. In the example shown, "electrical" and "charge" are shown as two separate entries on two separate tracks.

Figure 6, a sketch of the translation system, gives an impression of the size of the equipment. The search electronics could readily be reduced in size by converting the high speed vacuum tube circuits to transistor circuits. Figure 7 is a sketch of the disc reader. The disc itself is mounted about half way up the unit, with the cathode-ray tube light source in the bottom section and the photomultiplier toward the top.

The design of the dictionary has utilized photographic techniques because photographic emulsions are the densest storage media known today. Although this storage is permanent, a great deal of work has gone into the design of equipment which can prepare new discs rapidly, thus allowing frequent updating of the list of entries in the dictionary.

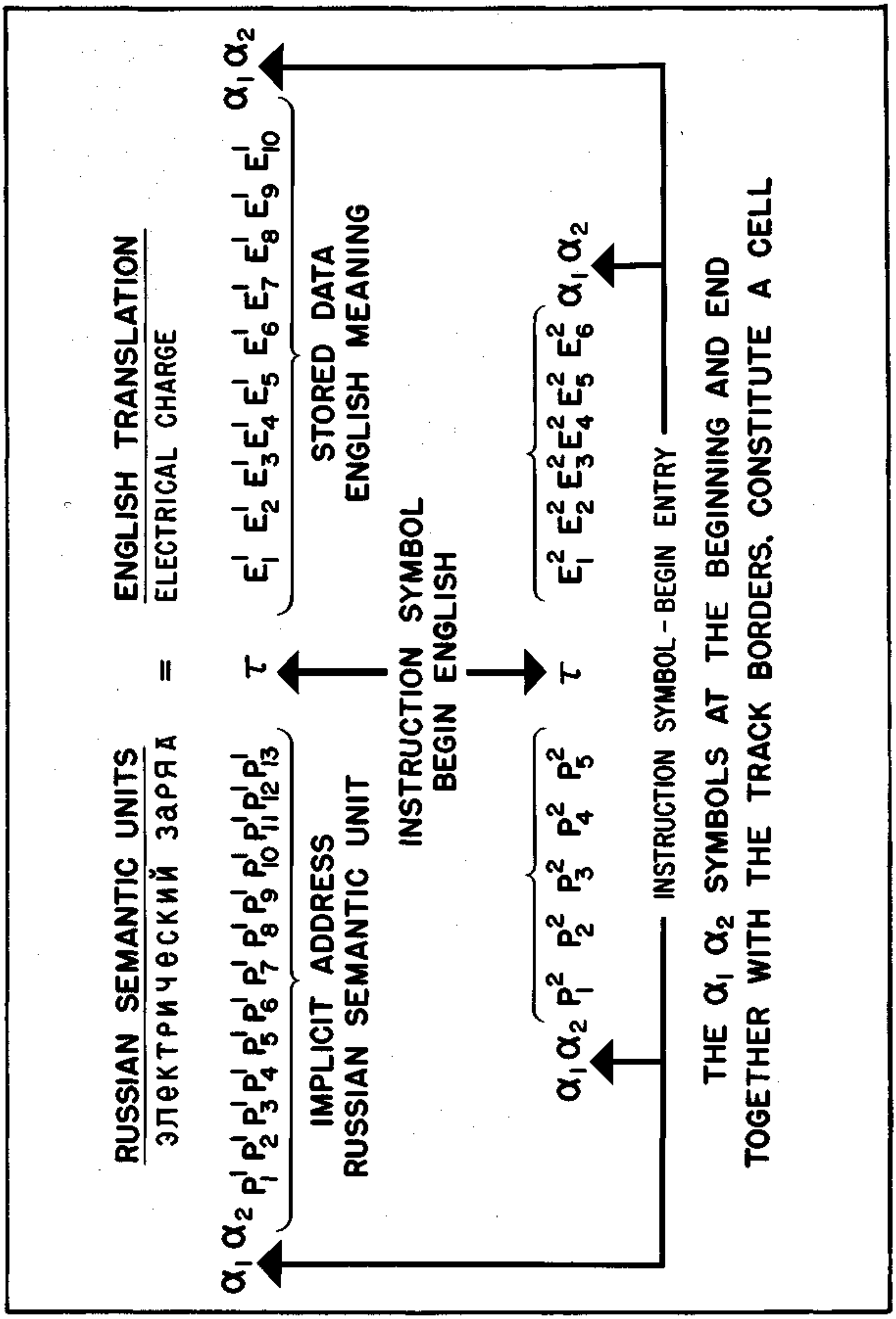


Figure 5 – Typical Lexicon Layouts

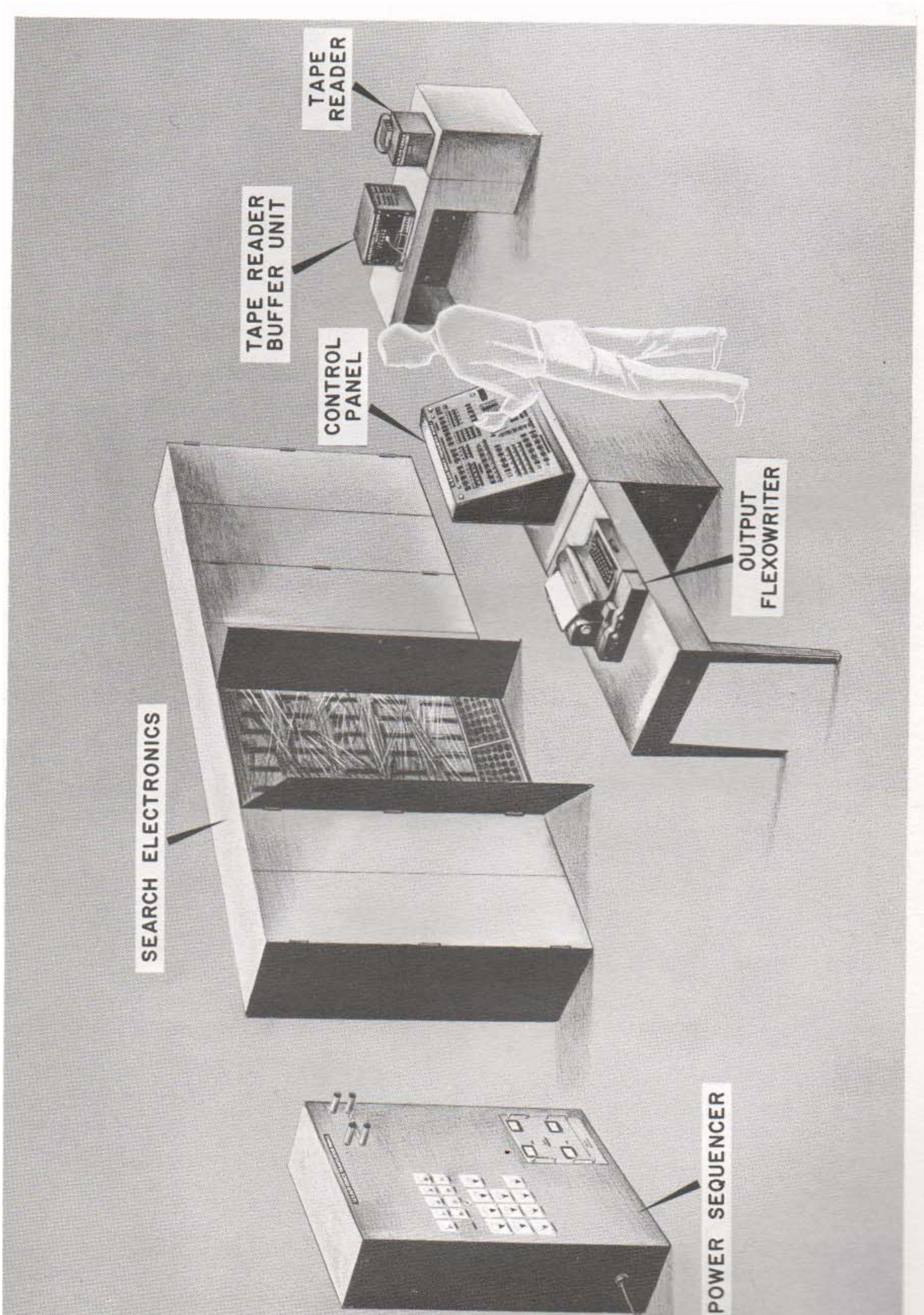


Figure 6 – Sketch of Translation System

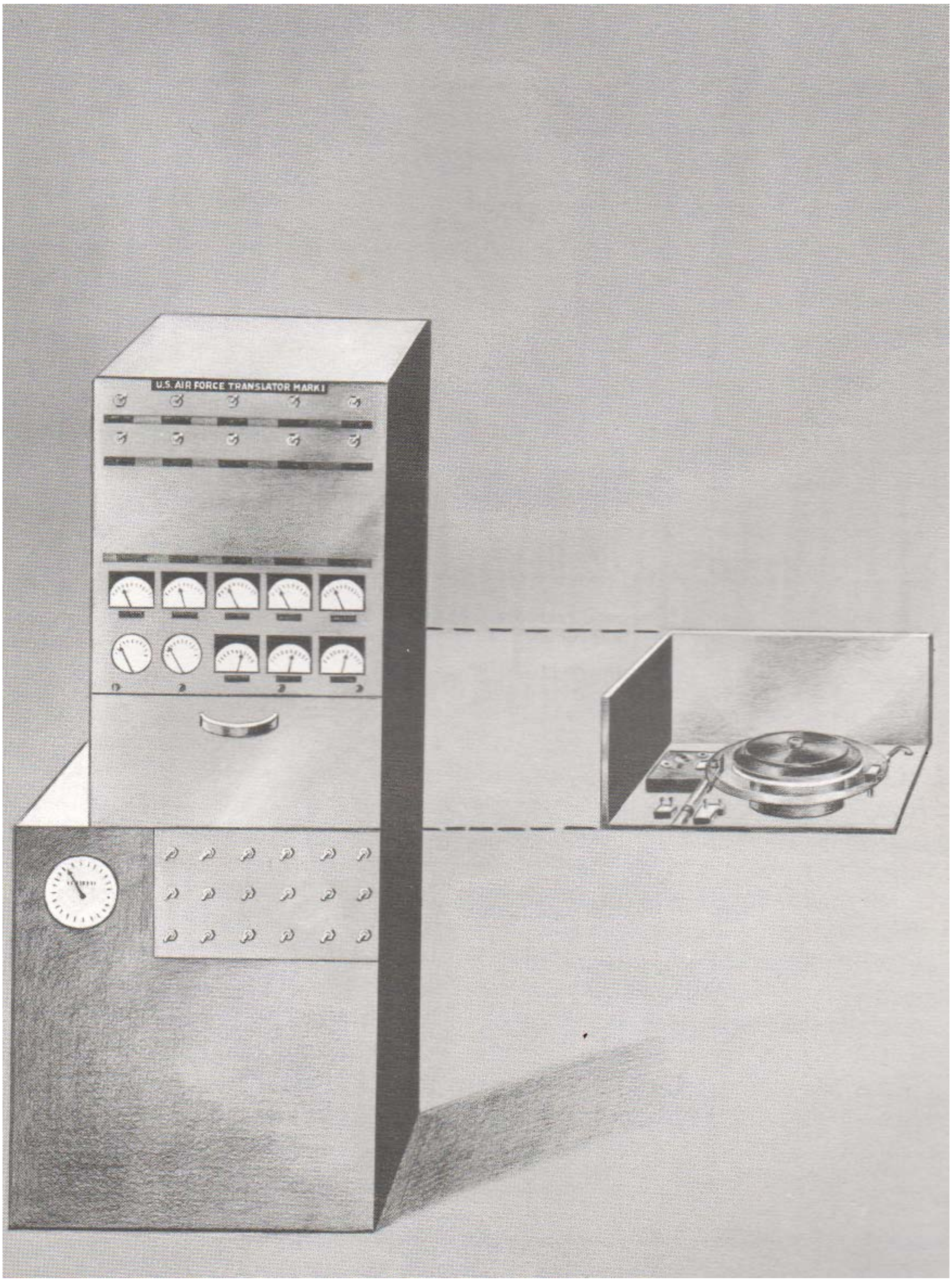


Figure 7 - Sketch of Disc Reader

The system for preparation of the disc is shown in Figure 8. It

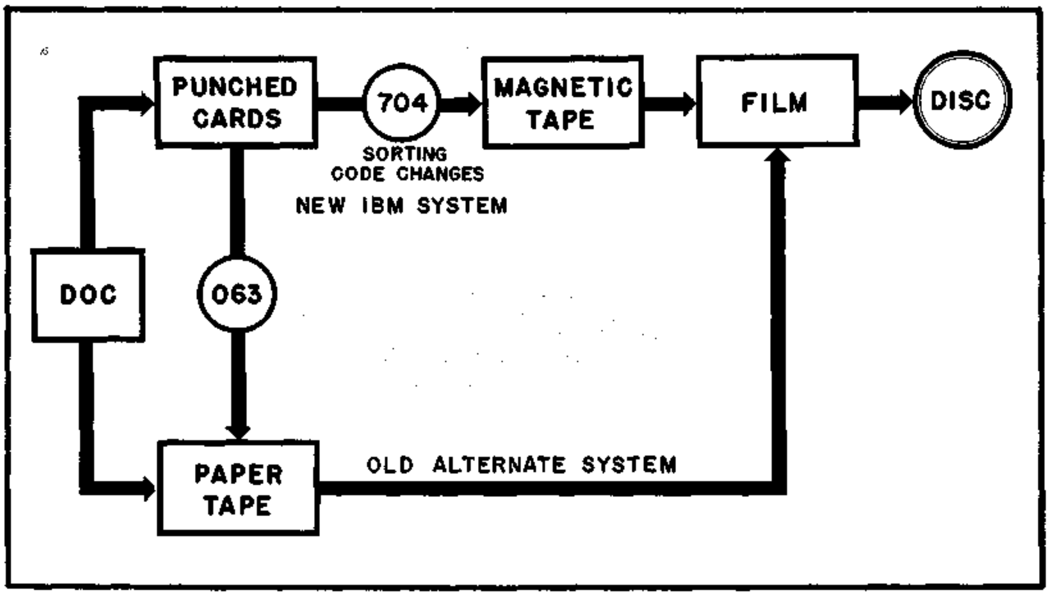


Figure 8 - Disc-Loading Systems

begins with a document which contains entries to be placed in the dictionary. These entries are keypunched into cards or paper tape. Since the card and magnetic tape system is the newest and is much faster than the paper tape system, it is expected that it will be used exclusively hereafter. Once the cards have been prepared, it is a simple matter for an IBM 704 computer to merge the new cards with the old by straightforward sorting procedures, placing the complete list of entries on magnetic tape. The 704 sorting program also will place any random mixture of dictionary entries into proper numerical order. Especially designed equipment now allows the magnetic tape to serve as input to a film-making machine which photographically codes entries on rolls of 70-mm film. The use of film as a preliminary step prior to making the disc substantially reduced the initial engineering problems (such as timing) and allowed faster progress in building a working system. A sketch of the machine is shown in Figure 9.

Since film-making is a photographic process (a cathode-ray tube light source is turned on and off in accordance with coded binary information arriving from the magnetic tape while the film *is* passed through the machine), photographic processing must follow the exposure. Although a standard Air Force processor is used

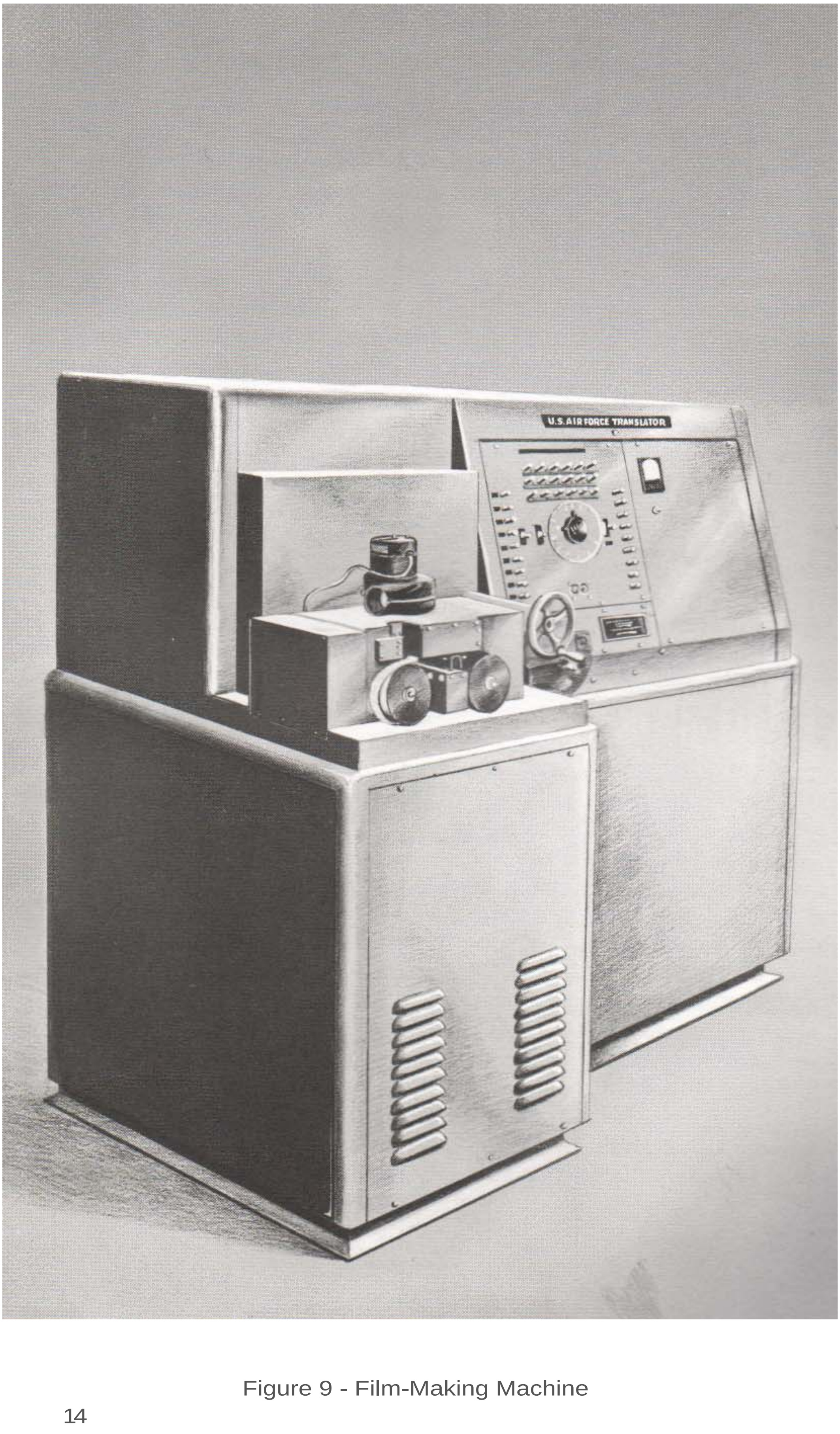


Figure 9 - Film-Making Machine

at present, some improvement appears desirable for future systems. Toward this end, Research is developing a special film processor (see Figure 10) which makes the processing automatic and also avoids flaking by winding the film so that the emulsion side never touches the rollers.

Information on the film is recorded on the disc by means of the Disc Making Unit (see Figure 11). Here again a cathode-ray tube light source is used, along with a mirror and lens system for passing light through the film to the emulsion on the disc. A servo system is utilized for accurate focussing. The disc is turned at one revolution per minute during exposure, with special precautions having been taken in the design to keep the speed and timing within close tolerances. The size of the information is reduced by a factor of about 55 during this process.

The photographic processing of the disc after the disc-making machine records the information is extremely sensitive to foreign particles in the developing and fixing fluids due to the extremely small size of the information bits (0. 00033 inches square). Commercially available solutions are completely useless until they are finely filtered. To overcome this problem, a special disc processor was designed (see Figure 12). This device minimizes the quantity of fluid used and then filters immediately before the fluid touches the emulsion surface.

As a result of the great care taken in the design of the disc-loading system, new dictionaries can be prepared on approximately a daily basis if desired. This speed meets the requirements of language translation by a wide margin. However, even if more rapid updating of the storage is required, a small erasable store such as a drum could easily be added. Figure 13 illustrates this possibility. In this system, the input address would initiate simultaneous searches in the large capacity photostore and in the small capacity erasable store. In most cases information would be found in the photostore only. Whenever a match would be found in both memories, the "logical choice" equipment would dictate that the erasable store be read out, since its information would be the most recent.

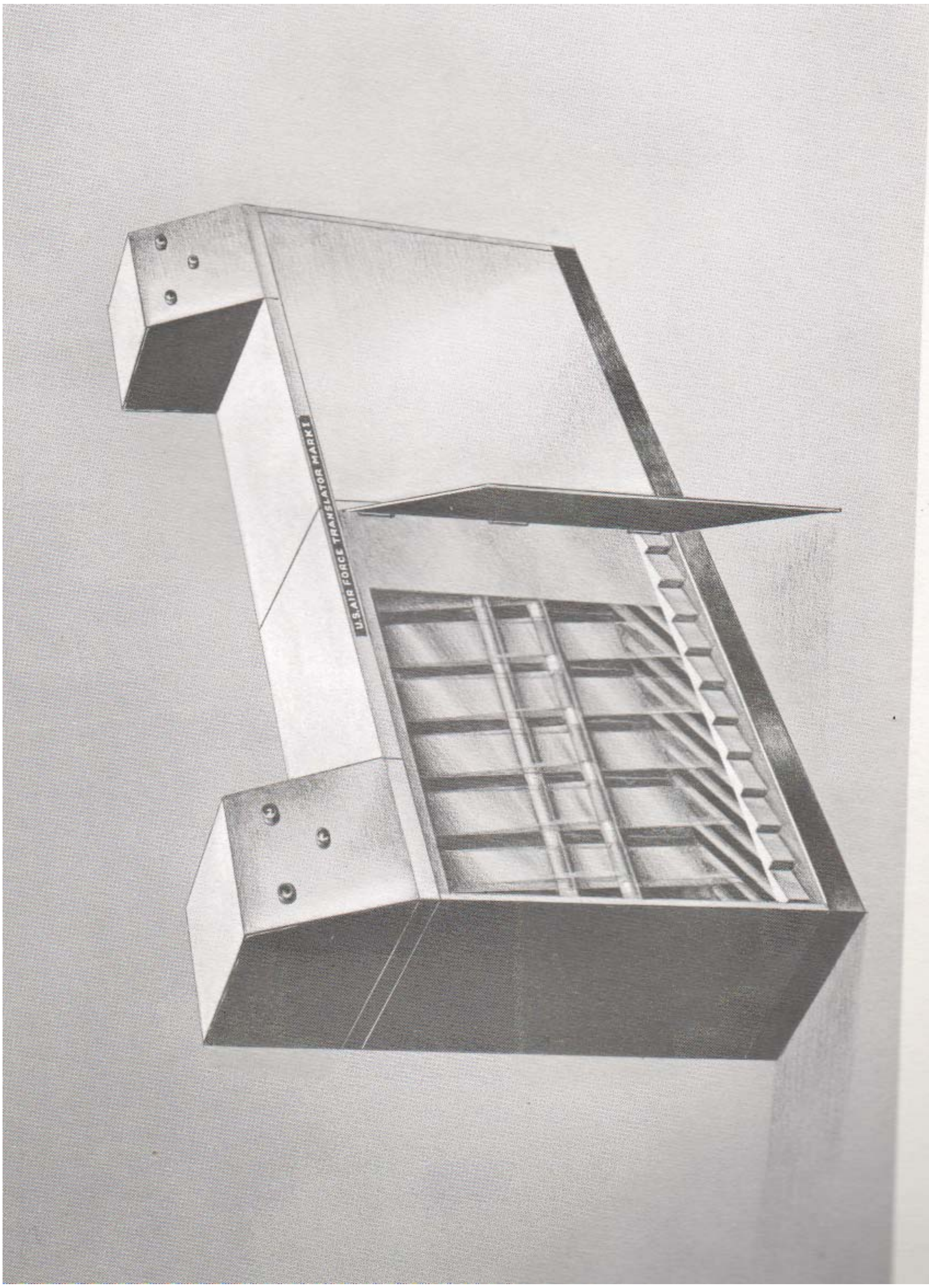


Figure 10 – Projected Film Processor (IBM)

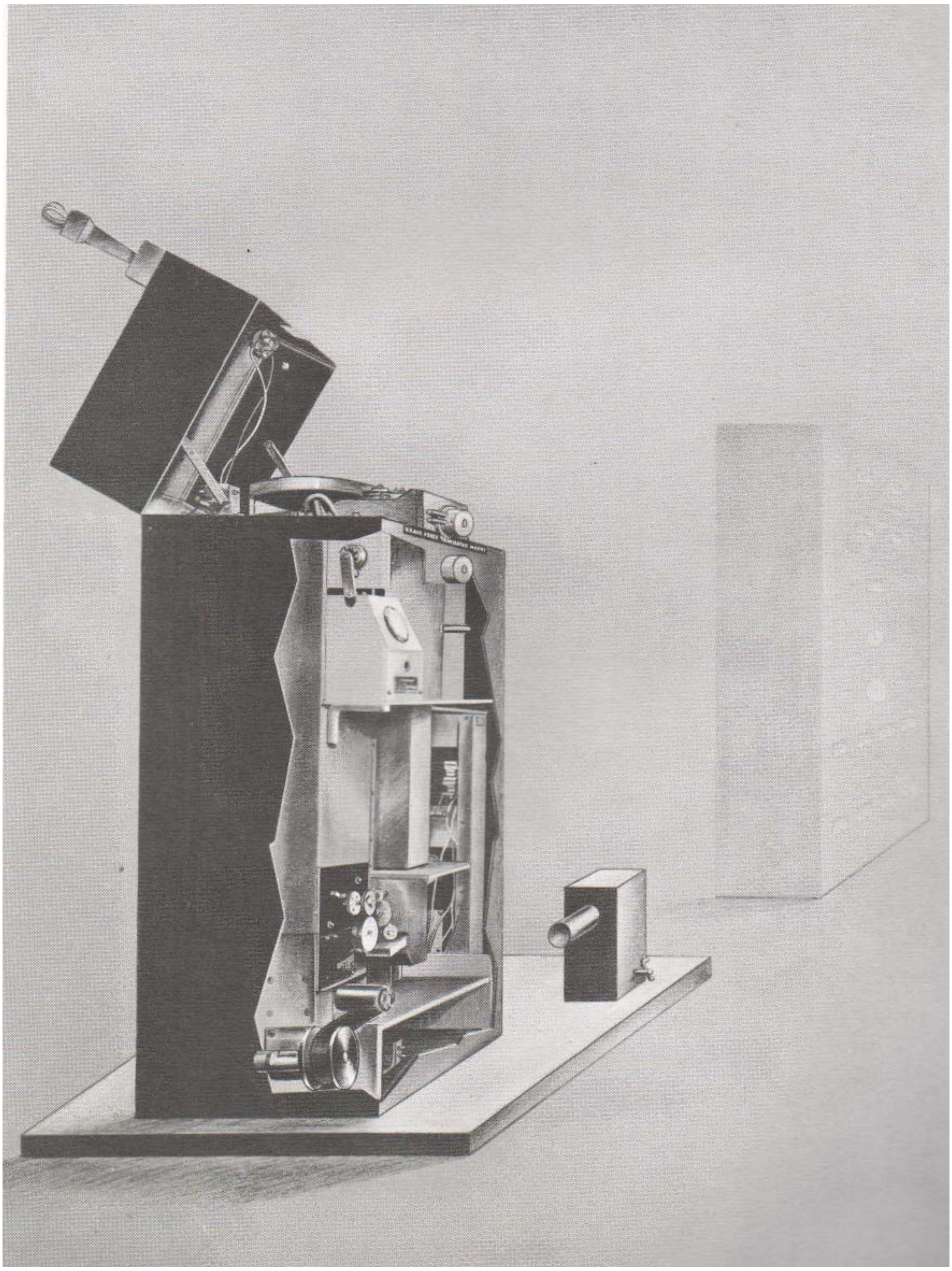


Figure II - The Disc Making Unit

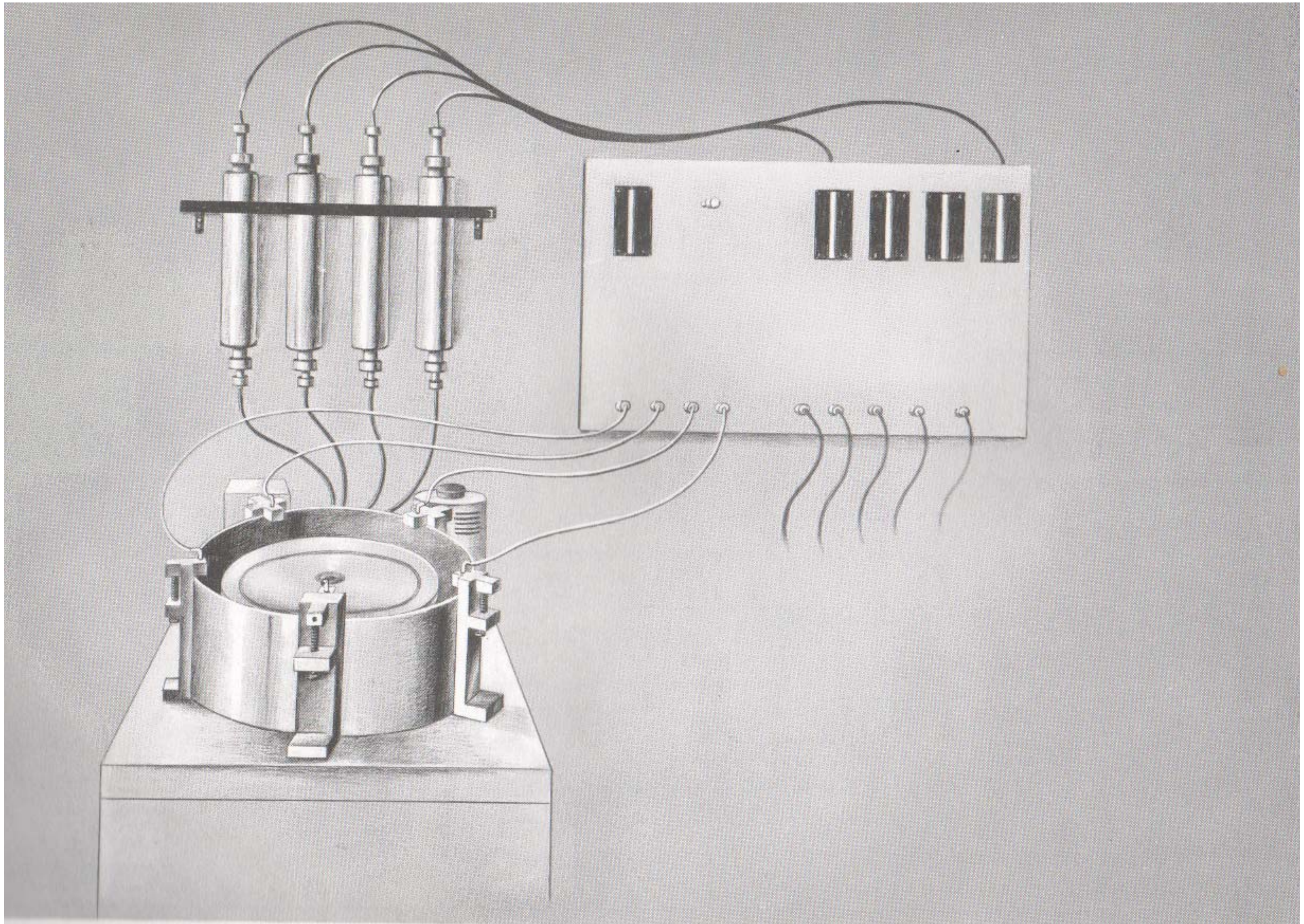


Figure 12 – The Disc Processor

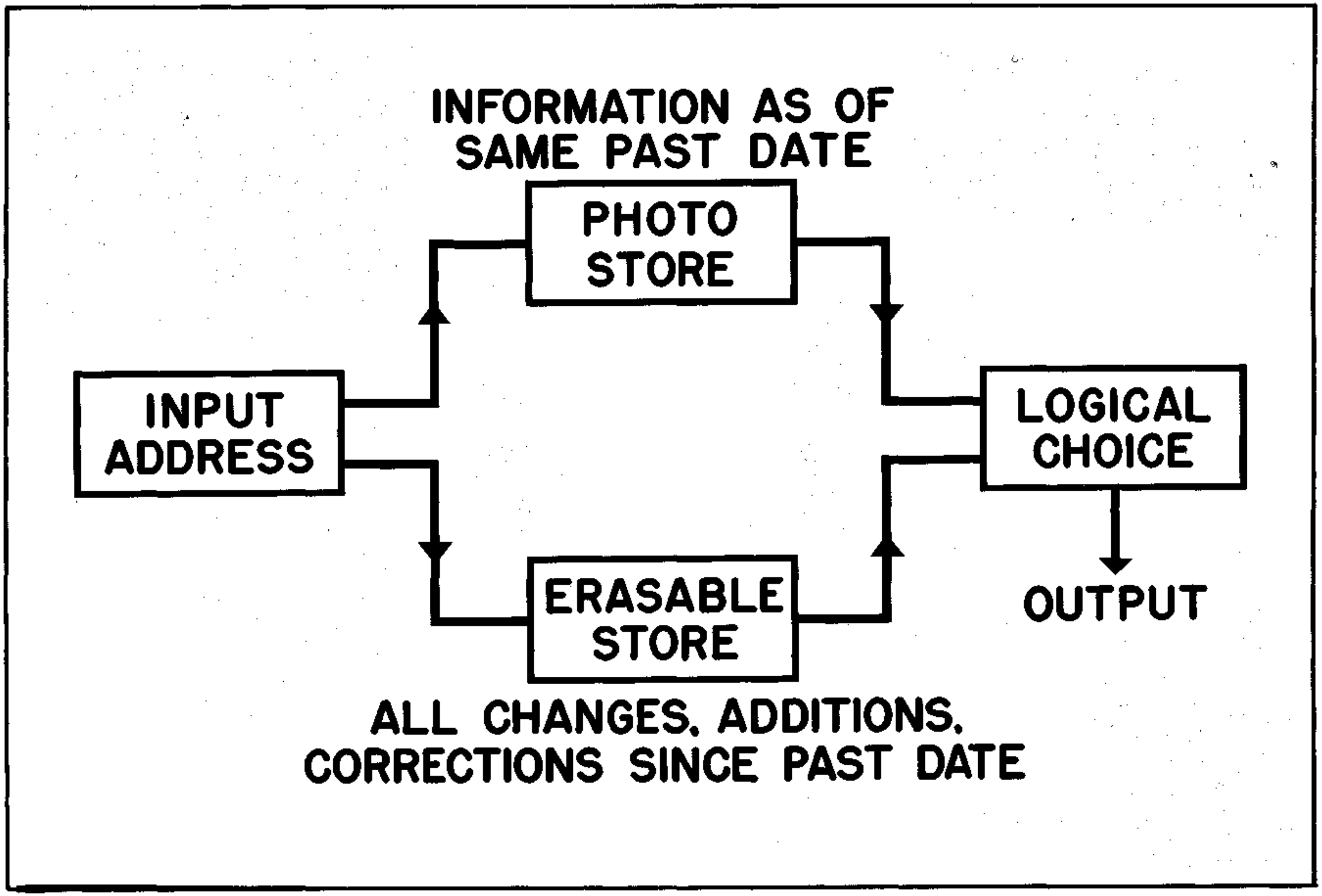
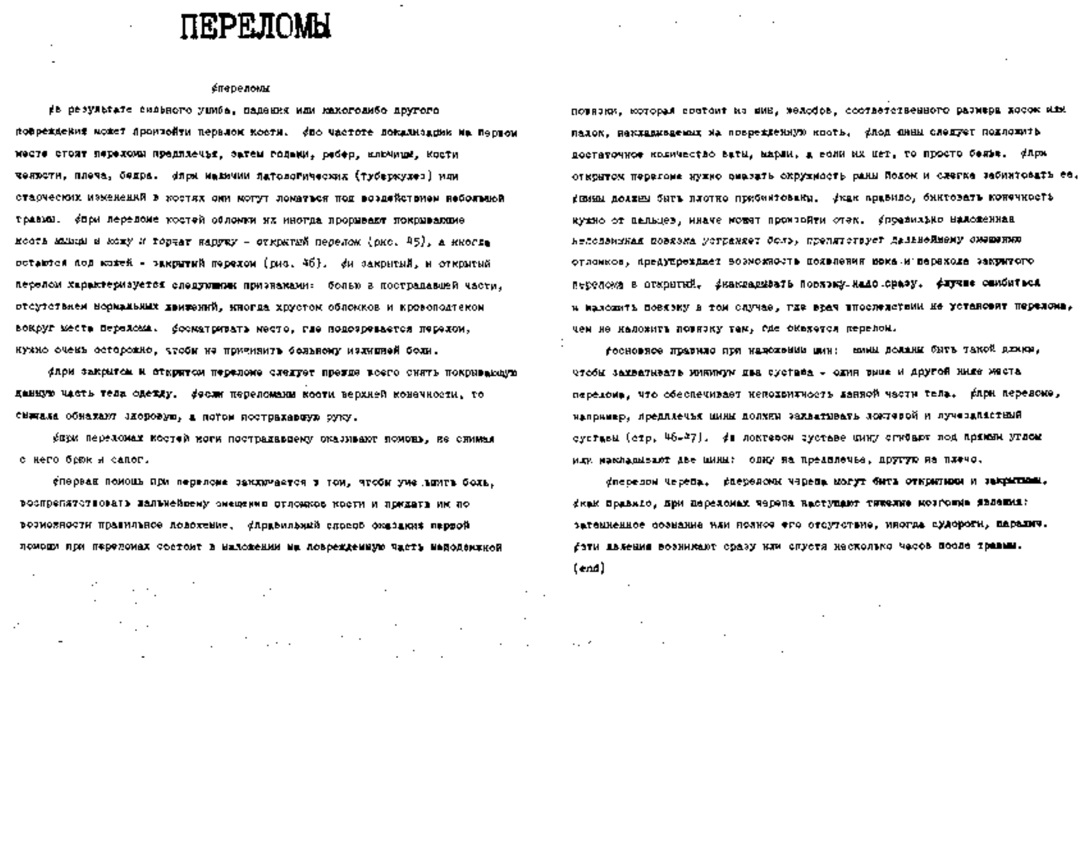


Figure 13 - Combination of Erasable and Permanent Storage

The equipment described in this report has been developed, designed, constructed, and tested out to a sufficient degree that useful and meaningful translations can be performed automatically in most cases. Although word lists for the dictionary have been very limited, we are now incorporating useful lexicon entries by modifying lists which have only recently been made available to IBM by the Rome Air Development Center.

The following is an example of a translation from a Russian first-aid booklet which has been produced by the translating system.

PHOTOGRAPH OF ORIGINAL TEXT



ПЕРЕЛОМЫ

¢переломы

¢в результате сильного ушиба, падения или какоголибо другого повреждения может произойти перелом кости. ¢по частоте локализации на первом месте стоят переломы предплечья, затем голени, ребер, ключицы, кости челюсти, плеча, бедра. ¢при наличии патологических (туберкулез) или старческих изменений в костях они могут ломаться под воздействием небольшой травмы. ¢при переломе костей обломки их иногда прорывают покрывающие кость мышцы и кожу и торчат наружу - открытый перелом (рис. 45), а иногда остаются под кожей - закрытый перелом (рис. 46). ¢и закрытый, и открытый перелом характеризуется следующими признаками: болью в пострадавшей части, отсутствием нормальных движений, иногда хрустом обломков и кровоподтеком вокруг места перелома. ¢осматривать место, где подозревается перелом, нужно очень осторожно, чтобы не причинить больному излишней боли.

¢при закрытом и открытом переломе следует прежде всего снять покрывающую данную часть тела одежду. ¢если переломаны кости верхней конечности, то сначала обнажают здоровую, а потом пострадавшую руку.

¢при переломах костей ноги пострадавшему оказывают помощь, не снимая с него брюк и сапог.

¢первая помощь при переломе заключается в том, чтобы уменьшить боль, воспрепятствовать дальнейшему смещению отломков кости и придать им по возможности правильное положение. ¢правильный способ оказания первой помощи при переломах состоит в наложении на поврежденную часть неподвижной повязки, которая состоит из шин, желобов, соответственного размера досок или палок, накладываемых на поврежденную кость. ¢под шины следует подложить достаточное количество ваты, марли, а если их нет, то просто белье. ¢при открытом переломе нужно смазать окружность раны йодом и слегка забинтовать ее. ¢шины должны быть плотно прибинтованы. ¢как правило, бинтовать конечность нужно от пальцев, иначе может произойти отек. ¢правильно наложенная неподвижная повязка устраняет боль, препятствует дальнейшему смещению отломков, предупреждает возможность появления шока и перехода закрытого перелома в открытый. ¢накладывать повязку надо сразу. ¢лучше ошибиться и наложить повязку в том случае, где врач впоследствии не установит перелома, чем не наложить повязку там, где окажется перелом.

¢основное правило при наложении шин: шины должны быть такой длины, чтобы захватывать минимум два сустава - один выше и другой ниже места перелома, что обеспечивает неподвижность данной части тела. ¢при переломе, например, предплечья шины должны захватывать локтевой и лучезапястный суставы (стр. 46-47). ¢в локтевом суставе шину сгибают под прямым углом или накладывают две шины: одну на предплечье, другую на плечо.

¢перелом черепа. ¢переломы черепа могут быть открытыми и закрытыми. ¢как правило, при переломах черепа наступают тяжелые мозговые явления: затемненное сознание или полное его отсутствие, иногда судороги, паралич. ¢эти явления возникают сразу или спустя несколько часов после травмы.

(end)

MARK I TRANSLATOR PRINT-OUT

FRACTURES

As a result of strong contusion, fall or any other injury may result fracture bone. With occurrences of pathological (tuberculosis) or *senile changes in bones they may break under* influence small trauma. During fracture bones fragments them sometimes tear covering bone muscles and protrude out - open fracture (fig. 45), and sometimes remain under skin - covered f- racture (fig. 46). And covered, and open fracture is characterized following symptoms: pain in injured part, lack normal movements, sometimes crunching noise fragments and bruise around place fracture. Investigate place, where is suspected fracture, is necessary very careful, in order not to cause patient unnecessary pain.

During covered and open fracture is necessary first of all remove covering given part body clothes. If broken bone upper limb, then first of all bare healthy, and then injured arm.

During fractures leg bones injured render aid, not removing from him/it trousers and shoes.

Proper way rendering first aid during fractures consists of tying around injured part rigid dressing, which consists of splints, troughs, appropriate size boards or sticks, placed on injured bone. Under splints is necessary place sufficient quantity cotton, gauze, and if they are not available, then simply linen. During open fracture is necesrary smear area around wound iodine and lightly bandage she. Splints should be tightly bandaged.

As a rule, bandage limb is necessary from fingers/toes, otherwise may result dropsy.

Properly tied rigid dressing does away with pain, opposes further travel fragments, prevents possibilitywith/fromt occurrence shock and transition covered fracture in open. Place dressing i- s necessary immediately. Better make mistake andtie dressing in the case when physician later will not find fracture, then not tie dressing in the case when will be fracture.

Basic rule during tying splints: splints should be such length, in order to cover at least two joint - one above and other below place fracture, which insures rigidity given part body.

During fracture, for instance, forearm splints should cover elbow and wrist joints (page 46 -47). In elbow joint splint bend at a right angle or place two splints: one on forearm, other on arm.

Skull fracture. Skull fractures may be open and covered. As a rule, during skull fractures *there result serious cerebral phenomena: affected consciousness or full he/it absence, sometimes* twitching, paralysis. These phenomena arise immediately or later a few hours after trauma. Sometimes during skull fracture from nose, mouth and ears flows blood.

The present status of the translation system was achieved only after the completion of extensive electrical and mechanical improvements in the original equipment furnished at the beginning of the contract. The initial equipment had never been completely debugged and tested and, moreover, had been subjected to two long-distance moves. Some of the major changes and improvements made on the system are described below in general terms. Detailed descriptions of the modified equipment are included in the five subsequent volumes of this report.

The film making procedure was greatly speeded up through the previously mentioned development of a magnetic tape input to the film-making machine and the preparation of IBM 704 computer sort routines to properly order the dictionary entries. The operation and reliability of the Film Making Unit was substantially improved by redesign of some critical timing circuits and control flip-flops. Modifications were also made which permitted the more desirable Microfile film to be used in place of the Linograph type. Control of film exposure in the Film Making Unit was improved to allow careful studies of the optimum exposure-development factors with reproducible results.

The quality of the finished discs was greatly improved as the result of a number of mechanical modifications based on a careful analysis of minute variations observed in the disc speed as it rotated in the Disc Making Unit. The principal result of the changes was more uniform exposure of the disc. Such steps as the installation of rotating cleaning brushes and a pressurized container for the disc were also taken to insure a greater degree of cleanliness during preparation.

The utility of the Disc Making Unit was increased by modifications which permit either the film or the finished disc to be read electronically at slow speeds. It is thus possible to check discs for exposure, defects, etc., without tying up the main translating system. This feature has proved extremely valuable during investigations seeking the optimum exposure-development factors in the disc preparation.

A major step in disc making was made with the design and development of the special Disc Processor mentioned earlier.

Major revisions in the search electronics were required to bring its operation to a satisfactory level and to aid in troubleshooting and maintenance. In general, the major electronic problem was the inability of many of the control circuits to operate at the speed required by the asynchronous character of the data from the photostore. Almost all the control circuits were modified to extend their high frequency response, and approximately one half of the pluggable units were extensively modified to correct their marginal operation under asynchronous conditions. Considerable additional forced air cooling was supplied to the electronic sections and the physical positions of many pluggable unit components were changed to reduce the excessive ambient temperatures. A few major logical errors were discovered in the search electronics and appropriate corrective measures taken.

The electronic regulators for the motor generator power supplies were modified to improve the transient response and the output voltage regulation. Several of the low voltage transistor supplies were replaced with Zener diode supplies to increase their reliability.

Originally the dc voltages to all sections of the system were fed through a single fuse for each voltage. The necessary fuse capacity did not provide adequate protection against severe physical damage to plugs and pluggable units in the event of accidental shorts between power supply voltages. In addition, short circuits were sometimes difficult to locate. To overcome these two problems, a power distribution panel was added which isolated the various sections of the system by means of low current fuses. The reduced fuse ratings eliminated the problem of physical damage and the sectionalization of the power distribution helped pinpoint troubles to a much smaller part of the system.

Considerable redesign was done on several of the circuits of the disc reader. Some of the circuits modified included the CRT focusing controls, intensity servo, and the photomultiplier amplifier. Circuits to actuate the track stepping were also developed. Mechanical revisions on the equipment included complete repackaging of the electronics and regrinding of the disc mounting spindle.

The disc reading circuits, usually referred to as the digit detector, were redesigned to utilize solid state components. In general, the logic of the original circuits was retained. However, the new circuits are more reliable and more readily adjustable.

The above listing is not intended as a complete enumeration of the problems faced in bringing the equipment to its present operational level. It does indicate to some extent, however, the engineering effort which was devoted to the equipment.

Appendix A-Project Personnel

Following is a list of the personnel in the Lexical Processing Department who contributed to the development work.

W. F. Anderson	H. C. Fox
C. L. Barcia	D. A. Grafton
A. Brannigan	H. H. Herd
H. W. Chang	D. Johnson
E. P. Clarke	G. W. King
J. L. Craft	E. W. Prusik
W. J. Deerhake	E. T. Rowe
J. A. Duffy	W. B. Strohm
I. T. Ellis	T. T. Tanimoto
H. G. Ferrusi	G. O. Tarnawsky

George Shiner was the Project Engineer for the Rome Air Development Center.