Unlocking The Disk Drive Story
IBM Almaden Research

Transcripts of five interviews held between Nov 2001 and Mar 2002 regarding RAMAC and other early IBM San Jose projects.

Conducted by: IBM Almaden Research Center

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Stable URL: http://www.computerhistory.org/collections/catalog/102739924

Excerpts From Wes Dickinson's Autobiography Entitled "I Was Lucky"

Attachment 1
Unblocking The Disk Drive Story
Oral histories conducted from Nov 2001 to Mar 2002
IBM Almaden Research, Almaden CA USA

North American Aviation

In 1946 I worked in the Electrical Laboratory at Wright Field in Dayton, Ohio. I wanted to get out of the air force, but I had no job lined up. I had never had a civilian engineering job. Fred Eyestone, a good friend of mine in the laboratory, left to work for North American Aviation in Los Angeles, California. That seemed as good a place as any so I applied for and got a job there. Averyl, John, and I arrived in California about mid-December 1946.

At first I worked in a big building adjacent to the Los Angeles airport -- one of the North American buildings. They assigned me to work on accelerometers. The accelerometer was to be part of an inertial-navigation system for guided missiles. (At that time I had not yet become a pacifist, and did not mind working on "war" stuff.) The general idea was to measure acceleration in two directions, both perpendicular to earth's gravity, and from the double integration of each of the two accelerations obtain the position change from the starting point.

The first accelerometer I worked on was simple. It had a pivoted arm with its center of gravity offset from the pivot. A coil of wire in a magnetic field, mounted on the arm, was fed current to hold the arm stationary when accelerated. The amount of current required at any instance was a measure of the acceleration. The problems I faced, working on this device, were to (1) minimize the effect of friction at the pivot point, (2) minimize the effect of the wires leading to the coil from the base (the base was stationary relative to the pivoted arm) and (3) to make the force on the arm directly proportional to the current to the coil. I don't remember how long I worked on that simplistic thing; I am sure for at least a year. It had too many problems to ever be practical; although it was an obvious way to measure acceleration we had no good way to doubly-integrate the current.

We were saved when an engineer came up with a better idea. It was called a Kinetic Double Integrating Accelerometer, KDIA, for short. A powerful name for a non-obvious (brainy) idea. This device was not simple. It had the following basic parts: 1) A motor suspended in a low-friction bearing. 2) The motor case weighted so its center of gravity was offset from the axis of the low-friction bearing. 3) An angular position sensor of the motor case relative to the mounting base. 4) A means to keep track of the motor's rotation. 5) A motor controller that kept the angular-position offset of the case near zero.

This is how the KDIA worked. [If you can't follow this explanation, I'm sorry. It is not necessary that you do.] "Rotor" refers to the motor's rotor (essentially a conventional motor's rotating part); "Case" refers to the motor's case which floats in a minimum-friction bearing and can freely rotate (a limited amount). Whenever the Rotor is accelerated by motor current the Case receives an equal force in the opposite (rotational) direction (Newton's law). Imagine the instrument mounted on a platform so that the instrument's low-friction axis is parallel to gravity vertical. (In that position gravity will not try to turn the Case. The angular position sensor will be centered and the motor controller will not rotate the Rotor.) If the "platform" is accelerated in a direction perpendicular to the line between the low-friction axis and the center-of-gravity of the Case, then the Case will begin to turn. The motor controller, in response to the angular displacement of the Case, will accelerate the Rotor to balance this accelerating force (on the Case). The clever part is that the angular rotation of the Rotor is directly proportional to the distance moved in the accelerating direction. That is why "double integrating" got into the name.

I was at North American from about January 1947 until September 1952. I worked on the two above accelerometers during that time. Most of that time I worked on the KDIA. We used an air bearing for the low-friction bearing. The motor case was suspended on a film of (moving) air fed by a compressor through many small jets. There were a lot of problems to overcome, but it had the potential of being successful.

Often members of congress visited our

laboratories. They were escorted and briefed by our higher management. The exaggerated performance fed these visitors disturbed me. The results of our tests conducted under ideal laboratory conditions were assumed to apply to missiles without consideration of the drastic changes in the instrument's environment.

While at North American I learned a lot. About servo-mechanisms, also called feedback control systems, from Walt Evans the inventor of a widely used method called Root-Locus. Walt even gave me a mention in his book for a technique I came up with. I also learned about coordinate transformations from John Moore using what he called the unit-sphere method. Since we were navigating a missile in space, coordinate transformations played an important part in our computations. I used the servo knowledge later at IBM.

So much for the work at North American -- later it became North American/Rockwell and now I don't think North American is in the name at all.

At IBM in 1952

When I began work at IBM in September 1952 I immediately knew that I had made a wise choice in leaving North American. My co-workers at IBM were smart and industrious and Rey Johnson, the lab manager, inspired me whenever I spent time with him. Despite all that, I never imagined that out of this lab, with only 50 people, would come the genesis of a product that would for many years produce billions of dollars of income for IBM.

An old concrete-block building, which once might have been a laundry, housed the lab. It was at 99 Notre Dame Avenue in downtown San Jose, two blocks north of the DeAnza Hotel.

Before I arrived, an aircraft factory had approached IBM with a proposal. They wanted to test airplane structures by gradually loading the wings and fuselage while monitoring their deflections with hundreds of strain gauges. Johnson gave me the job of building an analog to digital converter as part of the solution for their proposal. This converter was to change low input voltages, from the strain gauges, into accurate digital values.

Had I been at North American, where I had spent years working only on accelerometers, I would have thought this job would take at least a year. At IBM surrounded by about 15 engineers, with varied experience, I had completed my converter in two months. The input voltages were in the millivolt range and my converter was accurate to about two microvolts. When I started on the job I had had no hope of doing that well.

But as often happened at IBM, my work never was used. Someone in upper management decided it was not a product IBM wanted to market. Although an initial disappointment, I soon knew they made a good decision. IBM, at that time, had just introduced their first big computer, the 701 model. It was estimated that only about ten (!) of these computers could be sold in United States. Our laboratory goal was to create things to make IBM computers more powerful and useful.

We tried everything we could think of that might be useful for a computer. Rey Johnson, guiding us toward our goal, set aside Friday afternoons as a time when everyone stopped their normal work and looked only for new ideas. Some fifty years earlier Marconi had used coherers to detect radio signals; in Rey Johnson's lab coherers got resurrected. I never worked on them, I thought they were a waste of time, but we didn't want to miss any bets and Rey kept us thinking. For a while I worked on cathode-ray tubes for display and later for memories. (They later were used for both of these applications.)

During those days we did a little "horse play" once in a while. For example, I shared a cubical with Dick Weeks and we came up with a trick to play on guys on another project. Each cubicle had temporary walls about six feet high surrounding our desks, file cabinets, etc. Guys in two cubicals on opposite ends of ours worked on the same project. To save time walking back and forth, they installed a pair of surplus army telephones, one in each of the two cubicles. The connecting pair of wires ran along the top edge of our cubical. One day Dick and I decided that we could fool them by connecting a battery into those two wires, which would cause both phones to ring. We took a couple of sharp needles, each wired to a battery terminal, and shoved them through the insulations. It worked. At each end we heard someone say, "What do you want?" and the other end saying "What do you mean, what do I want, you called!" We did this infrequently over several days before they figured out what was going on.

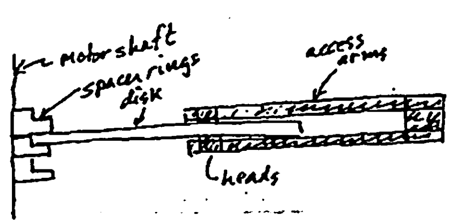
The 701 used tape drives to store large chunks of memory. It had tiny, doughnut-shaped ferro-magnetic cores for its dynamic memory. I believe the 701 machines had 32,000 characters of memory. In our groping for ideas someone suggested using magnetically-coated disks for memory. Soon, I and almost everyone in the laboratory, worked to develope that idea. That was the beginning of an exciting time in my life.

At North American I had developed expertise in servomechanisms. This skill I was to use on the second disk drive model we created, the disk file that became a part of the RAMAC (An acronym for Random Access Memory Automatic Computer) -- the first computer with quick random access to huge quantities of stored information that could be either read or written. Tape drives hold a lot of information, but only the information under the read head is quickly accessible. To read (or write) something at the end of the tape could take many minutes. In contrast to the tape drive moving the information to the head the disk memory moved the head to the information. We expected to access anything on our disk memory in about half a second. Originally, at least, the tapes could hold much more information than the disks.

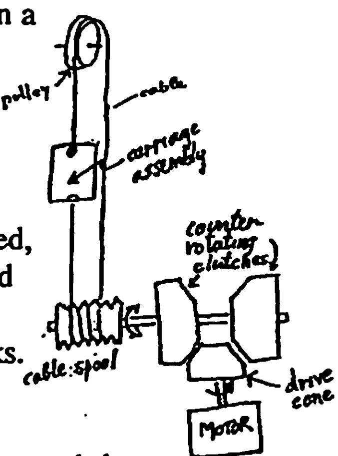
An early model to test reading and writing had 24 inch diameter disks on a horizontal shaft. This model helped develope the early read-write heads and the technique used for magnetically coating the disks.

Both I and Bill Goddard, who came from North American about six months after I joined IBM, knew about the air bearings we had used at North American. We both knew that air bearings could keep the read-write heads close to a disk, yet not touch it. However, Bill and I hesitated to disclose the air bearing since all the work at North American was secret. In the end, air bearings were selected. I do not know whether Bill told them or if someone else came up with the idea -- which, after all, seemed obvious.

The first RAMAC file took about eight months to build. It had 25 aluminum disks, each 24 inches in diameter. They were stacked on a shaft, about 10 inches in diameter, with spacer rings which created about 0.6 inch between adjacent disks. Since making read-write heads was difficult for us, we planned to use only three heads. One head was fixed mounted to read a clock track on the outside of the top disk and the other two heads were mounted in the ends of a pair of moveable steel arms. These arms, joined at the outer end, but separated on the "head" ends, stradled a disk to read any of 100 concentric tracks on either side.



The arms were mounted in a carriage, which when detented at a disk position, allowed the arms to slide in and out. With the arms retracted outside the disk and secured, the carriage detent released and it could move up or down to any of the 25 disks. A continuously running motor, driving a pair of counter-rotating clutches, moved the arms and carriage by means of a bi-directional cable. To move from a track on the top disk to a track on the bottom disk, for example, the cable first pulled the arms out clear of the disks, then secured the arms and freed the carriage, the cable then pulled the carriage to the bottom disk where the carriage was detented and the arms freed, finally the cable moved the read-write heads in to the desired track.



My job was to speedily position the read-write heads to any of the 5,000 tracks. Although I knew I had an imposing task, I felt confident and excited by the challenge. This was my kind of fun. The task required sensing the position of the carriage, the arm position relative to the carriage, controlling the detent to free the arms and lock the carriage or vice-versa, and controlling the magnetic clutches to move the heads to the desired position as quickly as possible. All done in such a way that the process could be repeated thousands of times. I had several months to study this problem. One problem I worried about, and spent a lot of time on, was the elasticity of the drive cable. That turned out not to be a problem. That's the way engineering goes, but had it actually been a problem, I had some ideas to solve it. One of the first requirements was position sensors. To sense the arm position we used an accurate rotary potentiometer turned by movement of the arms relative to the carriage. Nothing was commercially available to sense the carriage position, which moved about 2 feet vertically. We located a company called the Markite

Corporation, in New York City, which made a special resistive strip for us with 25 taps on it, one for each disk position.

The hard part was the electronic control of the magnetic clutches. We still used vacumn tube electronics then and it took a couple of big vacumn tubes to provide the necessary current. The general idea of a servomechanism, or feedback control system, is to mechanically move an object at maximum speed to the desired destination. This controller was complicated because although the same magnetic clutches drove the arms and the carriage, the arms were light compared to the carriage assembly. I resorted to the use of a non-linear resistor, called a thyristor, to improve the controller performance. Shortly after everything was assembled, I was able to go the maximum distance, from the inner track on the bottom to the inner track on the top, or vice-versa, in 0.55 seconds, or about the time it takes to blink your eye. I still remember the doubting tone of Al Stone's remark when he first saw it, "How long you think it'll last?" -- Al had been a customer engineer for several years before he joined our lab. (I later received a $5000 award from IBM at the Waldorf Astoria in New York City for my servomechanism work.)

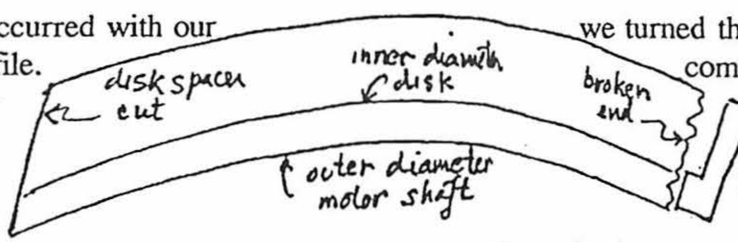
Once we got the positioning mechanism working well we turned to the next task: to test reading and writing on the disks. Leonard Seader, a recent graduate from the University of California, Berkeley, joined me on this work. We had a very simple-minded tester at first. We wrote the same character on every disk track and then tried to read all tracks. This test only required the read-character to match the write-character. It failed. We could read parts of some disks, but that was not good enough. We traced the problem to clocking. The clock-track head was supposedly fixed, but even that head could move a tiny bit in its socket. A head on the access-arm, however, could not only move in its socket, but the arm holding the socket, even though clamped by a detent, could move. We had naively assumed that the clocking and reading used on magnetic drums in that era would work on magnetic disks. It wouldn't. Magnetic drum heads were clamped solidly, they didn't move.

At this point Leonard saved us. He invented the 'self-clocking' scheme, in the next day or two, a scheme that made magnetic disk memories possible, and which I am sure is used today on all magnetic disk memories. Although simple, it was a brilliant idea. Leonard said, "Since every character on the disk has at least one '1' bit, we can use the written data to clock itself. I will use two oscillators, with only one turned on at a time. Whenever a '1' bit occurs the two oscillators switch modes. Thus, an oscillator need only run, at most, for eight bit times during which time it just can't get out of step. To write, one oscillator will stay on during the entire write time."

Leonard implemented his scheme in the next few days and we tested it. Leonard was right, we read through the entire file again and again, with NO errors! I believe we could have read accurately even with the access arm vibrating.

It was only when we rewrote the file with other characters, several times, that we found a second problem. We then experienced failures to read correctly for another reason. Only by observing the signals from the read head did we deduce the cause. Again it was related to the positioning of the magnetic read-write heads. Since a head could not be radially positioned exactly the same every time on a track, when we were off a little and wrote on a track we did not completely erase (i.e. writeover) some of the old information. I solved this problem, by means far simpler than the self-clocking solution: we replaced our head with two heads, both on the same track, but with the front head wider than the rear head. The new read-write head was used in either of two ways: (1) The front head erased the path during writing, and the rear head wrote the information behind it. Or (2) The front head wrote the information, and the rear head read the information. Either method worked equally well. I hold the patent on that idea.

To my knowledge, both the self clocking and the dual read-write heads were used on all subsequent files. Without both, disk files would have been unreliable.

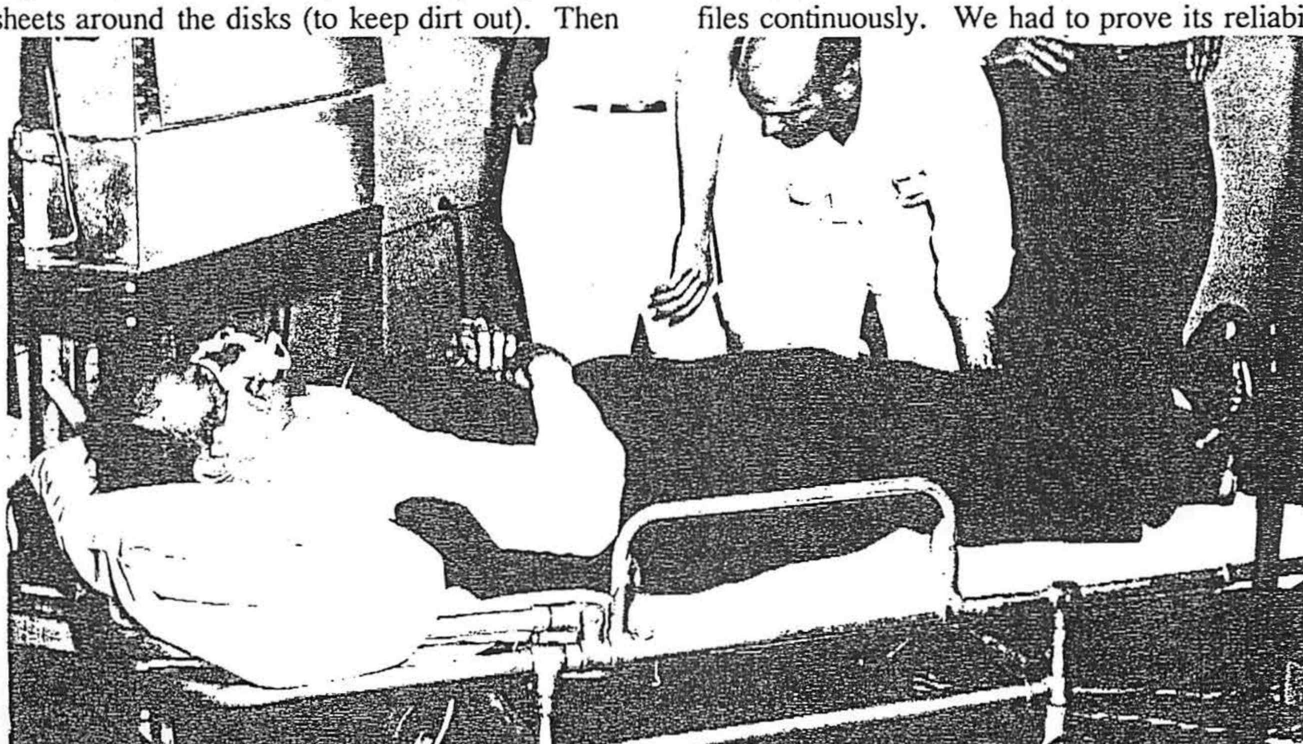


An accident occurred with our first assembled file. To understand what happened, I'll give an abbreviated description of the machine. Twenty four inch disks for our machine were separated by what we called disk-spacer rings. These rings had an inner diameter to fit the motor drive shaft, about 10 inches, and two outer diameters, one to match the center hole of the disks, and the second, a larger diameter whose thickness provided proper spacing between disks. The disk-spacer rings fitted so tightly to the drive shaft that assembly was difficult. Someone suggested cutting a slot through these rings to ease assembly, which was done. For our first machine, since we lacked 25 disks for a full assembly we assembled a skeleton machine. We put only a top disk and a bottom disk on the shaft, but used all 25 rings for proper spacing. A threaded ring, on the top of the shaft, screwed on at the end of assembly, clamped the rings solidly together.

Leonard Seader and I, prior to running tests, waited until Don Johnson, one of the mechanical engineers, had fastened cylindrical plexiglass sheets around the disks (to keep dirt out). Then we turned the motor on and waited for it to come up to speed. When it reached full speed it exploded. The centrifugal force on the 23 split disk rings, which had no disks constraining them, broke one, and then most of the other rings broke. The broken rings blasted through the plexiglass sheets. One ring cut through a tendon connected to Leonard's thumb. Another ring broke my nose and caused a contusion on my right temple. We both ended up in the hospital.

Leonard's tendon was stitched together and my nose was reset. Had Don's plexiglass sheets not arrived when they did, we would have run the machine without them. Undoubtedly we both would have been more severely hurt. The sector of the ring which broke my nose and hit my temple, missed my right eye by a fraction of an inch. We were lucky.

The rest of the problems we encountered with the RAMAC file were minor. I had worried about keeping the read/write head sockets clean enough to be reliable, but with the disk file enclosed and the air filtered for the head's air bearings, my fears were not confirmed. After the file had worked reliably, for several months, we ran one or more files continuously. We had to prove its reliability.



Me, on a gurney, after the accident, on my way to the hospital.

Many of us worked one of three shifts around the clock. Sometimes guys on one shift, to relieve their boredom, pulled jokes on a following shift. For example, one gang connected a whistle to the laboratory air supply through an electrical valve. A timer, set for the wee hours of the morning, activated the valve, and the shrieking whistle panicked that crew until they discovered the trick.

Jake Hagopian, one of the early IBM engineers, felt that the air bearings for the read/write heades were not necessary. He felt that the head could be made to 'fly' over the rotating disk. In a relatively short time he proved this idea feasible. Although the RAMAC used an air-compressor to supply the air bearings, later disk files had flying heads. A significant development.

When the RAMAC moved toward production I had a choice of continuing as a manager or working on technical problems. I chose the latter, which ended almost all of my disk work.

My recognition work

After I stopped working on the RAMAC I worked on character recognition.

In the late 50's there was considerable interest in machine recognition of numbers printed on bank checks, so checks could be sorted by bank and within a bank, by user and amount. A group at Stanford Research Institute (SRI) wanted to put magnetic particles in the ink and recognize the characters by the magnetic pattern seen when scanned through a vertical slit. IBM engineers proposed an optical recognizer that viewed the entire character. To permit either approach to be used, a cooperative effort between IBM and SRI shaped the funny looking numbers, which still are used on bank checks, to improve recognition accuracy.

Several engineers in San Jose and in Endicott New York worked on this project. We sent data and results back and forth within IBM and also communicated with SRI to demonstrate that the changes we suggested would improve their recognition accuracy as well as ours.

While working on character recognition in 1957 I had an idea that I thought would make the recognition easy. A key portion of my idea required inverting a 26 X 26 matrix of numbers. I did not know any short cut to invert the matrix and the way I did know I figured would take me (or someone else) about three months on a desk calculator if a number was entered every ten seconds. It would be impossible to do that without making a mistake. Doing it that way was ruled out. I went and talked to Charlie Hoppel who had an IBM 650 machine housed in an abandoned store building on north First Street. Charlie said, "I've got a program that can invert that matrix." His key punch operator keyed in my 676 numbers and when Charlie ran the matrix inversion program on my data the answer came out in about five minutes.

I went through an instant conversion. I became a born-again programmer. Within a week or two I was programming that 650 myself. At that time all programming was in machine language (Assembly language came later). By machine language I mean entering something like 57 127 202 which might mean reset the accumulator (57) and add the contents of storage location 127 to the contents of location 202. I have failed to mention that my inverted matrix did not solve the recognition problem for me, but more importantly that matrix inversion led to my conversion. From that time on I programmed anything and everything that I could on the computer. I had multiplied my computational ability by factors of thousands and later millions. I could solve problems that previously I had automatically rejected.

After the character recognition work, I worked for a few of years trying to recognize spoken words. That was much more difficult (which is why I said "trying to recognize"). About the best we could do was good recognition of about fifteen commonly used words, like the numbers, spoken by a single speaker.. Words for numbers have evolved to sound different since, unlike common words of speech, they don't have much context in use. That made them good candidates for this problem.

A simple-minded recognizer of the digits built in our lab was shown as part of the IBM exhibit at the 1962 Seattle World's Fair. A fair that our family attended.

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A trivial happening about that time of my life ...

IBM, during the 50-60's, sent their THINK magazine to all employees and to many libraries around the country. One issue had an article about insects. In this article they made the statement that there are 10 to the 20th power insects in the world. (I think that was the number) I always check numbers in print for order-of-magnitude accuracy.

I computed the volume of air over the earth from ground level to one mile up. It was then obvious that their estimate was far too high. I wrote to the magazine and questioned their estimate, but did not say why. In due time I got a letter back in which they said they were correct. They said that the New York Museum of Natural History told them that, if anything, their estimate was too low.

I had them where I wanted! I sent a letter in which I showed that the volume of air from ground level to one mile up over the entire earth would have over 200 insects in every cubic inch if their number of insects were true.

In time I got a reply which said, we concede, you are right. But they never printed a correction. Anyway I got a kick out of that interchange.

I have a habit of rough checking numbers I see in publications. I also sometimes exercise my mind while driving by computing things in my head. For example, I recently wondered how much an inch of rain covering San Jose would weigh. I knew that a cubic foot of water weighs about 62.5 pounds, that a mile is 5280 feet, etc. So for a square mile one inch of rain would weigh about (5000 X 5000 / 12) X 60 = 5000 X 5000 X 5 = 125,000,000 pounds. Easy. San Jose is about 100 square miles so my answer was 12,500,000,000. Then I could go on and compute the energy needed to raise it to say, 10000 feet, etc.

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Sometime about 1962 or 63 I started working for Dr Ed Quade at IBM. Ed was a person I loved and admired more than any man I've known. He was fun to be around. He always was pleasant and I don't think a day went by when he didn't tell me (and others in the lab) a joke. He had a knack for getting to the core of problems and offered suggestions for solving them. I learned a lot from Ed. He always made me feel like a special person, but I don't think that I was alone in that respect. He did not restrict his involvement to his projects, rather he circulated in the lab all day long, talking with the engineers, secretaries, librarians, etc. and left a trail of good feelings behind him.

While I was not religious, Ed was. If I happened to come in early I'd always find that he was reading his bible. Yet, he respected the religious beliefs of others and did not push religion on them. He acted, I believe, as he thought Jesus might have acted. He was soft spoken, a great listener, and caring.

All the while Ed worked for IBM (from 1952 until about 1964) he knew his life could end at any time. It wasn't until after he died that I learned that while Ed had worked on the Manhattan bomb project for Westinghouse he had accidentally been exposed to a huge dose of radiation. There was no known treatment that could help him. He never told anyone in the lab that I know of.

Shortly before he died he went to San Francisco where he stayed the remainder of his life in the Christian Scientist's convalescent home. George Price, a technician in Ed's department, and I saw him there a couple of times. Ed was in bed, but didn't appear very ill and didn't want to discuss his condition. He talked about our work, made a few suggestions, and listened to what we had to say, in other words he was himself. His death, a few days after our last visit, came as a shock.

After Ed's death many of us established an Ed Quade Memorial Fund and used the money to support several children around the world. One was a young Chinese girl, Yim Mui, that lived in Hong Kong. We later brought her over to visit us in our laboratory. She was a bright young lady, who by then had learned English and spoke it well. She made us proud of having helped her along the way.

Automatic Computer Design

In the early 1960's, a young engineer named Mike Larriva and I designed a small computer, which used a conventional IBM Selectric typewriter for input-output and a magnetic delay line for its memory. This computer was programmed by the user by entering sample 'lines'.

We used a type of memory which neither of us were familiar. A pulse into the sending end of a magnetic delay line twists the end of a long steel wire. The "twist" travels along the wire and at the receiving end produces a signal. Each 'twist' corresponded to a 'bit' in this memory. The received bit would normally be written back into the sending end making it a circulating bit. The number of bits that could be stored in the delay line depended upon the length of the wire, the propagation speed along the wire, and the size of the "twist". An electronic clock identified the bits stored in the memory.

George Price, an imaginative technician in our department, designed a mechanism that fit under and connected to an unmodified IBM Selectric typewriter, which made the typewriter an input-output device.

We intended our computer to produce invoices, bills, and the like. Our computer had two modes of operation: Learn and Run. In the Learn mode, the user keyed a line typical for his application to establish what we called a template. A selector switch permitted several such Learn-mode templates to be stored. In the Run mode, the user switched to the desired template. The machine tabbed to each field and stopped if it required an entry or else it typed the calculated results. For example in Learn mode, if the user were making an invoice she/he might enter the identification of the item, the number ordered, a multiply symbol, the price per item, an equal symbol, and the extended price. (The extended price being the number ordered times the price per item.) Our computer's (built in) program considered the identification as an alphabetic field; the number ordered, the price per item, and the extended price as numeric fields; and the multiplication sign and the equal sign as arithmetic operands. In the run mode for this example, the computer would wait for the user to enter the identification, number ordered, and price per item, and would print the extended price and then return for next-line entry.

Mike and I began working on the design needed to implement such a computer. We worked independently on different sections of the design at the same time, but because of interdependencies, we recognized the need to know each other's changes. To solve that problem we put each machine instruction on a separate punched card. We duplicated these cards so we each had our own deck. The changes that each of us made, were put into the part of the deck we had changed, and then that part duplicated for the other person. This deck, thus provided us with a machine readable description of our computer.

No one can write a significant program or do a computer design without mistakes so I got the idea that I could write a program which could simulate the computer that we described with our deck. It turned out to be easier than I had thought. Within about ten days I had such a program, while Mike had continued to improve the design by himself. The Fortran program I had developed, read in our design deck and wrote, as output, another Fortran program that simulated our design. Using this simulator program Mike caught errors which neither of us had suspected.

Overjoyed by my sucess, I thought I could use the same deck to define the hardware. I was successful.

We planned to use Motorola circuits, that had at most a few NAND devices on each chip, for our basic building block. Each chip was soldered to a small printed circuit card, which in turn could be plugged into sockets that provided power and input-output terminals. Our design was mainly done in NANDS, which simplified my program considerably.

My physical design program turned our design deck into NAND circuits connected to perform the instructions described by our card deck. The program chose the type of Motorola chip to use, it printed NAND diagrams of all the logic, listed the chip type needed in every socket, listed the point to point (manual) wiring needed to connect the sockets, and cross referenced the diagrams to the design instructions.

This was, to my knowledge, the first time a machine-readable design was used both for simulation and physical design of a computer. If the resulting machine failed to work properly, it was the fault of either the simulation to catch the error or the physical design to implement the design.

When our simulation performed properly, we created the physical design. Unfortunately, the technicians who wired from our listing miss-wired the board, so that when we got the board for testing we had to check almost every wire-net (A wire net is all the points wired together). It took us over a week to find and rewire all the mistakes they made. (We probably could have done the entire wiring faster ourselves. When we ran our tests there were only two timing errors found. (A failure of our simulation to catch!) These were easily fixed and the machine worked as designed.

The machine was displayed at many places in IBM, which led to a problem we had not anticipated. When the person who demonstrated the machine wanted to show how the electronics were constructed, he would pull one of the small cards to show the chip and the ten leads going to the socket. Often when the card was reinserted, it was misaligned and resulted in bent contacts and open circuits. The board could not withstand this treatment. After a while it became such a hassle to repair that damage that we gave up, but by that time the machine had been transferred to our Lexington Division. (In retrospect, we should have had a few dummy sockets the demonstrator could have used.)

At Lexington they decided to use a magnetic-core memory. Without benefit of our design system the redesign took so long that the project died because of a too-high projected cost.

That machine started my automated computer design work, which I pursued during the rest of my time at IBM.

*****

Several years later I tried IBM's way of doing chip design on a cathode ray tube screen. I tried to design a latch circuit, which requires only two transistors. It took me an incredible time to do. I decided I could write a program to design circuits faster. That decision led to my doing chip design by computer from then on.

Over the years I always used a logical description of the circuit as my input. A simulation program checked the logical description for validity.

My first programs were able to design entire chips, but that was back when 1000 transistors on a chip was the normal limit. My design took into consideration the parts of the logic that required higher speed, it adjusted bus widths to compensate for voltage drops, etc. I created a few chips with those programs which were used for data compression. The chips worked as well or better than what I had predicted during the design.

Because my first programs required a specific design method, I switched to a less constrained approach and did designs near the end of my work that used thousand of transistors.

On the last project I worked on, my programs designed what was called the "hard" parts of the logic. Some of the logic for this 32-bit chip involved laying out one bit's logic and replicating that logic 31 times, with slight modifications, to design the "easy" part of the chip. The "hard" part was over half of the chip's logic that had no discernable pattern and thus was called random logic. That was the part my programs designed in detail.

Rey Johnson's Presentation
To The ~~IDEMA Meeting~~ DATA STORAGE FORUM
On September 19, 1989
Fairmont Hotel, San Jose, CA
Rey received a standing ovation!

THE FIRST MAGNETIC DISK FILE

Good evening. Thank you for the introduction. I'm delighted to be able to spend the evening with you.

I'll be talking this evening about some of the highlights in the development of the first random access disk product -- the IBM RAMAC 350 file -- The why, where, when and how of the first disks.

This is the product that spawned the magnetic disk storage industry -- an industry that has since come to generate an annual revenue of 23 billion dollars. I think it's fair to say that the RAMAC 350 has carved a place in history for itself.

Let me begin by showing you a few minutes of footage from an old 16-millimeter film. It was made by the IBM sales department when the product was introduced back in 1957. With that you'll get a good idea of what the machine looked like, and how it did its job.

(Film clip shown here)

I am sure that many in my audience were not born in 1951 when my story begins. Let me therefore set the stage for the events, most of which took place in San Jose, a few blocks from here.

In 1951, San Jose was a city of 100,000 people. Its economy was based mainly on agriculture. At the same time, IBM was a rapidly growing company, with data processing as its main business. Its revenue in 1951 was about $250,000,000.

After IBM had developed two large computers that were intended strictly for scientific applications, IBM management saw little evidence that computers would become profitable business products. In fact, in 1951, an extensive survey of all potential computer customers yielded statistics that indicated that 17 or 18 computers would saturate the market.

At that time, Thomas J. Watson, Jr., was succeeding his father, Thomas J. Watson, Sr., as president of IBM. He decided to build 19 scientific computers. The first of them was completed in 1952.

IBM's business in punched card equipment was growing as rapidly as we would build products. Expansion was in the air at IBM.

In 1951, IBM corporate headquarters in New York decided to establish a research laboratory on the West Coast. Research was a term that at that time covered all types of engineering activity.

The West Coast was chosen because IBM's customers in the aircraft industry were creating innovations and modifications that were considered to be potential products. For example, the first card programmed calculator originated with engineers at the Northrop Corporation.

The bay area was chosen as the site of the new IBM research laboratory because it was between Los Angeles and Seattle, where those innovative customers were based.

San Jose was chosen as the specific site because IBM already had a punched card plant here, at 16th and St. John. This plant housed the district manager, an accounting department and a cafeteria. Under the direction of Roger Williams, IBM's community relations were very good.

During the first week of January, 1952, I was told of my appointment as West Coast laboratory manager. I was told that I would have free rein in hiring a staff of 30 to 50, and that I would be free to choose projects to work on. One-half of my projects were to be new IBM products and one-half were to be devices in support of customers' special engineering needs. No projects were to be duplicates of work in progress in other IBM laboratories. The laboratory was to be dedicated to innovation.

My first act as manager of the new laboratory was to rent a building, and the second act was to place an ad in all West Coast daily papers, announcing that IBM was opening a laboratory in San Jose. The ad noted that positions were available for scientists, engineers and technicians, and it brought in 400 applications.

The IBM Research and Engineering Laboratory opened its doors at 99 Notre Dame, a few blocks from here, on February 1, 1952.

I was told that my flair for innovative engineering was a major consideration in my selection to manage the new laboratory. During 18 years with the IBM Endicott laboratory, I had had responsibility for numerous IBM products -- test scoring, mark sensing, time clock products, key punches, matrix and non-impact printers and random card file devices. By 1952, I held over 50 patents, some of them fairly good.

To be given freedom to choose our projects and our staff made the San Jose laboratory an exciting opportunity, especially since funding was guaranteed -- at least for a few years.

The first few months of 1952 were consumed largely in interviewing and hiring a balanced staff of talented and experienced engineers, technicians and administrative personnel.

Except for one person from each of our two New York laboratories, and one engineer from my department in Endicott, New York, we were under orders not to recruit people from the Eastern sites of IBM. As a result, our first crew all came from the West.

Among the first projects undertaken during the start-up were a non-impact printer, a test scoring machine, source recording equipment and a random access replacement for tub files.

It was the search for an automatic random access system to replace tub files that led us to explore magnetic systems.

In 1952 IBM was producing sixteen billion Hollerith cards per year. Each of these cards had to have information entered into it in the form of punched holes before it could be usefully processed by accounting machines. Manual key punching was one of the most costly items in customer data processing operations. In many applications, most of the information in a card was unchanged from week to week. In a payroll application, for example, only hours worked may be new. An automatic tub file would automatically enter status information and the key punch operator would be relieved of punching anything but new data.

After deciding that our random access component was to be based on a magnetic recording system, we proceeded to explore the most probable magnetic media. We explored magnetic drums, magnetic tape loops, magnetic plates, magnetic tape strip bins, and even magnetic wires and rods.

Rotating magnetic disks came out on top in our analysis, chiefly because of its rotational dynamics, the potential of multiple accesses and the efficient surface-to-size ratio.

As time went on, our engineers became inspired by the possibility of developing a product that gave essentially instant access to file data, not only when connected to key punches, but also when connected to accounting machines and maybe even to computers.

Two events in 1953 turned out to be fortuitous for our disk project. We ended an automatic data reduction project being done under contract with the McDonald Douglas Aircraft Company. This released a half-dozen talented electrical and system engineers, who were then available for reassignment to the disk project.

The second fortuitous event was the receipt of a request to bid from the U.S. Air Force Supply Depot in

Ohio. They called for a material information flow device. They wanted instant access to each of their 50,000 item inventory records.

We were simultaneously studying file applications in wholesale grocery and wholesale paper supply companies in the bay area.

We pooled these insights and information and prepared a set of specifications for a general purpose random access memory. These specifications recorded in February, 1953, in his notebook by Art Critchlow, turned out to be almost identical to the RAMAC 350 disk file specifications announced two years later.

Going from the wish list provided by the specifications to a reliable operating model required solving many technical problems. With added staff available we proceeded to attack all key problems simultaneously. What kind of disks could we use? How could we get them to run true? How could we best paint them with the iron oxide paint? What kind of magnetic transducer should we use? How could we keep the read/write head close to the disk without having it wear out? And finally, how were we to move the head to any one of 50,000 tracks in less than one second or in one accounting machine cycle?

We proceeded to test our ideas.

We tested the dynamics of rotating disks by mounting 120 aluminum disks two feet in diameter on a shaft with about 1/4 inch spacers and rotating this array at 3600 rpm. One test run of this model allayed our fears about problems of excessive wind, vibration, power requirements and even excessive disk wobble.

However, one problem that turned out to be quite difficult was coating the disks with iron oxide paint to a uniform thickness and smooth finish. The oxide paint we were using was essentially the same as was used to paint the Golden Gate Bridge. One of the engineers suggested pouring the paint near the center of a rotating disk and allowing centrifugal force to spread a smooth uniform coat over the disk surface. Another engineer found that filtering the paint through a silk stocking got rid of lumps in the paint. Another engineer showed that by filling a tray of paper cups with just the right amount of paint, the coating thickness would be the same from disk to disk. This system was used for many years. It was later incorporated into the equipment that automated the process.

Another group of engineers was assigned to develop a small thin head for the record and readback functions. None of our staff knew much about magnetic recording. So we hired a consultant, Al Hoagland, who at that time was a graduate student at UC Berkley and an expert in magnetic recording. About the only magnetic transducers in use in 1953 were those used with magnetic drum and magnetic tape equipment. Both of these had entirely different space and positioning constraints than we had.

Early in the development of the read/write head we decided to protect the head against wear by using air pressure with nozzles in the face of the flat head. The air flow spaced the head a uniform distance from the sometimes wobbly disks. Air pressure was also used to force the head toward the disk after it reached its destination.

Stored bit density at the center tracks was made the same as the state of the art density in magnetic drums, 100 bits to the inch and 20 tracks to the inch. This was better than a 4,000% improvement over punched cards in information density and the data was alterable and erasable.

In our first file model two-foot diameter oxide-coated disks were mounted on a horizontal shaft at 1/2-inch intervals. Fifty-one disks gave 100 inside surfaces. Two opposite facing heads were mounted on one access arm. The access arm was moved so as to place the heads on any of the 100 tracks on each of the 100 disk surfaces, at a speed that would match an accounting machine cycle, which was less than one second. We had anticipated that there would be a need for as many as twelve access stations on each file. A provision that proved to be excessive. The maximum travel between addresses was 36 inches. The minimum travel between addresses was one-twentieth of an inch.

Two access drive systems were designed and modeled, one mechanical and one electronic-servo system. We finally chose an electronic-servo system for the first file model.

The tub file application led us to test out the disk performance by pairing it with a keypunch, because the keypunch could be used for entering information and for recording in punched holes the information read back from the disk file.

On February 10, 1954, this first sentence was fed into and read back from the disk file --------- "This has been a day of solid achievement".

By March, 1954, tests of components and the card to file machine made us confident of being able to build a product. Lou Stevens was made the manager with full development responsibility.

He and his staff of very capable engineers initiated a program of re-design that started in mid-March 1954. By November this design had matured into a "magnetic disk processing machine". RAMAC was on its way. Hopes were high that this revolutionary concept would develop into an IBM product.

The potential for large random access memory was attested to by activity among competitors who were using very large drums, drum arrays, tape loops and even the surface of a power station fly wheel as recording surfaces.

The IBM vice-president for marketing, L. H. Lamotte, stationed his long range planner, F. J. Wesley, in our laboratory mid-summer, 1954. On October 8, 1954, Mr. Wesley sent a memorandum which he called a "pontifical announcement", to his boss. In part it stated, "we must immediately attack accounting problems under the philosophy of handling each business transaction as it occurs, rather than using batching techniques". Wesley's memo was widely circulated among IBM management and, needless to say, in our laboratory. The promise of developing a product for more than a file tub replacement led to a corporate decision in November 1954 to build at least five prototypes of our product to field test.

Initial specifications for the RAMAC were prepared December 17, 1954.

The non-RAMAC projects of the research and engineering laboratory moved to Julian Street to open more space for the RAMAC team. At the Julian Street laboratory work continued on advanced ideas for disk files. Gliding heads and multiple parallel access arms were developed and eventually transferred to Lou Stevens domain where these features were incorporated into disk file products that followed after the RAMAC 350.

Lou Stevens and his engineers at 99 Notre Dame successfully demonstrated and operated the Model II file on January 16, 1955. Debugging of this machine continued around the clock for months.

Early in 1955, a corporate decision was made to build 14 RAMAC 350 machines for internal use and field testing.

On May 6, 1955, IBM held a press conference to announce that it was bringing out a new product "that takes information from a stored program using a multi-million character random access memory that makes it possible for the new system to do a whole job automatically without using batch processing".
On August 25, 1955, the San Jose Mercury News published a short article which said, "IBM plans a giant new San Jose plant that may employ more than 5,000 here".

The first RAMAC was shipped to Zellerbach Paper Company in June, 1956, by an outstanding San Jose manufacturing team. Mr. Porter remembers the event.

T. J. Watson Jr., President of IBM, announced the RAMAC on September 4, 1956. He said in part, "This is the greatest product day in IBM's history and I believe in the office equipment industry".

The RAMAC was featured in the United States exhibit at the World's Fair in Brussels --- and in the United States Technical Exhibit in Moscow. Chairman Khrushchev of Russia came to San Jose in 1959 to visit the RAMAC plant.

The American Society of Mechanical Engineers designated the RAMAC an international historic landmark on February 27, 1984.

The first four years of disk file history have been reviewed in my remarks. In the 33 years since the RAMAC 350 left the laboratory, tremendous advances have been made in product development, manufacturing and research, as you all well know.

As a review of this history lesson, I would like to show a few slides.

#1. Prune Valley before it became Silicon Valley

#2. 99 Notre Dame - 2 blocks from the DeAnza Hotel

#3. The first and most important test of the disk file

#4. An 026 keypunch supported by an automatic tub file - our first product target using a disk file

#5. The ultimate RAMAC disk

#6. Air head models

#7. Heads that worked

#8. The first model of the disk file

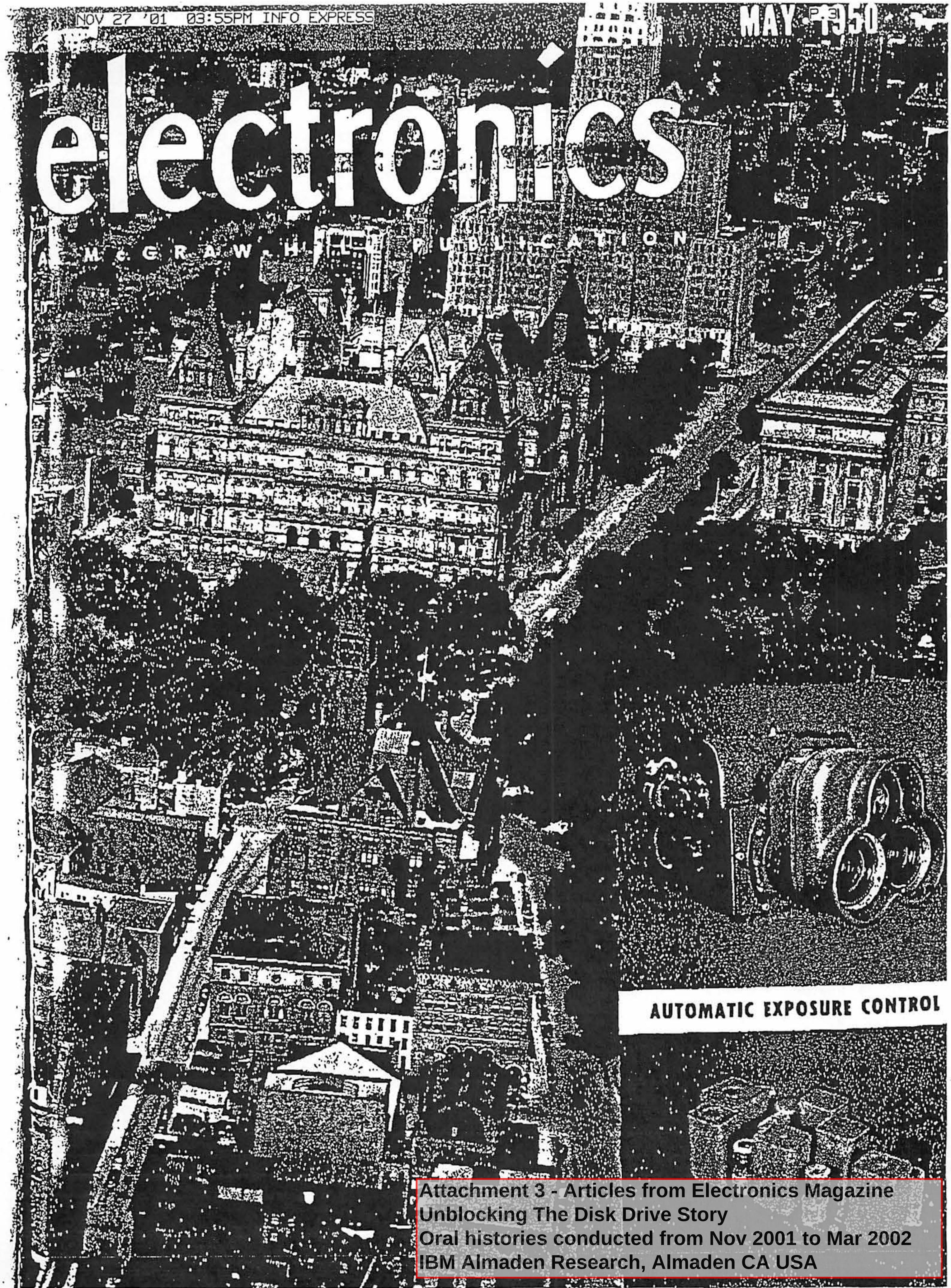
#9. The first model of the redesigned disk array with vertical shaft being tested by Wes Dickinson

#10. The RAMAC 305 with the 350 disk file

#11. Khrushchev visits IBM

#12. International historical mechanical engineering landmark plaque

#13. The first disk file and the last RAMAC 350 in Building 10 at IBM



Attachment 3 - Articles from Electronics Magazine
Unblocking The Disk Drive Story
Oral histories conducted from Nov 2001 to Mar 2002
IBM Almaden Research, Almaden CA USA

ELECTRONIC MACHINES for Business Use

A machine that satisfactorily solves differential equations will not necessarily perform every-day clerical work. The circuit principles are applicable, but much engineering must be done before the office-equipment market can be tapped

By W. B. FLOYD
Research Division
Sears, Roebuck and Co.
Chicago, Ill.

BUSINESSMEN, as well as mathematicians, are fascinated by the possibilities of electronic computation. What they see, primarily, are payroll savings. Of secondary importance, they see the possibility of securing additional facts about their businesses.

When a businessman reads in the newspapers about a machine that will do in thirty minutes what it would take thirty people a month or more to do manually, he naturally asks, "When can I get one of these machines!" He may not think to ask whether or not the machine will actually do the particular clerical jobs that have to be done in his office. He is likely to assume that any machine that will solve difficult mathematical problems will do ordinary clerical work with ease.

This assumption is understandable. The principles of electronic computation are applicable to much of the clerical work encountered in business. Automatic electronic machines undoubtedly will effect a clerical revolution. But some more engineering will have to be done before that happens. A machine that will solve differential equations is not necessarily a machine that will do the everyday paper work of business concerns, and do it economically.

The engineering that remains to be done, before the market for automatic clerical machines can be tapped, is by no means all electronic engineering. First, an industrial engineering job must be done. Business problems must be understood in detail before ideal machines for their solution can be built.

The General Pattern

No two companies have quite the same clerical problems. This fact has been the despair of more than one office-equipment salesman. Nevertheless, a common pattern is discernible in most clerical work.

The pattern starts with the creation or receipt of an original document. A purchasing agent notes an item to be bought; a receiving clerk lists incoming merchandise; a salesperson writes a sales check; a meter reader writes down some numbers. Or a purchase order, subscription, remittance or complaint is received. Millions of entries and papers such as these are the starting point of virtually all of the clerical work that is done in business. They are the input of whatever system is used to ship merchandise, charge customers, maintain stocks, schedule production and account for income and outgo.

The remaining steps are internal to the system itself. They almost invariably include:

One or more lookups, to secure additional information or to check information that is shown on the original document.

A few simple calculations, such as totaling an account or extending an invoice.

Recording the transaction, often under not one but several captions.

Typing final documents such as purchase orders, shipping papers, voucher checks, acknowledgements and hosts of similar papers.

Summarizing the data that has been recorded from the constant flow of business papers. Most accounting and statistical work belongs in this category.

If you think of almost any clerical procedure you happen to be familiar with, you will see that it does involve all of these steps. And in most cases, sorting, lookups, posting and typing far outweigh the arithmetical work that is done.

With the foregoing pattern of clerical work in mind, we can now see some of the important points of contrast between the mathematical computers that have been built and

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The CUSTOMER Speaks

BUSINESS BRIEFS (p 60, March) recently called attention to the fact that an *"Important trend everywhere in evidence is an engineering struggle to combine the functions of electronic measuring - telemetering - calculating - indicating - recording devices with those of the garden variety of business machines."*

It was pointed out that

"What is needed is a bridge between the two devices, one that need not be monitored by human hands."

This article, by Mr. Floyd, tells what a typical businessman expects of design engineers

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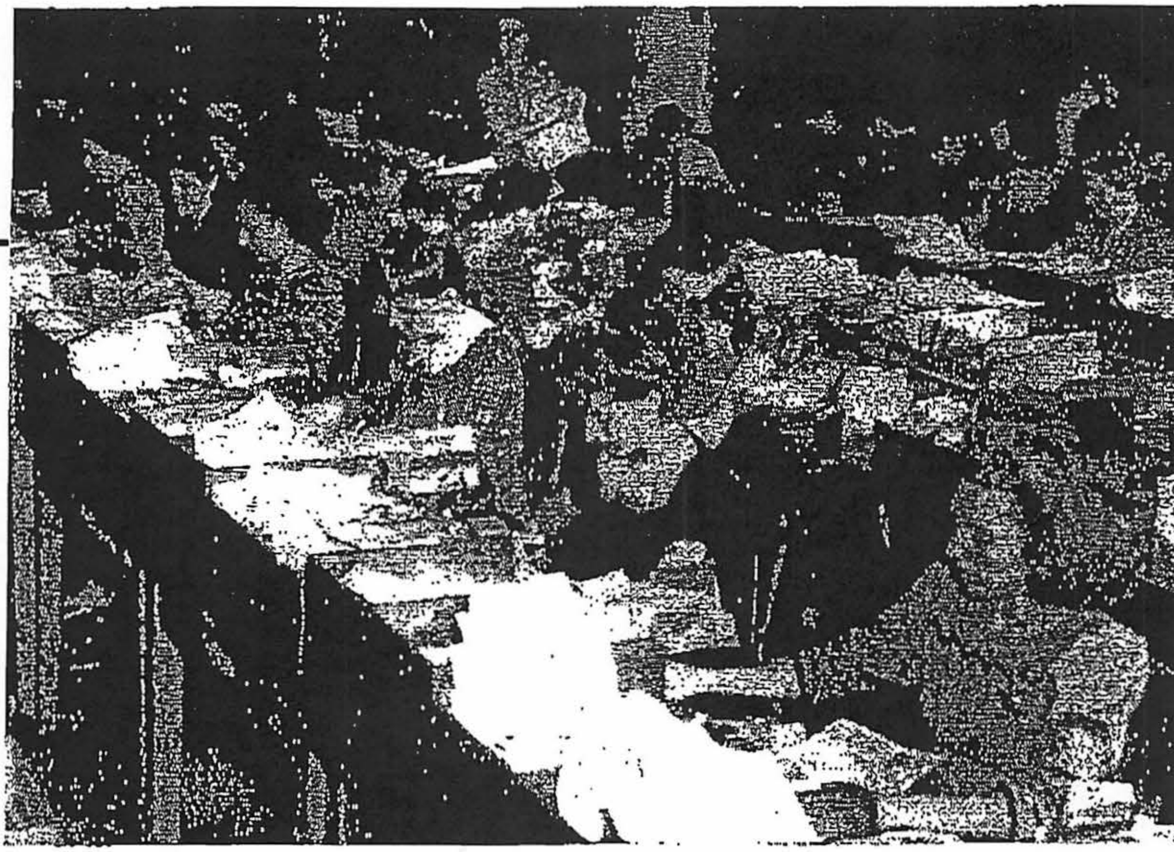


Clerical help in one of many departments of a big business concern, typical of the offices where completely automatic electronic machines are needed

the clerical machines that will be built. These contrasts bring out some of the still-unsolved problems in building an ideal clerical machine.

Machines vs Computers

The Input Problem. One fundamental difference between mathematical and clerical work can be stated this way: While mathematicians often have to perform a great many complex operations on a relatively small amount of data, clerks in business offices must perform a few relatively simple operations on a vast amount of data.

Two implications as to machine design are immediately apparent. Input and output capacities assume greatly increased importance. Computation assumes less importance.

To handle clerical input economically, we must do more than merely use the fastest possible keyboards. Every conceivable means must be found to eliminate the manual keyboard altogether, or to hold the required number of key depressions at an absolute minimum and so minimize manual labor.

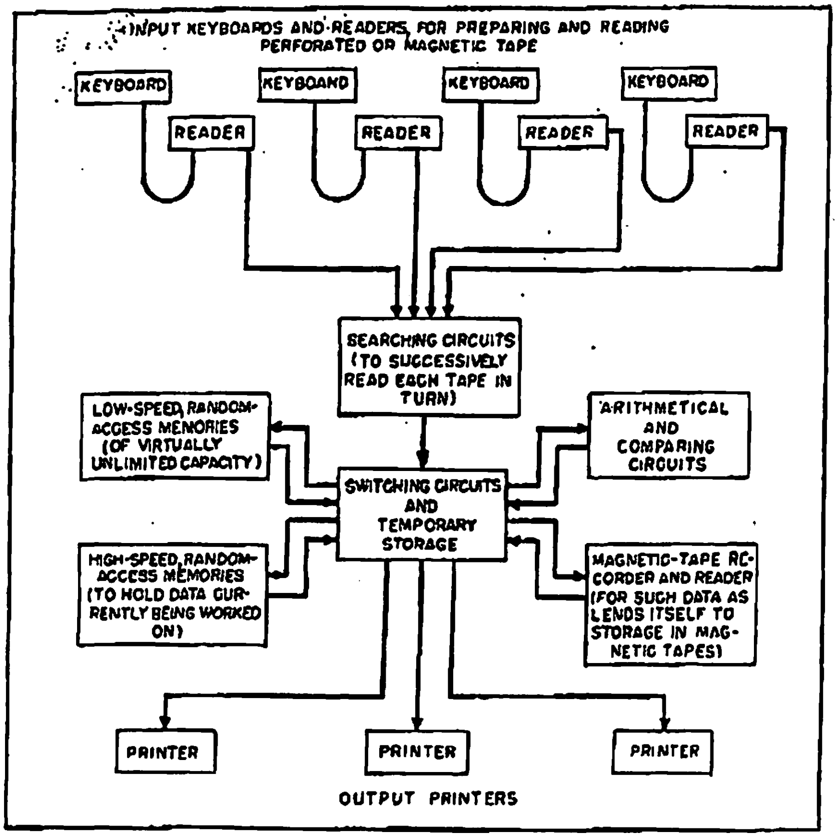
One way to reduce key strokes is to record manually only reference numbers, relying upon the machine's memories to supply all of the remaining data that is regularly associated with these reference numbers. For example, the price and description of a product are usually associated with a stock number. Similarly, the name and address of a vendor or customer can usually be associated with a vendor number or customer number.

Better than reducing manual input is to eliminate it altogether, by producing original documents in machine language to begin with. Equipment recently developed for the retail garment trade illustrates this principle. The marking tickets that are placed on garments are prepared by a special machine that perforates as well as prints code numbers on the tickets. Thus the garment ticket stub, which is removed when the item is sold, can be automatically read by the machines that record and summarize sales.

Much thought is being given to more generally useful means of producing original documents so they can be read automatically. The problem is one of inter-company standardization rather than of finding technical solutions to the problem. There is a need for more standard business documents that can be read mechanically as well as visually. When it costs nearly as much to put data in such form that a machine can use it as it would cost to produce the final documents themselves by manual means, nothing is gained by mechanization.

The Output Problem. The output problem cannot be solved in quite the same way as the input problem. Our whole purpose is a big output of invoices, purchase orders, receiving records, shipping papers, payment vouchers and summary reports. What we must do here is to speed up the output device itself.

A better solution must be found than that of driving electric typewriters automatically. No matter how fast they are driven, we are still printing only one character at



Basic components of the desired electronic machine for general business use

a time. Output printers for commercial use will almost certainly have to be of the line-at-a-time type. Perhaps several lines, or whole documents, will be printed at a single impression. Over 1,000 lines per minute is considered a worthy goal by some engineers who are working on output printers.

Selective Memories. Another basic contrast between most mathematical and clerical problems is the contrast between a batch of work and a flow of work. A big statistical problem constitutes a batch of work. Business documents, like the assembly lines to which they are tied, constitute a flow of work.

Preparing 10,000 invoices may be comparable, in machine time, to solving a single problem in mathematical physics. Yet, in addition to differences in the volumes of input and output, there is another fundamental difference between the two undertakings. All of the data for the mathematical problem can be assembled, in predetermined order, and handled as a unit. The invoices, however, must be prepared as goods are shipped. They cannot be held until a convenient batch of work has accumulated. What this means from a machine-design point of view is that the clerical machine must be able to take work in random order.

A flow of work in random order requires the use of selective memories. The problem is similar to that of a telephone exchange. Telephone calls are received, by the central exchange, in random order. Selectors must be used to connect with the parties called. Were it not for their relatively low speed, telephone selectors could be used, as is, to solve many selective memory problems that will be encountered in designing machines for business use. The computing machine companies must find a faster and less expensive solution.

Electrostatic memories and acoustic delay lines are fast enough, and selective enough, but far too expensive for all but limited use. Magnetic drums are a step toward lower-cost memories of the selective type. But they too are rather expensive.

Memory Capacity. The contrasts we have already mentioned lead to a fourth, important contrast between mathematical computers and clerical machines. This is the difference in required memory capacity. Low memory capacity has been a limiting factor even in some of the mathematical computers that have been constructed. The problem becomes more acute with business machines.

Hundreds of thousands of stock-keeping units are not unusual in a business concern. A large manufacturer must buy and stock a great number of different parts and materials. A large mail-order house has as many as 800,000 stockkeeping units, counting each color and size advertised in each current catalog as a separate stockkeeping unit. Relatively small department stores have from 20,000 to 60,000 stock-keeping units.

When we come to the names and addresses of suppliers and customers we again run into thousands, if not millions, of separate blocks of information to be referred to. Large companies have from 5,000 to 10,000 suppliers. Popular magazines have several million subscribers, and large distributors have hundreds of thousands of names on their mailing lists.

Since so many separate registers or addresses are required, memories will have to be cheap. Ten cents might be more or less arbitrarily taken as the maximum cost of any one register, including whatever circuits or mechanisms are necessary to locate and read it. A cost of one cent or less would be more nearly ideal.

Fortunately, this severe cost limitation is partly offset by another consideration. Density of reference will be low. During any given period of time, selective reference will be made to relatively few of the total number of memory units. This permits relatively slow reference speeds. Several references can be made simultaneously, to different sections of the memory. By making several references simultaneously, look-ups can be kept ahead of computing speed.

A look-up machine, consisting of banks of reference memories together with appropriate selectors, may very well be entirely separate from the computer itself. Information may feed from several input machines, to a look-up machine, to a computer, and thence to several output printers. All of the machines would be electrically connected. It should not be necessary to manually carry work, in any form, from one machine to the next.

What Business Needs

Electronic clerical machines of the future can have one tremendous advantage over all of their predecessors. They are inherently capable of doing a whole clerical job, from beginning to end and including any foreseeable variations, exceptions or irregularities that may arise. They are inherently capable of being completely automatic, rather than semiautomatic. The selective-sequence principle of electronic computers, or their ability to solve logical as well as mathematical problems, is the key to their promise in this respect.

The nearest pre-electronic approach to automatic clerical equipment is, of course, punched-card machines. They are widely and economically used. Yet these excellent machines have not completely replaced manual operations on all routine clerical jobs, and there are good reasons why they have not done so. Resistance to punched-card methods does not rest on ungrounded conservatism or blind sales resistance. Punched-card machines can be made to perform virtually any series of clerical operations. But, in some applications it costs as much to do the job by machine as it does to do it manually.

The reasons are three-fold: First, a series of separate mechanical operations is required to produce a single result. Cards must be punched, verified, sorted, collated and tabulated before even the first report is forthcoming. Second, few machines are completely automatic. Cards must often be fed in and manually taken away. In addition, there is a manual card-filing problem. The third and greatest handicap of punched-card machines in some applications is their inability to handle certain irregularities. The machines are ideally suited to large volumes of identical work. But variations usually require either a different series of separate manually-attended operations, or manual prehandling, to get work in such form that it can be fed into the regular flow of work. When we see operators going from one machine to another with little groups of cards, or when we see large clerical staffs getting work ready for the machines, we are often witnessing an application that might just as well be performed manually from beginning to end.

The great promise of electronic equipment lies in its inherent ability to overcome these three limitations. A limited manual input may be required, when documents are not in machine language to begin with. But from then on we are dealing with electrical pulses which travel over wires. We do not have to manually carry data from one operation to the next. The machines can operate unattended. And, since they can compare and select, they can recognize and handle irregularities. Whatever rules can be given to a clerk can be given to an electronic machine.

The heart of the fully automatic clerical machine of the future will be the selective-sequence principle. This principle is used in all of the digital computers that have been built. These computers handle information very much as a clerk does, only faster. All information pertinent to the problem at hand is assembled, including complete instructions as to what to do with each item of information. Each item of information is placed in a definite location on a magnetic drum, in an acoustic delay line or in an electrostatic memory.

Programmed instructions then tell the machine to switch information from one location to another until all desired operations have been performed. Numbers to be added are switched to an adding unit and the sum is switched back to a given memory location. Other arithmetical operations are performed in the same manner. Most important of all, from a clerical point of view, is the fact that different items of information can be compared to determine agreement or non-agreement or to determine the larger or smaller. Depending upon the outcome of a comparison, the machine can switch to one prearranged sequence of subsequent operations or to another. It is in this way that irregularities can be recognized and handled.

All of the circuits that are required to do these things are well proven. Computer men may differ as to the best circuits, but we do have workable circuits. Better input, less expensive random-access memories and faster printers are needed, but we already have in selective-sequence computers what is probably the most difficult component of a completely automatic clerical installation.

The Job Ahead

What remains to be done is to decide what sort of machines to build. What components, of what speeds and capacities, are to be put together to do a given clerical job with maximum economy? Before precisely the right machines can be assembled, the requirements of the job must be understood in detail. This is an undertaking for industrial engineers.

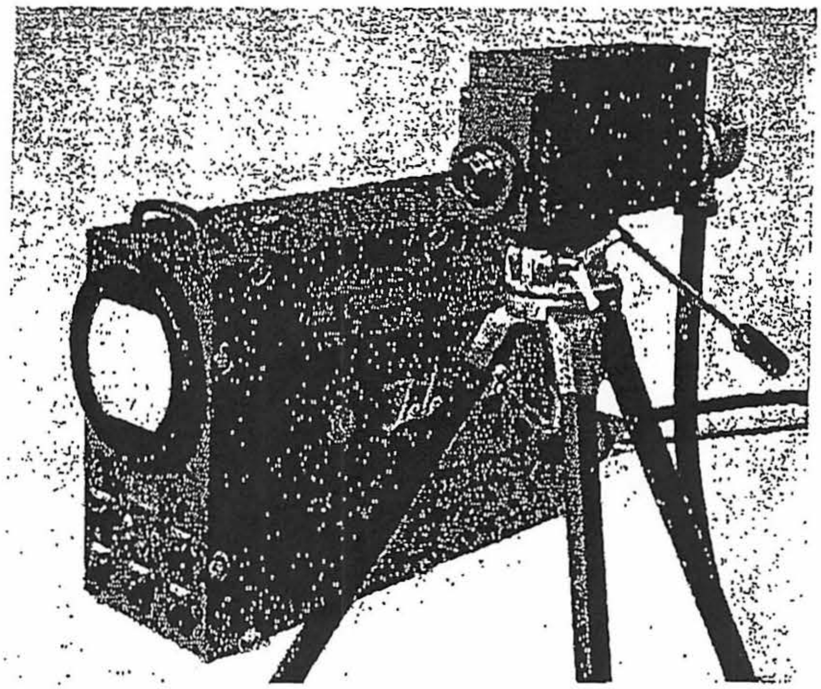
All or most clerical work may follow the same general pattern. But similarity ends when we go beyond generalities. No two clerical jobs are identical. Common parts and common sub-assemblies will no doubt be used in all electronic clerical machines, but to do the whole job each machine will almost certainly be modified to suit individual performance specifications.

The industrial engineering that remains to be done is thus twofold. First, enough must be known about clerical work of all types to design the best possible common components. Second, each application must be analyzed in detail before the machine for that application is finally put together.

The desirability of an ideal machine for each clerical job can, perhaps, be overemphasized. Less-than-ideal machines can be sold. But anyone who has experienced the compromises and the borderline decisions that often have to be made in using present-day office equipment cannot help dreaming of a machine that is engineered for their particular work.

Such machines would sell themselves.

The Vidicon



Miniature television camera employing the vidicon pickup tube[5], with standard image-orthicon camera in background

THE PHENOMENON of photoemission of electrons has been widely used for the light-sensitive surface of television pickup tubes. This is true for the image orthicon[1] as well as for its predecessors, the orthicon and the iconoscope.

The related phenomenon of photoconductivity has not been employed in any commercially useful pickup tube. However, this application of photoconductivity has by no means been ignored either in the experimental laboratories or in the patent literature. In fact, one of the earliest proposals for a television system envisioned the use of a selenium photoconductive cell in combination with a mechanical scanning disc. Actually, the sluggish frequency response of the selenium cells made them inadequate for this application. Photoemissive cells which became available in the early part of this century were found to be much more suitable.

During the middle 1930's, work on photoconductive targets for television pickup tubes was carried on in this country[2], as well as in England[3] and Germany.[4] In these experiments an electron beam similar to that used in the iconoscope scanned the photoconductive target. This mode of operation allowed the possibility of obtaining increased sensitivity by means of storage. Furthermore, the photoconductor needed to respond to changes in light intensity no faster than thirty cycles per second as compared to the several million per second that is required for nonstorage operation.

None of these experiments resulted in a useful tube able to compete with the iconoscope available at that time. The principal defects were insensitivity, retention of images and spurious spots on the target. Once again photoconductivity for pickup tubes was set aside at least temporarily in favor of photoemission whose processing art was somewhat more advanced.

Work done during the war on photoconductive materials for infrared detectors has served to focus attention on the basic advantages which photoconductivity has to offer to television pickup tubes. It is well known that the light sensitivity obtainable with photoconductive cells greatly exceeds that reported for any photoemissive cells. Whereas a sensitivity of 50 microamperes per lumen (about 0.10 electron per quanta) is considered good for photoemission, tens of thousands of microamperes per lumen (many electrons per quanta) are not uncommon with some photoconductive materials. (An image orthicon employing a photocathode giving 50 microamperes per lumen has an operating sensitivity comparable to

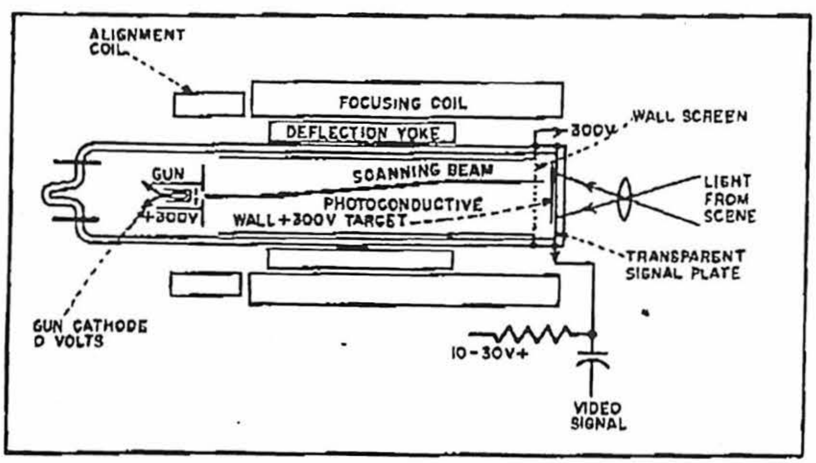
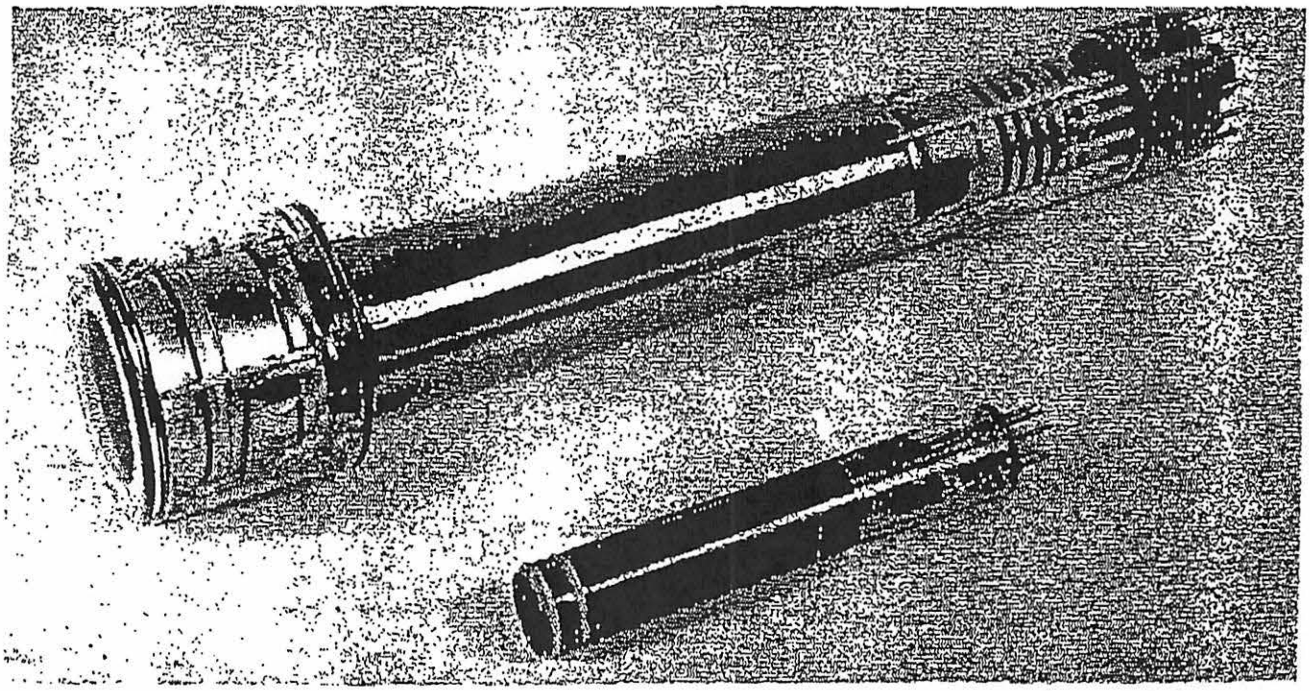


FIG. 1—Cross-sectional diagram of an experimental vidicon photoconductive television pickup tube

Presented at IRE National Convention, New York, March 1950.



Experimental one-inch-diameter vidicon, with the standard commercial image orthicon in the background

Photoconductive Camera Tube

Simplification of design, high sensitivity and good resolution are available in a new tube having a photoconductive target. Its application results in economy of equipment designed for unattended industrial applications as well as broadcast use

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that of the human eye.)

If high-sensitivity materials suitable for pickup tube targets could be found, the benefits could be used in two ways. Perhaps least important at present would be the possibility of developing tubes capable of operating at much lower light levels. An improvement of about 10 times over that of the present day image orthicon' is theoretically possible, assuming that on the average, the best photoemitting surfaces are only 10 percent efficient. Second and more important, any sizeable increase in target sensitivity would permit such simplification in pickup tube design as to open up entirely new fields of application. The electron image section and the electron multiplier, which have been required in the image orthicon for good sensitivity, may be entirely eliminated. The tube is reduced to the basic elements of gun and target. This makes for economy, compactness and simplicity of operation.

In addition, all the tube dimensions may be scaled down, if desired, because the extra target sensitivity is available to compensate for the reduction in target area. It was easily conceivable that a simple, compact and dependable television pickup tube would find many applications in industry, business and in scientific investigations far wider than that of entertainment broadcasting.

Work on photoconductive pickup tubes has been carried on intensively at RCA Laboratories during the past several years. High-sensitivity materials suitable for targets have been found and many experimental photoconductive tubes of various sizes have been tested. The name "vidicon" has been coined to distinguish these tubes from the photoemissive tubes.

The particular form of vidicon to be described is in an advanced stage of experimental development. It is one inch in diameter and six inches long, and is particularly suited to industrial applications. It appears likely that both larger and smaller forms of vidicons will eventually become available for other applications.

The comparative sizes of the vidicon and the image orthicon are shown in an accompanying photograph. A miniature television camera[3] employing the vidicon is also illustrated.

One-Inch Vidicon

The cross-sectional diagram of an experimental tube given in Fig. 1 shows the relative positions of the gun and the target.

As shown in Fig. 2, the photoconductive material is deposited on the transparent conducting signal plate and scanned directly by the electron beam. A uniform magnetic field is used to focus the beam. The velocity of impact of the beam may be either below first crossover as in the orthicon, or above first crossover as in the iconoscope. The video signal is taken from the target by connecting the amplifier to the transparent signal plate. The wall screen shown in Fig. 1 provides a uniform field in front of the target, but does not appear in the transmitted picture.

Charge-Discharge Cycle

For purposes of explanation, assume that a low-velocity orthicon-type scanning beam is used. A fixed potential of about 20 volts positive, relative to the thermionic cathode, is applied to the transparent signal plate. The beam deposits electrons on the scanned surface of the photoconductor charging it down to thermionic cathode potential. Although considerable field is thereby developed across the opposite faces of the photoconductor, its conductivity is sufficiently low that very little current flows in the dark.

If a light image is focused on the target, its conductivity is increased in the illuminated portions, thus permitting charge to flow. In these areas the scanned surface gradually becomes charged a volt or two positive with respect to the cathode during the 1/30-second interval between successive scans.

Photograph of picture transmitted by a one-inch vidicon

The beam deposits sufficient electrons to neutralize the accumulated charge, and in doing so generates the video signal in the signal plate lead. It will be noted that the target is sensitive to light throughout the entire frame time permitting full storage of charge.

The charge-discharge cycle is identical to that of the orthicon with the exception that the positive charging effect is achieved by photoconduction through the target itself, rather than by photoemission from the scanned surface. This mode of operation requires that the resistivity of the photoconductive target be sufficiently high that its time constant exceeds the 1/30-second television frame time. A dark resistivity of 10^{12} ohm-cm or greater is satisfactory.

Many materials such as selenium, sulfur, as well as the sulfides, selenides and oxides are known to be photoconducting. Several of these materials when properly processed have been found suitable for pickup tube targets. The spectral response is a function of the material and the processing. Targets which are sensitive to the entire visible range of the spectrum have been made.

Operating Characteristics

Photoconductive targets free from the spurious spots and lag which troubled the earlier workers, have been made. Sensitivities in excess of 1,000 microamperes per lumen are obtainable. Resolution is limited only by the electron optics of the beam while in the image orthicon a fine mesh screen at the target limits resolution.

The one-inch diameter vidicon is capable of resolving more than 600 lines. Under similar conditions the larger image orthicon will give about fifteen hundred lines. The capacity of the target may be made sufficiently large in any size target that the high light signal-to-noise ratio of the output signal can be as high as needed.

The signal-vs-light curve is linear at low lights as in an orthicon, but with some flattening off at high light levels. In general, the photoconductive targets made to date will not accommodate as wide a range of light levels for a given lens aperture as an image orthicon. For extremely bright illumination on the target, the picture loses contrast without any tendency for unstable charge up as in the early orthicon. An image orthicon under similar conditions would maintain good contrast by virtue of the redistribution of secondary electrons on the picture side of the glass target.

In general, pickup tubes with photoconductive targets are simpler in operating adjustments than an image orthicon. The electron image focusing control is completely eliminated, and the target voltage adjustment is somewhat less critical.

The high signal level obtainable at the target removes the need for an electron multiplier whose contribution to spurious spots and shading in the image orthicon has been a steady source of concern. The beam-current adjustment is accordingly less critical. In short, the simplicity of operation of the photoconductive targets combined with their adaptability for small tubes has made them particularly suitable for equipment designed for unattended industrial applications.

Sufficient satisfactory tubes have been constructed in the laborataory to demonstrate the advantages listed above. However, questions of tube life, allowable temperature limits and reproducibility of results will require additional intensive development before equipment reliable enough for industrial use can be made available. For example, conditions necessary to ensure targets free of objectionable time lag are still in an experimental stage.

Sensitivity of the Tube

A one-inch vidicon possessing a target sensitivity of 300 μa per lumen will transmit a noise-free picture with a scene brightness of several foot-lamberts using an $f/2$ lens. Since this light level is less than ordinarily present in most laboratories or factories, special lighting is not required.

It is impossible to compare the relative sensitivities of the vidicon and the image orthicon without specifying at what light level the comparison is being made. At intermediate light levels, with a few foot-lamberts scene brightness, the two tubes will transmit a picture having about the same signal-to-noise ratio. At higher light levels, the vidicon will deliver a higher signal-to-noise ratio than the image orthicon since its target capacity is higher. At lower light levels its signal-to-noise ratio will be inferior to that of an image orthicon with a multiplier.

This follows from the fact that the noise background for the vidicon is the amplifier noise that remains fixed at all light levels, while for the image orthicon it is shot noise in the scanning beam, which may be reduced somewhat for low signal levels. With the development of still more sensitive targets, the vidicon without a multiplier may be expected to exceed the present image orthicon at all light levels.

It will be noted that the elimination of the electron multiplier will require a stronger beam current at the target of the vidicon than in the image orthicon. Assuming the input noise of the video amplifier to be 2×10^{-3} microampere, a target current of 0.2 microampere is required for a signal-to-noise ratio of 100. This current is about ten times that required in the image orthicon.

Some explanation as to why a smaller pickup tube may require a more sensitive target for equal scene brightnesses is in order. If the entire tube and optical system are scaled down in size, keeping the same f number lens, the quantity of light in lumens intercepted by the lens is reduced. The output signal of the tube in microamperes is also reduced unless the target sensitivity in microamperes per lumen is increased.

On the other hand, if the lens diameter for the small tube were kept the same as for the large tube, no increase in target sensitivity is necessary. However, for the same angle of view this means a faster or lower f number lens. Such lenses, if available at all, are likely to be less highly corrected and more expensive. Thus, in general, the smaller tube will be operated with smaller diameter lenses requiring

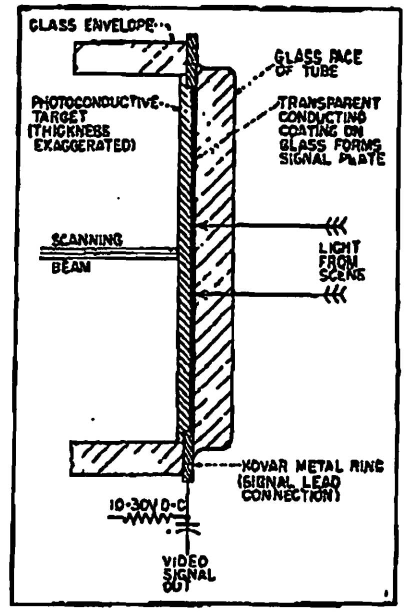

FIG. 2—Detail of the target construction in the experimental photoconductive camera tube

higher scene brightnesses or more sensitive targets. The gain in depth of focus accompanying the use of the smaller diameter lens may, however, be very useful. Motion picture 16-mm lenses have been found to be satisfactory.

The writers wish to thank V. K. Zworykin and Albert Rose for their continued interest and advice during the course of this work. The construction and testing of tubes has been greatly aided by the cooperation and assistance of A. D. Cope and P. G. Herkart. We are indebted to S. M. Thomsen for preparation of photoconductive materials. The development of miniature camera equipment by R. C. Webb and J. M. Morgan has facilitated the evaluation of tube performance.

REFERENCES

(1) Rose, Weimer and Law, The Image Orthicon—A Sensitive Television Pickup Tube, *Proc. IRE*, 34, p 424, July 1946.
(2) Iams and Rose, Television Pickup Tubes with Cathode Ray Beam Scanning, *Proc. IRE*, 25, p 1048, Aug. 1937.
(3) Miller and Strange, The Electrical Reproduction of Images by the Photoconductive Effect, *Proc. Phys. Soc.*, 50, p 374, 1938.
(4) Knoll and Schroeter, Transmission of Pictures and Signals by Insulating and Semi-conducting Surface, *Phys. Z.* 38, p 330, 1937.
(5) Janes, Johnson and Moore, Development and Performance of Television Camera Tubes, *RCA Review*, 10, p 191, June 1949.
(6) Webb and Morgan, Industrial Television System, paper presented at IRE National Convention, New York, March 1950.

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PROPOSAL
FOR
RAPID RANDOM ACCESS FILE

ABSTRACT

Multiple requirements exist in business, scientific computers and industry for high capacity, rapid, random access memories. It is probable that no one method will satisfy all requirements so that many methods must be studied. This study will be carried out in two sections to satisfy both immediate and future needs.

An immediate application for a Random Access File exists in the Source Recording System which requires that a method be chosen in the near future which can be quickly developed to supply this need. In addition, it is necessary to study and do experimental work on several techniques to determine their long-range suitability for such varied needs as accounting, inventory control, production control, library search, table look-up, etc.

Magnetic methods are most promising for immediate application. Long-term study, however, will include such diverse techniques as electromechanical, ferroelectric, coherer, electroplating, electrostatic (both CRT and the newly developed open surface storage) and optical methods.

The purpose of the various designs illustrated herein is to describe some of the approaches which will be the subject of study under this proposal.

February 6, 1953

1050
500

ACKNOWLEDGMENT

Many members of the IBM Research and Development Laboratory at San Jose participated in the formulation of this proposal.

A. J. Critchlow
February 6, 1953

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Evaluation of Rapid Access High Capacity Storage Systems

STORAGE PROVISIONS

Number of bits per storage unit

Number of bits per sq/in access
    Access area required for 25,000 records - plotter area

Number of bits per cu/in of storage unit
    Volume required for 25,000 records

Provisions for variable length record

Provisions for variable number of records at one address

Insurance against loss of information

Editing-erase and rewrite

Division into varying field sizes

Growth possibilities

INPUT PROVISIONS

Initial file preparation
    Possibilities of pre-stored files

    Parallel read-in

Input Means Available

    Keyboard (Typewriter, etc.)

    Punched Cards

    Magnetic Tape (Or Paper Tape)

    Magnetic Drum

    Other Storage

Writing Means

    Static or semi-static

    Speed of Writing

    Proof of writing accuracy

OUTPUT PROVISIONS

Access

    Access from multiple stations

    Access time (maximum and average)

    Emergency access during equipment failure

Output Means Available

    Read-out to communication lines

    Cards

    Typewriters and Printers

    Teletype

    Accounting Machines

    Other Storage

Search Mechanism - mass moving mechanisms

Speed of Reading
Maximum Read-out speed (section of memory)

Proof of accuracy

Multiple concurrent reading

Provisions for parallel read-out

Static or semi-static read (to eliminate need for buffer storage)

CONTROL AND ACCESSORY EQUIPMENT

Input encoder

Control switch panel

Plugboard

Buffer Storage

Search sequence control

Output coder

PHYSICAL CONSIDERATIONS

Overall size
Portability

Power Requirements
Electronic

Electro-mechanical

Required Operating Conditions
Temperature

Humidity

Dust-free Room

Serviceability
Number of Components

SPECIAL FEATURE AVAILABILITY

Provisions for: Sorting, Adding, Extending, Table-look-up, Translation, Cross-Indexing, Sound Recording, Facsimile Recording

Feasibility of Changing Codes

Maintenance of History

Growth Possibilities

DEVELOPMENT

Present State of Development

Development Required

Development Cost

COST

Production

Installation

Operator Training

RAPID RANDOM ACCESS FILE - (Magnetic Recording Considerations)

Some general performance estimates are given here for consideration in connection with the Rapid Access File application.

The various schemes are placed in one of two possible: (1) systems with heads in contact with the recording surface (2) systems with heads in non-contact with the recording surface. Contacting heads are considered practical up to about 100" /sec. of relative speed between head and recording surface.

(1) Contacting Head Systems

a. 20 tracks per inch appears possible for methods using single movable heads.

b. Read head voltage approximately 20 mv. /ft. /sec.

c. Linear desity up to 200 bits per inch appears possible but is regarded as marginal. 100 bits per inch is considered more practical.

d. Estimated head life approximately 1000 hours.

(2) Non-Contacting Head Systems

a. 20 channels per inch may be possible: 10 recommended

b. Read head voltage approximately 5 mv. /ft. /sec.

c. Maximum linear density approximately 100 bits/in.

d. Head life indefinite but critical positioning required.

Some additional comments regarding the individual systems follow: - Recorded clock channels appear feasible on all systems except on rods and wires. However, with a clock channel precise alignment of heads in all cases and between heads and feed guide in the tape and plate systems is required. The worst situation would exist in the plate system where a skew angle of only 1 minute between plate and guide edge would move the clock pulses out of registration with the recorded bits.

Where a clock channel is not feasible, as in the case of rods and wires, self-clocking may be employed. One method is the recording of plus, zero and minus magnetization and reducing the density sufficiently to provide recognizable zero axis cross-overs of the playback signal. Somewhat complex wave-shaping and gating is required to generate the clock pluse train in this manner but the technique is straightforward. Another self-clocking method uses a recognizable bit spacing and an electronic recognition circuit as described for the wire recording.

With drums, plates and discs, the continuous inspection and coating process control, which is given magnetic tape as a result of the large production involved, may not be possible. Poorer uniformity of magnetic coatings should, therefore, be expected on these media as compared to tape and so that density figure of 100 bits per inch may be optimistic.

In connection with the need for erasing, it is believed that some reduction in the number of channels per inch below the estimated 20 may have to be made because of anticipated cross-channel erase effects, particularly in non-contact head systems.

In addition, for maximum reliability complete erasure and re-recording on an entire digit is recommended to avoid effects from clock channel misregistration. For the high speed disc and drum systems special ferrite erase heads appear necessary since the frequency of the erase current must be in the region of 500 KC.

A possible way to reduce registration errors in erasure and re-recording is by using 8 bit spacing for information and then leaving 12 vacant bit spaces in each character space to allow for slight misalignment. This requires erasure of a complete digit,of course.

Development of new types of magnetic heads appears feasible. Use of 2nd harmonic modulator effects (as described in Bell Patent 2,608,621) seems especially promising. Another possibility would use magnetic non-linearity to detune high-Q oscillators.

CLASSIFICATION OF STORAGE METHODS

Magnetic Storage Configurations

1.1 WIRE MATRIX - 0.0046" diameter 24" long 0.040" on centers

1.2 ROD ARRAY

- 1.2.1 Luhn's Longitudinal Recording - 0.070" rods x 24" long - (Two accesses 0.100" on centers)
- 1.2.2 Stevens' Circumferential Recording - 0.125 rods x 6" long - (Two accesses 0.175" on centers)

1.3 TAPES

- 1.3.1 Tape Matrix - Telecomputer
- 1.3.2 Multiple Tape Spools - Short lengths individually clutched or constantly running - Multiple Access - Flat Array
- 1.3.3 Endless Tape Loops - Continually running with vacuum tension - Multiple Access
- 1.3.4 Cylindrical Array - Multiple Tape Spools - Multiple Access

1.4 DISCS

- 1.4.1 Rabinow's Notched Discs - Toroidal Arrangement 20" diameter - Kicked to rotate
- 1.4.2 Hotham's Discs on longitudinal shaft - Continuously running 15" diameter - Multiple Access

1.5 MULTIPLE DRUMS - Circular Arrangement - Rotating Head 10 drums - 15" diameter x 25" long

1.6 PLATES - Rigid - Shuttle Mechanism

1.7 FERROMAGNETIC CORES - (See Matrix Storage)

Other storage methods which will be considered are the following: Many of these are in the idea stage only:

Three Dimensional Matrices

2.1 SATURABLE FERROMAGNETIC CORES

2.2 ELECTROCHEMICAL STORAGE - "Passive Iron Wire Nerve Model" and similar Phenomena

2.3 FERROELECTRIC CRYSTALS

2.4 COHERERS

Electrostatic Storage

3.1 CATHODE RAY TUBE

- 3.1.1 Williams Tube
- 3.1.2 Selectron

3.2 DIELECTRIC SURFACE CHARGE STORAGE

- 3.2.1 All mechanical configurations described under magnetic methods

Optical Methods

4.1 PHOSPHOR STORAGE*

4.2 FILMSTRIP ARRAY

4.3 ELECTROSTATICALLY CHARGED - XEROX POWDERED PLATES - Optical Read

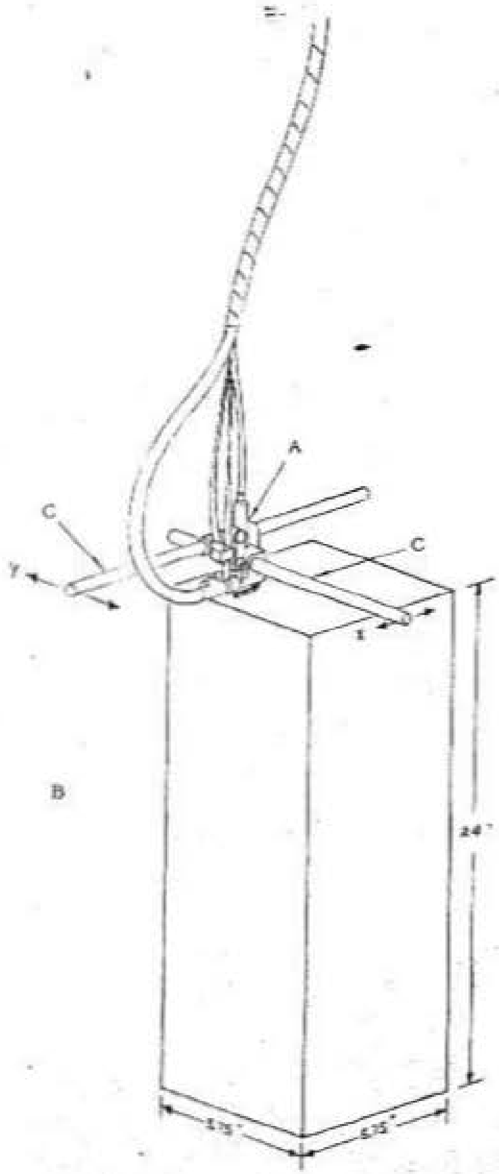
4.4 ELECTROPLATED PHOTO-CONDUCTIVE SURFACE - Optical Read

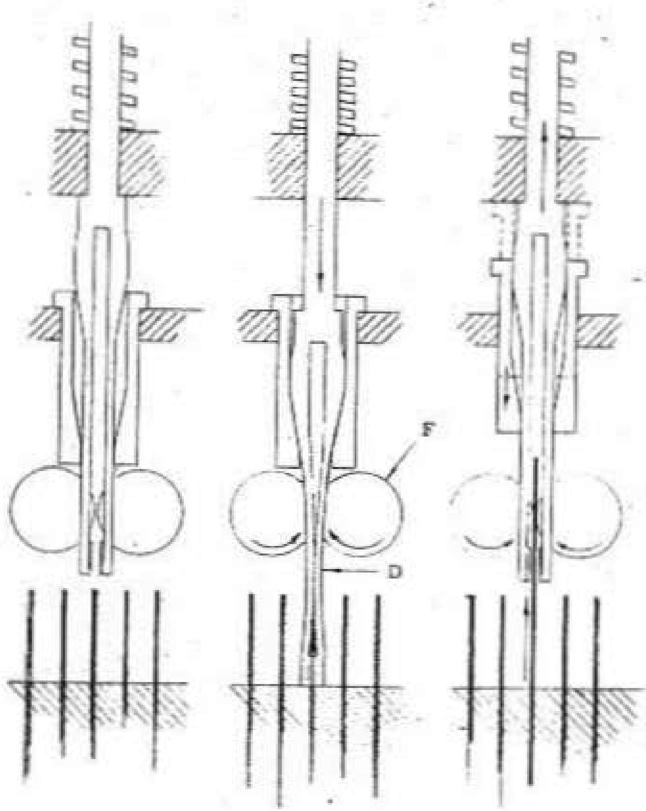
4.5 PUNCHED CARDS - Optical Read

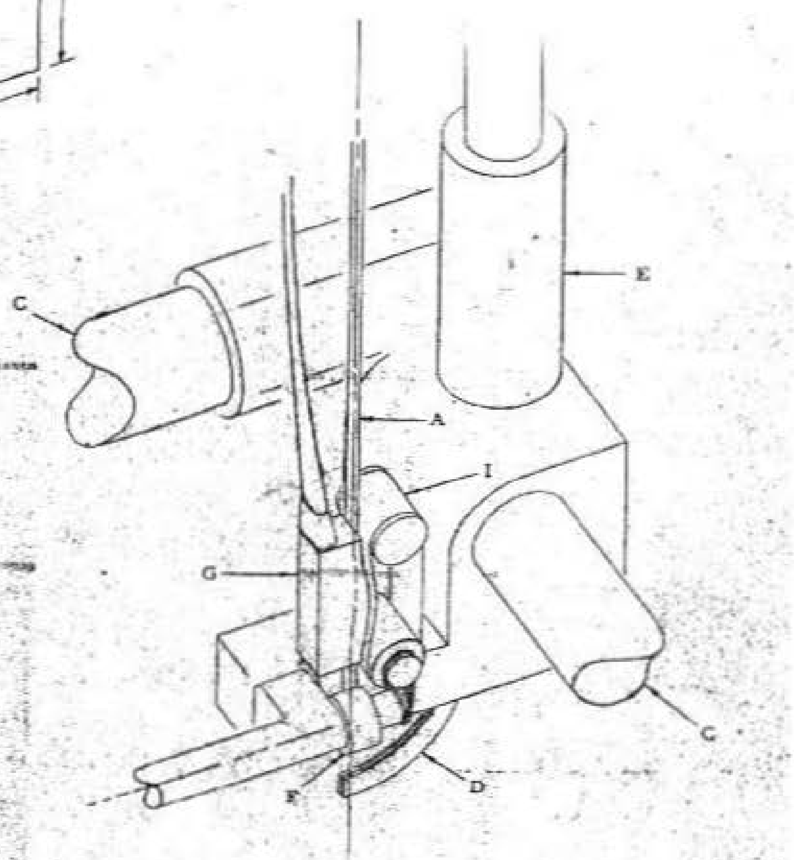
Mechanical Recording

5.1 PHONOGRAPH RECORDS

5.2 PIERCED HOLES IN HEAT-SEALABLE SUBSTANCE







A - Head

B - Record Storage

C - Plotter Printer Mechanism

D - Wire pick up jaws

E - Air cylinder

F - Wire drive rollers

G - Read, erase and write heads

H - Wire guide

I - Wire Hold down belt

WIRE MATRIX - WIRE PICKUP AND READER

WIRE MATRIX

The proposed record storage contains 25,600 wires, each capable of storing 200 characters or one complete card. The wires are .0046 inch in diameter, 20 inches effective length, with an assumed bit density of 100 bits per linear inch. The storage density is 41,600 bits per cubic inch. The wires are spaced .040" on centers. The head, which selects the required wire, is positioned by means of the plotter-printer mechanisms, already under separate development.

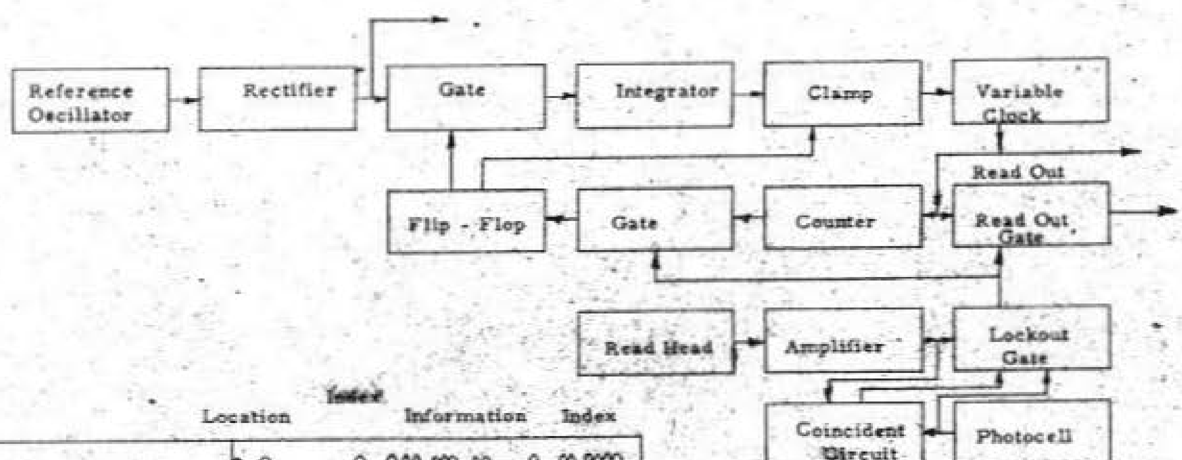
Location of the wire requires a maximum time of 1 second, a minimum time of .1 second, with an average location time of less than 1/2 second. Once the proper wire is located, the wire pickup jaws are lowered by the pressure in the air cylinder, seize the wire and raise the tip of the wire to engage in the wire drive rollers. The wire rises past the read, erase and write heads and into the wire guide. A contact near the top of the wire guide stops and reverses the wire drive rollers before the lower end of the wire emerges from the record storage box and the wire is returned to its proper storage location.

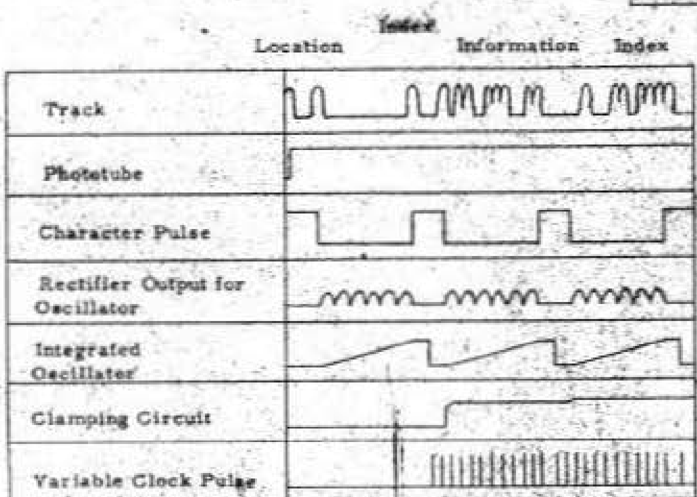
During readout, the wire system is hampered by inherent lack of positive indexing for location of any given character. It is believed that a reliable mechanical indexing system would be accurate to approximately 0.010" which is not sufficient for the storage density chosen.

An electrical method of indexing appears feasible: A cycle with 12 cycle points consists of a timing pulse at the first cycle point; two blank cycle points; eight coded information points and two blank cycle points. The indexing system, shown in the block diagram form, contains a reference oscillator and an integrating network which sums up the oscillator output for the time elapsed between the first and tenth cycle points. The output of the integrating network is clamped at its value at the tenth cycle point and serves to control the time intervals of a generated clock pulses for the following cycle. The system thus corrects the timing of the cycle points for each cycle by the indicated elapsed time for the previous cycle. Approximately correct timing is maintained by a synchronous motor drive and inertia of the drive system.

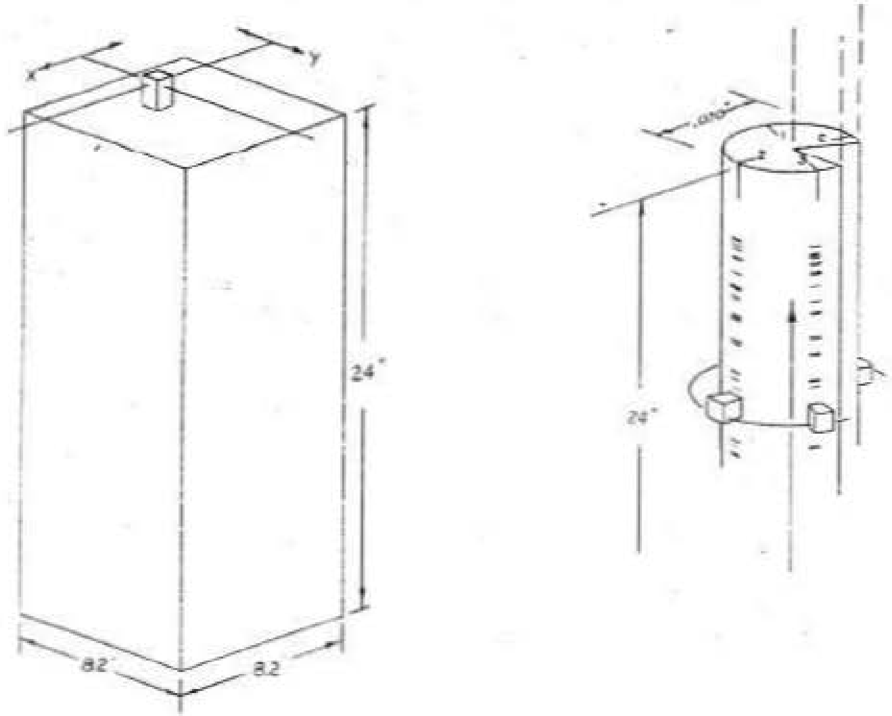
Because of the indexing method, a storage system capable of storing 200 alphanumerical characters appears necessary. The four blank cycle points allows the use of A.C. erasure, which makes indexing less critical than that required by pulse erasure.

Due to the high volume density of stored information, multiple access appears feasible by using additional record storage boxes, all containing the same information, with a common read-in means and separate read-out means.





WIRE MATRIX - CLOCK CIRCUIT



LUHN'S LONGITUDINAL RECORDING ROD

Information is stored in 3 tracks and a clock track spaced around the circumference of a V-grooved 0.070" diameter rod. (Originally, 10 tracks were to be stored around the circumference, but a limit of 20 tracks/inch allows only 4.) The V-groove provides a location point to allow indexing of one magnetic head to pickup a selected track. Tracks run along the rod at a density of 100 bits/inch so that a 24 inch rod is required for each record or a total of 20,000 rods.

Volume storage density is 30,000 bits/cubic inch

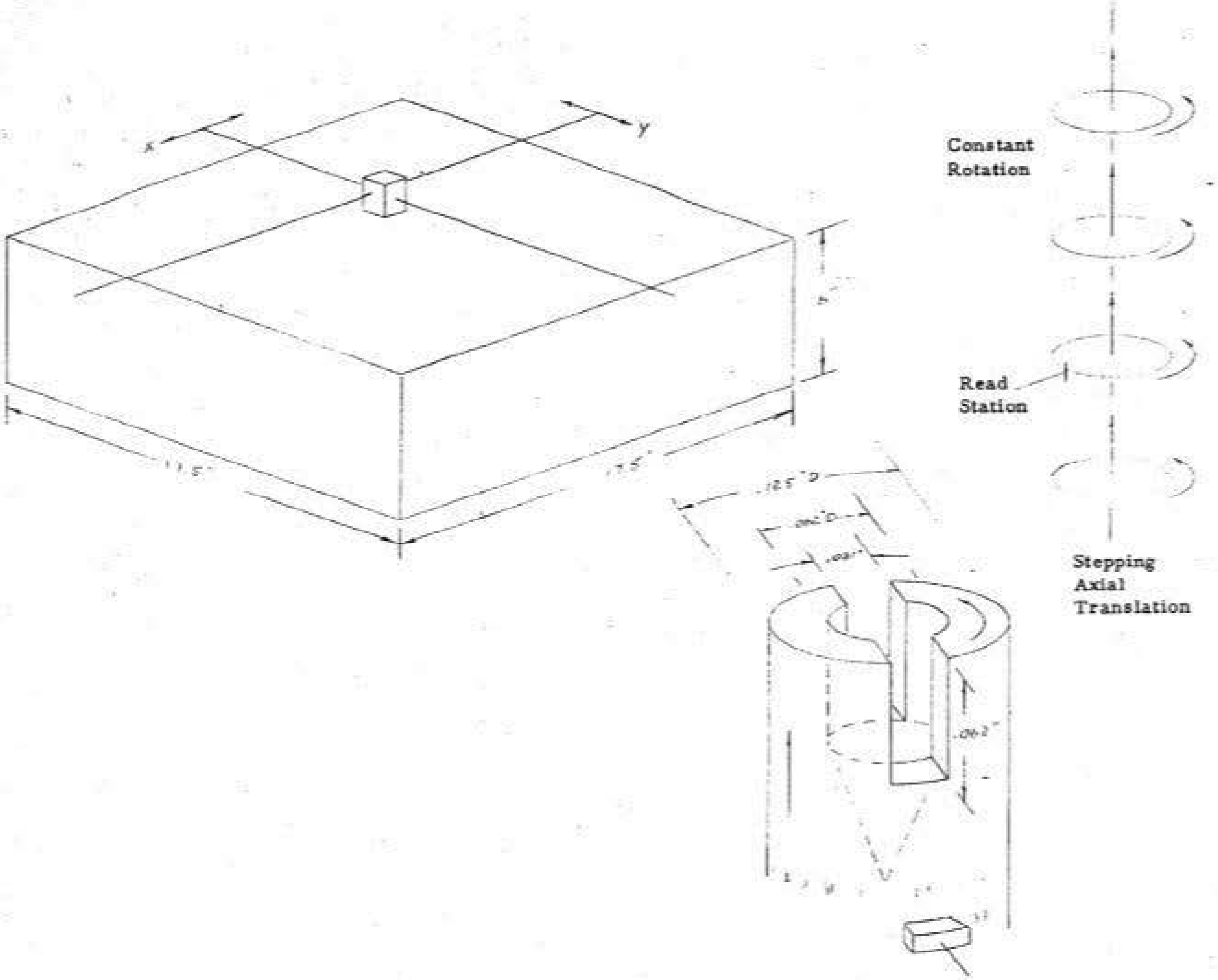
Access time is about 0.5 second, using an X-Y drive similar to a plotter mechanism. Pickup of the rod will be similar to that shown for the wire matrix. Double access is possible by pulling rods from either end of the support honeycomb.

Advantages

Main advantages of this method over the wire matrix are the V-grooves for angular alignment and the availability of a clock track for indexing the stored information.

Limitations

Possible trouble in locating from the V-groove is the major limitation.



ROTATING ROD STORAGE

This storage device would utilize ten-thousand aluminum rods 0.125" in diameter and 6" in length each of which would be capable of storing 400 alphanumeric characters on its nickel plated magnetic surface. Any rod could be selected by an electromechanical device capable of locating in a fraction of a second, any one of 10,000 points in a 100 x 100 matrix, upon command of a four-digit address. The rod would be rotated to facilitate magnetic reading and recording.

Information would be stored on 100 rings or tracks, on a rod. Each ring would contain 4 information characters and one control character. A total of 35 bits are thus stored in each ring if a 7 element code is used for representation. Each ring of information is treated as an independent unit and may be read, recorded or erased, during one revolution of the rod. The rotation rod is translated 1/20 of an inch to read, record or erase the succeeding ring. A buffer storage, capable of storing the contents of one ring, would be required in order to utilize the time required to step the rod from ring to ring.

Since each rod may store 400 characters, it may be thought of as 2 unit records of 200 columns each, 4 records of 100 columns each or 5 records of 80 columns each.

The following advantages are characteristic in this device:

1. Variable and asynchronous reading speed of the information on one rod from a very slow rate to a maximum rate of 200 characters per second. (May supply data to a typewriter or a 407)

2. Mechanically and electrically simple - Existing techniques are utilized.

3. No foreseen problem in erasing or modification of stored data.

The device is subject to the following limitations:

1. Multiple station access is provided only by duplication of the file.

2. The size is greater than some other possible devices.

TAPE METHODS

There are two general "tape" methods -- the tape matrix proposed by Telecomputing which is essentially equivalent to the rod or wire systems, and methods in which a more conventional tape drive is used.

The conventional systems are of two types -- individually clutched spools and continuously running endless belts. The clutched spools appear to be ruled out by the large number required and short usable length of tape (50 - 100") with each.

Assuming that continuously running separate tapes are to be used, the principle configurations considered are: (1) side by side, (2) cylindrical and (3) pigeon hole. For sake of example, assume that 250 tape units, each 50" long, will be required. For the side by side configuration, the mechanical selection will consist of driving the head in one axis for a travel of 250". The minimum tape volume will be 250" x 13" x 13". Multiple assess is unlimited.

For the cylindrical configuration, selection will consist of rotating a 40" arm to the prescribed position out of 360°. The minimum volume will be an 80" diameter cylinder, 25" long. Multiple access is unlimited.

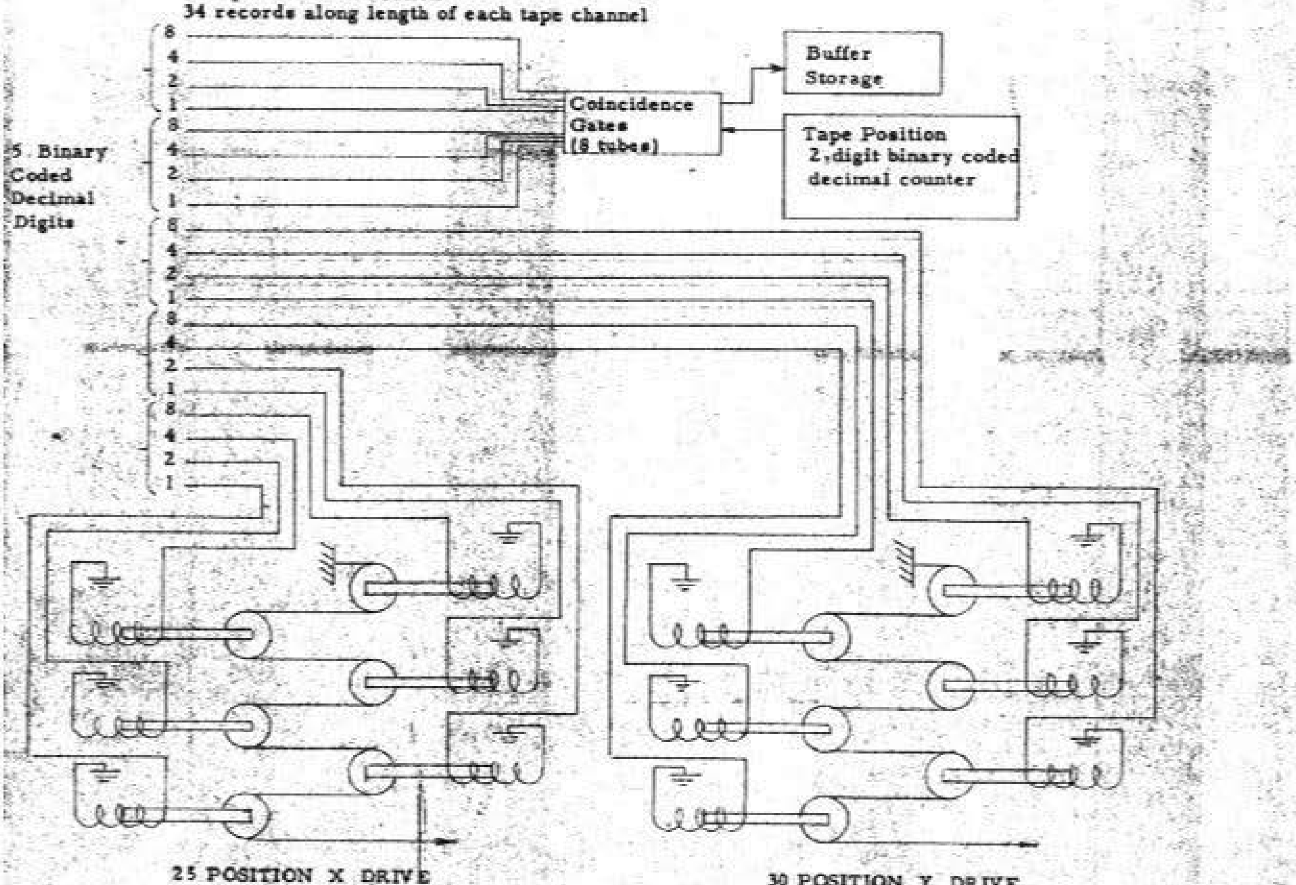
For the pigion hole arrangement, assuming the tape can run over rollers spaced 1/2" between centers, selection will be made by driving the head a maximum of 12" in each of two axis. Minimum volume will be 12" x 12" x 25". Access is limited to two stations, one at each end. A "wheel-spoke" variation of the pigeon hole would provide access by one rotation of a 6" arm and a maximum translation of 6". Volume would be a 60" diameter cylinder, 6" high. Access would be limited to one station.

For all tape systems address within a single tape can be obtained by adjacent tracks of magnetic or optical recording.

Bits/inch	Tracks/inch (Also equals no. of heads.)	Required Tape Area - sq."	Aver. Tape speed inch/sec.	(1/2 sec.) Max. tape length per head inches	(1" wide) Required No. of tapes
100	14	36,000	100	50	720
			500	250	144
100	20	25,000	100	50	500
			500	250	100
200	14	18,000	100	50	360
			500	250	72
200	20	12,500	100	50	250
			500	250	50

PIGEONHOLE SYSTEM:

25 tapes in "X" direction
10 tapes in "Y" direction
34 records along length of each tape channel



25 POSITION X DRIVE

30 POSITION Y DRIVE

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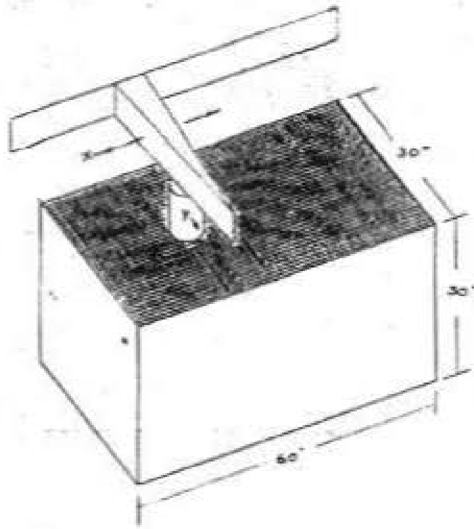
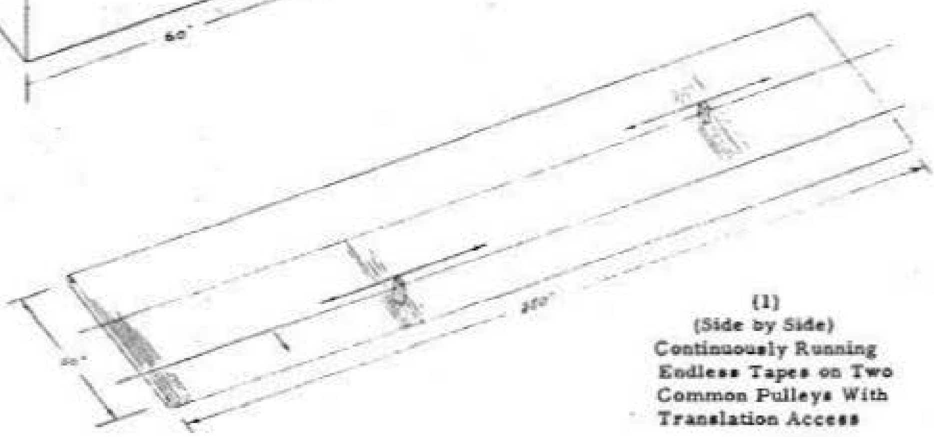
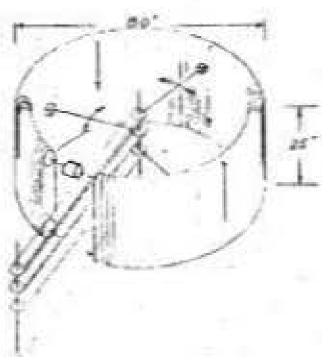


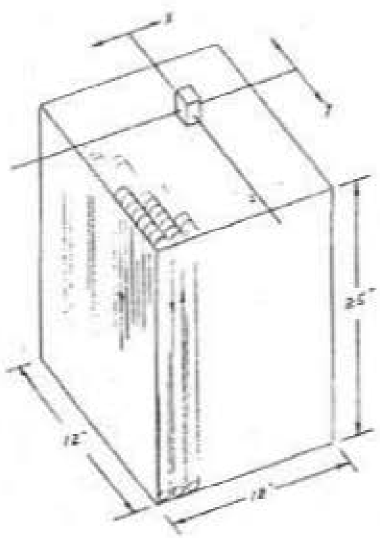
TELECOMPUTING
TAPE MATRIX



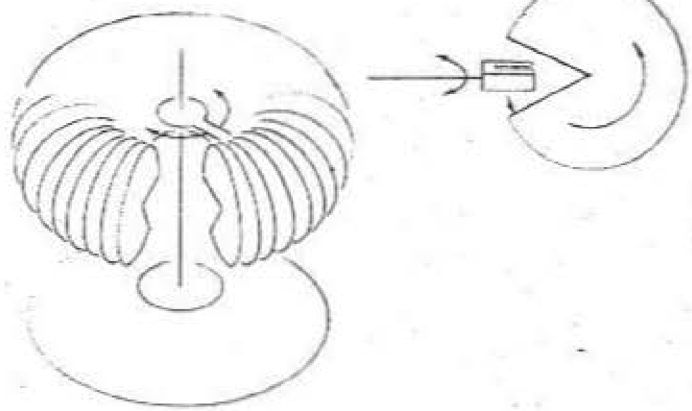
(1)
(Side by Side)
Continuously Running
Endless Tapes on Two
Common Pulleys With
Translation Access



(2)
(Cylindrical)
Continuously Running
Endless Tapes On Two
Common Flexible Shafts
Driving Individual Pulleys
With Rotational Access



(3)
(Pigeon Hole)
Continuously Running
Endless Tapes On Tiers
Of Pulleys With X and Y
Translatory Access



RABINOW'S NOTCHED DISCS

Jacob Rabinow, National Bureau of Standards, describes a notched disc memory in Electrical Engineering for August, 1952.

Discs 20" in diameter are arranged on a common shaft which is bent into a circle so that the resulting envelope is a toroid or "doughnut." Each disc has a deep V-notch extending nearly to its center. The notches are aligned so that a magnetic head assembly can be rotated about the axis of the toroid and through the V-notch. A record is selected by rotating the head assembly to the desired disc and then rotating the disc so that it passes between the recording heads of which there are 64 on each side of the slot provided for the discs. Reading from the proper head provides for track selection. Access time is about 0.5 seconds.

Recording densities of 13 tracks/inch and 100 bits/inch are used so that 500,000 bits may be recorded on each 20" disc. Provision for 20,000 records, as a comparison with other methods considered, would require 80 discs.

Notched discs do not provide multiple access, but it does seem feasible to provide for plugboard character selection by a method similar to that described for the longitudinal disc array. Buffer storage will not be necessary for many applications because of the high reading speed available.

Advantages

Considerable development already completed. Latest reports (February 4, 1953) indicate that mechanical problems have been solved but some magnetic problems remain.

Plugboard column selection may be possible.

Buffer storage not required for many applications.

Limitations

Simultaneous multiple access not available.

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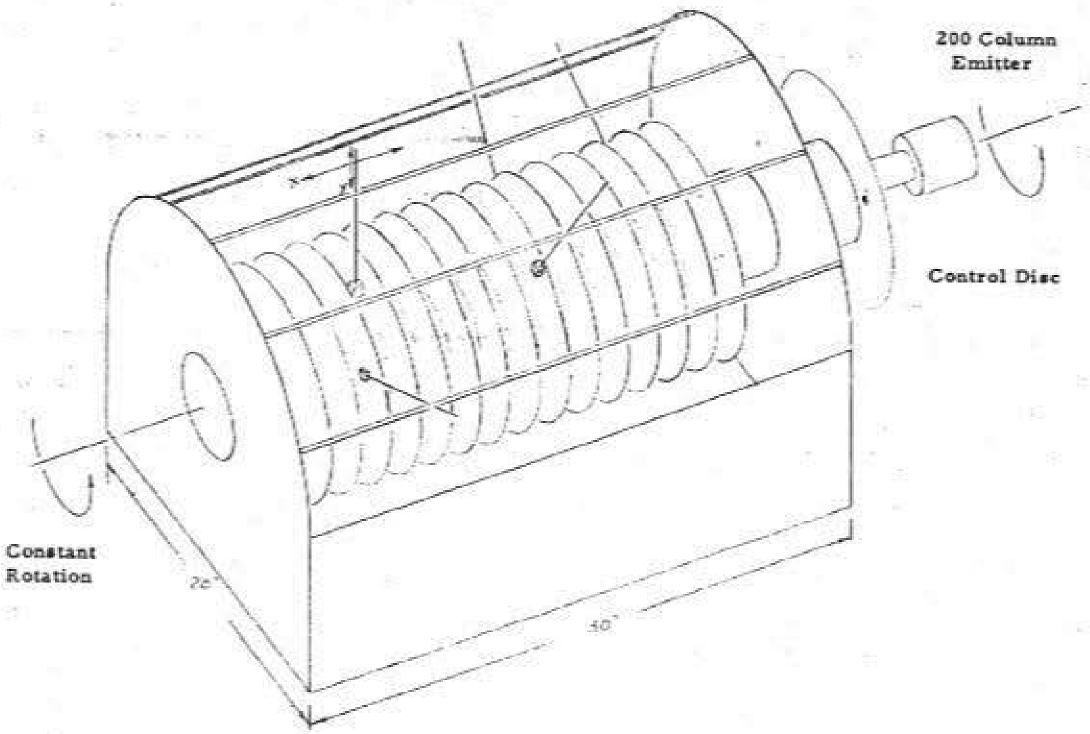

MAGNETIC DISC - LONGITUDINAL ARRAY

An array of 50 magnetic discs mounted on a longitudinal shaft and rotated at speeds up to 16 revolutions per second has been previously described in "Proposal for Source Recording System" by A. J. Critchlow. (February 2, 1953)

Discs are 15" in diameter by 0.006" thick and are made of aluminum coated with magnetic oxide or plating on each side so that 100 surfaces are available. Densities of 20 tracks/inch and 200 bits/inch per lineal inch allow storage of 200 records of 200 columns per record on each disc to provide a total of 20,000 records.

Selection of a desired record is accomplished by a 100 position X-drive along the longitudinal axis and insertion of a magnetic head between the discs by an electronic counter-controlled Y drive which is positioned simultaneously. Access time of 0.2 seconds appears feasible. Read-out of a selected record to buffer storage is possible in 0.06 seconds.

Buffer storage may be eliminated by reading one character per revolution into an 026 printing punch. Entry from a keyboard may be accomplished in the same way, as shown by diagrams on the following pages.

Advantages

Multiple access using either multiple X-Y drives and multiple heads or multiple buffer storage from one head is possible.

Plugboard column selection is possible with simple equipment.

Limitations

Size is larger than some other systems

Head wear and disc vibration may be problems.

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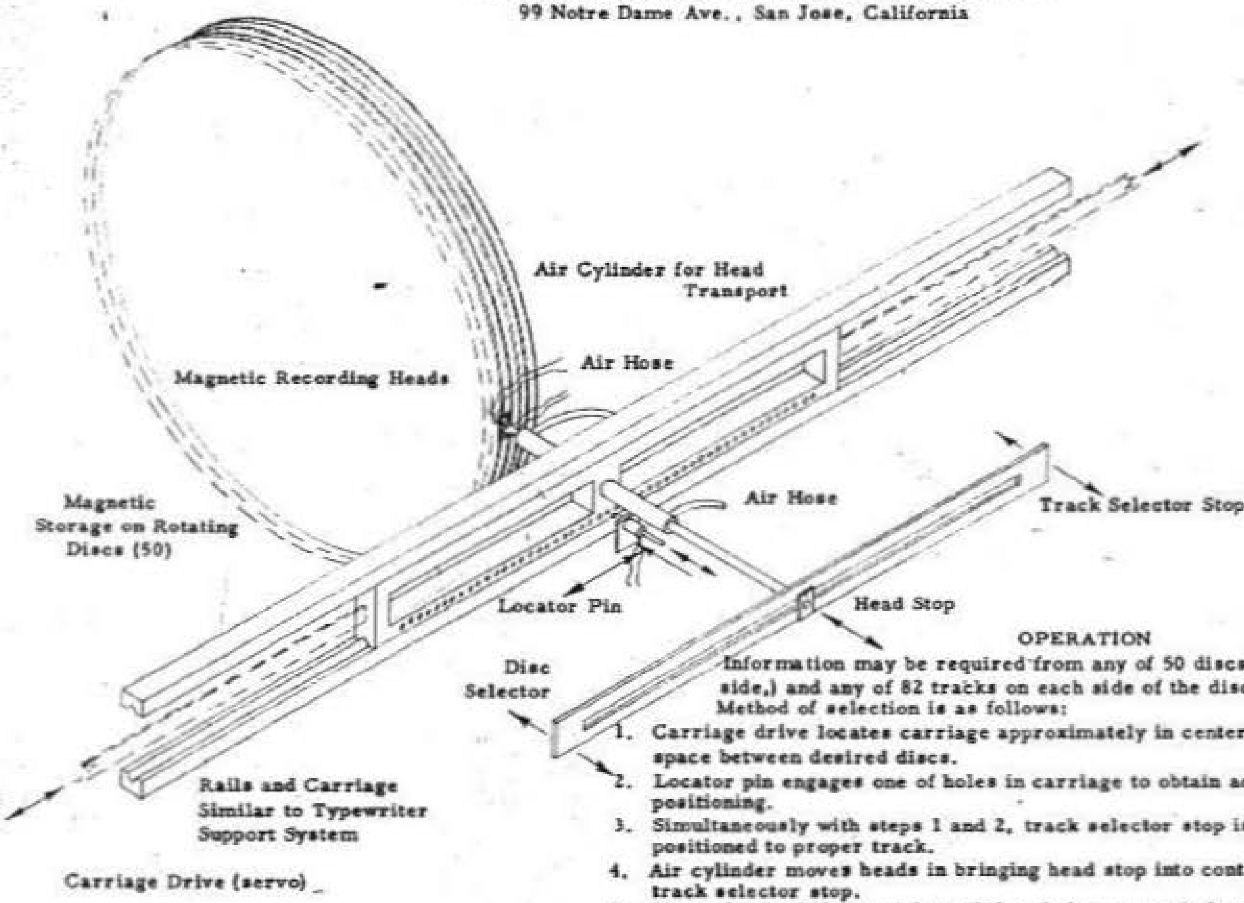
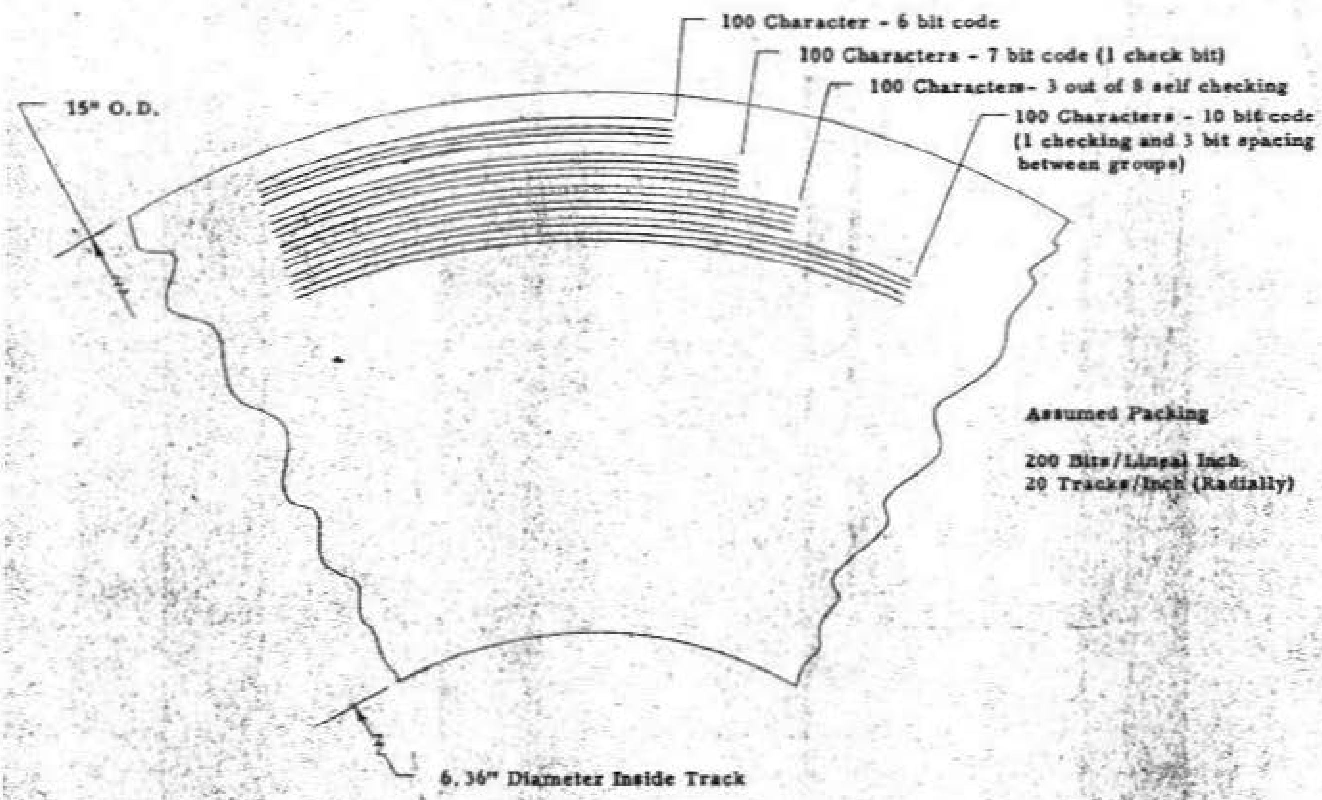


OPERATION

Information may be required from any of 50 discs (either side,) and any of 82 tracks on each side of the discs. Method of selection is as follows:

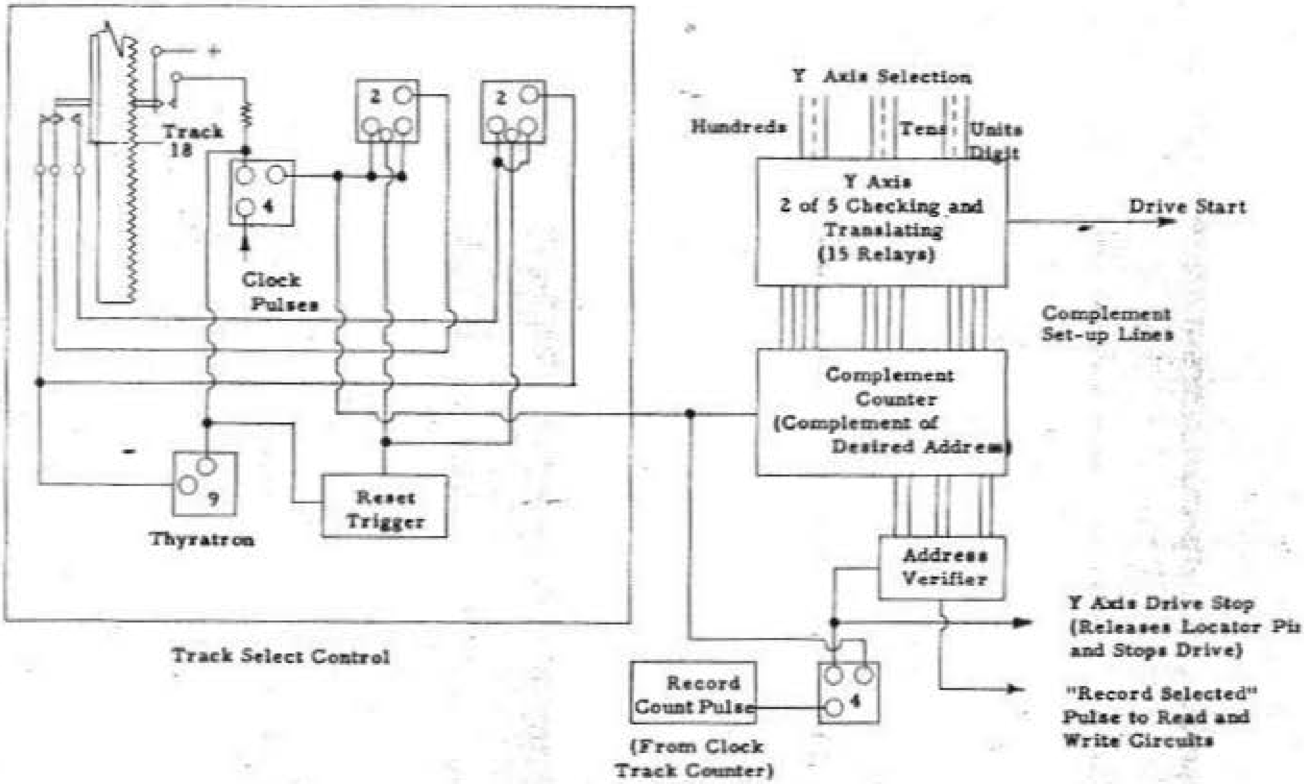
1. Carriage drive locates carriage approximately in center of space between desired discs.
2. Locator pin engages one of holes in carriage to obtain accurate positioning.
3. Simultaneously with steps 1 and 2, track selector stop is positioned to proper track.
4. Air cylinder moves heads in bringing head stop into contact with track selector stop.
5. Disc selector indexes right or left to bring magnetic head into contact with selected disc.
6. Desired information is read out.
7. Disc selector returns to neutral.
8. Air cylinder returns heads to select position.

HEAD LOCATING MECHANISM - MAGNETIC DISC
LONGITUDINAL ARRAY - RANDOM ACCESS FILE

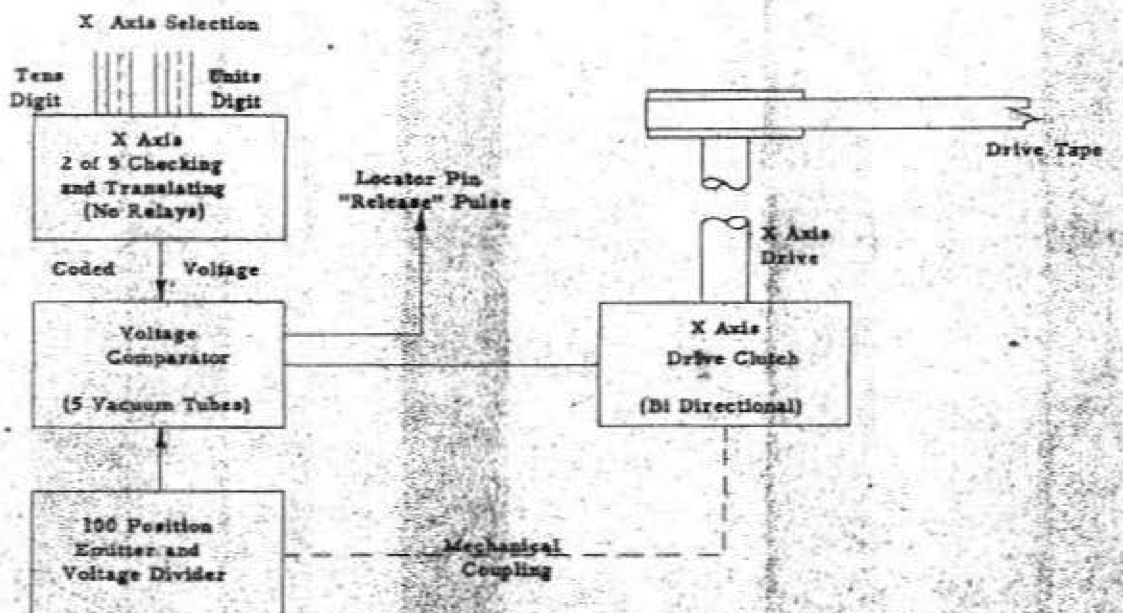


POSSIBLE CHARACTER CODING - MAGNETIC
DISC LONGITUDINAL ARRAY - RANDOM ACCESS FILE

February 6, 1953



Y AXIS DRIVE CONTROL
MAGNETIC DISC - LONGITUDINAL ARRAY



X AXIS DRIVE CONTROL
MAGNETIC DISC - LONGITUDINAL ARRAY
RANDOM ACCESS FILE
February 6, 1953

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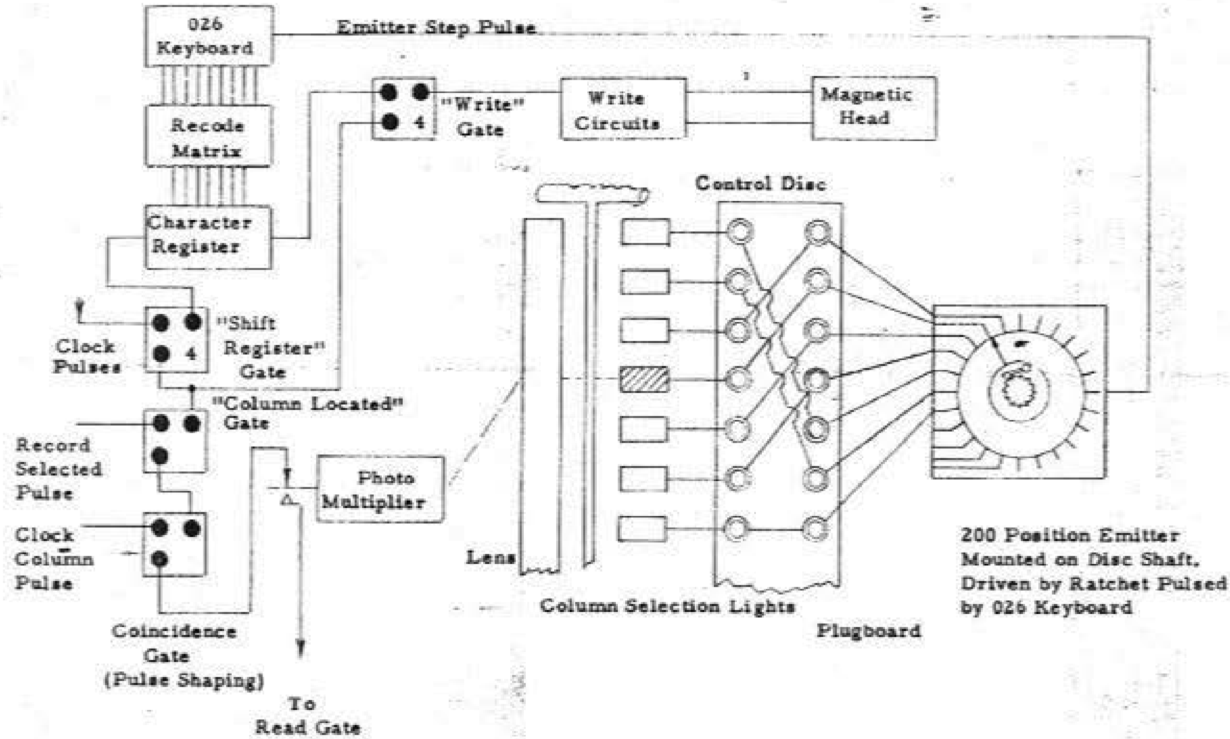
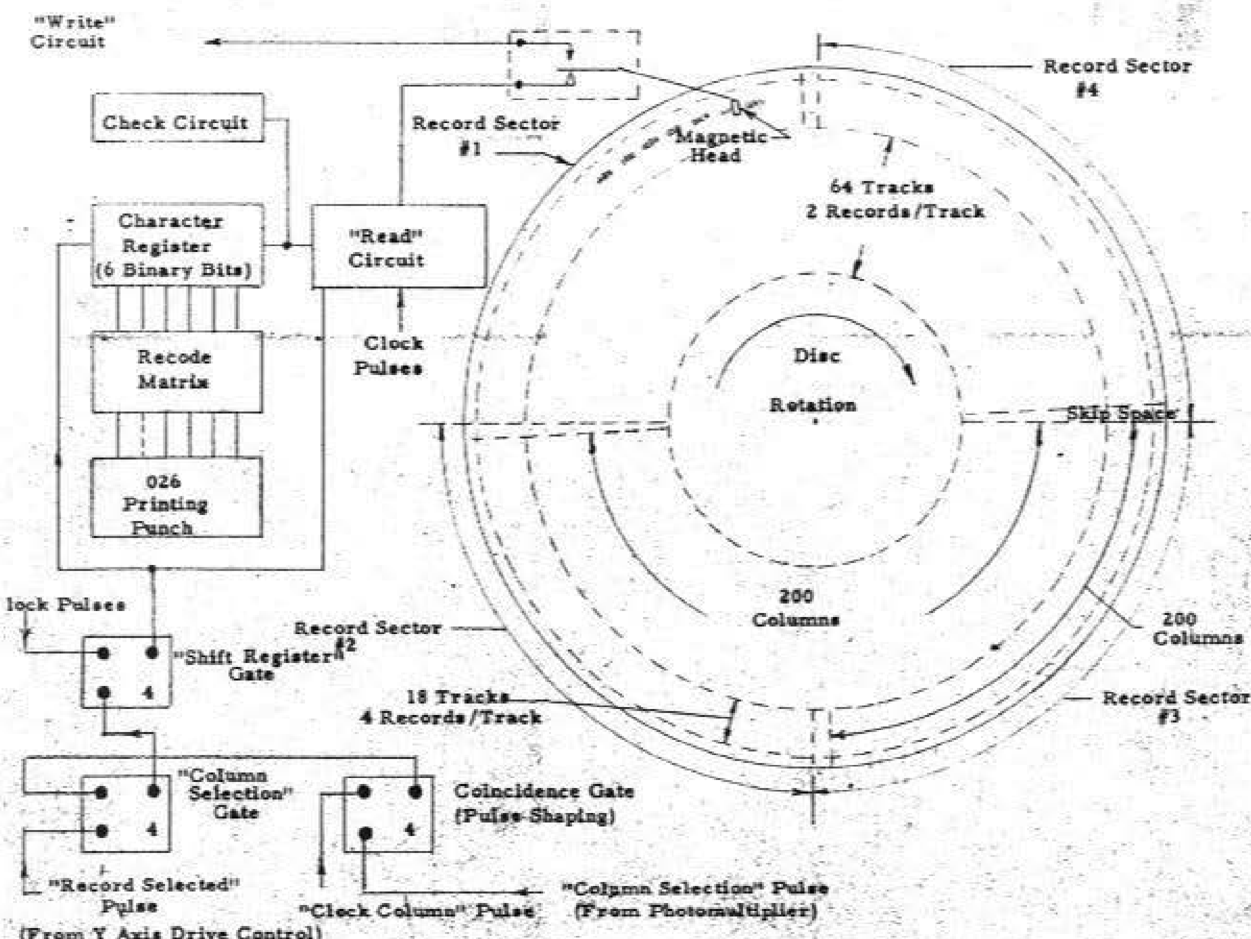


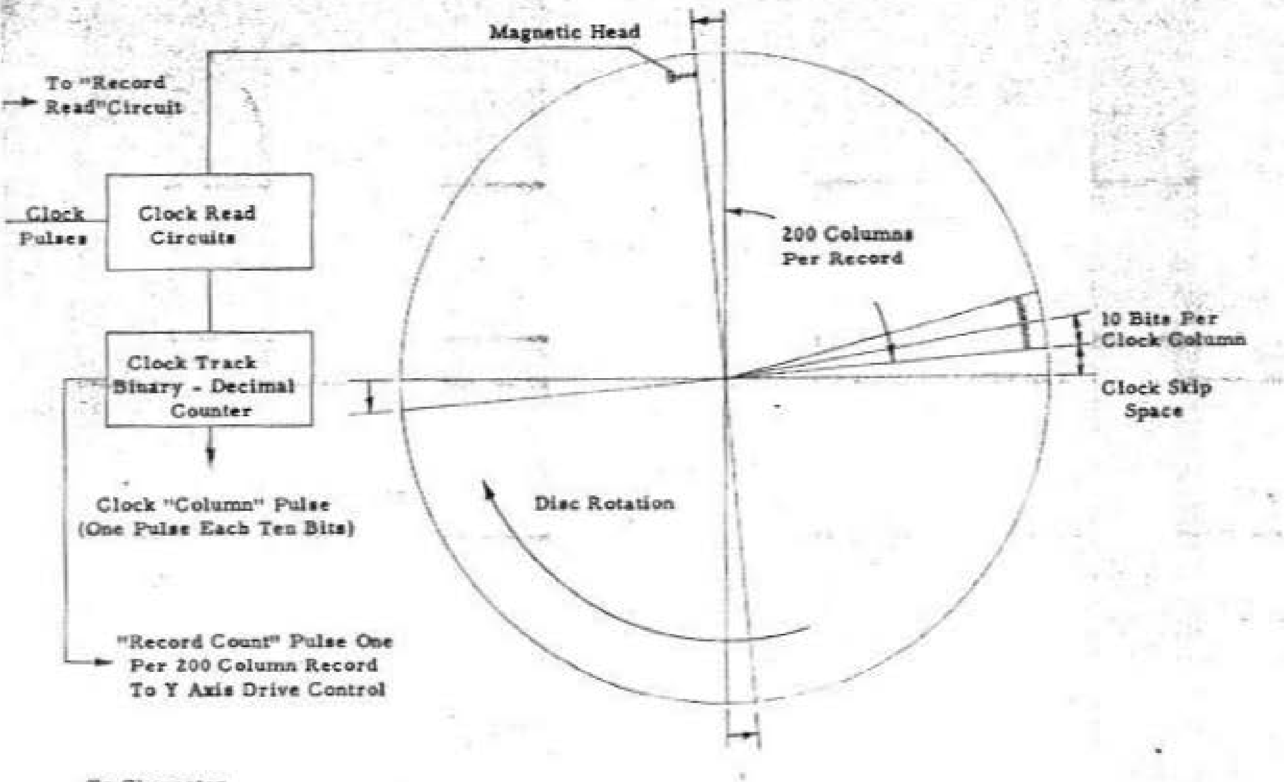
ENTRY INTO MAGNETIC DISC MEMORY FROM 026 KEYBOARD



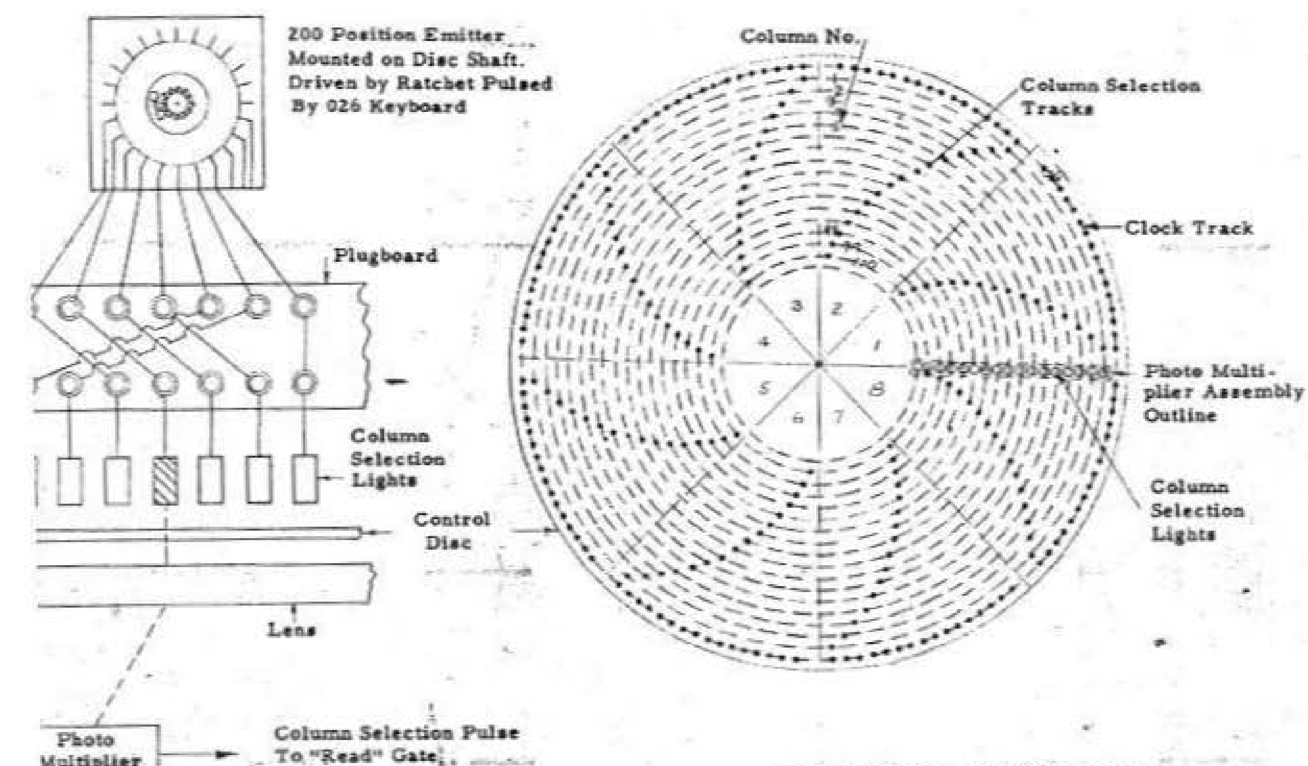
READOUT FROM MAGNETIC DISCS TO 026 PUNCH

ENTRY AND EXIT

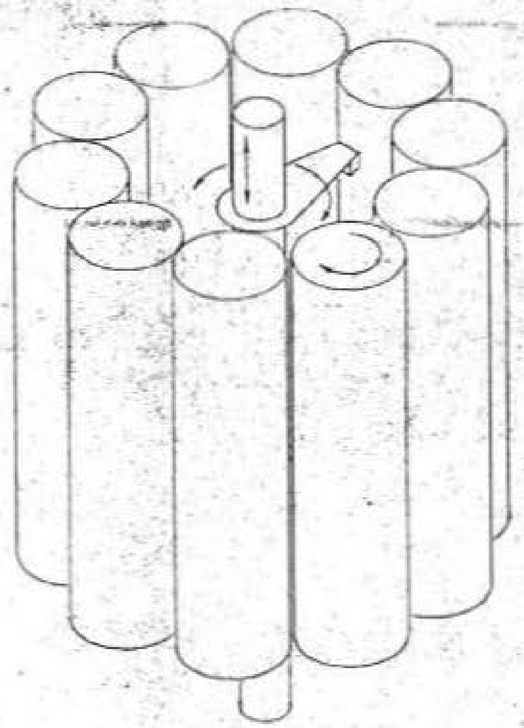
MAGNETIC DISC-RANDOM ACCESS MEMORY



CLOCK CIRCUITS - MAGNETIC DISC
LONGITUDINAL ARRAY
RANDOM ACCESS FILE



CONTROL DISC - MAGNETIC DISC
LONGITUDINAL ARRAY
RANDOM ACCESS FILE



MULTIPLE DRUM ARRAY

The multiple drum array would use existing drum techniques applied to 10 or 20 drums arranged in a circle with the drum axis parallel to the circle axis. Access would be by one magnetic head rotated and translated to the selected track on a selected drum. Drum rotation would provide the third degree of freedom for access as usual.

Ten drums, 20" long and 16" in diameter arranged on a 65" diameter circle will provide the desired storage for 20,000 records of 200 characters each if 20 tracks/inch and 200 bits/inch recording are used. Other configurations can be used of course.

<u>Advantages</u>

Well developed techniques

Buffer storage not required for many applications

<u>Limitations</u>

Size is much greater than other systems

Cost may be quite high

MULTIPLE-PLATE MAGNETIC STORAGE

In the multiple plate type of storage, information is stored on both sides of a coated aluminum or plastic sheet in the form of magnetized spots. From a closely packed stack of these plates, the proper plate is selected by moving the entire stack until the selected plate is opposite the reading station. The selected plate passes through the reading station as it is withdrawn from the stack. It is then returned to its original position by passing it back through the reading station in the opposite direction.

The reading (or writing) station is composed of 16 combination read-write heads, of which 8 are located above the selected plate and 8 are located below. If 200 columns of information are placed across the length of the plate, each head may read any one of 25 columns. All heads are positioned together by means of a sequencing unit. If the information in column 18 is to be read, the reading heads will be positioned at columns 18, 43, 68, 93, 118, 143, 168 and 193 simultaneously. The selection of the desired column of these eight is determined by accepting pulses from only the proper reading head. This switching may be handled electromechanically. The positioning of the heads and selection of the proper head is carried out simultaneously with the selection of a plate.

Clock pulses are provided by a single column of spaced magnetic spots at one end of each plate. As this storage method provides for an 8 bit self-checking code, it is necessary to provide a three stage flip-flop type counter to accept pulses from the clocking head. A new alphanumeric character is read each time after reset of this counter.

Movement of the plate may be accomplished by either feeding rolls or by a gripper type of movement similar to the 407 Tabulator card moving mechanism. As the plate is moved from the stack, any one of the heads on one side of the plate is active. During the return of the plate, the corresponding head on the opposite side of the plate is active.

Access time to any single column of information is estimated at 2/3 seconds maximum. This is estimated on the basis of the time re-uired to move 35 pounds through a displacement of 6.3 inches. This is comparable to the time and forces required in moving the 405 type assembly.

The erasing heads are so placed as to allow either read-erase or erase-write in one operation.

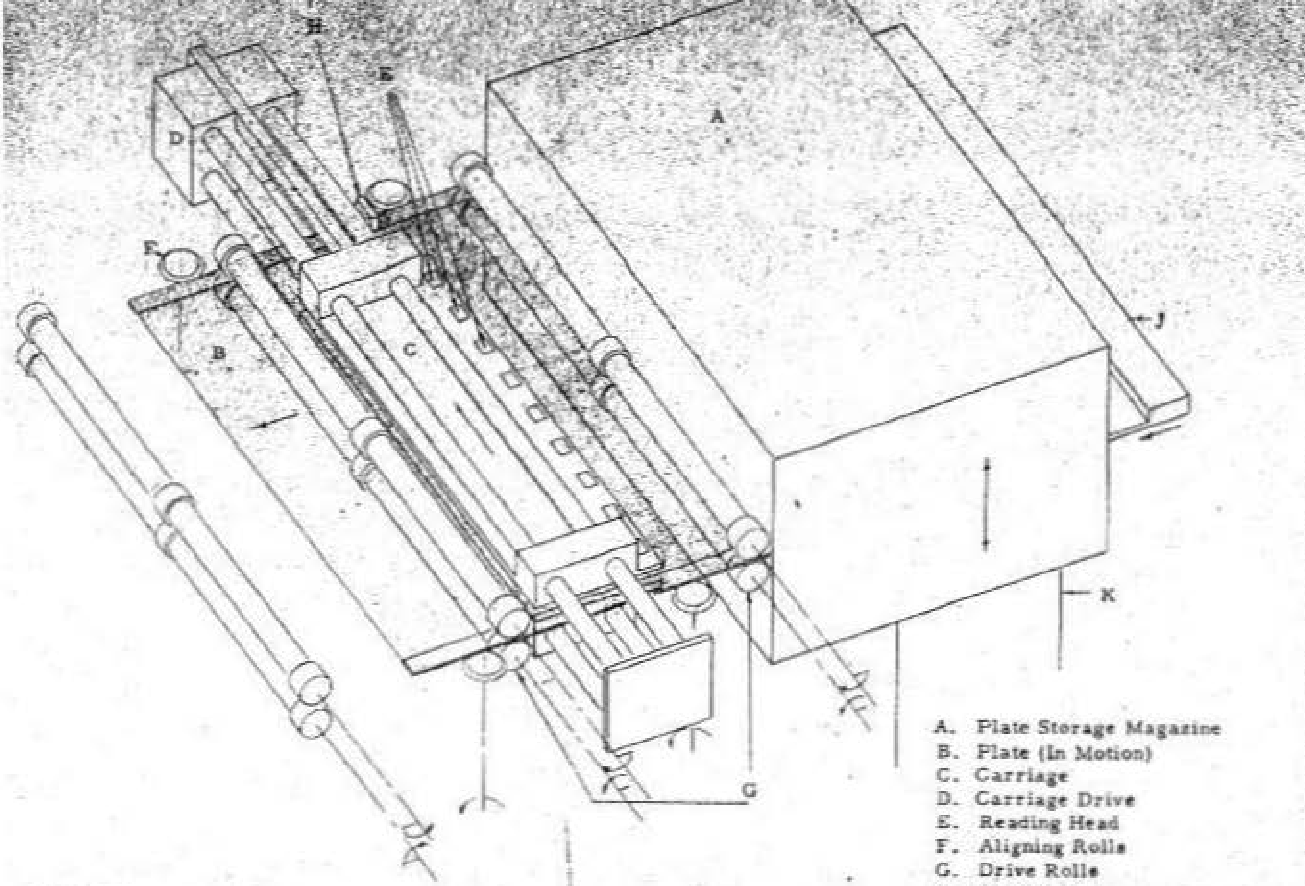
The following advantages are characteristic of multiple plate storage:

> If more than a single column of information is needed for any one item, the information may be stored or read by repeatedly moving a single plate back and forth through the reading station and activating each of the 8 reading heads successively.
>
> The speed of reading may be variable from 1 1/2 in/second (speed of the 026) to the maximum limit of the mechanical drive independently of access time. This feature makes the memory file more independent of input and output mechanisms, removing the need for buffer storage in a large number of applications.
>
> Since the plates are stacked as a unit, the entire memory file may be easily and quickly changed.
>
> The physical size of this type of system is relatively small.

The file is subject to the limitation that it is adaptable to simultaneous multiple access only by duplication of the file.

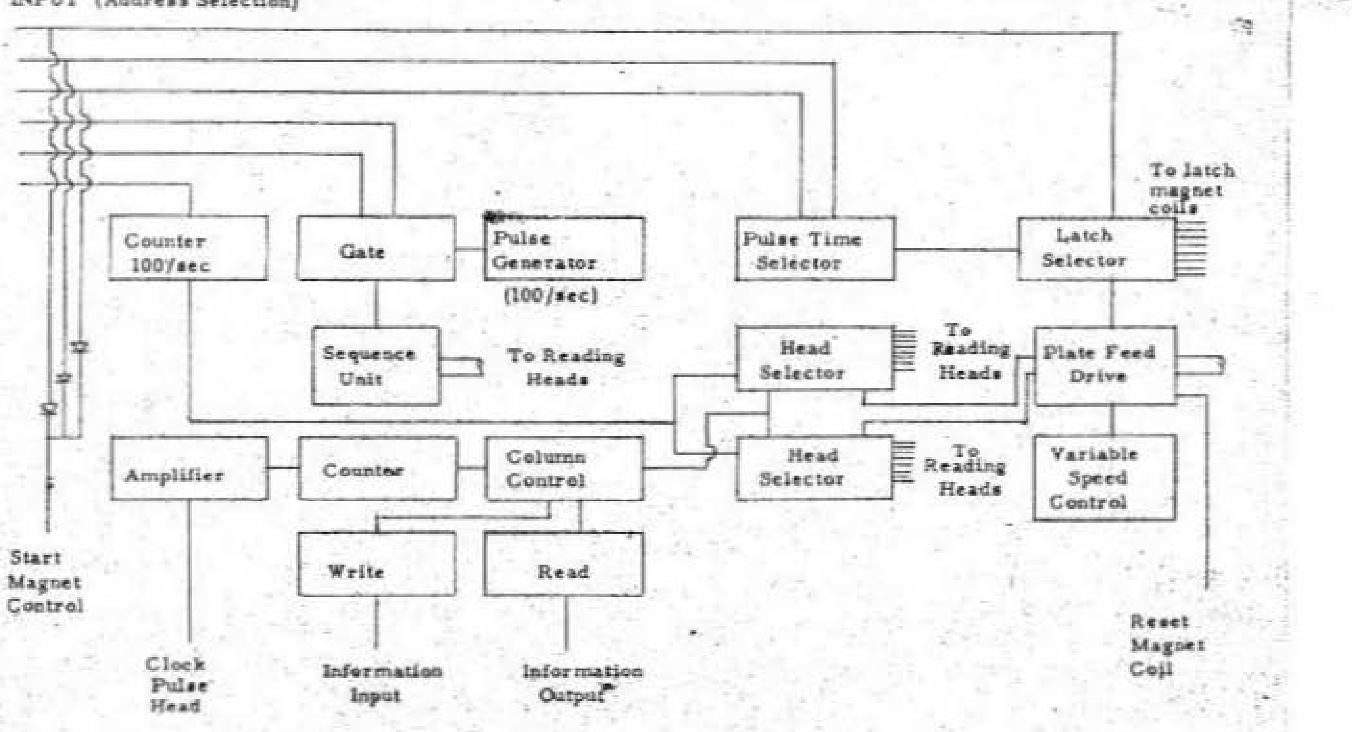
TABULATION OF MULTIPLE PLATE CHARACTERISTICS

Storage Bits per Inch	Columns per Inch	Plate Dimensions (Active Area)	Storage Bits per Plate	Number of Plates	Weight of File (lbs.)	Height of Stack (inches)	Decimal Digits Needed for Address	Volume Density of Storage Bits/in.^{3}
100	14	3 x 6	50,000	636	35	39.7	6	44,800
100	14	6 x 8	134,400	239	35	14.9	6	44,800
100	14	8 x 7.2	160,000	200	35	12.5	6	44,800
100	14	8 x 14.3	320,000	100	35	6.25	6	44,800
200	20	3 x 6	144,000	222	12	14	6	128,000
200	20	6 x 8	384,000	84	12	5.25	6	128,000
200	20	8 x 7.2	457,000	70	12	4.36	5	128,000
200	20	8 x 14.3	914,000	35	12	2.18	5	128,000



A. Plate Storage Magazine
B. Plate (In Motion)
C. Carriage
D. Carriage Drive
E. Reading Head
F. Aligning Rolls
G. Drive Rolls
H. Clock Head
J. Plate Feed Knife
K. Vertical Magazine Drive

MULTIPLE PLATE
MAGNETIC STORAGE



BLOCK DIAGRAM - MULTIPLE PLATE MAGNETIC STORAGE

PRELIMINARY INVESTIGATION OF APPLICATIONS FOR A RANDOM ACCESS MEMORY TO GENERAL PURPOSE DATA PROCESSING SYSTEMS

141

WHQ W. W. McDowell San Jose Laboratory

Preliminary report on applications for a Random Access Memory

April 29, 1953

The enclosed report is forwarded for your information. This report presents the results of a two week study concerning applications of a random access memory to data processing systems.

This material was presented to Messers Rubidge, Gifford, Hardway, Carr, of the Product Planning Division and Mr. Perkins special representative in San Francisco on their recent visit to the Laboratory.

JWH

J. W. Haanstra

JWH/lb
Enclosure
cc: R. B. Johnson
L. D. Stevens

LABORATORY ONLY

IBM RESEARCH AND DEVELOPMENT LABORATORY
San Jose, California

ABSTRACT

A study is made of the applications of a Random Access Memory to data processing systems. A series of machines is proposed, the simplest of which would handle problems such as file reference and the most complex would be capable of handling the complete range of business problems. The emphasis in the planning is toward an inexpensive and relatively slow machine adapted to the needs of small to moderate sized applications. The results of the study indicate that systems of this type would find wide application in almost all phases of business operations. Recommendations for increased effort in developing an effective Random Access Memory and for continuance of this type of study are made.

PRELIMINARY INVESTIGATION OF APPLICATIONS FOR A RANDOM ACCESS MEMORY TO GENERAL PURPOSE DATA PROCESSING SYSTEMS

by

LABORATORY STAFF

IBM RESEARCH AND DEVELOPMENT LABORATORY
San Jose, California

ABSTRACT

A study is made of the applications of a Random Access Memory to data processing systems. A series of machines is proposed, the simplest of which would handle problems such as file reference and the most complex would be capable of handling the complete range of business problems. The emphasis in the planning is toward an inexpensive and relatively slow machine adapted to the needs of small to moderate sized applications. The results of the study indicate that systems of this type would find wide application in almost all phases of business operations. Recommendations for increased effort in developing an effective Random Access Memory and for continuance of this type of study are made.

TABLE OF CONTENTS

TITLE: PRELIMINARY INVESTIGATION OF APPLICATIONS FOR A RANDOM ACCES MEMORY TO GENERAL PURPOSE DATA PROCESSING SYSTEMS

BY: LABORATORY STAFF

Introduction

This paper presents the results of a two week study by five members of the San Jose Laboratory Staff to examine the potentialities of a Random Access Memory as the basic component of a general purpose data processing system. A previous paper (1) has described some of the possible approaches to the development of a Random Access Memory; another paper (2) has presented the application of this type of device to the Source Recording Problem. In this paper a Random Access Memory of certain characteristics is assumed and consideration is given to the possible machines which could be built around this component.

Many times in the planning it has been possible to reduce operation times by adding equipment, or reduce equipment requirements by increasing operation times. The latter choice has been taken whenever reasonable in order to arrive at a series of machines which would find wide application for small to medium-sized data processing requirements. It is felt that appropriate combinations of the components planned could provide a good solution to moderately large data processing requirements. For the very large requirements, machines such as the Tape Processing Machine are considered applicable.

This study has indicated that a series of machines may be best suited to the full utilization of the capabilities of a Random Access Memory. This series ranges from a source recording or file reference machine, through machines capable of preparing accounting and statistical reports on a limited basis - applicable to requirements somewhat below those where card machines are best utilized - on up to a General Purpose Data Processing System with complete flexibility for preparing any type of accounting or statistical report. This complete data processing system is somewhat slower than a card system; however, it may eventually prove superior with its reduced operator requirements and its greater applicability to business procedures in areas where the card system offers only the tub file or the key punch. For the more immediate future, the machines planned around a Random Access Memory compliment the card system, and offer a new type of machine applicable to business requirements where the versatility and speed of the card system in preparing wide varieties of reports is not required.

2. Data Processing Systems Planned About a Random Access Memory

2.1 Random Access Memory

(1) "Proposal for a Random Access File" A. J. Critchlow, IBM Research and Development Laboratory Report, February 6, 1953

(2) "Proposal for A Source Recording System" A. J. Critchlow, IBM Research and Development Laboratory Report, February 2, 1953.

The Random Access Memory about which the machine planning has proceeded consists of two hundred magnetic disks spaced along a linear shaft. These disks rotate at a speed of 20 revolutions per second. With two dimensional motion of magnetic heads which read the disks, it is anticipated that the access time to any record in the file will be of the order of 1 second. Estimates as to the ultimate storage density indicate that a capacity of 40,000,000 alphanumeric characters may be achieved. Two characteristics of the disk system important to the applications considered are the multiple accessibility and the rapid systematic scanning facility. Figure 1 summarizes these characteristics.

Assuming the information in the Random Access Memory to be divided into 400,000 records of 100 columns each, it can be seen that this file will store practically all information of interest in even moderately large business applications. Thus given a storage facility capable of holding all information of interest, given access to any record in the file in one second, and given the facility of automatically reading the record once obtained with no loss of time, one can proceed to consider many types of processing machines based on such a system.

2.2 The File Reference - File Maintenance Machine

Figure 2 shows the addition of three types of components to the Random Access Memory. The keyboard-printer units, called transactors, are used for remote interrogation or entry of data to the file, and read out from the file. The transaction processing unit is provided to perform the necessary control of information between transactors and Random Access Memory, and to provide arithmetic and control facility to operate on the data from the keyboard and data from the Random Access File. A transaction recorder is provided to give a printed record of all transactions.

The simplest application for this machine would be that of file reference where it is necessary to obtain information from a central file at remote stations. If the facility for addition, subtraction, and limited programming is added to the transaction processing unit, this machine becomes a very effective tool in the area of file maintenance. Thus it would be possible in say a sales application to process orders by obtaining complete commodity and customer information on incoming documents. The arithmetic facility along with simple programming would allow up to the minute balance forward operations on commodity files. In general this system would provide facility for a large part of the "in line" or random data processing so necessary in almost all business applications. A few of the potential applications are:

Commodity Sales and Distribution

- Wholesale Grocery, Drug, etc.
- Department Stores
- Military Supply Operations

Banking Operations

Checking, Savings, Christmas Club, etc.

Inventory Control

Applicable to most any business

2.3 File Reference and File Maintenance with Card Processing

In all businesses there is a requirement for processing of data periodically to produce various types of reports. Examples are:

Sales Analysis
Commission Statements
Monthly Statements
Inventory Reports

The IBM Card system is a valuable tool for the automatic preparation of such reports. Figure 3 illustrates how the card system could be utilized along with the machine described in the previous paragraph. A card punch is used as the transaction recorder and the cards so produced may be processed by conventional means with card machines. This system offers much over the conventional card system in that the new machine supplies facility in the areas where the card system is weakest.

2.4 Systematic Processing with a Random Access Memory

While the system described in section 2.3 will handle very effectively a wide range of business applications, there are some shortcomings. Among these are:

Duplication of files in the Random Access Memory and the Card System

The Card system often forces one into a more elaborate accounting system than is required.

The number of operators required in a card system is expensive

Information is being handled in two different ways, usually resulting in inefficiency.

Since all information which is required for the periodic processing and report preparation is available in the Random Access Memory, one is immediately led to the consideration of a mechanism to process this information directly without transferring the information to a medium such as cards.

In the past few years a tremendous engineering effort has been expended toward the development of General Purpose Computing Equipment. Machines of this type have been very large and very fast, and for the most part have been slanted toward solution of mathematical problems. The problems encountered in business applications are nothing but a rather simple class of mathematical problem. A General Purpose Computer then can handle any business problem with ease. In many cases the reason for the size of these computers has been the high speeds required, in other cases the reasons lie more in the infancy of the art resulting in a lack of suitable components. It is felt that by not requiring very high speeds and by utilizing some of the newer components that are now becoming available one can begin to think in terms of general purpose data processing units of a moderate size.

Figure 4 shows a data processing unit associated with the Random Access Memory. It is assumed that this unit is substantially a general purpose stored program arithmetic unit with the facility for handling alphanumeric characters, and one in which time has been sacrificed in the interests of minimizing equipment wherever possible. As indicated in the diagram this unit has associated with it one or more serial printers and an input unit. The addition of the data processing unit will permit the same type of flexibility in data processing and report preparation as may be achieved with the card system but with a reduced operating speed.

If a few card machines are retained, cards may be sorted in the order required for reports, and the cards used to program the sequence of reference to records in the Random Access File. Without any cards sorting and collating may be done using the data processing unit; however this is a rather slow operation and would not adapt itself too well to sorting in many ways to produce a variety of reports.

2.5 Historical File

In many applications it is necessary or desirable to retain detailed records for some fixed period of time. While these records have been completely processed there is always the chance that some new report involving this information will be required It is not feasible to consider keeping information of this type for long periods of time in the Random Access Memory, as it would soon use all of the available memory capacity. For this reason, it is considered necessary to provide an optional facility for the storage of this type of data. Figure 5 shows the addition of the Historical File to the previous system.

Several alternatives for the historical file are suggested in section 4 of this report. It should be noted that it is net necessary to always have this facility since a printed record may form an adequate historical file. The addition of this unit would be for applications where automatic re-entry of historical information is deemed necessary.

2.6 Sorter-Collator

It was pointed out in section 2.4 that to produce the wide varieties of reports sometimes required in business applications it is necessary to sort and collate the records prior to processing. This can be accomplished with the aid of card machines as an adjunct to the system, or for applications where a small amount of sorting and collating is required, the data processing unit will suffice. The former solution requires card files of records containing the information on which sorting may be required, and the latter solution will be a time consuming one.

In order to avoid the difficulties referred to above, it is thought desireable to provide a sorter-collator as an optional machine for this system. Figure 6 shows the complete system with the sorter-collator added. This machine would be designed specifically for these tasks and would hence be a relatively small, special purpose device. Four independent accesses to the Ramdom Access Memory are provided to allow full utilization of the systematic searching facility provided by the disk type of Ramdom Access Memory. This machine would provide for sorting records at a rate of about 80 records per minute independent of the length of the sort control field.

2.7 System Operating Speeds

Preliminary estimates of the operating speeds of the systems described in the previous paragraphs indicate the following:

Ramdom Access to Memory	1 second
Systematic Search of Memory	20 records per second
Processing of a single Record	1/2 second
Sorting with the Data Processing Unit	5 records per minute*
Sorting with the Sorter Collator	80 records per minute*

These operation times are based on assumptions as to the characteristics of the various units mentioned. It should be noted that should some of these times prove excessive in certain applications, it is possible to improve most of them by the addition of extra equipment.

3. Applications of the Planned Systems

It is difficult to describe the operation of the various phases of the proposed system without considering specific problems on which the machine might be used. Even with a specific problem at hand, a detailed program would be necessary to completely indicate the particular manner in which a problem is solved. While it has not been possible to program a problem in detail, two broad applications for the planned systems are described in this section.

3.1 The Banking Problem

---

* This is the time for a complete sort and is independent of the length of the sort control field.

We shall now indicate briefly how a Ramdom Access Memory and its related equipment (as described in sections 2.1 - 2.7 above) can be applied on progressive levels to some information processing problems involved in banking.

3.1.1 Savings Deposit Accounting

The initial problem in savings deposit accounting is the actual transaction at the teller's window. Using conventional methods the customer must make out a transaction ticket and take it to the teller's window. With a card system, the teller sorts through a master tube file and selects the customer's account card. Once the transaction is completed the master card must be returned again to the master tube file. This costly and time consuming hand sorting and filing would be eliminated with the use of a Random Access Memory.

With a Random Access Memory replacing the present tube files of master account cards, each deposit or withdrawal transaction could be completed in a shorter period of time. Assuming that it takes approximately one minute for a teller to walk over to the master tube file and hand pull the customer's account card, we see that a Random Access Memory could speed up savings deposit transactions by a factor of about 60. This would mean that fewer tellers would be needed to handle the daily transactions, customer lines in the bank lobby would be reduced, the filing space would be decreased, and there would be practically no chance of mis-filing cards.

With the Random Access Memory, the customer would take his transaction ticket and passbook to the teller's window, the teller would key in the relevant information, the customer's account would be automatically modified to correspond with the transaction ticket, and the corrected up to date account information would be printed out into the customer's passbook. This would give the customer a permanent history of his account including a record of every transaction.

With the addition of a Data Processing Unit, it would be possible to automatically calculate the interest for each account and modify the record accordingly. Since a record of the lowest balance for every 30 day period is kept in the customer's account, the data processing unit could be instructed monthly to go through every account, multiply the interest rate by the low period balance and add this amount to the current balance. The total interest paid out would also be recorded. It should be mentioned that the machine would keep a daily record totaling all of the deposits and all of the withdrawals so that the books could be balanced more rapidly at the end of each business day.

Additional accounting and statistical reports that the bank may require would be produced by the data processing unit.

3.1.2 Checking Accounts

It is not difficult to visualize how the above mentioned equipment could be applied to checking accounts. It would probably store in the memory a record of the monthly activity of each account. This history would be kept up to date constantly and at the end of each 30-day period it could print out the customer's statement.

3.2 Commodity Sales and Distribution Applications

A great many business operations may be characterized as Commodity Sales and Distribution applications. This area includes the complete area of middleman distribution such as wholesale grocery and drug, meat packing houses and many others. Department stores and mail order houses may also be classified in this area. The paper processing required in these applications is quite large, and it is felt that the planned systems would lend themselves well to increased efficiency in these operations.

3.2.1 Applications of the File Reference - File Maintenance Machine

The basic File Reference - File Maintenance Machine described in section 2.2 would be used for:

Entry of information from orders

Reference to Customer file for credit report, address information, etc.

Reference to Commodity file to check on availability, cost, etc.

Entry of information from order to a transaction file. This file would consist of records containing information necessary for subsequent processing.

Entry of information from receiving department

In order to maintain an up to date record of commodity availability, information on received commodities may be entered in the commodity file upon receipt.

Maintenance of an up-to-date record of what is in stock

The stock records would be kept up to date, and it would be possible to print out an inventory list to check against the physical inventory.

In this manner the machine is performing the functions of processing orders as they are received and also maintaining an accurate record of commodity availability which may be referred to rather rapidly. A futher function of the machine is the entry of all information which will be required in subsequent processing to produce various reports and statements. In cases where this machine is to be used in conjunction with a card processing system, transaction cards would be pun ched containing all information necessary for preparation of the required statements and reports.

A list of steps which might be used in processing an order is given below:

1. Supervisor audits order to verify that necessary information is present.

2. Operator keys customer account number, machine prints customer name and address for verification. In the event that only customer name is available on the order, a catalog such as a flexoline file will have to be used to obtain customer account number.

3. Following verification, the machine assembles all customer information necessary for subsequent processing in a transaction record.

4. Operator keys item number for first commodity on the order. The machine prints commodity description for verification.

5. Operator keys the item amount. The machine checks availability of of commodity and notifies the operator if the required quantity is available. It it is, the quantity ordered will be subtracted from the number on hand. If it is not, operator will be so informed and may substitute, backorder, or perform any other appropriate operation.

6. The machine places the information concerning the item in the transaction record for subsequent processing.

7. Repeat steps 4, 5 and 6 for all items on the order.

8. The transaction record may now be punched into a card (or cards) where card processing is to be used, or may be entered in the transaction file portion of the Random Access Memory where a data processing unit is available for preparation of reports and statements.

While this series of steps may be incomplete for any specific application, it is given to present an idea as to how the machine may be utilized. Sufficient flexibility would be engineered into the machine to allow adaption to the requirements of any specific application.

3.2.2 Applications of the Data Processing Unit

There are a wide variety of statements and reports which must be prepared from the information associated with orders, and the other operations characteristic of this type of application. Among these are:

Invoices
Daily Cash Journal
Accounts Receivable Statements
Collection Commission Statements
Sales Analysis Reports
Inventory Reports
Customer Analysis Reports
General Ledger Work

These and other reports may be prepared using the Data Processing Unit. For a relatively small operation, each report may be prepared by scanning through the transaction file, selecting the transactions applicable to a particular section of a particular report, processing the information in the data processing unit, and printing out the data required on the report form. Alternatively a portion of the Random Access Memory may be set aside for each report to be produced and the information may be distributed to the proper sections as it is entered. This procedure would require more memory space, but would permit more rapid report preparation.

In applications where neither of the above approaches are satisfactory either from the point of view of requiring too much equipment or too much time, sorting of information in the transaction file will have to be used. This may be accomplished by punching transaction cards when the transactions occur, sorting the cards according to the sequence required for the report and using the cards for selection of records from the transaction file. Alternatively the transaction file may be sorted by the data processing unit, or if this is too slow, the sorter-collator described in section 2.6 of this report may be used.

4. Technical Description of the Planned Machine

The purpose of this section is to present and discuss block diagrams which describe in somewhat more detail the functions of the various component units which have been previously considered.

4.1 Random Access Memory and Buffer Storage

As indicated in Figure 3, a single magnetic drum provides buffer storage between the Random Access Memory and the various information processing units. The manner of utilization of this buffer storage drum varies among the units, but in no case need it store more than a few records at a time. It can, therefore, be of rather modest proportions.

4.2 Transaction Processing Unit

This equipment, shown in block diagram in Figure 4, when connected to the Random Access Memory, would form the simplest and least expensive useful configuration of components. It would perform the functions of file reference and file maintenance.

The equipment consists of one or more Transaction Keyboard and Verifying Printer Assemblies used to enter references to the Random Memory and to display verification and file contents data, an Input-Output Exchange which prevents inquiry by more than one operator at a time and directs the reply to the proper receptor. An Arithmetic Unit capable of altering the contents of the file in accordance with data entered at the keyboards, a Transaction Recorder which produces either a printed form or punched cards, or both, listing the details of each transaction.

The operator inserts at the keyboard the address code of the desired file entry together with any additional data not contained in the file but which must be entered on the transaction record or utilized by the machine in altering the stored data. (In the stock control application, for instance, such additional data might consist of the customer's order number and the quantity ordered). There are then two options open to the operator, (a) he may make a simple inquiry, in which case the contents of the file is printed out at his station (perhaps with some arithmetic manipulation, for example to determine whether billing the order would violate the danger or reorder levels), or (b) he may initiate a transaction (of which there may be available several varieties) in which case the indicated alteration of the file is performed in addition to the foregoing.

In any case once an inquiry or a transaction is initiated by any keyboard, the Input-Output Exchange prevents access to the Random Access Memory by all other keyboards and keeps the channel open to the active keyboard until the operation is complete. It is visualized that a transaction would take about 3 seconds, including access to the memory, performance of necessary arithmetic and printing out. Priority of access among the keyboards may be on a "first come-first served" basis or on a rotational basis.

The Arithmetic Unit, capable of addition and subtraction only, performs the simple operations necessary for file maintenance and can be connected to alter the program in the event of a negative balance (as would be required in the event that filling an order results in violation of the danger level or permitting a withdrawal produces an overdrawn account.

The program and Control Unit, operating on the instructions of a plugged program provides the necessary electrical signals to control the flow of data between the other components.

It is visualized that the Transaction Recorder would be either a serial card punch or a serial printer or both. While it would be possible to fill the memory initially from the keyboard it is likely that many customers would already have the necessary data on punched cards. The card machine could then be used for this purpose.

The details of each transaction can be recorded internally in chronological order in a section of the Random Access File reserved for this purpose. This feature will be found necessary in conjunction with the Data Processing Unit described in the next section.

4.3 Data Processing Unit

The next step in the evolution of the machine is the addition of the Data Processing Unit shown in Figure 5. This is essentially a general purpose computing facility in that it has a stored program which is alterable by the results of computation. High speed, however, would be sacrificed for simplicity of equipment.

The same magnetic drum which is used as a buffer storage for the other processing units stores the required instructions, the few records at a time withdrawn from the Random Access Memory for processing, and the summary results of computation. Instructions (and perhaps original data) is entered initially onto the drum via the Input Unit which will probably be a serial card reader.

The primary function of the Data Processing Unit is the preparation of final reports and other documents. The information necessary for such reports is all continued in the section of the Random Access Memory reserved for a chronological recording of transactions but the sequence must be rearranged in the order desired for reports. The rearrangement can be accomplished in several ways. In the first method "pigeon holes" by categories for each of the more important reports are reserved in a separate section of the Random Access Memory. Enough spaces must be reserved in each category for the maximum number of entries possible in that category (unless some method of systematically handling overflow is resorted to). Then periodically the Data Processing Machine scans the chronological transaction file and routes each entry to its proper slots in the several records. During this process whatever documents (shipping tickets, bills of lading, confirmation of deposits, etc.) necessary for each transaction are produced.

It is to be noted that the above procedure, while conservative of machine time in some respects is wasteful of storage space in the Random Access Memory and should therefore be resorted to, if at all, only for a few reports (perhaps 4 or 5) which are certain to be required each reporting period.

Special reports and perhaps even routine reports can be handled by sorting down the entries in the chronological transaction file for each report successively. This can be accomplished in several ways. (a) The card file of transactions accumulated by the Transaction Recorder of the Transaction Processing Unit can be arranged in proper sequence by a conventional card sorter and used to program the Data Processing Machine to extract records in proper sequence from the internal chronological transaction file. (b) The Data Processing Machine itself can perform sorting and collating operations by a process of field comparison in the arithmetic unit. Or, (c) if it is desired not to introduce the punched card and alternative (b) is deemed too wasteful of machine time, the separate unit described in Section 4.4 can be employed.

The choice of methods of rearranging transaction for report preparation obviously depends on the application, the number of reports involved, the number of transactions in the period, the number of digits in the sort, and the number of report categories, but, due to the general purpose nature of the Data Processing Unit, the method need not be specified in advance.

As many printers might be provided as there are levels of detail in the desired reports. That is Printer No. 1 might be producing a sales report by State, Sales office, salesman, and invoice number while Printer No. 2 produces a report by State and office with summary data for each salesman. Fifty characters per second serial printers are proposed.

4.4 Sorter Collator

For those applications in which (a) sorting is required for special report, (b) it is desired to divorce the system entirely from the punched card and (c) the Data Processing Unit is too commpletely occupied otherwise to perform the sorting operation, a separate electronic Sorter-Collator Unit will be provided. A block diagram of this unit is shown in Figure 6.

Registers A, B, and C are sections of the Buffer Storage Drum common to all processing units. Initially the first two entries from the chronological transaction file are brought, via the Record Address Selection Unit and the Switching Unit to Registers A and B. These two entries are compared in magnitude in the Comparison Unit on as many fields and in any field sequence as is selected by the control panel of this unit. A signal from the Comparison Unit indicates to the Control Unit which is the smaller and this number is returned as the first entry to Space X on the Random Access Memory, and is also entered in Register C.

The next entry from the chronological transaction file is then brought to the Register just vacated by the smaller number above and compared with the contents of the other two Registers. If both A and B are larger than C, the smaller of the two is returned as the second entry to Space X. If A or B but not both is larger than C, the larger is returned to Space X. If neither is larger than C then the ascending sequence being established in Space C would be broken by entering either, and so the smaller is entered in Space Y to start a new sequence.

After the chronological transaction file has been exhausted in this manner, another pass is made on the data now stored in Spaces X and Y. If there are n entries in the transaction file it will take no more than $\log_2 n$ passes to completely order the file in ascending sequence. Of course, descending sequences can be achieved as well.

A fixed program for accomplishing the above is provided by the Program and Control Unit.

4.5 Historical File

It is possible to maintain summary data in the Random Access Memory for extended periods for purposes of quarterly or annual reporting, but, because of legal requirements or user policy, it may be necessary to retain data for such long periods that this solution is untenable. In this case it is desirable to make provisions for storing such information externally to the machine yet in such a form that it can easily be re-entered if necessary. The cards produced by the Transaction Recorder could be used thusly, but since it is a detailed record it might soon become unwieldly.

It might prove feasible to solve the historical file problem by recording summary data on certain discs of the Random Access Memory reserved for that purpose and physically removing these discs from the assembly at periodic intervals for storage. Alternatively, equipment to preserve the summary data in punched cards or tape, shown in Figure 7, can be provided as an option.

5. Conclusions

This study has indicated that the Random Access Memory is extremely useful as a component for data processing systems. A series of machines may be constructed around this component which would be capable of handling the complete range of business problems. It might be said that a Random Access Memory is a component which has the possibility of eliminating the need for a physically independent unit record such as the punched card. This of course cannot extend to the area where cards are used as documents.

This study has indicated that in addition to the random access time, one should be concerned with the rate at which a random access memory may be systematically scanned. It is important in the preparation of records and statements that the systematic scanning speed be in the region of 10 or more records per second.

Several times during this study it has been noted that a Random Access Memory as a component would make an excellent input-output unit for a data processing system such as the Tape Processing Machine. The remote entry of data to such a unit would make the tape processing machine much more adaptable to large applications such as manufacturing control, magazine subscriptions and the larger applications of the business operations discussed in Section 3 of this report.

Due to the variety in size of applications encountered it has not been possible to specify requirements on the size of Random Access Memory. Probably the best general statement that could be made is that it should be capable of holding all the information contained in active card files for a card installation. If a high speed loading facility is available with the Random Access Memory one could probably interpret active as meaning active in a given day or week rather than active in a given month or year.

While the use of a General Purpose Data Processing Machine has been taken for granted in this study, it is recognized that no such device exists for a reasonable cost. The utility of such a device in even the small applications indicates that there is a need for a low cost General Purpose Data Processing Unit. It would seem to be very necessary that in the near future IBM take steps to find out just how low priced a unit such as this might be. On the surface it looks as though a magnetic drum and about 500 tubes should be adequate for such a unit. The use of some of the newer storage techniques may well reduce the tube requirements. At any rate, it doesn't seem that such a unit represents any more equipment than say the 604 electronic card punch.

Finally the question of reliability should be mentioned. The machines discussed in this paper have the characteristic of doing more of the data processing job per machine than card machines do. There is also the point that the machines represent a higher level of automatic operation than do the card machines. For these two reasons machines of this type will seriously affect the operation of a business when they are inoperative and hence will have to be either more reliable than card machines, or study will have to be devoted to alternatives such as automatic error correction or possibly duplication of machines in order that a breakdown will not halt business operations.

6. Recommendations

The importance of the Development of an effective Random Access Memory can hardly be overestimated. Since this report has indicated that this component can be the basis for a very effective series of data processing machines it would seem that the efforts toward development of this type of component should be increased substantially.

It is further recommended that the study of the problems treated in this report be continued with the view of

1. Producing designs for the machines planned in sufficient detail to allow realistic cost estimates to be made.

2. Extending the application studies to other problems and to more detail in order to evaluate the planned systems in terms of their cost, speed and effectiveness in solving the problem of data processing in business applications.

7. Participants in the Study

This report is the result of a two week study at the San Jose Laboratory. Participants in this study include:

J. W. Haanstra
D. W. Kean
M. E. Maron
A. J. Critchlow
T. Leary

Mr. Haanstra had the responsibility for the study and preparation of the report. Mr. Kean and Mr. Haanstra concerned themselves with the technical aspects of machine planning. Messers Maron, Critchlow, and Leary did the application studies which were of invaluable importance in formulating requirements for the planned machines.

RANDOM ACCESS MEMORY

CAPACITY : 40,000,000 CHAR

RANDOM ACCESS : 1 REC/SEC

SYSTEMATIC SEARCH 20 REC/SEC

FIGURE 1

RANDOM ACCESS MEMORY

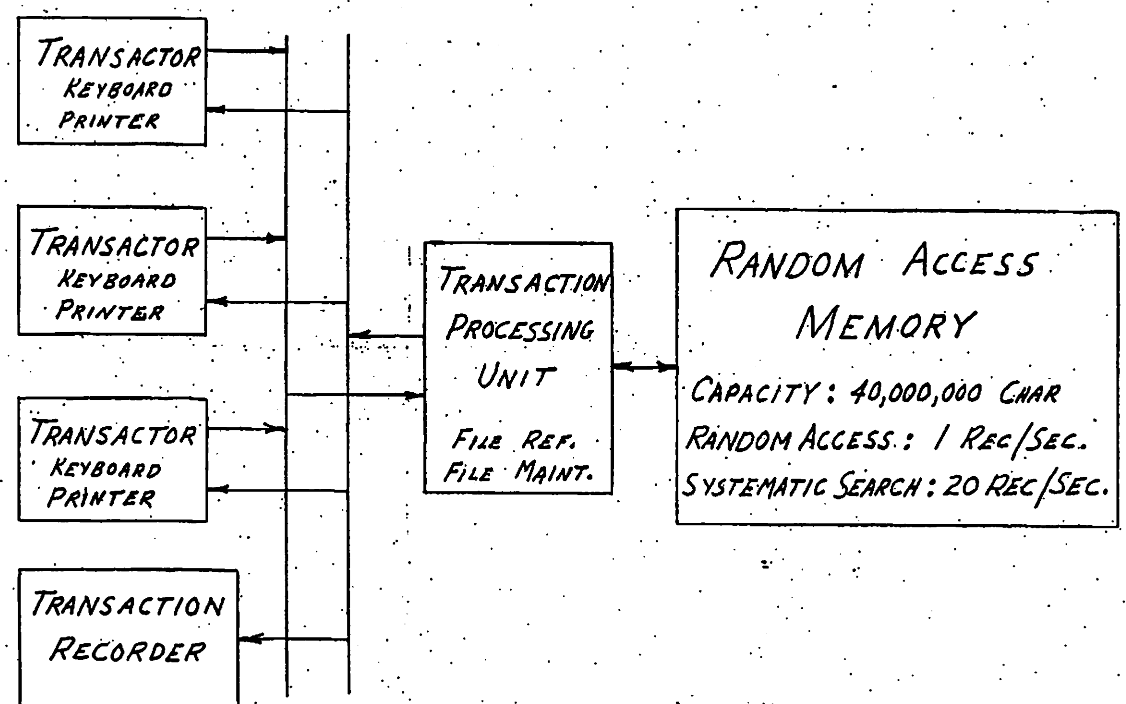


FIGURE 2

FILE REFERENCE - FILE MAINTENANCE MACHINE

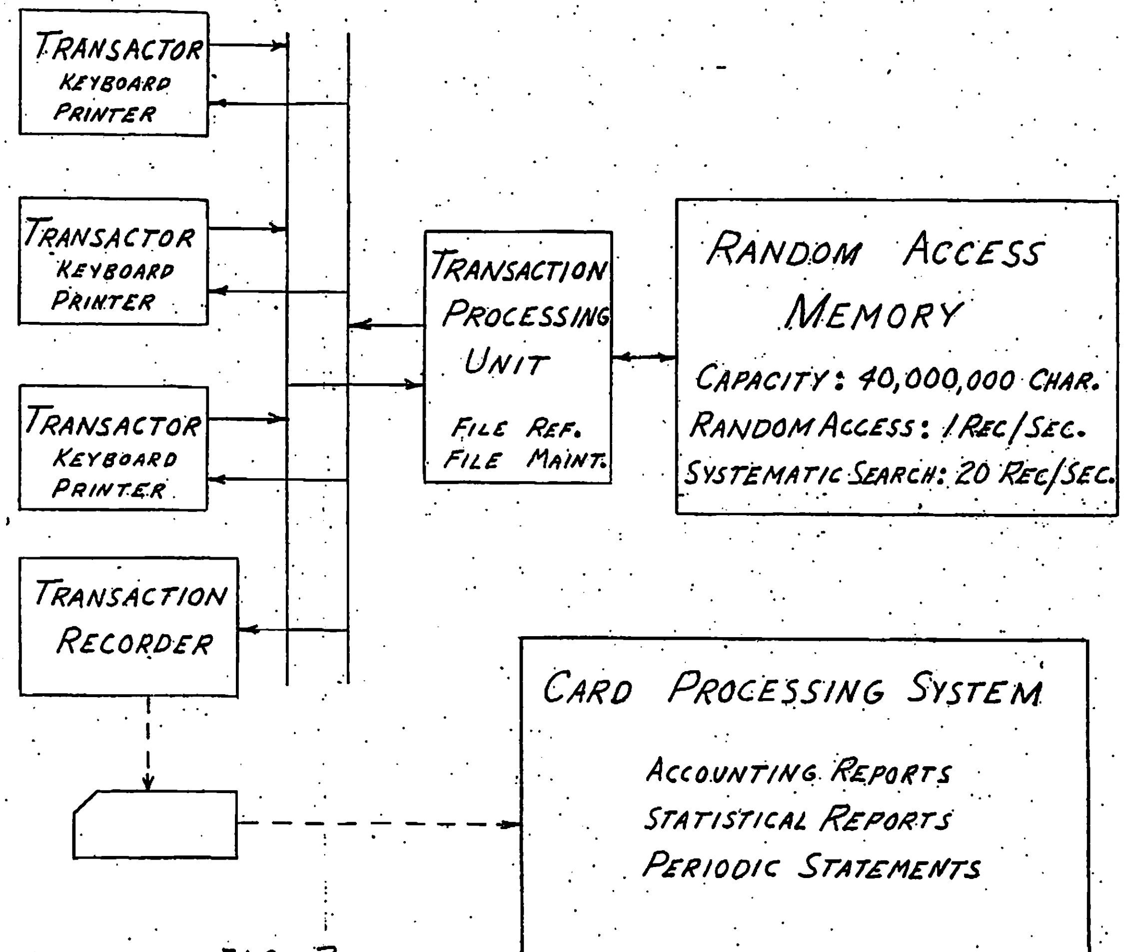
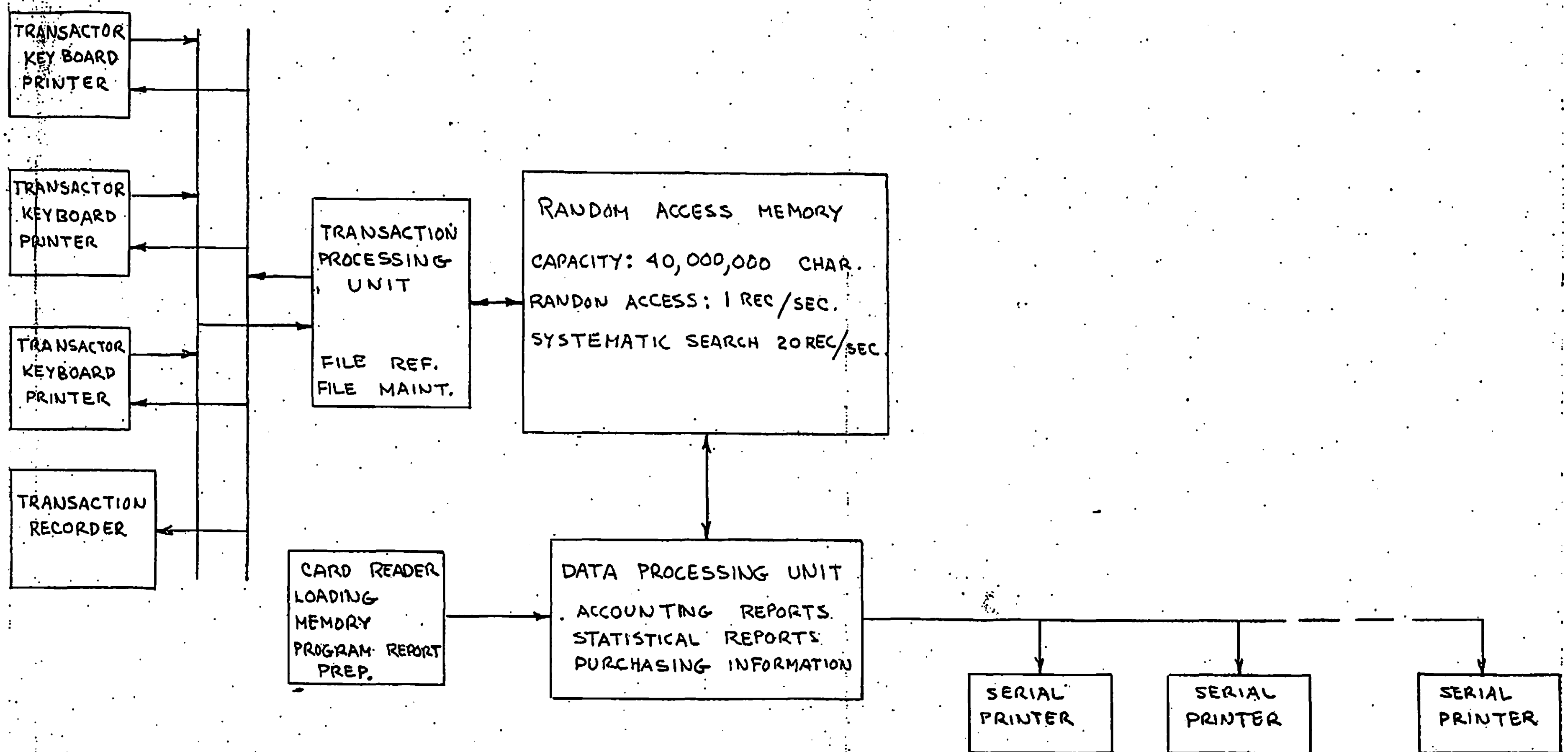


FIG. 3

FILE REF. — FILE MAINT. MACH
WITH CARD PROCESSING SYSTEM.

DATA PROCESSING UNIT

FIG. 4



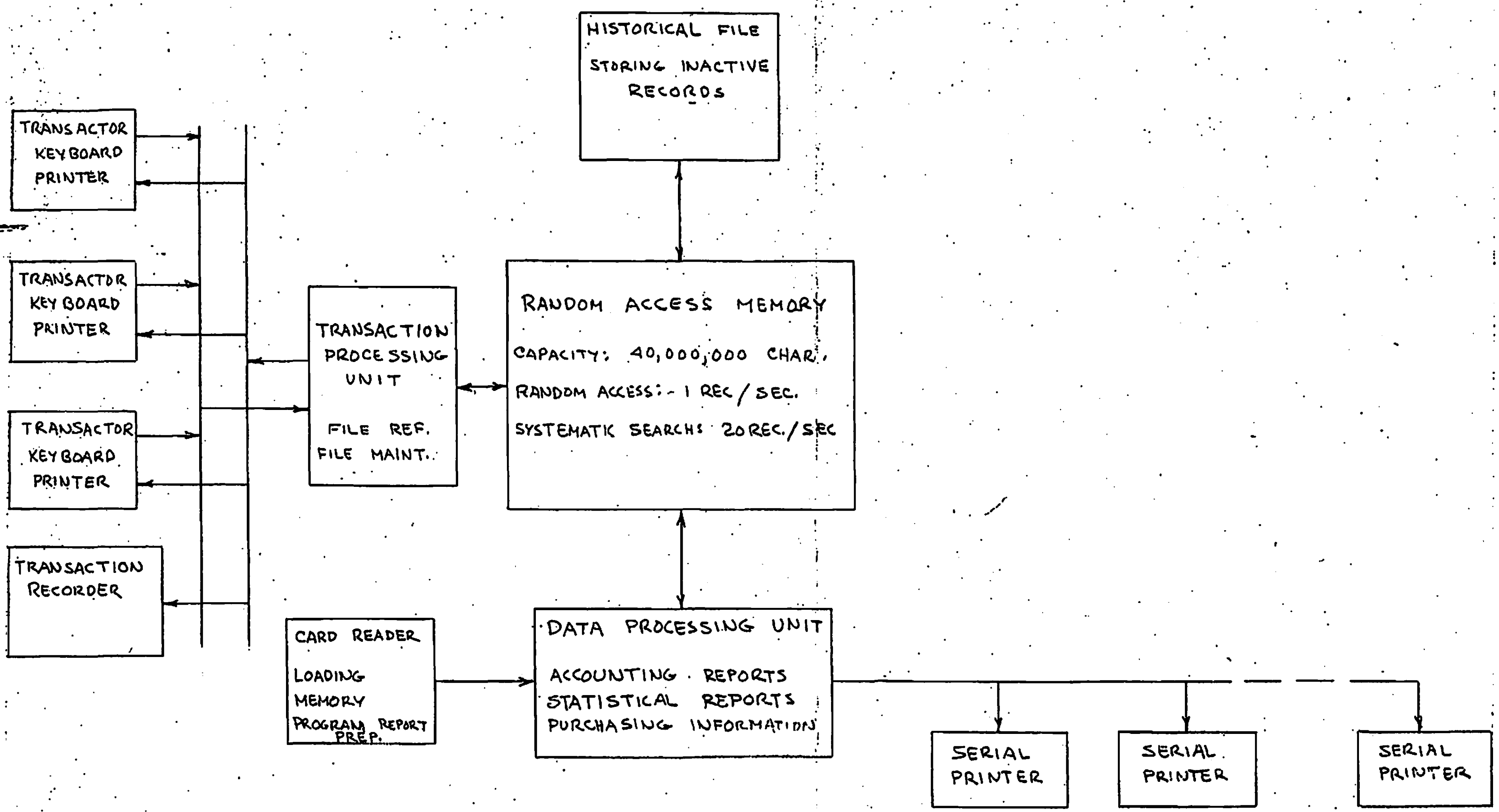


FIG. 5

DATA PROCESSING UNIT WITH HISTORICAL FILE

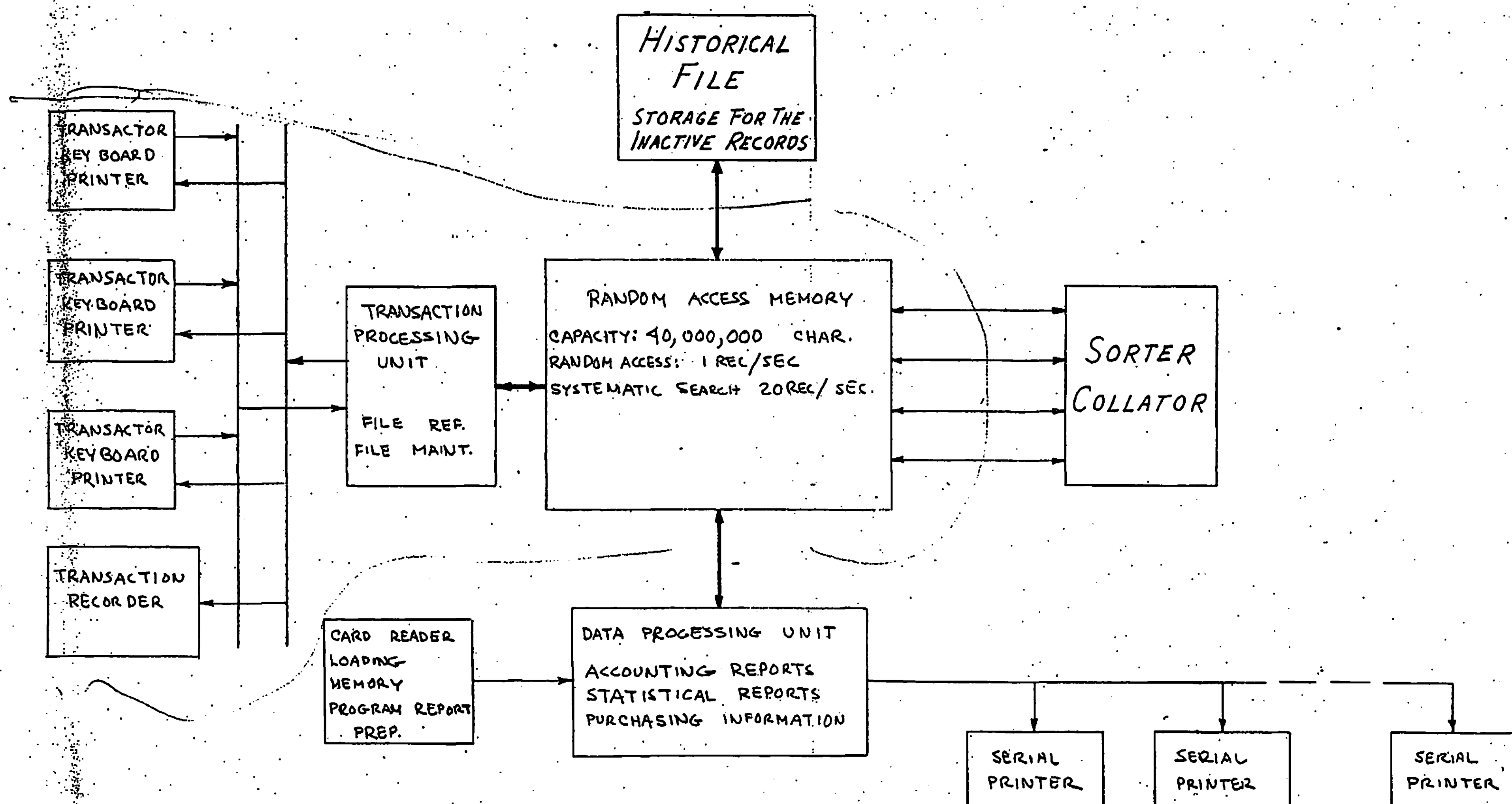


FIG. 6
COMPLETE DATA PROCESSING UNIT

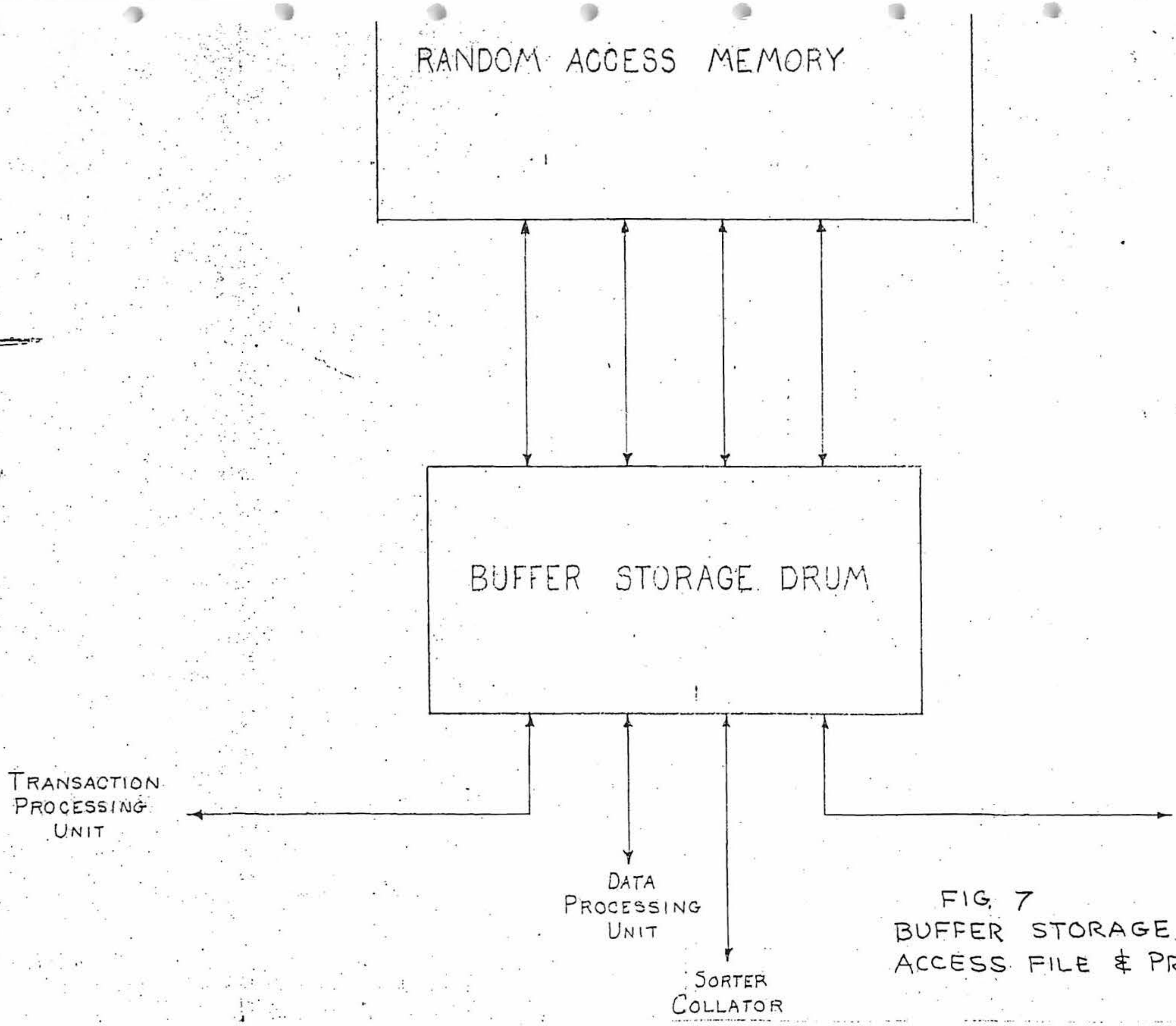


FIG. 7
BUFFER STORAGE BETWEEN RANDOM ACCESS FILE & PROCESSING UNITS.

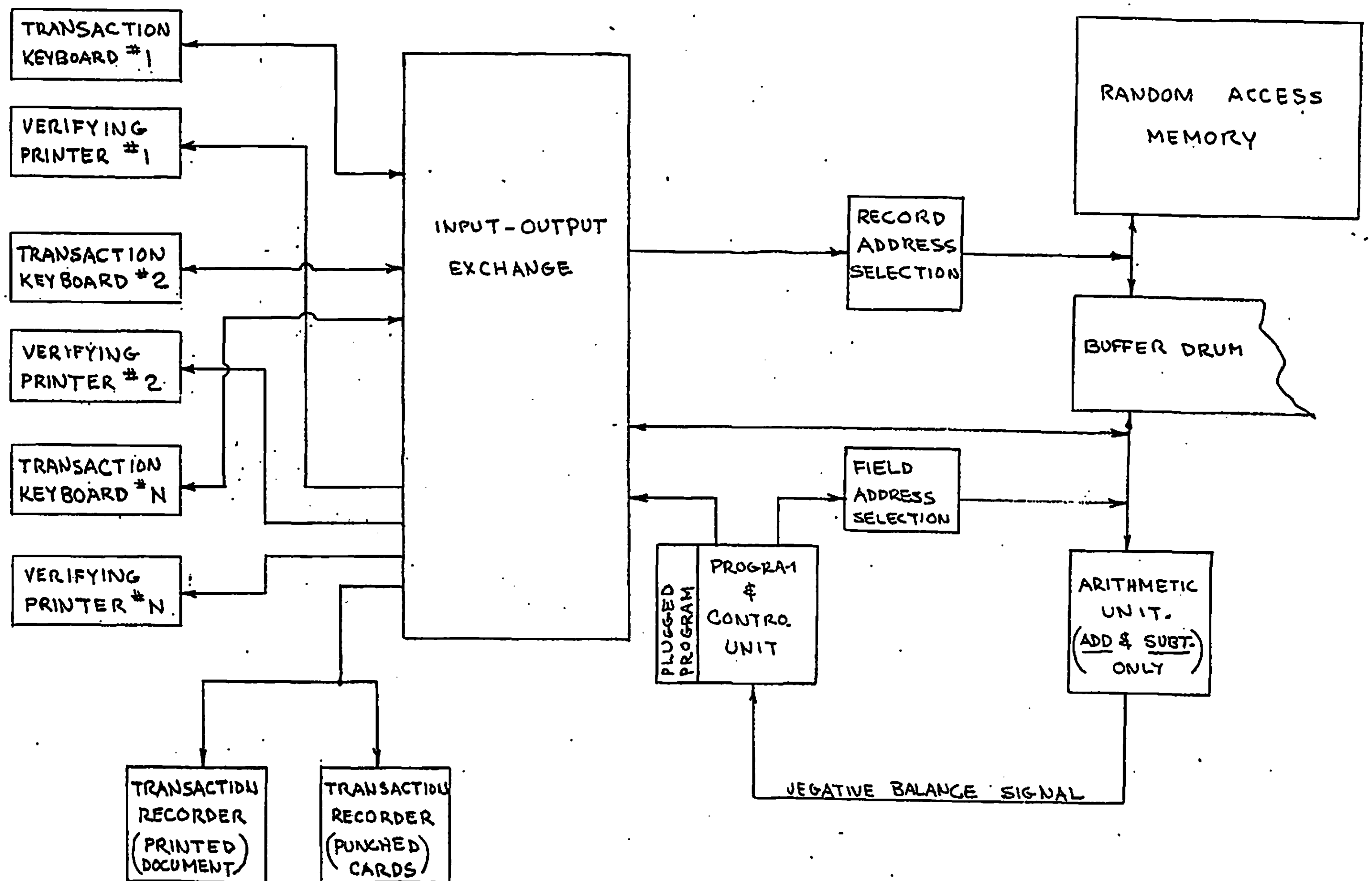


FIG. 8

TRANSACTION PROCESSING UNIT

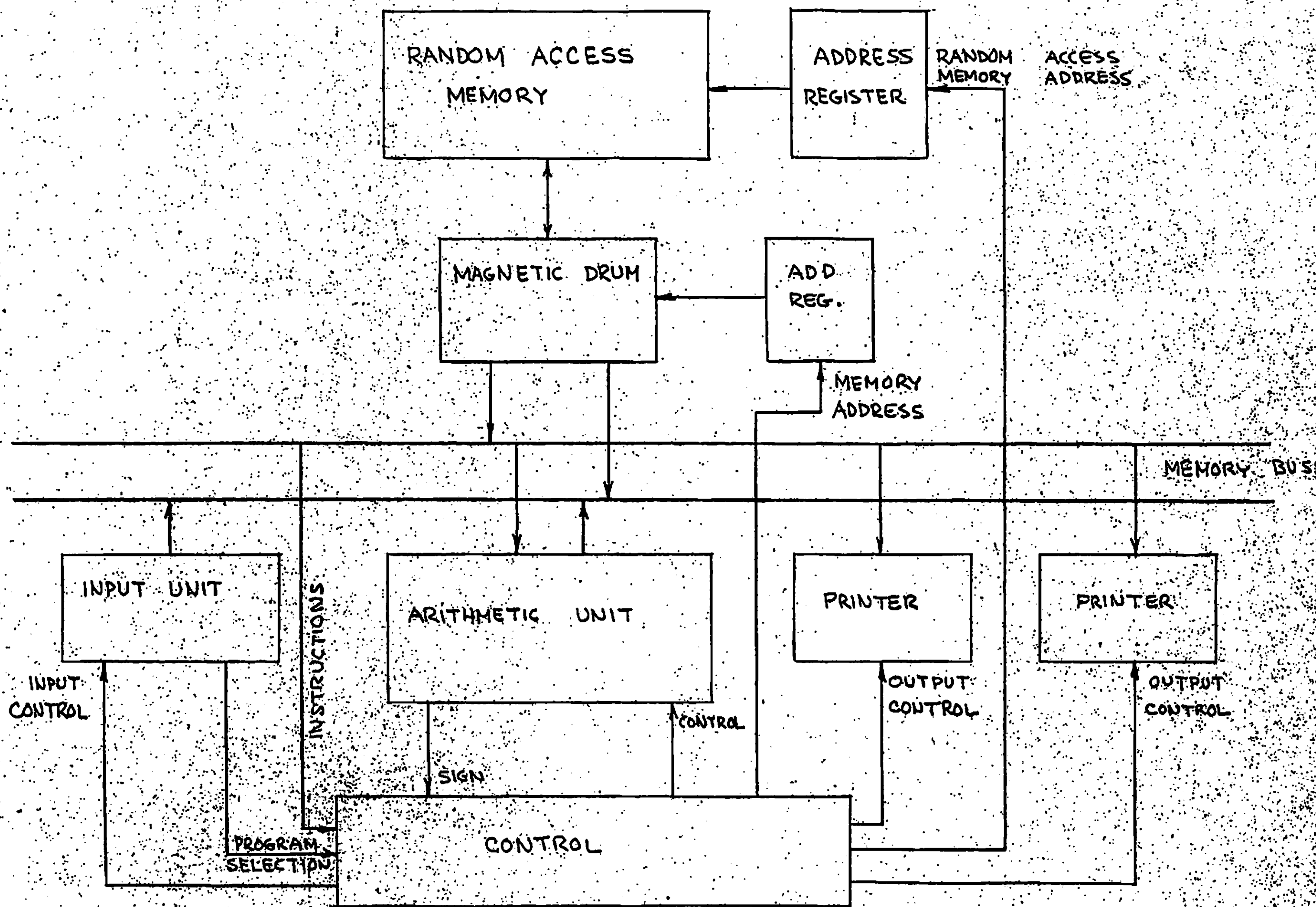


FIG. 9
DATA PROCESSING UNIT

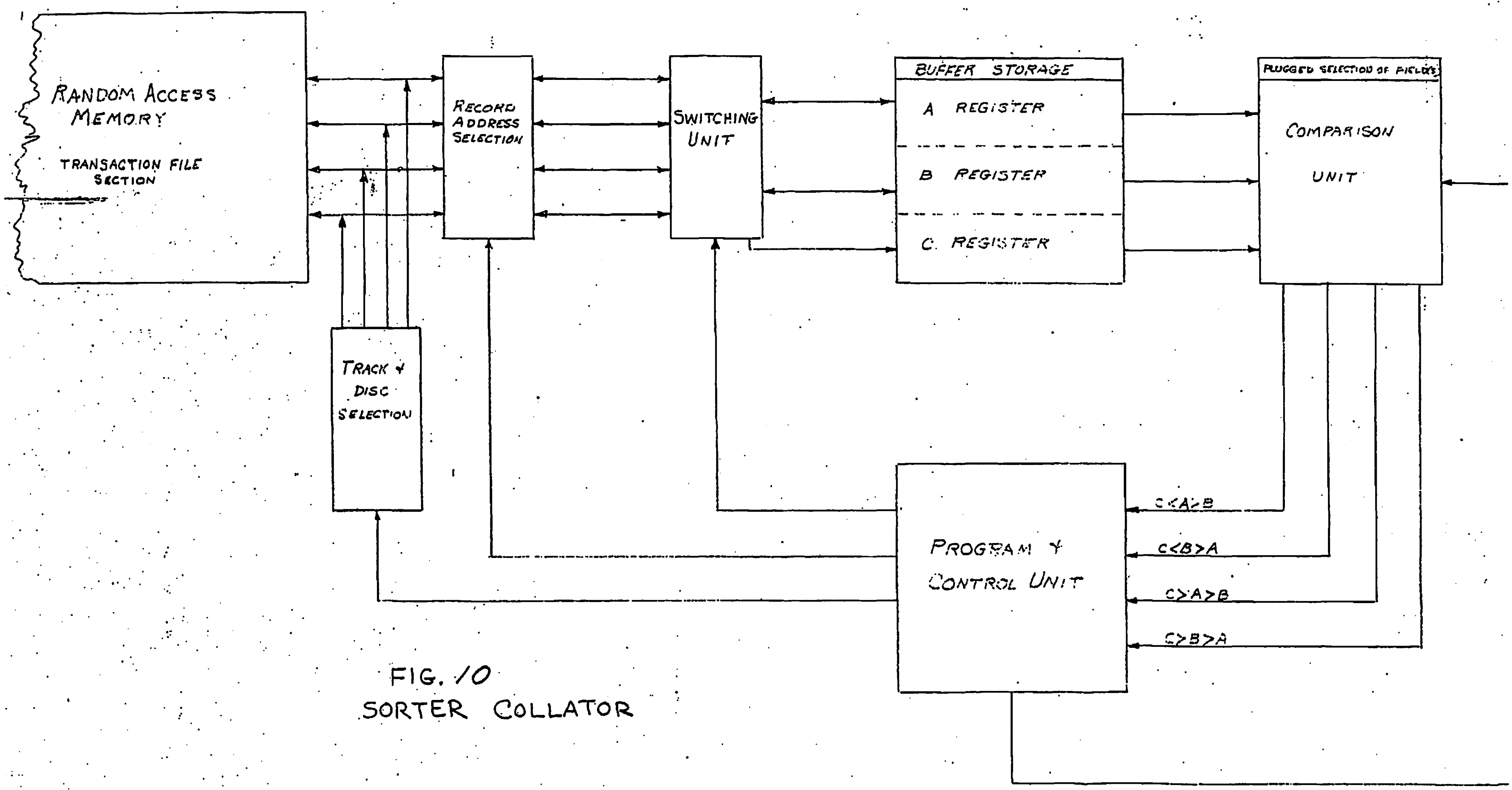


FIG. 10
SORTER COLLATOR

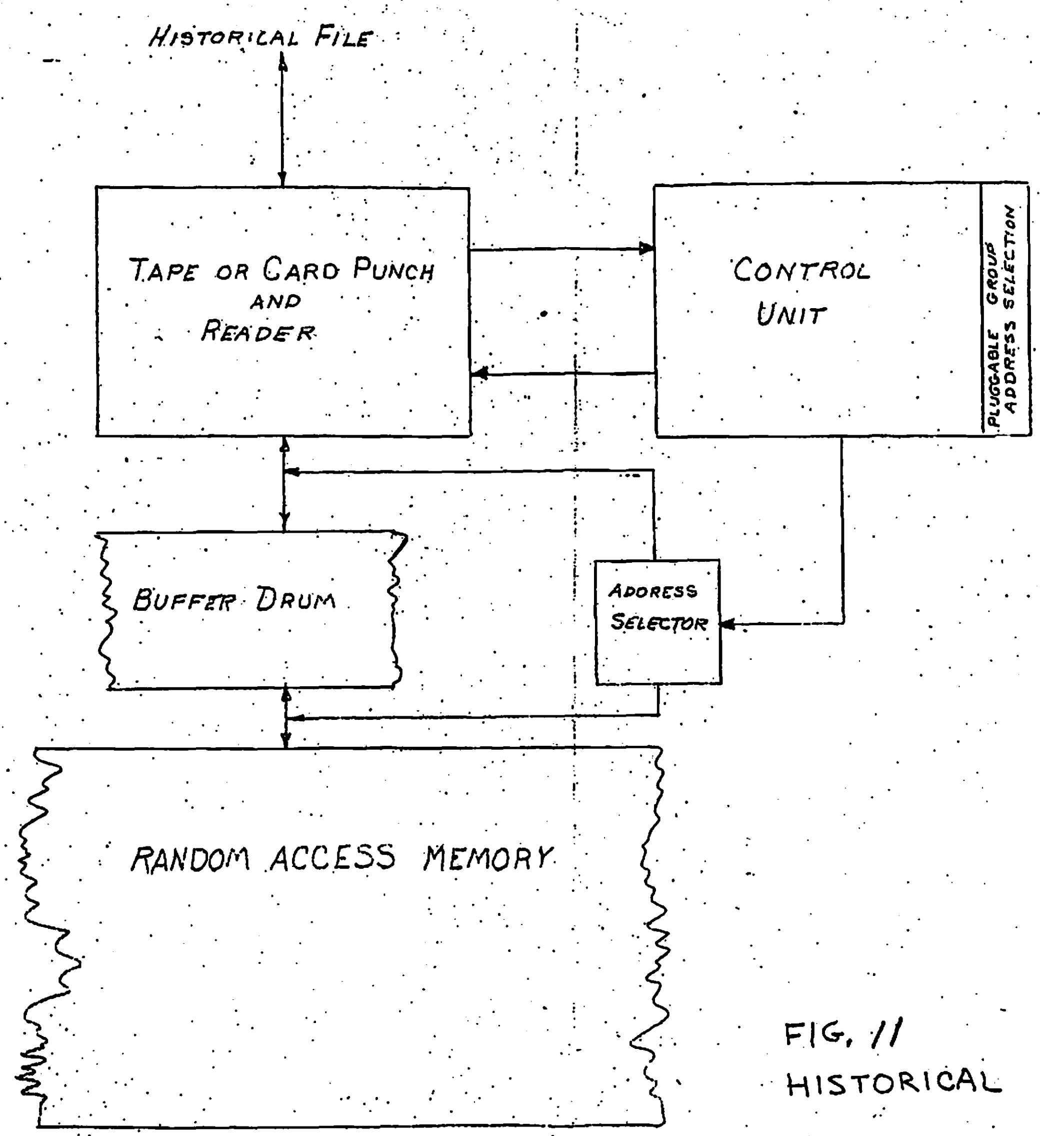


FIG. 11
HISTORICAL FILE

Random Processing Machine

1.0 Objective - to study the possibility of associating a data processing unit with the Random Access Memory to provice a complete data processing system.

Deadline
Apr 27

Stated in another way the objective is to provide a low cost machinge capable of the functions of the TPM. It is felt that it is possible to accomplish this by planning a relatively slow machine.

This appears to be Stevens' copy of a document prepared by Haanstra on April 15 (pgs 1-16) and April 19, 1953 (pgs 17-36). Pages 31 and 33 appear to be missing.

First page transcribed by:
T. Gardner 10/30/2007

2.0 Meeting 3:00 PM Wednesday April 15

attending - Haanstra
Kean?
Maron
Critchlow
} Committee for consideration of the machine

Tremelling
Leary
} Consultants on IBM Applications

SNM 4-15-53 (1)

Stevens

RANDOM PROCESSING MACHINE

1.0 Objective - to study the possibility of associating a data processing unit with the Random Access Memory to provide a complete data processing system.

DEADLINE APR 27

Stated in another way the objective is to provide a low cost machine capable of the functions of the TPM. It is felt that it is possible to accomplish this by planning a relatively slow machine.

2.0 Meeting 3:00 PM Wednesday April 15

attending - Hoorstra, Dean, Maron, Critchlow } Committee for consideration of the machine

Tremelling, Leary } Consultants on IBM applications

2.1 Project Organization

It was decided that the method of approaching this problem is

2.1.1 to survey typical business applications and select three which best illustrate the use of the machine

2.1.2 to make a critical analysis of each of the chosen applications thus arriving at what must be accomplished by the machine

2.1.3 To postulate a machine and subject it to the requirements found in 2.1.2. this procedure should show up any defficiencies in the planned machine.

2.2 Initial division of effort

Maron, Critchlow, and Leary to review typical applications for such a machine

Haanstra and Keon to arrive at a tentative proposal for the machine.

3.0 Preliminary outline of machine organization

3.1 Random access memory of ~ 400,000 100 col records. Access to any of the records in about 1 second

3.2 It is visualized that the machine will operate simultaneously in two distinct ways

3.2.1 It will handle the file reference (perhaps maintenance) prob by operating on data and instructions from Keyboard entry.

3.2.2 It will handle the systematic type of processing such as monthly billing sales analysis and the like through the medium of an independent access to the memory, and a general purpose arithmetic and logical unit.

3.3 One of the central problems is to discover for general applications where to draw the line between the Random (In Line) type of processing and the Systematic (Batch) type of processing.

It would seem to be reasonable to attempt to limit the Random processing to File reference (becomes essentially data input where it has been assumed that a data processing unit operates on the same file) since this approach does not require arithmetic in this portion of the machine.

? Utilizing a single arithmetic unit for both random and systematic processing would seem to complicate the design and may well involve more equipment than separate units for each.

3.4 Definitions

3.4.1 "Random" or "in line" processing will be used to denote handling of information eg orders, bank deposits etc as the occur without any sorting

3.4.2 "Systematic" or "Batch" processing will be used to denote handling of

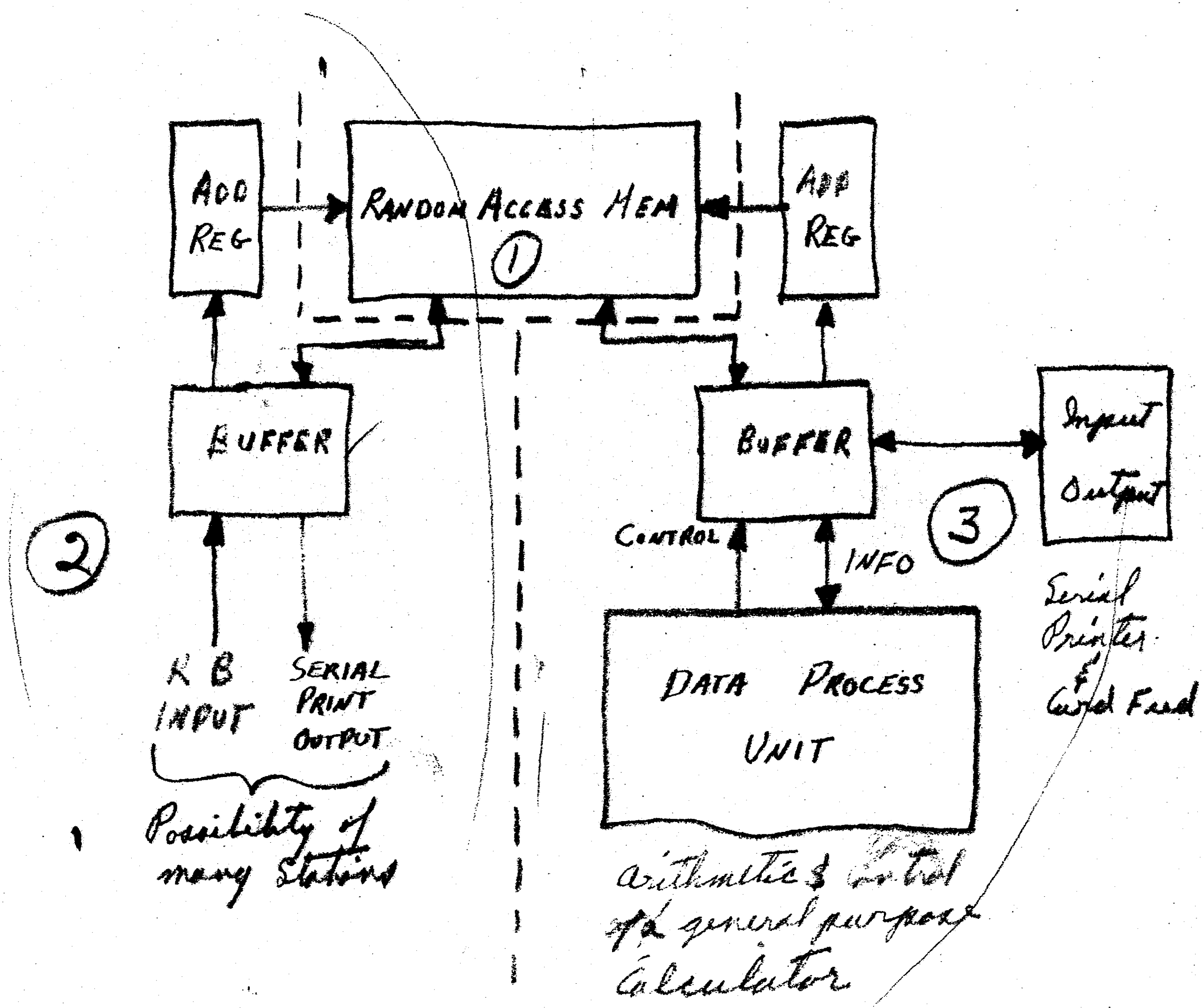
information in a group system
ie the processing is not initiated
until a fair amount of
pieces of info are available
for processing.
This system is characteristic of
the present day card system
and of the tape Processing
Machine.

3.4 Records & Fields

3.4.1 The geometry of any of the proposed random access storage methods seems to indicate that the length of records should be fixed in the machine design. Some consideration should be given to automatic grouping of records by twos or threes to provide for possibility of record expansion

3.4.2 The field assignments within a record must be pre assignable for any given problem or application. The assignment of fields may be less easily changed than in say the TPM because once a high capacity random access storage is loaded with specific field assignments it will be a major job to change the whole file. For 026 operation the complete loading of the random access memory would require 550 hours (23 days at 24 hrs/day, 14 weeks at 8 hrs/day).

3.5 A very preliminary block diagram of the machine is given below.



3.5 Cont'd

Perhaps the only feature worthy of note at this stage of the game is the division of the machine into three distinct portions (1) Random Access Memory which is common to (2) the in line processing portion of the machine and (3) the Systematic processing portions

the in line processing shows no arithmetic facility, this may have to be changed, I hope not!

4. Considerations on Presentation to Planning Group

Some thought has been given to the problem of presentation of this concept to the planning group which will visit the laboratory. At this stage of the game it is difficult to know whether the machine under consideration will be feasable or not. Assuming that it is, the problem of "selling" the idea to this group presents itself.

It is thought that a verbal presentation with appropriate visual aids would be the first step. It would be well to accompany this presentation with a report which presents the same information along with additional details

Jim Welsh has suggested overlay type of diagrams as a visual aid. that is the machine would be built up in a series of drawings, each drawing adding a component with an explanation of the requirement for and application of the component added

I feel that this might be quite effective. A possible extention which might really go over would be to also have an overlay type of flow chart for a typical application of IBM machines on a problem suitable for the proposed machine. It may be possible to very effectively develop the machine step by step in conjunction with the illustration of what portions of a normal IBM data processing job are being accomplished with the added portion of the proposed machine.

Further considerations are difficult without a more concrete idea of the possible results of the study. this phase of the project should be discussed with Lou Stevens & Mr Johnson to obtain further info on the nature of the

5. Meeting: 1:00 PM thursday april 16
Purpose: Selection of typical data processing applications
attending: Hannata
Maron
Critchlow
Tremelling
Leary

5.1 A rather extensive group of pamphlets on IBM applications were obtained from the San Jose Sales Office, and the group had previously searched these for suitable applications.

I was decided that the commodity distribution problem as typified by Zellerback, wholesale grocery, wholesale drug, etc. would fit the machine as well as any. In order to arrive at a reasonable distribution of work, this application was divided into two problems -

5.1.1 the distribution problem involving

Order placing
Invoicing
Billing
Accounts Receivable
Sales Analysis
General Ledger Work

this is perhaps one of the most illustrative examples possible and Art Critchlow and Tom Leary will consider this problem carefully with the objective of detailing precisely what information is involved and what must be done to this information. Particular emphasis is on

1- the input-output requirements as opposed to the data processing requirements

2- Drawing the line between the In Line and Systematic processing requirements.

3. Obtaining figures on typical applications including

No of Customers
No of items
Rate of transactions

It is expected that this analysis should go a long way toward forming requirements for the machine design.

5.1.2 A second class of operations associated with the commodity application was defined as the acquisition problem involving operations such as

Reorder
Backorder

Suppliers
Accounts Payable
Receiving
Inventory Control (File Maintenance?)
Supply Control (Due in etc)
Other related problems

Kieth Tremelling volunteered to spend what time he could spare on this problem

5.2 In order to have requirements on applications other than the so called commodity problem described above Bill Maron has undertaken to analyze some rather detailed IBM applications in Banking operations. The choice of this application was on the basis of

5.2.1 We have obtained some good detailed descriptions of these applications

5.2.2 The differences from the commodity application should reveal possible limitations not shown by that application.

Some of these differences are

1 — a smaller number of required records. Each record probably larger

2 - a more severe requirement on the data processing

portions of the machine.

3- What might be rather different input-output requirements.

6. Machine Organization Cont'd

6.1 Buffer Storage

If we assume a random access memory which we do not want to (or cannot) continually read during processing, we must provide a sizeable buffer storage. Since the machine is to remain low cost the use of a magnetic drum as the buffer storage seems inescapable. Since we can probably get along with storage for three or four records at the maximum, the drum may be small probably no more than 4 or 5 tracks to provide buffer storage for both the In line and systematic processing portions. Syncronization of the drum to the random access memory will probably have to be electronic rather than gear or belt drive. Drum rpm will considerably exceed that of the disks to obtain a 50 bit/inch density with a drum of small diameter.

It is interesting to note that the data processing portions of the machine can be thought of as the computing portions of the TPM with a drum memory substituted for the William's tubes. We hope the drum & allowance for lower speed operation can offset the high cost of the TPM.

6.2 Arithmetic Registers

the use of revolvers on the drum for arithmetic registers is very appealing but does not seem feasable for two reasons

6.2.1 Short revolver length with parallel by bit serial by digit information transmission. (It may be well to go to serial serial transmission on the drum for this & to keep the number of drum heads down).

6.2.2 With variable field lengths within the records it is hard to see how revolver start points could always line up with field start points. This is really the killer but perhaps

YNH 4-16-53 (14)

remembering the relative permanency of field assignment once made (see 3.4.2) there may be an out.

6.2.3

assuming no solution to the problems enumerated above, core or tubes represent the available solutions. From recent reports from Pok. the cores look to be the best solution.

6.3 Programming

6.3.1 If no arithmetic or only a slight amount is included in the In Line processing a plugged program seems best there.

6.3.2 In the data processing unit the programs may get rather involved. It would seem that the flexibility of a stored program may be warranted. There is the added point that for extensive programs storage facility may be cheaper than a large number of plugged program steps.

6.3.3 A reasonable approach may be to store all routines to be used ~~as~~ a few records in the random access storage and call the desired routine to the drum for a particular data processing application.

6.4 Machine speed and expansion facility

Assuming an access of 1 sec, average processing 1/2 sec and 1 1/2 sec print out, the data processing will proceed at a rate of about 20 records per min. While this seems slow with respect to card processing (100 records / min as slowest processing link in chain) the long term average processing speed in card installations probably is not too much greater than this.

The speed may be increased somewhat by reading two or more sequential records to the buffer storage at a time.

Gross speed increases may be obtained by the addition of another data processing unit with an independent access to the [illegible] the drum [illegible] available could easily supply buffer storage facility for several such data processing units.

6.5 Cost

It is too early in the program to be able to estimate any costs. An upper bound is available in that the speed considerations indicate the potential performance to be about equivalent to a representative IBM installation of sorter, collator, reproducer, 602A, and tabulator. This along with key punches and verifiers represents about $1000/mo. Figures should be added to this for the operators eliminated and the greater adaptability to many problems that the machine offers because of the random access memory.

All in all on the basis of present IBM machine capabilities & cost, $2500/MO seems like a conservative estimate of the machine's value. It is hoped that further study will reveal the cost to be considerably less than this!

Talk with Haanstra
4-21-53

JWH 4-19-53 (17)

7. Information Stored in Records Stevens

7.1 Zellerbach Application

Pages 18, 19, and 20 are tables prepared by Art Critchlow giving the information which must be stored in the Commodity and Customer files for the Zellerbach application.

the amount of information is quite large but could be substantially reduced by using coding in conjunction with table look up as suggested by Art. as an example the name and address giving purchasing info on the commodity record could be indicated by a code with enough digits to define all suppliers. a table would then be provided to allow translation of code number to name & address when required in an ordering procedure.

7.2 Transaction File

For the Zellerbach application it has seemed reasonable to think in terms of three files, Commodity,

(1) Storage Space Required for Commodity Information File to Provide for Complete Accounting Functions

	INFORMATION	EXAMPLE	No. of Characters	Character Address	First Used Operation - Remarks
1	Commodity Number	A215B4	6	00-05	
2	Commodity Description	108 ½ P Filler Paper	25	06-31	
3	Dept. and Group	21-5	4	32-35	
4	Selling Unit	12DZ	4	36-39	
5	Unit Price	1.15	6	40-45	
6	Unit Cost	0.89	6	46-51	
7	Unit	DZ	2	52-53	
8	Weight (unit)	2 lbs.	4	54-57	
9	Load Units (Bulk)	001 (0.1 cu ft)	3	58-60	
10	Cash Discount Allow.	2 (2% coded)	1	61-61	
11	Charge Tax	3 (Coded City & State)	1	62-62	
12	Zone (Cost Variation)	3	1	63-63	
13	Quantity Discount 10	10-100 (10% - 100 [illegible])	5	64-68	
14	Quantity Discount 15	15-500 (15% - 500 [illegible])	5	69-73	
15	" " 25	25-5000	6	74-79	
16	Warehouse Location	2Z512	5	80-84	
	Inventory Information				
17	Stock Balance	11,558	6	85-90	
18	[illegible]	1000	4	91-94	
19	[illegible] Level	100	4	95-98	
	Purchasing Information				
20	Supplier Name	Crown-Zellerbach	25	99-123	May code this to supplier add., [illegible]-More [illegible] supplier
21	Supplier Address	[illegible]	25	124-148	
22	Supplier City-State	[illegible]	25	149-173	
23	Size of Order	12000	5	174-178	
24	Amount Payable	1256.05	7	179-185	Accounts Payable (More than [illegible])
25	Date Due [illegible]	[illegible]	10	186-195	
26	Obligation [illegible]	[illegible]-27292	9	196-204	
27	[illegible]	[illegible] 1291	9	205-213	
28	Available for Sale	9,750	6	214-219	

(2) Storage Space Required for Commodity Information File to Provide for Complete Accounting Functions

	INFORMATION	EXAMPLE	No. of Characters	Character Addresses	First Used Operation Remarks
29	Suggested Sales Price		6	220-225	
30	Suggested Profit		6	226-231	
31	Record Cont.-Address	300,001	6	232-237	
32	How Shipped	R. Ex. (Rail Express)	4	238-241	
33	Means of Payment	Check-Credit (Coded)	2	242-243	

Storage Space Required in Customer Account File to Provide for Complete Accounting Functions (Billing, Invoicing, Accounts Receivable, Sales Analysis, Financial Control, Purchasing, Receiving, Accounts Payable)

	INFORMATION	No. of Characters	Character Addresses	First Used Operation — Remarks —
1	Customer Account Number	5	00 - 04	Invoicing, -
2	Salesman Number	3	05 - 07	"
3	Customer Name	25	08 - 32	"
4	Customer Street Address	25	33 - 57	"
5	Customer City - Code for City, State	20	58 - 77	"
6	Route Number	2	78 - 79	"
7	Folio Number	3	80 - 82	"
8	Trade Class	3	83 - 85	"
9	Tax Class	1	86 - 86	"
10	Discount	1	87 - 87	"
11	Zone (Price Range)	1	88 - 88	"
	Accounts Receivable Information			Store for each invoice.
12	Order Date	6	89 - 94	" , from customer order
13	Customer Order No.	10	95 - 104	" " " "
14	Invoice Date	4	105 - 108	" emitted
15	Invoice Number	6	109 - 114	" emitted from counter
16	Branch	2	115 - 116	"
17	Amount	7	117 - 123	Computed cost extension
	Invoice # 2 Invoice # 3 Invoice # 4	35 35 35	} 124 - 228	
	Aged Balance Information			
18	Total	8	229 - 236	
19	Current	8	237 - 244	Sum of respective invoice amounts diminished by payments.
20	30 day	8	245 - 252	
21	60 day	8	253 - 260	
22	Record Continued - Address	6	261 - 266	Refers to location of overflow record.
23				

A J C
[illegible]

26

7.2 Cont'd

approach does not require having space in all customer records for the maximum number of transactions during any period. The difficulty lies in either recording a total order in a record thus having either variable record length or wasting space by providing room for the maximum (perhaps average) order and using more records when an overflow occurs.

7.3 Efficient Utilization of Storage Space

The above paragraphs indicate that there are many aspects to this problem of efficient utilization of storage space. It is probably true that no one approach will prove best for all applications hence the machine should be capable of providing for use of more than one system. The approaches of coding, record expansion, and provision for a transaction file all present different aspects of this problem. It would seem that economy dictates storing only necessary info however this processing where it appears to be better to duplicate storage of certain information.

This undoubtably is a case where it will be possible to trade equipment (storage space) for time. It will be necessary to obtain more precise application information before a decision can be made as to where the proper compromise lies.

8. Preparation of information for processing

In discussions Friday concerning various applications of the machine it became evident that facility must be provided for rearrangement or selection of records from the file according to almost any conceivable system. The requirement for this arises from the necessity of preparing varieties of reports with different fields within the records determining the arrangement in the report. Examples are:

Summary report of monthly sales, by salesman
Monthly billing
Sales analysis, by area and commodity
Ordering info, by supplier

Within the random access memory the information may be addressed in only one way. Since the information must be obtained in a variety of ways for the variety of reports that may be required, it is essential that it be possible to do one or more of the following.

1. Sort the information on any field or set of fields then process
2. Select the information on any field or set of fields processing each item as it is selected

this problem presents some serious problems particularly in view of the time required

8.1 Sorting and Selection from a Random Access File

In this section the number of accesses to memory required for sorting or selection of information in the random access file will be considered

8.1.1 Sorting

In order to be able to sort information

file it is necessary that the sorting facility and adequate storage be provided. three methods available for sorting are

1. Sorting by collating 4 pockets
2. Sorting by bit 2 or 4 pockets
3. Sorting by digit or character 10 or 64 pockets

It is desireable to choose a method which does not require very many pockets since in this case pockets constitute storage space

In sorting by collating if the file has N records, $\log_2 N$ successive collations will produce a sorted file. this method is independent of the number of digits in the sort control field. the number of accesses to memory is

$$N \log_2 N$$

In sorting by bits, the ones may be extracted first (for an descending sequence) then the ~~ones~~ zeros. this method requires two scans through the file per bit and only requires two pockets. If we assume 6 bits per character and a sort control field of 6 characters this method will require

$$12CN$$

accesses to memory for a complete sort. By utilizing 4 pockets the ones and zeros may be taken off in a single pass and the number of accesses is reduced to

$$6\ CN$$

By utilizing more pockets the number of accesses can be reduced further. Figure 1 plots the number of required accesses vs the number of items in the file for sorting by collating and sorting by bit with four pockets available.

It can be seen that sorting by collating is more efficient where the sort control field can specify more items than are in the file that is:

$$\log_2 N < 6C$$

and sorting by bit is more efficient when the reverse is true

$$\log_2 N > 6C$$

In practice either situation can occur however it would seem that the former would be more prevalent and hence sorting by collating usually more efficient.

8.1.2 Selecting from the file

In applications where the number of categories into which the information falls is relatively small, it is more efficient to process by going completely through the file for each category. this occurs when

$$\text{No. of categories} \begin{array}{l} < \log_2 N \\ \text{or} \\ < 6C \end{array}$$

the number of accesses required for processing by scanning is shown on figure 1 along with the data for the two types of sorting.

actually if this method were to take advantage of the four pockets available for the sorting schemes, the number of categories on the curves should be multiplied by three. this technique would however require a comparison of the sorting field against three numbers as each record is examined.

8.1.3 Time to prepare for processing

If it takes 1 sec for each access to memory, the time to prepare for processing becomes excessive. a vertical time scale in hours is shown on figure 1. this scale was constructed by assuming that each access requires 1 second.

For a typical problem say to perform billing on a chronological transaction file for the Zellerbach application the requirements might be 1000 customers, 30,000 transactions in a month. It can be seen from Figure 1 that sorting by collating will be the best way of preparing for the processing, and 120 hours would be required. this is an excessive amount of time. In the next section it will be shown, that by utilizing the fact that systematic scanning of a disk type of random access memory can provide substantially lower average access times, a good reduction in the preparation time

For the present let it be noted that access times of the order of 1 second lead to excessive times for the preparation of information for processing. Also note on figure 1 a curve of the performance of an IBM card sorter in relation to the sorting & scanning methods proposed for this machine. For the job given above the sort time would be about two hours for a 3 digit sort.

8.2 Reduction of average access time by Systematic scanning

8.2.1 Characteristics of the Disk System

20 rev / sec
av access time on a track = .025 sec
100 tracks per disk
1/4 sec assumed to switch tracks
3/4 sec assumed to switch disks

In systematic scanning the average access time would be

$$\underbrace{5\text{ msec}}_{\text{Record time}} + \underbrace{\frac{250}{10}}_{\text{Track switching every 10 records}} + \underbrace{\frac{750}{1000}}_{\text{Disk switching every}} \text{ msec}$$

= 30.75

If something must be done to a record before the next is read, we must take the average access time on a track rather than the record time and we have

$$\text{av access} = 25 + \frac{250}{10} + \frac{750}{1000} = 50.75 \text{ msec}$$

8.2.2 Sorting

In sorting, to take advantage of the reduced access time by systematic scanning, it is necessary to provide a head for each pocket. With the extra heads provided it is still necessary to provide two access times around a track, one to get the next record and one to write it in the proper pocket. thus for sorting the average access time for each record read is:

$$50 + \frac{250}{10} + \frac{750}{1000} = 75.75 \text{ msec}$$

this is a factor of 13 improvement over the situation described in section 8.1

8.2.3 Scanning

In scanning for a particular category being processed, the records can be successively scanned until a record at that time the processing takes place and when it is complete, an access time around a disk must be allowed to continue scanning where it was left off. If there are F categories, NF must be scanned for complete processing. N(F-1) will be scanned without a break, and N will be scanned with a break. the time for the complete preparation for processing is then

$$30.75\ N(F-1) + 58.75N \ \text{msec}$$

Figure 2 gives curves of preparation time vs no of records for sorting and scanning using the relationships for av access time derived in this and the preceding section

8.2.4 Preparation time Using Systematic Scanning

the application referred to above is still best solved using sorting by collating but the time is now about 7 hours as opposed to 120 hours. the 7 hours is still rather long and consideration will be given to ways of reducing this.

programming the processing of reports. This would clearly remove the requirement for the machine to sort, however at the present stage of thinking it seems to imply keeping an IBM card file in parallel with the random access file. The card file may be necessary for other reasons & hence this solution should be kept in mind.

It would not seem desireable in the long run to tie such a machine to the card system, however in the immediate future it may well be a good solution pending development of a random access file capable of rapid systematic search.

8.4 Conclusions on modes of Preparation

8.4.1 Based on the material presented above it is clear that the Random Processing machine will be considerably slower than was indicated in paragraph 6.4. This may be overcome by either

1- adding equipment
2. Utilizing a random access memory

8.5 Machine Implications

the material discussed so far in this paragraph has indicated a need for some major changes in the machine philosophy. at this time it seems that sorting by collating gives the best all around solution to the preparation problem if one does not allow keeping a parallel card file

Fortunately the equipment needed for scanning would be about the same as that needed for sorting by collating and hence it would seem that the machine design could well include provision for either scanning or sorting by collating. the choice would merely be one of programming. Further equipment would allow to sorting by bits also but it does not seem that this is justified.

It is felt that the scanning approach will be most valuable for special jobs such as finding a particular customer's bill, or deciding whether or not it is time to order from a unfortunate to have to go through a complete sort for such applications

a further consideration is that the ability for sorting could be an optional feature. the standard machine could be provided with facility for searching according to a card program thus utilizing Tom Leary's card sorting proposal. the extended machine would provide sorting facility and hence eliminate the need for the parallel card file.

This Exciting Device Stores 5 Million Thoughts

IBM Engineers at San Jose Perfect New Machine

TWO years of intensive work by some 50 men in the Advanced Engineering Laboratory of International Business Machines Corp. at San Jose has resulted in a startlingly new electronic device.

Known simply as IBM 305, it is destined to make significant contributions to the business world by speeding up bookkeeping procedures and cutting costs.

So far only engineering pilot models of the "random access" memory device have been constructed but the day of general manufacture and use is approaching.

The experimental unit stores 5,000,000 characters, and, when combined in multiple units for use with a single electronic data processing system, will provide a business information memory bin of almost unlimited capacity.

The new memory unit is made up of a stack of magnetic discs, mounted on vertical shafts and slightly separated one from another. Data are stored as magnetized spots on the discs. At the side of the stack is a reading and writing arm which moves under electronic control directly to the "address" or location of the data desired.

A good example of how IBM 305 might be used is this:

Installed in a department store, the device could record the inventory of thousands of different kinds of items. When a sale is made it would credit the sales person with a commission, deduct the item from the available inventory and add one to the list of reorders. It would also charge the item to a customer's account and give the store a constant running record of its total overall inventory. Buyers would have an up-to-the-minute picture of how their merchandise is moving and would thus know when new orders should be placed.

Cards conveying appropriate information would be available for the sales, payroll, shipping and purchasing departments.

Such department store bookkeeping is now performed by far slower and costlier methods.

Random access memory permits return in principle to the accounting methods used in business houses long ago when there was no necessity for batch-processing of records as today. Then, clerks on high stools adjusted all affected records

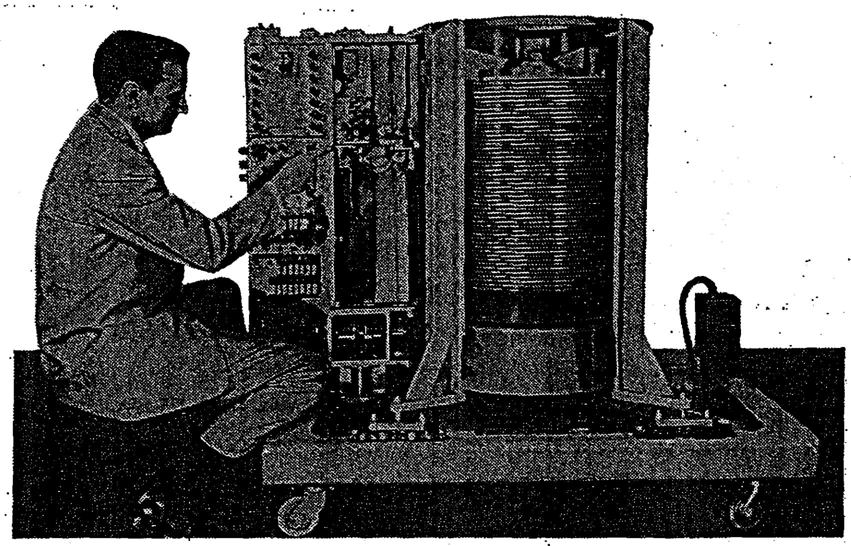
action occurred. But the 305 borrows only the old philosophy, and, using a multi-million character memory and taking instructions from a stored program, it does its job automatically and at very high speed.

The new equipment will be used with both punched cards and magnetic tape-operated machines, and also will be the heart of a new line of IBM electronic processing machines.

The IBM laboratory at San Jose was established in 1952 to augment a plant installation started 10 years previously. In the initial stages of the 305, a wide variety of schemes and ideas were generated in engineering "brainstorming" sessions. Whirling rods, spinning drums, endless tapes, wires, bands, plates and spirals were all considered as possible "memory" units.

Each idea was pursued to the point where its individual limitations were established. The in-line philosophy of machine accounting was developed with the aid of sales, engineering and product planning people cooperating.

The 305 will serve the smaller business as well as the large national corporation and the military organization with vast supply operations. IBM expects to find extensive use in such diverse fields as banking, insurance, manufacturing, distribution, transportation, retailing and many others.



THIS IS IBM'S new magnetic disc "memory" device. Wesley Dickinson, associate engineer in IBM's development group at San Jose, points to the reading and writing arm that permits instantaneous access to any one of five million characters which the machine can store.

Million Will Enjoy Yosemite This Year

According to the National Park Service 1,060,000 persons are expected to visit Yosemite National Park this year. This will be an increase of 109 per cent over 1940 when 507,000 enjoyed the famous California region.

This summer an estimated 19,000,000 persons are expected to tour our national parks, which are equipped to handle only 9,000,000, the Park Service has announced.

A total of 1,568 students from 87 different foreign countries were enrolled on the various campuses of the University of California during the

G. E. Will Double Size Of Palo Alto Laboratory

A 100 per cent expansion of the new General Electric microwave research laboratory on Stanford University land has been announced only six months after the laboratory was first opened.

Scientists at the laboratory are busy developing new and improved microwave tubes which will make possible new wonders in the American home and in the field of communications.

According to H. R. Oldfield, Jr., laboratory manager, microwave tubes will be used for home cooking, instant defrosting of frozen foods and visual telphones based on television principles. Tubes now under study may make possible transoceanic television.

L. D. Seader

A Self-Clocking System for Information Transfer

Summary

This paper describes a circuit which generates a continuous train of clock pulses bearing a fixed phase relationship to information pulses. By switching two gated oscillators, the information pulses continuously correct the phase of the clock pulses.

Introduction

In digital data-storage and transfer systems, a clock signal is required in order to detect the absence or presence of information bits. The clock signal is merely a train of pulses of uniform spacing which has a fixed phase relationship with the information bits. Coincidence between a clock pulse and an information pulse indicates a "one" bit while anti-coincidence indicates a "zero" bit for the bit slot corresponding to that particular clock pulse.

In some synchronous systems, such as a magnetic-drum storage system, it is possible to generate the clock signal so that it inherently maintains the proper phase relationship with respect to the information bits. In some asynchronous systems, such as a magnetic-core storage system, the phase and frequency of the information bits is determined by an independently generated clock signal. In addition, however, there are some systems where it is either inconvenient or impossible to use an independently generated clock signal. These systems require that the clock signal be derived from the information bits. The purpose of this report is to present a method of deriving clock pulses from information bits which has proved to be both simple and reliable. The circuit is called a phased clock-pulse generator.

Block diagram description

A block diagram of the circuit is shown in Fig. 1 and the idealized waveforms are shown in Fig. 3. A binary corrected trigger is driven by the information pulses so that every time a pulse is received, the trigger changes status. The two outputs of the trigger are used to gate two oscillators such that one oscillator is on and the other oscillator is off. An incoming information pulse reverses conditions and the oscillator which was previously on is turned off and vice versa. The oscillators are of a type which start with a known phase so that phase correction is inherent in the switching of the oscillators. The outputs of the two oscillators are mixed in an "or" circuit to provide a continuous train of clock pulses, and the overdriven amplifier serves to square up the half-sinusoidal output of the "or" circuit. The output of the circuit, then, is a continuous train of square clock pulses which maintain a fixed-phase relationship with the information pulses.

Detailed circuit description

The phased clock-pulse generator was originally developed to overcome certain clock-phasing problems associated with the IBM random-access memory. Because of the mechanical tolerances in the access mechanism a proper phase relationship between the data and a recorded clock track could not be maintained over long periods.

Figure 2 is a detailed circuit diagram of the phased clock-pulse generator as it is used in the RAMAC 305 computer in conjunction with the random-access memory. The circuits are designed for a nominal clock frequency of 80 kc. NRZI recording is used.

Figure 1 **Block diagram of the circuit.**

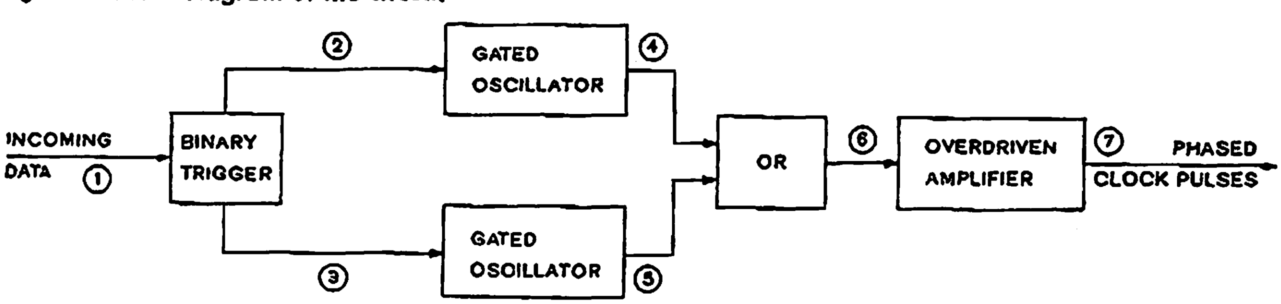


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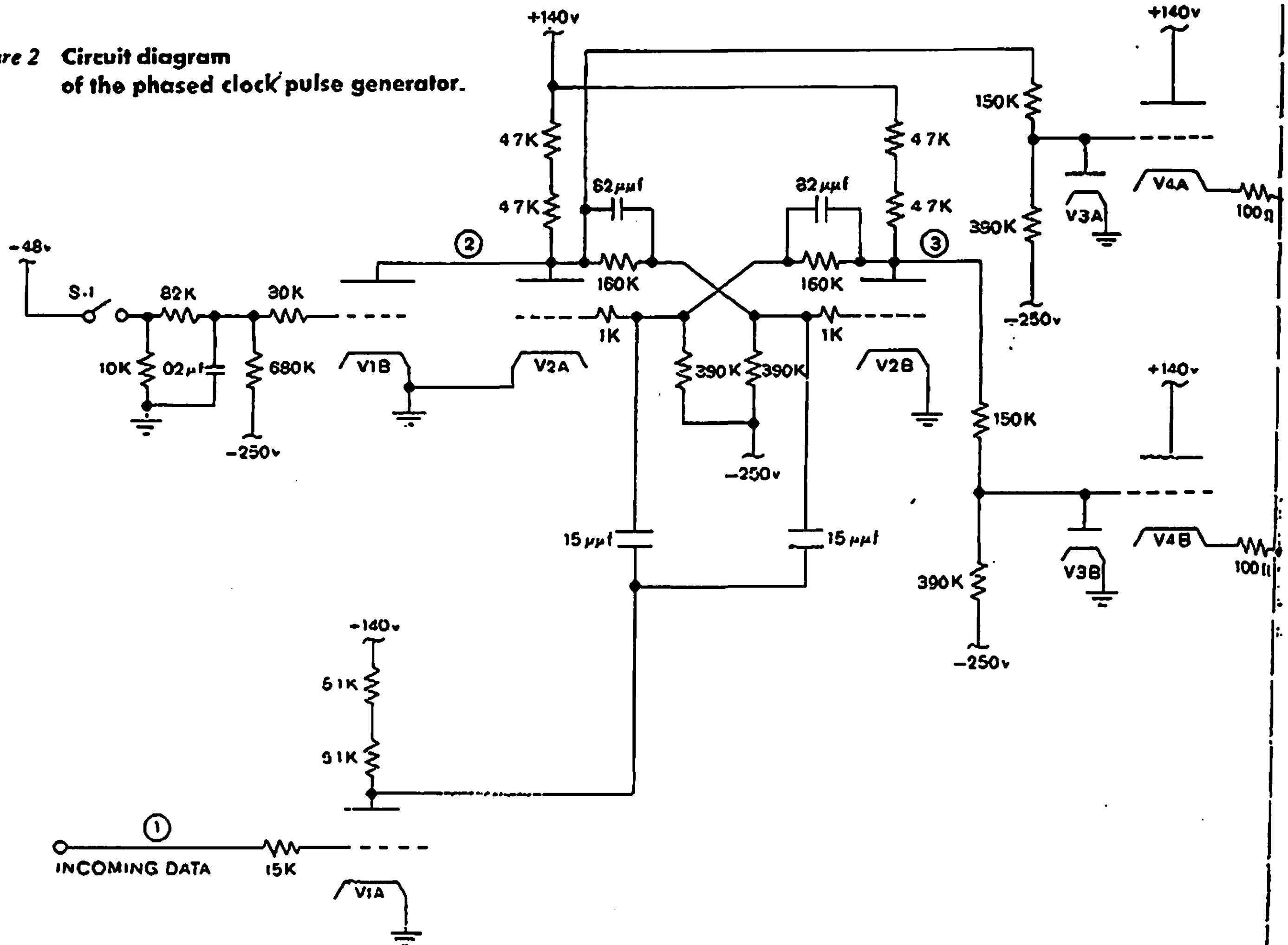
Figure 2 **Circuit diagram of the phased clock pulse generator.**



Reading

For reading information out of the memory relay point $S-1$ is open. V1B is, therefore, cut off and does not affect the operation of the trigger. Incoming data pulses are inverted by V1A and fed to the binary-connected trigger so that the trigger changes states with the leading edge of each data pulse. The trigger is a standard Eccles-Jordan type with capacitive-coupled triggering. Each plate of the trigger is d-c coupled to a gated Hartley oscillator. V4A and V4B provide the gating functions for the two oscillators while V5A and V5B provide low-impedance outputs and supply energy to the tank circuits to sustain oscillation. The initial amplitude of oscillation depends upon the L/C ratio of the tank circuit and the cathode current of the gating tube (V4) just before the tube is cut off. The relationship is given by the equation

$$V - 2I\sqrt{\frac{L}{C}}, \tag{1}$$

where I is the cathode current of V4, V is peak-peak initial amplitude of oscillation.

The outputs of the two oscillators are mixed in a negative "or" circuit consisting of V6A and V6B. A negative "or" circuit is used since the gated Hartley oscillator starts in a negative-going direction. The voltage level of the "off" oscillator is such that the "or" circuit clips off the positive half of the signal. The capacitor shunting the load resistor of the "or" circuit allows a certain control over the symmetry of the clock signal by smearing the positive going edge of the half-sinusoid and thereby changing the width of the clock pulses. The half-sinusoidal signal is squared up by the overdriven amplifier consisting of V7A and V7B.

Writing

For writing information into the memory, a continuous train of clock pulses is required. This is obtained by closing relay point $S-1$. V1B, then, conducts and clamps the trigger to the state in which V2A is conducting and V2B is cut off. The clamp renders the trigger immune to any impulses from V1A. The grid voltage of V4A is about -35 volts while the grid voltage of V4B is 0 volts. Under these conditions, the Hartley oscillator associated with V5A is allowed to oscillate while the oscillator associated with V5B is highly damped and produces no signal. Sufficient feedback is provided in the Hartley oscillator for the amplitude of oscillation to build up to the point where

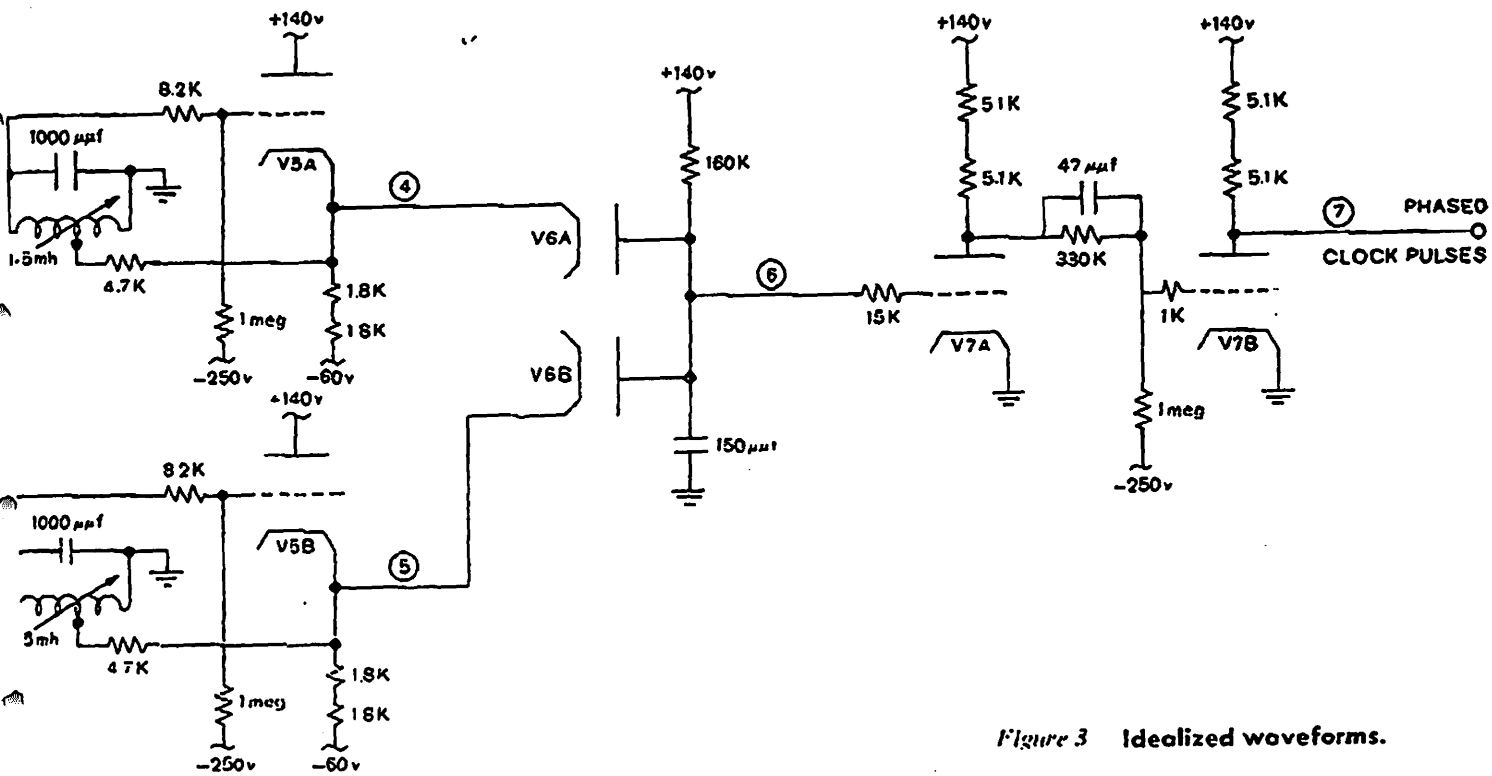
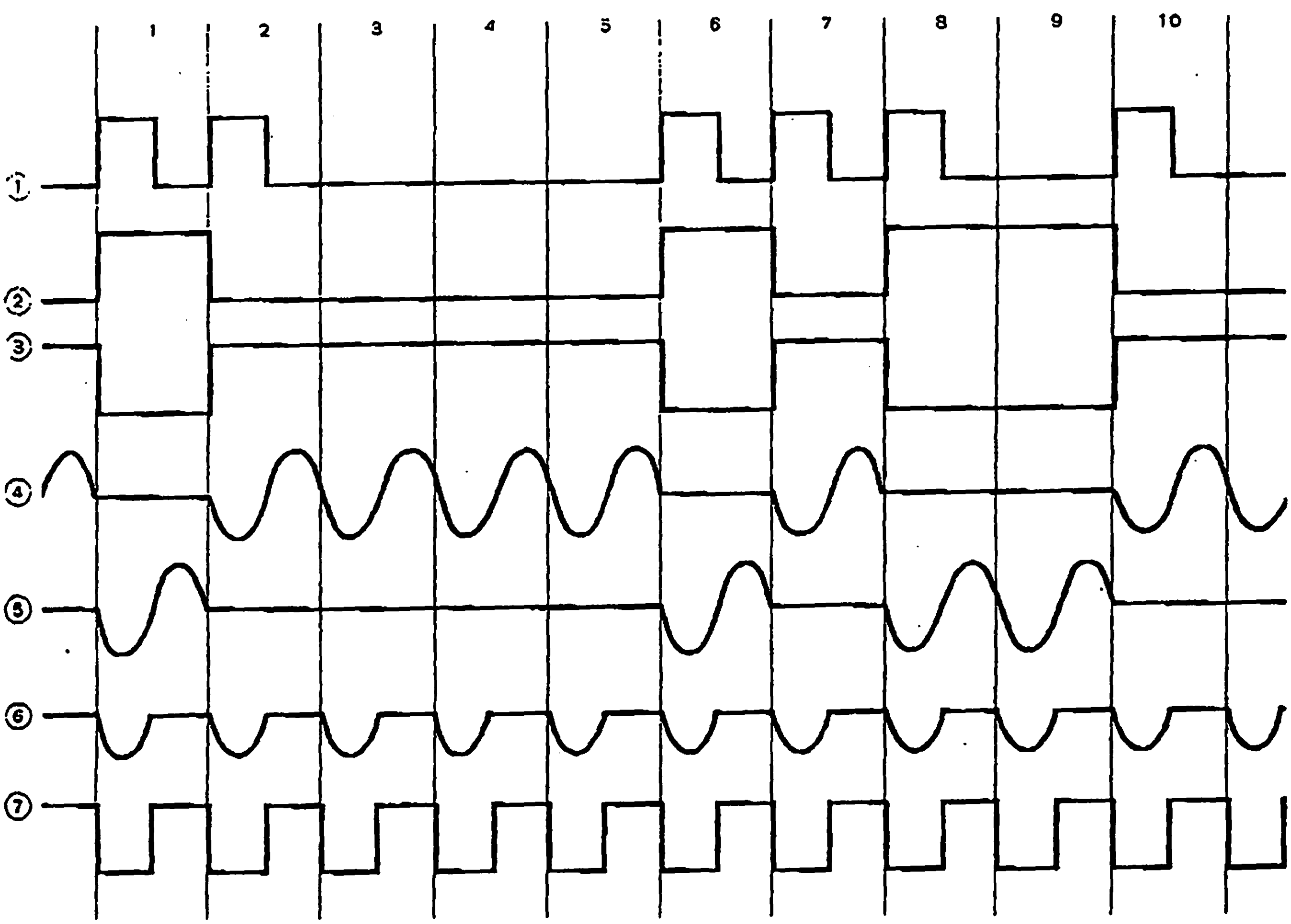


Figure 3 **Idealized waveforms.**



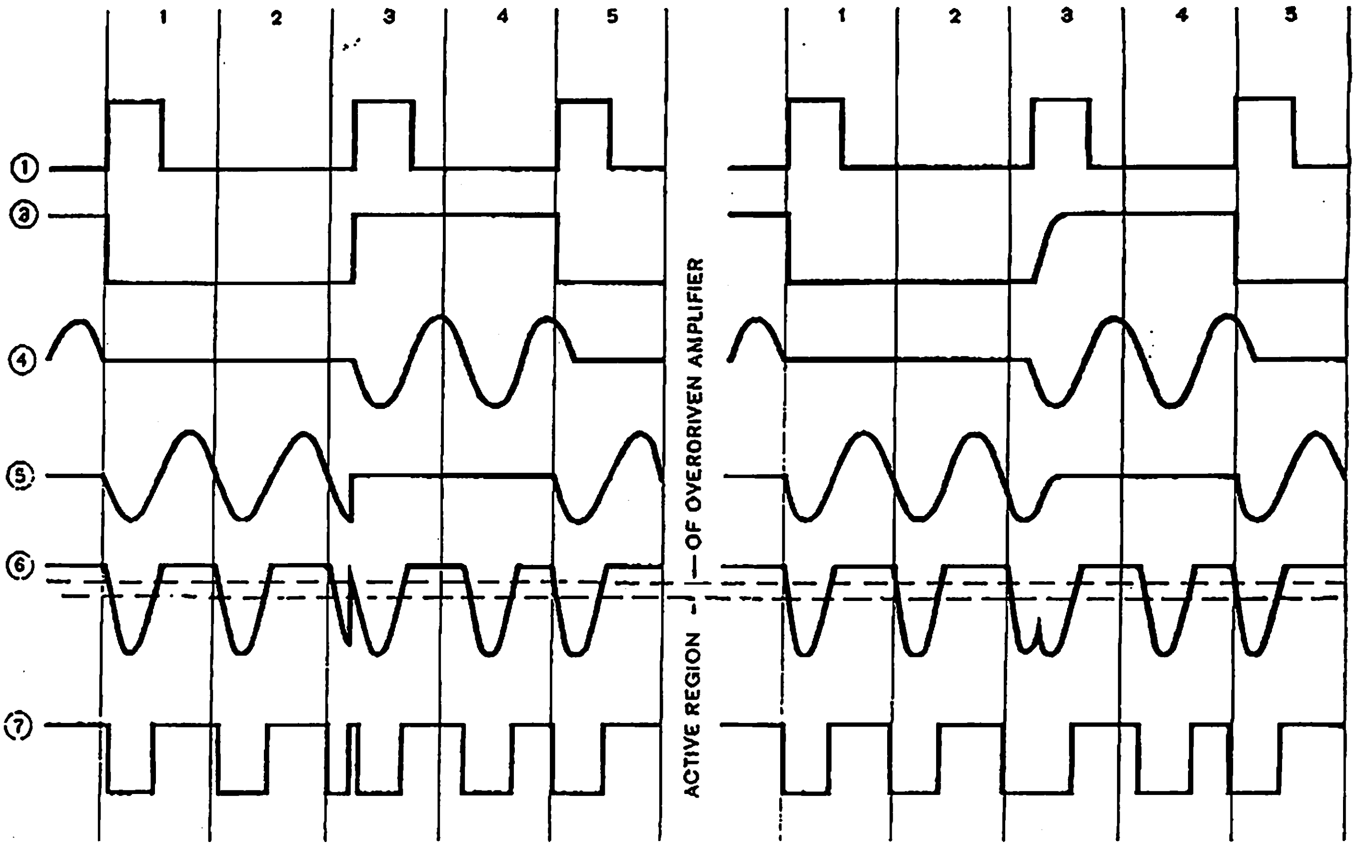


Figure 4 **Sliver elimination.**

V4A will conduct on the negative peaks and limit the buildup. The feedback is not so great, however, that any appreciable distortion occurs from the limiting action.

Special considerations

Figure 4 illustrates two special considerations which must be taken into account in the design and application of the PCPG. Both of these considerations arise from the fact that individual data pulses may be out of phase with respect to adjacent pulses.

In the left half of Fig. 4, it will be noted that the data pulse in slot 3 is lagging in phase. As a result of this, oscillator (5) generates an extra fraction of a cycle which operates the overdriven amplifier. Assuming the ideal waveshape shown at (3), oscillator (5) is abruptly shut off at the leading edge of the data pulse while oscillator (4) is turned on and starts down at a sinusoidal rate. It is seen, therefore, that a sliver will be generated equal in width to the time it takes oscillator (4) to get through the active region of the overdriven amplifier.

The solution to the sliver problem is shown in the right half of Fig. 4. By slowing down the rise time of the waveform at (3) so that oscillator (4) crosses the active region before oscillator (5) recrosses the active region the sliver is eliminated. In the circuit of Fig. 2, the rise time of the trigger is inherently poor with respect to the fall time because of the 82 $\mu\mu f$ compensating capacitors.

The second special consideration is seen in the waveform of (7) in the right half of Fig. 4. It will be noted that when a data pulse is out of phase the negative going edge of the clock pulse bears no fixed relationship to the leading edge of the data pulse, but the positive going edge always occurs half a bit time after the leading edge of the data pulse. Any data standardizing system using the PCPG must take this fact into account for reliable operation.

While the PCPG will tolerate rather large phase errors in individual data bits, the long-term data rate must be held quite accurately, depending upon the maximum number of cycles which may occur in the system between data pulses. The relationship is given by the equation

$$\frac{\Delta f_{max}}{f} = \frac{.5}{N} \qquad (2)$$

where Δf is the difference in frequency of oscillators and data, N is the maximum number of cycles between data pulses.

This is a theoretical limit and a safety factor should be employed to take into account short-term phase errors and finite rise and fall times of the circuits. When properly designed and applied, the PCPG has resulted in reliability and simplicity previously unattainable.

Received January 15, 1957

S-evens

PRODUCT DEVELOPMENT LABORATORY
SAN JOSE
OCTOBER 22, 1957

MEMORANDUM TO: Mr. R. L. Palmer

SUBJECT: Large Capacity Random Access Memory Study

REFERENCE: September 27, 1957 Memo on Reference Subject
J. W. Haanstra to R. L. Palmer

Our study of the Large Capacity Random Access Memory area has been completed from the Engineering viewpoint and we would like to submit the attached report for your consideration. Mr. L. C. Wood is conducting a series of four applications studies to further define the requirements in the Large Capacity Memory Area. We plan to combine the information in this report with the application study results to form a joint Product Development-Product Planning report and recommendation for presentation at the Top Priority meeting scheduled for November 14, 1957.

We have contacted all of the organizations listed in the attachment to the reference memorandum and have summarized and interpreted as best we can what we have learned. Our three directions of study- competitive situation, requirements, and Engineering status of devices and technology- have been investigated. In the competitive area we concluded that there is no significant threat at the present time, however, the pressing requirement for Random Access Memory in Business Data Processing will undoubtedly foster competition in the future. In the requirements area there was very little in the way of specific detailed information, however, there was a general unanimity of opinion concerning the importance of Random Access Memory and the direction and priorities that should be associated with our future efforts in this area.

We have reviewed the status of Large Capacity Memory Developments in IBM and elsewhere, and have studied the related component technology as it exists in IBM. We have concluded that three development programs

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should be implemented to assure a position of leadership for IBM in the Large Capacity Random Access Memory Area.

Our recommendations based upon the results of this study are as follows:

A. Product Development Programs

1. Increase the capacity specifications of the Advanced File Program to 50 million characters and expand this program to assure release in the last half of 1959.

2. Initiate development of a tape strip bin file with a capacity goal of 1 billion characters. Anticipated release date for this product would be in 1961.

3. Formulate a program for development of a 1 million character 10 millisecond access time Random Access Memory unit.

B. Other Programs

1. Formulate an aggressive program to explore the Systems Applications for Random Access Memory with the view of further refining the specifications for the above developments and providing a sounder IBM knowledge in the application of Random Access Memories than presently exists.

2. Emphasize Research in the areas necessary to provide a technological basis for extensions in performance beyond that which can be attained in the programs recommended above.

The attached report contains a discussion of the various aspects of the Large Capacity Random Access Memory Area that led to the above conclusions and recommendations, along with detailed information concerning the recommended programs. We have included in the appendix written information from the departments contacted during this study whenever possible. Some of this information is not yet available. It will be incorporated when received.

We plan to work closely with Mr. L. C. Wood in preparing the final recommendations for Division Management to be presented at the November 14, 1957 Top Priority meeting. I plan to discuss this report with you before that time in order that we have a chance to incorporate your thinking on this subject in the final recommendations.

J W Haanstra

J. W. Haanstra

JWH:mf

cc: Mr. C. F. Earley
Mr. W. W. Simmons
Mr. M. B. Smith
Mr. L. D. Stevens
Mr. L. C. Wood

PRELIMINARY
LARGE CAPACITY RANDOM ACCESS
MEMORY STUDY

PRODUCT DEVELOPMENT LABORATORY
SAN JOSE

M. M. Gibson
J. W. Haanstra
T. Noyes

October 22, 1957

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1. INTRODUCTION

Within the Data Processing Division there is an increasing realization of the importance of Large Capacity Random Access Memories in future Data Processing Systems. The correspondence enclosed in Appendix 7.1 indicates the concern that the planned effort in the Random Access Memory area may not be sufficient to follow through fast enough on the initial entry of the 305-650 RAMAC into this area. Accordingly, an initial survey of current Research effort was made and is documented in Dr. Piore's report of September 12 (Appendix 7.2). A Product Development study was then initiated to evaluate the readiness of Research efforts for Product Development and to recommend specific programs to develop Random Access Memory Units. A concurrent Product Planning survey of requirements will verify the need for the recommended programs and final recommendations will be jointly presented.

The purpose of this report is to explain and substantiate the recommendations resulting from that study, and thus form a basis for securing the recommended increase in the presently planned research and development effort on Random Access Memories.

The problem is to recommend development programs for Random Access Memory units in the most important market areas timed within range of present technology and ahead of competition. Programs for high capacity units requiring more advanced development must also be recommended along with fast access units to complete coverage of the Random Access area. Of course, rental targets must be kept within a marketable range.

2. SCOPE

In order to formulate a recommended program for early management decision, a quick three pronged approach was taken. First, a review of the competitive situation, second, an evaluation of available devices and proposals, and third, a determination of application requirements and markets.

2.1 Competitive Situations

An analysis of the competitive situation was obtained from Business Machines Analysis, and is enclosed as Appendix 7.3. With the possible exception of the small drum area, there is no evidence of a serious competitive threat. In view of this information we have concentrated on recommending a comprehensive development program for all market areas. Vigorous implementation of this program should minimize the risk of competition gaining any substantial lead.

2.2 Technology

The various devices and proposals in Research and Product-Development at all Laboratory locations were considered and discussed with the engineer's advocating them. To make valid comparisons between various proposals, the important characteristics such as bit and track density have been evaluated on the common basis of what would have an excellent probability of reliable operation within a normal development cycle.

2.3 Requirements

Rather than taking the time for a general requirements survey without any proposed hardware in mind, the following approach was chosen. First, a general idea of requirements was formed from several interviews with key people and groups within the Division. Product Planning and Engineering Planning at Endicott and Poughkeepsie, Advanced Planning, Market Analysis, and the various Product Planning and Research groups in San Jose have been interviewed and the written comments will be attached in the Appendix when available. Second, a proposal to develop three basic memory units to cover the requirements is made in this report. Third, Product Planning is to verify the developments chosen by checking the selected functional specifications vs. various industry requirements and markets. Their verification will be both an immediate effort to back up the recommended program and a longer term program to provide further guidance during early development.

3. REQUIREMENTS CONSIDERATIONS

3.1 Cost, Capacity, and Access Time Relationships

In order to provide a framework for stating capacity and access time requirements and the consequent cost of meeting them, Mr. Haanstra's proposal to relate these three by means of the square root relationship:

$$\text{(Rental)} \quad \text{Cost} = k\sqrt{\frac{\text{Capacity}}{\text{Access Time}}}$$

was adopted as a working hypothesis. The assigned constant k is $1000 for disk files in the 10 to 100 million character region, about $500 for bin configurations in the billion character region at access times longer than 0.5 second, and about $2000 for faster access drum or disk storage in the one-million character region. These relationships are illustrated in Figure 1.

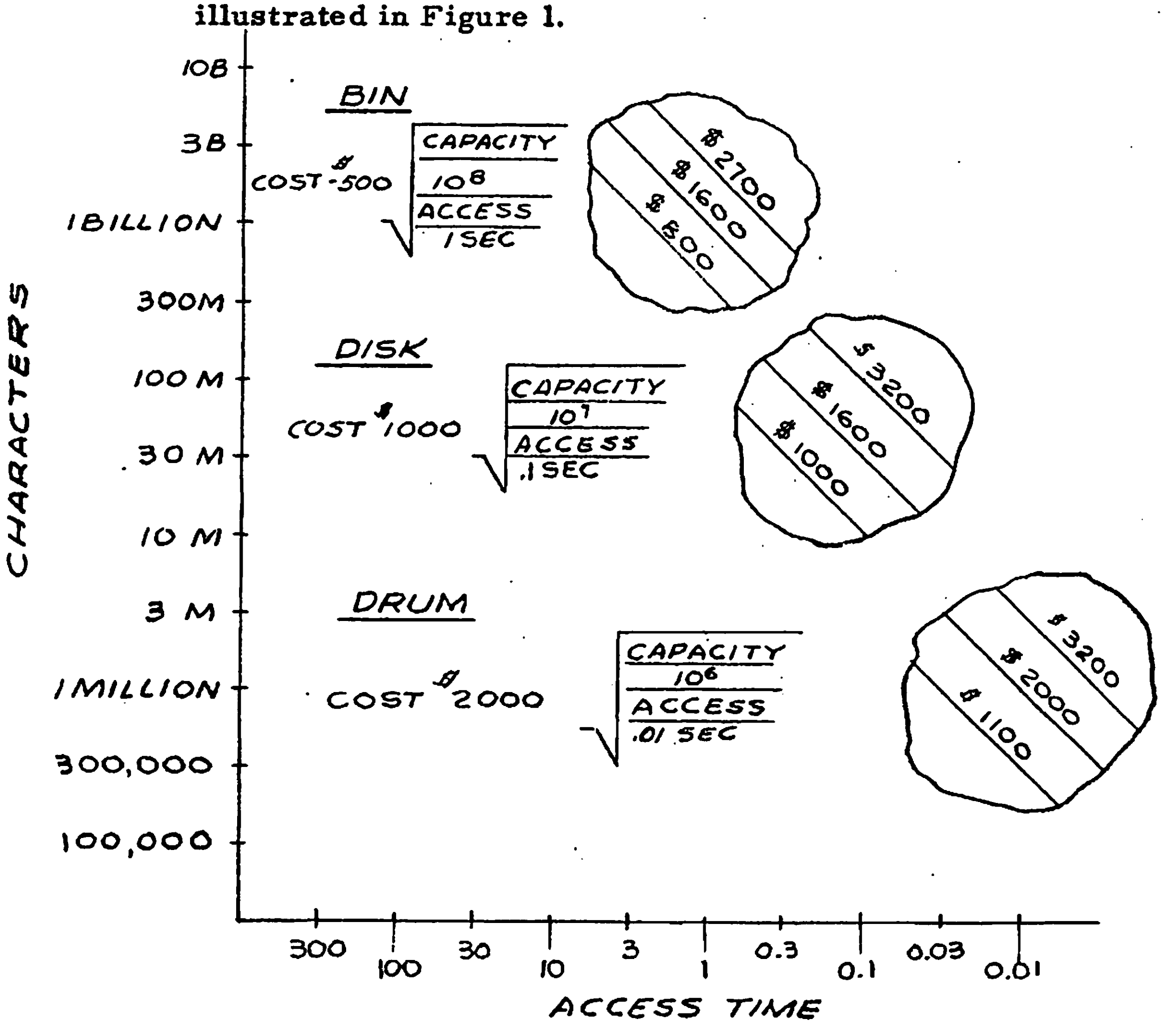


FIG 1 COST, CAPACITY, & ACCESS TIME RELATIONSHIPS

Note that this square root approximation applies only to choice of basic module, for example a 40 million character disk module would be expected to cost twice that of a 10 million character module of the same access time. Once the module size is chosen, the cost varies directly -- two 10 million modules obviously cost double that of a single 10 million module. Thus to minimize cost and achieve reasonable reliability, module size should be chosen as large and as fast as technology permits, yet the basic module should not be larger than the majority market needs.

A few reference activity percentage lines have been sketched in to illustrate that an increase of 10 in capacity requirements also implies either an increase of 10 in access time (transaction) requirements or a decrease of 10 in the reference activity percentage. This distinction becomes important for constant percentage reference activity requirements (eg. -3% for insurance) in the billion character-0.1 second access time region where no device is presently postulated. See Figure 2 below.

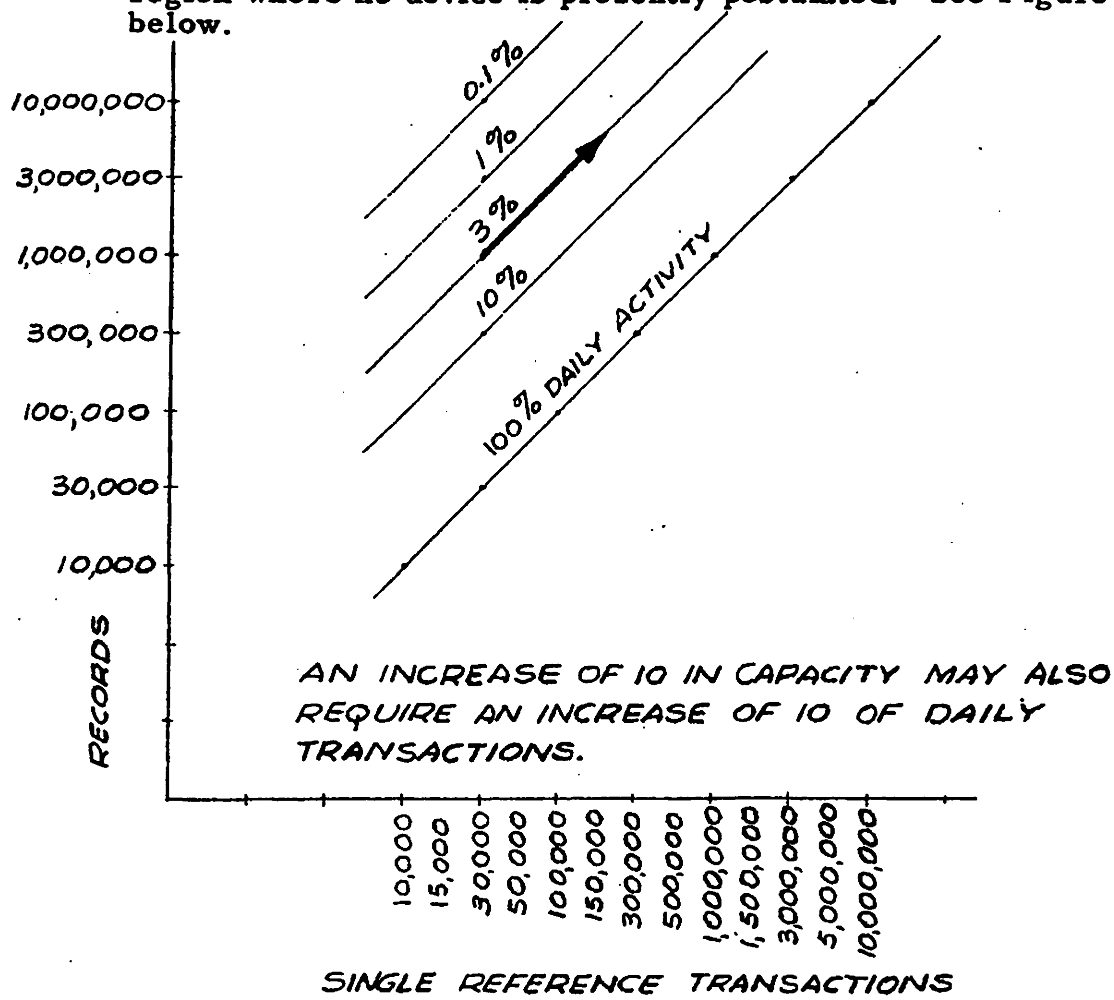


FIG 2 FILE REFERENCE ACTIVITY

3.2 Requirement Opinions

3.2.1 Sales

Mr. Jones' feeling of the Sales situation is that, although the billion character region is important for prestige, the most urgent requirements are in the 100 million character region and that we must find a way to increase the capacity of our disk files before our competition finds a way to increase the access of their tape arrays. He is anxious for IBM to retain their leadership in the Random Access Memory field, and thinks that we have only about two years time before we are threatened with losing business, although even if competition were first, they wouldn't develop the market as fast as IBM. He feels that rental should vary as the square root of the capacity (as proposed).

Mr. Wesley feels that there is no need to go over 100 million characters for commercial markets except in special industries such as insurance and military applications. He believes two units of 50 million characters would handle 90% of the business. Since techniques in the large capacity region are more unknown he would spend 75% of the effort on the unknown concurrently with 25% on the known. He stressed the need for flexibility and pointed out that the "furnace type" construction is the only practical method of achieving such modularity outside of extreme miniaturization. Perhaps his most important contribution was calling our attention to our lack of knowledge of the hows and whys of System Requirements - that we should know what other industries are thinking, that we should know the future growth and trends in banking, public utilities, insurance, because we can largely guide the future, not run along trying to catch up.

3.2.2 Endicott

Mr. Renner (Product Planning) feels the most pressing need is for Random Access Memory capacity from 20 million to 100 million characters, and that not nearly as much business is in the 100 million to 400 million capacity area. He feels that customers can afford quite high prices, based on the 700 series sales and the relative inefficiency in scanning tape. Mr. Renner made several other very valid points: (1) the need for a preliminary file processor unit to translate the address, access the file to the record, and deliver the record to the computer's working storage, thus making the file more self-sufficient and increasing the processor's speed, (2) the need for modularity and flexibility to tailor make a system for each application, (3) the concept of removable cartridges of records that can combine the advantages of Random Access and sequential processing, (4) the limit to consolidation of records for processing with tape machines.

The comments of Endicott Product Planning and Engineering Planning will be attached to Appendix 7.5 when available.

3.2.3 Poughkeepsie

Engineering Planning at Poughkeepsie (Mr. Winger) had worked on the Air Material Command requirement for 80 million characters of storage and had briefly considered requirements for insurance, Michigan Bell (1 billion at 1 second), and California Motor Vehicle (400 million at 0.1). Product Planning at Poughkeepsie (Mr. Pendry and group) had not yet given too much consideration to Random Access Memories, being very involved in providing higher tape speeds. They were considering Random Access Memory Units more as memory extensions to work like several tape units. They considered tape units more practical for cyclic processing up to daily cycles but not for cycles more frequent than daily. Actually the daily cyclic processing areas were felt to be most vulnerable. The new tape units for Stretch will be too fast for 700 main frames, so the 700 series has reached the limit of tape speeds with the 729 III. At our request, both groups more carefully considered use of Random Access Memory units with the 700 series machines - their comments will be attached as part of Appendix 7.5.

3.2.4 Corporate (Advanced) Planning

Corporate Planning in their September 23, 1957 Priority List of Research and Development projects lists "Large Random Access Memories of 100 million to 10 billion characters in modular increments of capacity and access time" as being the highest priority development needed in Long Range Systems Hardware in the next ten years.

Mr. Crawford (Advanced Planning - Ossining) feels that our number one long range need is to provide for the efficient mechanization of historical storage. He feels the future need will be more in management science (operation research et. al.) than in "hot" data processing so that he thinks future systems would be centered on Historical Record Storage. Essentially, he feels historical record storage should be "open ended" the same way present card file cabinets are - perhaps fewer girls (access mechanisms) assigned to the older storage but nevertheless all storage should be quickly and easily accessible. It would be preferable to transport the reader to the storage media rather than transporting the media to the reader.

Mr. Crawford gave us an excellent example with his study of Cincinnati Gas and Electric to illustrate that any reasonable approach to a random access solution must consider inherently cyclic transaction requirements separately from inherently random requirements. The point was (1) the reduction of apparent requirements by handling each type of transaction differently and (2) the need for independence of access and capacity.

He also stressed the importance of a fast access-lower capacity storage to bridge the gap between files and internal memories of processing units and thinks that fast access storage devices and the historical storage device should form the basis of the rest of the system. He was impressed by our proposed cost-capacity-access formulation and would consider application requirements further in that light. His further comments will be attached in Appendix 7.5 when available.

3.2.5 Market Analysis

Mr. McManus (Market Analysis) gave us some feeling for the market situation derived from a recent survey of regional representatives. There seemed to be an overall need for (1) combined batch and in-line processing and (2) for low cost large capacity Random Access Memory Units. He felt half of all 705 series installation would order large disk units of 50 million modules on up.

Over 15% of 705 installations are for life insurance applications. Each million policies requires 300-400 million characters storage with 1.5 to 3% daily total policy reference. He felt 90% of the life insurance companies were potential Random Access Unit customers. Another 15% of the 705 business is in the fire and casualty field where units of 100 million characters would be needed. The General and Manufacturing Area (01) has 45% of the 705 business and again he felt 50% of that area have need for Random Access Memories of 100 million to 1 billion.

Mr. McManus has abstracted some of the remarks from the survey (Appendix 7.6). In addition he will make a market analysis for the proposed Random Access Memory Units. His informal estimates were for 1000 units of a 50 million module and/or 300 units of 200 million character module. Preliminary RAMAC II market estimates were for 2500 to 3500 systems with memory units in the 20 to 50 million character region. The formal market analysis requested will be attached as in Appendix 7.6 also.

3.3 Requirements Summary

3.3.1 100 Million Character Region

We can conclude from the various comments that there is no "average situation" which Random Access Memory capacity and access time requirements could be specified for, but rather that capacity and access time requirements are quite independent and are scattered widely over the requirements "spectrum". The consensus of opinion is that the largest market is for Random Access Memory Units in the 100 million character--0.1 second access time region and that availability in 1960 is desirable.

3.3.2 Large Capacity Region

There is a definite need for larger capacity Random Access Memory systems than appears feasible with disks. These requirements are generally based on present need without regard to future expansion (which, as Mr. Wesley points out, may be enormous for insurance) or to the need for essentially "open ended" historical storage as advocated by Mr. Crawford. Proceeding on a normal development cycle would permit delivery in 1962 which seems soon enough unless competition comes up with a surprise development much earlier.

Quick calculations in the large capacity region generally indicate a billion character file would have to access at 0.1 second or faster to handle the daily transactions. Present technology indicates no method of achieving such rapid access in economically feasible units. There are two practical system solutions to this problem, however, either or both may be applicable.

The first solution would take advantage of the fact that many activities follow the "Pareto" curve [1] such that 80% of the transactions occur on only 20% of the records. If the activity were of that nature, the smallest but most active percentage of records could be stored on a faster access unit as dictated by the economics of the situation.

The second solution would arrange the file records to speed processing of cyclic activity such as monthly billing. The apparent gross requirements in the large capacity memory area are generally much larger than the actual requirements need to be if the files can be arranged to process cyclic work efficiently. Most large capacity Random Access proposals move a mechanism within range of a block (e.g. a bundle of 10 or 20 tape strips) of records, and each reading pass makes available a group (e.g. one tape strip) of records. Additional access mechanisms may be added for areas of the file but interfere with each other in the same area. Thus, access time probably cannot be made as "modular" as in disk files. Therefore, the inherently random processing requirements need to be stated separately from cyclic processing requirements and careful consideration needs to be given to arranging the records so that processing the cyclic activity takes advantage of the Random Access Memory Unit's natural record group availability per access. Of course, the processing unit must have a corresponding ability to accept the groups of records in its internal or fast access storage.

Further individual evaluation is needed to boil the gross requirements down to realistic requirements; until then it is felt that Random Access Memory Units having a capacity of one billion characters at a one second reference cycle time probably can satisfy most known requirements with some systems organization ingenuity.

1. Joseph M. Juran <u>The Management Review 11-54</u>

3.3.4 Proposed Requirement Coverage

In order to "pin down" these scattered (capacity and access time wise) requirements we are proposing the following family of units chosen together to systematically cover the requirement range. The delivery given is based on devices capable of early development. The "family" would be system engineered to be compatible with each other and common processing units.

1. <u>50 Million Character Disk File</u>

Reference Cycle	0.2 to 0.1
Rental Target	$2000
Delivery	1960

Multiple independent accesses for reliability and for separation of input, output, and processing. Group access ability--perhaps 500 records per setting. Modular system capacity by adding up to 10 units.

2. <u>One Billion Character File</u>

Reference Cycle	1 second
Rental Target	$1500
Delivery	1962

Second access available for reliability (mandatory).
Dual access to any record (if possible).
Modularity of access for file areas (optional).
Flexibility by manually removable record cartriges.
Modular system capacity by adding up to 5 units.
Open ended (if possible or by adaptation).

3. <u>One Million Character Fast Access Storage</u>

Reference Cycle	0.02 second
Rental Target	$2000
Delivery	1961

Note: Reference cycle refers to time required to get a record, read it, and restore the changed record to the file exclusive of process time.

Figure 3 illustrates coverage of these devices on the capacity - access chart.

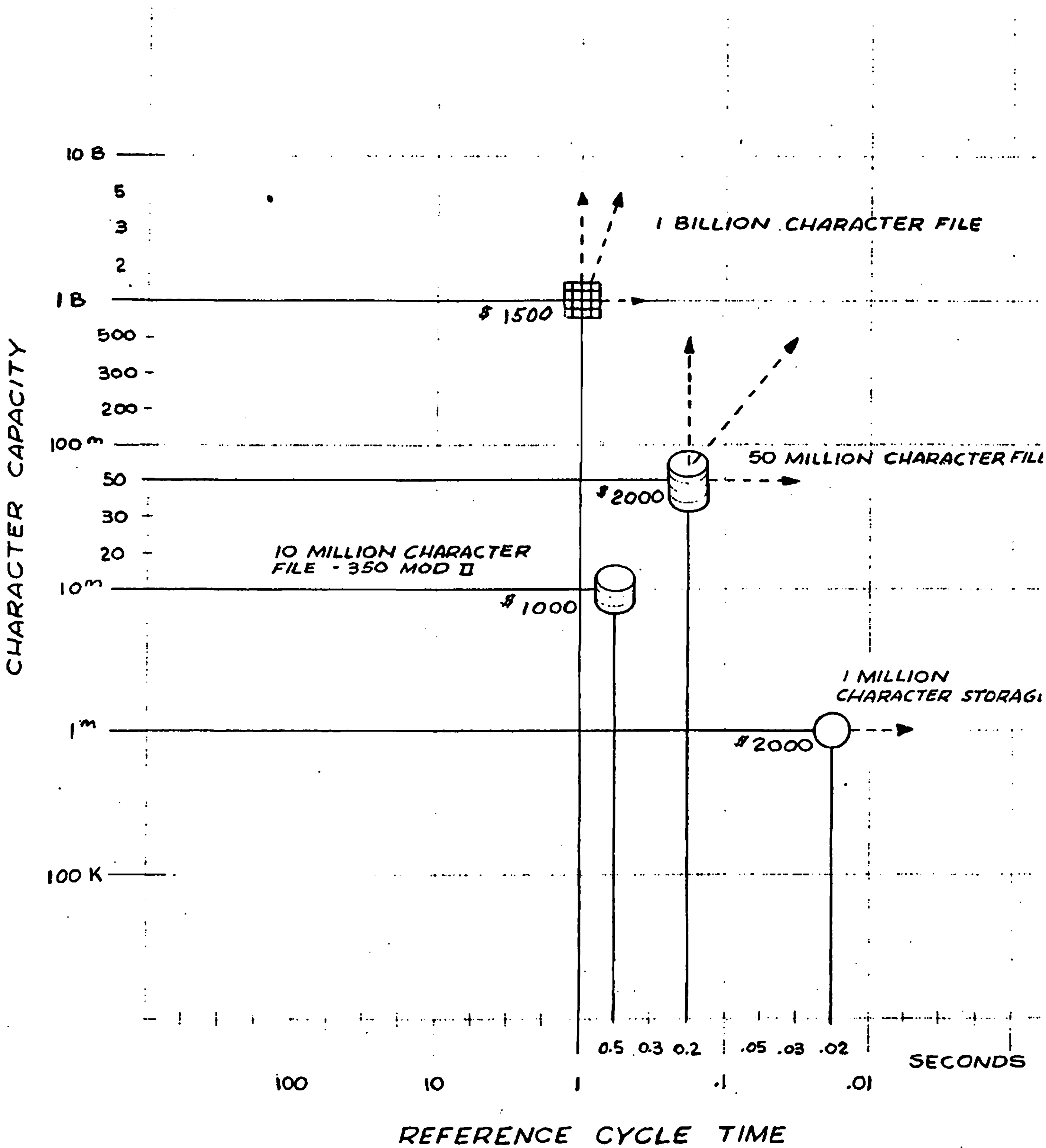


FIG 3 PROPOSED REQUIREMENT COVERAGE

4. Engineering Considerations

Based upon the engineering techniques known today, a Large Capacity Random Access Memory which can be developed at a reasonable price requires utilization of a relatively small number of read (record) elements, and a mechanical motion of the recording surface and/or the read (record) elements to allow these elements to operate on any part of the stored information. With this approach there are two basic aspects to the development of a Large Capacity Random Access Memory: The recording or storage technique, and the mechanical selection and registration. Before considering devices which are appropriate for handling the random access memory requirements outlined above, it will be well to consider each of these aspects of the random access memory.

4.1 Recording Techniques

Since we are interested in large capacity, the recording technique utilized should be such that high recording densities are possible. The two techniques that have been considered for this application are magnetic and photographic storage. Practically all of the existing or proposed devices to date have utilized magnetic recording. While there has been considerable work in the photographic area, at the present time, indications are that magnetic recording provides the best technique for exploitation in the immediate future.

Further work in the photographic area should be done toward overcoming the disadvantages of slow recording and/or the development process, and the expense and complications of both the recording and reading operations. It would appear that photographic techniques could offer considerably greater recording densities than magnetic; however, further research and component development is required before one could plan a product development on this basis. There are many who feel that photographic recording will never prove competitive with magnetic recording in the coded storage application. Even if this were so, continued work should be carried out on photographic techniques because of the promising possibilities in the facsimile or document storage areas.

4.2 Disk RAMAC Memory

During the past two years advanced development activities in Disk RAMAC memories have progressed to the point where Product Development of a RAMAC file having 10 times the capacity and about 1/5 the access time in a unit about the size of the 350 is possible. The developments which provide this possibility along with improved reliability are as follows:

1. Shielded recording heads providing greater linear and track densities.

2. Closer spacing, improved following and reduced cost in a gliding head.

3. Reduced access time by utilizing a "comb" (One head per disk) type of access mechanism.

4. Reduced access time and improved access mechanism reliability utilizing hydraulic drives.

5. Improved storage reliability with increased toughness of surfaces.

These developments, along with the knowhow in the disk area represented in the 350 design, indicate that the fastest and most effective Product Development that could be undertaken to further secure our position of leadership in the Large Capacity Memory area is with disks. The requirement in the 50-100 million capacity region to a large extent is derived from the general expectations within IBM that this is the next logical development.

Along with the capacity and access time characteristics, the magnetic disk configuration offers other features for a memory that will undoubtedly prove vital in future data processing systems. Among these are:

1. Data Flow rates of as high as 10 million characters per second. This feature is important for data rearrangement, associative addressing, and batch inquiry operations.

2. Independent multiple access to the stored information. This feature provides a means for high system dependability and reduced access time.

4.1 cont.

Recent developments in magnetic recording have indicated that quite high densities can be achieved. As we go to these greater densities we require that the dimensions of the recording head be reduced and we get less signal in the read-back process. With new fabrication techniques densities of several thousand bits per lineal inch are possible and track densities of 100 per inch and higher can be achieved. While the signal amplitude received in recording at these densities are quite small, the important parameter of signal to noise ratio can be kept at an acceptable level. These achievements allow one to consider the development of devices with densities in the region of 100,000 bits per square inch and above.

The limitations in magnetic recording appear to be more in the registration area than they are in the area of actual resolution of the magnetic recording system itself. This is another factor which makes one choose magnetic rather than photographic recording. Since we appear to be limited by mechanical registration not the resolution of the recording system itself, the greater resolution of photographic recording could not be utilized without significant improvements in the accuracy of positioning and registration. Meanwhile, with the accuracies that can be achieved the resolution of magnetic recording is adequate and the simplification of the recording and reading process, plus the erasibility feature make it the choice for the development of Large Capacity Random Access Memory devices for capacities up to a billion or more characters per unit.

It is felt that the magnetic disk configuration will provide coverage of the Large Capacity Memory Area of from 10 to 200 million character capacities and 1/2 to 1/20 second access time. The high performance end of this area will be covered by the 50 million character file and the remainder by the 350 and 350 improvements.

4.3 Design Considerations in the Billion Character Region

Since we have assumed magnetic recording as the basic storage phenomena in the billion character region, the choice of a memory device becomes one of selecting a geometry that allows maximum surface area in a volume. The arrangement of this surface area must of course be in a fashion that allows relatively rapid access to any portion of that surface with a precision sufficient to assure accurate reading at the densities used.

Virtually all of the proposals that have been made for devices in this capacity region suggest an arrangement of thin (.005" - .020") surfaces packed together in a volume. Access to the information is accomplished by withdrawing the element from the volume where it is stored passing it by the read/write element, and returning it to the storage location.

Assuming that in the immediate future storage densities of 100,000 bits per square inch are attainable (50-100 tracks/inch, 1000-2000 bits/inch), then one billion characters will require a surface area of approximately 100,000 square inches. This is about 700 square feet, or a square area 26 feet on a side. The geometry problem then is to cut this area up and pack it into a volume in a fashion that will meet the access time and accuracy requirements.

The accuracy or registration requirements appear to be the most difficult to meet, and therefore the most reasonable approach would appear to be to cut this surface into thin strips and record the information with tracks running along the strips. In this fashion the accuracy in the along track dimension is handled by electronic timing circuits, and the cross track accuracy problem is brought within practical limits by reducing the problem to strip selection and maintaining the required accuracies by registering the strip during reading or writing accurately to the magnetic head or to a point to which the head is accurately registered.

The above arguments bring one to a family of possible designs of which the SCRAM, the Telecomputing MAAS, Potter RAM, and the Electrodata Datafile are members. Before following this approach further it will be well to pause and consider devices that are not in this class with the view of understanding their design principles.

4.3.1 Non Strip Systems

CRAM

The CRAM (Condensed Random Access Memory) is an approach to large capacity random access memory that has been proposed in the Endicott Product Development Laboratory. A plate model of this device has been built and the mechanical principles tested. The device consists of a matrix of wires that are selected by a dual hole masking technique and the wires are driven from the storage location into feed rolls by an air jet. The magnetic recording is single track along the wire.

The wires can be arranged in the matrix at a density of about 1000 per square inch. For the same dimension tapes can be arranged at about 100 tapes per inch with say 50 tracks per inch of tape width. There is another factor of 2 increase for tape in recording on both sides. This gives a factor of 10 in density in favor of the tape strip. Magnetic recording principles would indicate that linear densities on wire and tape would differ by a factor of 5-10 in favor of the tape. These factors taken together give an advantage in volumetric efficiency to the tape strip approach of 50 to 100. In the very large capacity region it is felt that this difference is quite significant and, therefore, the wire matrix approach is not considered further in the very large capacity memory region.

The greatest advantage of the wire matrix approach lies in the fact that the accuracy problem is reduced to that of wire selection and this principle has been demonstrated. This factor must be remembered, and in the event that accuracy requirements in the tape strip area prove impossible to meet, the wire matrix may yet prove to be the best approach in spite of the relatively poor volumetric efficiency.

Other "Plate Like" Systems

From time to time there have been large capacity random access memory proposals utilizing a series of sheets or plates. The basic problem with proposals of this type is that very difficult accuracy problems must be solved to effectively utilize the potential magnetic densities. Usually the result is that the densities are severely compromised to ease the accuracy problem. This approach is acceptable when moderate capacity objectives are set and other characteristics of the design are important. (A familiar example in this category is the disk array.) For the billion character region compromises in maximum effective storage density cannot be tolerated and, therefore, the choice must be one which will allow maximum storage density in an arrangement where the accuracy problems can be handled. This choice essentially rules out the "Plate Like" systems and again the choice is in the tape strip area.

One further consideration in "Plate Like" structures is that the volumetric efficiency tends to be compromised in that the surfaces will be chosen to have a substantial thickness to simplify handling and to have some built in rigidity and hence accuracy reference to work from. In the tape strip area we can work with thicknesses in the 0.005" region. In the plate like structures we would tend to work with thicknesses in the 0.05" region, and hence we find a factor of 10 loss in volumetric efficiency.

4.3.2 Tape Strip Systems

The tape strip type of configuration offers the maximum volumetric efficiency for Random Access Memories in the billion character region. Considerable work has been done in this area upon strip selection. techniques. Means for maintaining the required registration have not been extensively tested, however, for reasonable tape widths (2" and below) this problem should be capable of solution in a reasonable time.

The specification of the exact configuration of a tape strip system will not be made here, but some of the considerations relating to this choice will be discussed.

The choice of tape width to a large extent is determined by the registration problem. Considering the accuracy required, and the means that would be used for guiding the tape, a width in the 1" region would appear to be the most reasonable choice. It should be noted that much of the technique for tape guiding that has been developed for tape units can be applied to the design of a tape strip random access memory system.

Given the choice of tape width, the remaining design decision required to pretty well specify the tape strip configuration is the length of tape and number of tapes in the system. In making this decision we are balancing access time against complexity of strip selection (assuming the capacity goal is specified). In general the access time requirement would appear to be the most important, and a design which stresses minimum access time would tend to specify relatively short lengths. A further advantage to a design with short tapes is that it would force the development program to face a more difficult strip selection problem and once this problem was solved, higher capacities could be achieved with relatively little development effort by lengthening the strips. The choice of short strips also leads one to a nice physical size where one could package the tapes in capsules that are changeable by the customer. This factor would extend the utility of the memory device in that the capacity may be greatly extended by manual capsule interchange.

Our review of the existing and proposed large capacity random access memory devices has shown many devices that fall into the tape strip category. While some excellent work has been done in this area, none of the devices are developed to the point where they could be immediately engineered into a product, nor do any of the devices appear to combine all of the features that might be chosen for a product in the billion character region. Comments on each of the devices proposed are given below.

SCRAM (Strip Circular Random Access Memory)

SCRAM is a tape strip random access memory in an exploratory development stage in IBM Research at Ossining. A detailed report on this device was included in Dr. E. R. Piore's report on Large Capacity Random Access Memories to Mr. L. H. LaMotte of September 12, 1957.

This program has been in existence about one year with two or three people assigned. Plans are to expand this program to about six people by the end of 1957 and to about ten by the end of 1958. The schedule for this program calls for completion of an experimental model by the end of 1958.

It is felt that many of the tape selection and handling techniques developed in this program would be applicable to the development of a Large Capacity Random Access Memory in the billion character region. The aspects of the design which appear objectionable from a product viewpoint are the oversize configuration and the proposed means for attaching the recording surface to the strips.

In the matter of configuration the circular array occupies approximately a ten foot diameter circle and is only about two feet in height. While there may be certain technical advantages to the proposed configuration, it is felt that they do not justify the unwieldy physical configuration. From a product viewpoint it is felt that a rectangular bin array would accomplish the same objectives in a physical configuration that is much more appropriate for office use. A further and very serious problem with the large circular configuration lies in the difficult accessability of the access mechanism. Maintenance problems with the configuration as proposed would be exceedingly difficult.

A further drawback of the circular configuration as proposed lies in the need for fairly long unused portions at each end of the tape. This factor forces the design to longer tape lengths in order to write off this wasted tape length over a large amount of information on each tape.

The present thinking on the SCRAM design is to attach standard magnetic tape to a steel strip. This has been selected as an expedient to utilize tape techniques in order to demonstrate the other principles of the device. It would seem that in a product design one would not use this technique, but would rather directly coat the steel or perhaps better yet, utilize the direct steel oxidation as developed in San Jose Research for the recording surface. Such an approach would simplify manufacture of the strips and provide the more rugged surface required in a random access memory.

Potter RAM

This device has been proposed in many configurations by the Potter Instrument Company. The development has only been carried to an early experimental stage and has been offered for sale to computer manufacturers, including IBM. IBM evaluation has indicated that there was not sufficient content to the development to warrent any purchase. It has been reported that Sperry Rand has purchased a device but there has been no indication of intent to use it in a product.

Electrodata Data File

This unit is announced and deliveries have been made. The present device is very slow (average 15 seconds access) and has a capacity of 20 million characters. This device has very long tapes (250 feet) and is a direct adaptation of the tape unit approach. While the tape densities and speeds can be expected to increase, it does not seem that this general approach could be adapted to the billion character capacity, one second access time region.

IBM Air File

This was an exploratory development in Poughkeepsie that demonstrated a simple means for driving a tape loop at high speeds. The volumetric efficiency of such an approach would be very low and the device does not appear feasible for storage in the billion character region.

A further disadvantage of this device lies in the continuous surface motion planned for very inactive data. It should be noted here that a billion characters split into say 500 character records would give 2 million records. An access time of 1 second would give an average record activity of one per 100 days. An approach which keeps a surface moving continuously for average reference of once per 100 days does not appear particularly appropriate.

Telecomputing - IBM MAAS System

This device was developed by the Telecomputing Corporation of Burbank, California with the sponsorship of IBM. The total MAAS system was to contain 5000 cells, housing a total of 1, 000, 000 tapes. Initial efforts were concentrated upon the development of the one cell unit with 100 tapes, means for selecting any tape in the cell, and means for recording (and reading out) information on the tape.

A patent application has been taken out upon this device in the name of Ward W. Beman. IBM sponsorship of the development provides for joint license of IBM and Telecomputing Corporation to the device.

The tape selection system was carried to a point beyond that where the SCRAM device is at the present time and some clever approaches were developed. At the time of this development recording densities were considerably below that currently achievable and hence the large number of tapes proposed to obtain a high total capacity. Actually, recording was done on the steel tape itself and very low resolutions achieved.

While this device would probably not be directly chosen as the Large Capacity Memory device, work was performed in this development that is applicable.

4.4 Low Capacity High Speed Random Access Memory Unit

Consideration of the full spectrum of Random Access Memory Units indicates a need for a device in the 1 million character region with access times in the order of 0.01 seconds. This device would be used for storage of very active records, indexes, alternate programs, and other information voluminous enough not to fit into the working memory of a data processing machine yet requiring access times faster than can be economically achieved with the larger memories.

A survey of the techniques that show promise in this area of capacity and access time indicate that the most appropriate approaches lie in extensions to drum technology or in small disk arrays. In order to meet the access time requirements it would be necessary to severely limit the mechanical motion involved in the access time or not have any at all.

Improvements in Drum Technology where the gliding head approach is used indicate the possibility of extending the capacity of relatively modest size drums up to the region of 1 million characters capacity. The head following techniques allow very close spacings and it is possible to consider 1 million characters stored on a drum approximately 12 inches in diameter and 10 inches long. Such a unit would have about 500 tracks; however, the head count could be reduced by incorporating a small amount of mechanical positioning to keep the price within a reasonable range.

An alternate approach to this problem has been proposed in San Jose Research where a drum and cylinder are given a superfinish and the drum supported on an air bearing within the cylinder. In this configuration the drum itself may be moved to substitute some mechanical positioning for a full complement of heads. This approach has some interesting possibilities in positioning technique and could well prove to be an excellent engineering approach for meeting this requirement.

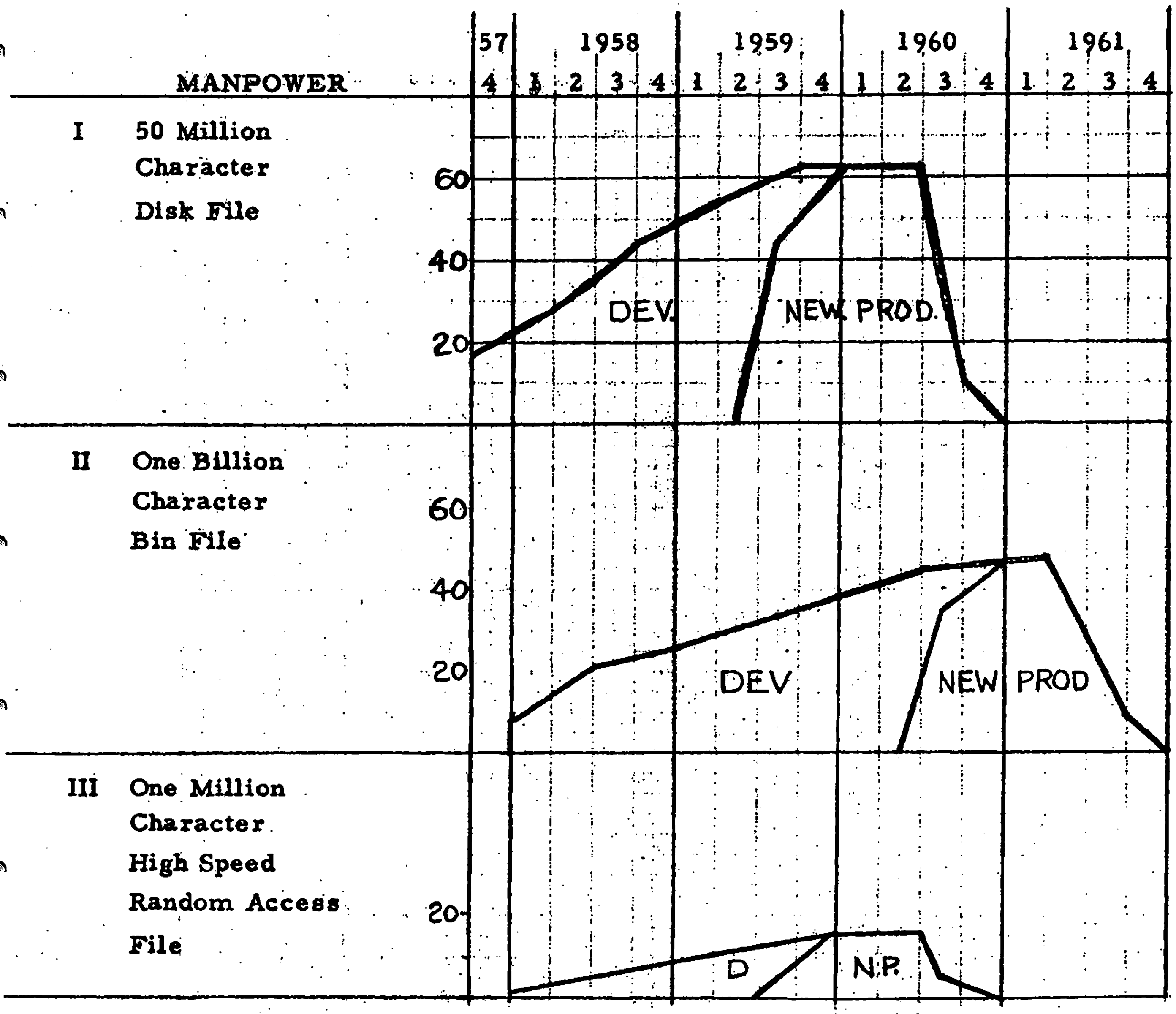
The technology is available today for development of the low capacity-fast access time memory unit. The low capacity goal does not have the sales appeal of very large capacity memories, however, it is felt that a unit with the stated characteristics will be an important component of future data processing systems.

5. Recommended Development Programs

Programs to develop Random Access Memory units in the three selected requirement areas are summarized on the following page and each program is detailed in the succeeding sections. Development and New Product funds are itemized separately, but only that portion of New Product funds required to support Product Development personnel is considered. Production release and pilot production is based on the now established San Jose Manufacturing organization so that an entire plant learning curve need not be superimposed on normal learning curves as initial RAMAC file development. Figure 4 summarizes program manpower requirements graphically and presents the program cost estimates.

RECOMMENDED DEVELOPMENT PROGRAMS

MANPOWER



COSTS

Costs in Thousands $ Based on $18K/Man Year.	57 D.	58 DEV	58 N.P.	'59 DEV	'59 N.P.	'60 DEV	'60 N.P.	61 DEV	61 N.P.	TOTAL DEV	TOTAL N.P.
I 50 Million File	76	640	0	490	497	0	630	0	0	1206	1127
II One Billion File	0	342	0	570	0	396	414	0	493	1308	907
III One Million File	0	95	0	121	81	0	153	0	0	216	234
	76	1077	0	1181	578	396	1197	0	493	2730	2268

10/22/57 - TN

5.1 50 Million Character Disk File Program

5.1.1 Target Dates

June 1958	Functional Specification Complete
January 1959	Experimental Model Complete
July 1959	Prototype Model Complete
October 1959	Product Test Starts
March 1960	Initial Production

5.1.2 Key Technical Problems

1. Precision location of disks axially and radially.
2. Precision location of heads to disk - radial, circumferential, gap spacing.
3. Access mechanisms - high speed - simplicity for extreme reliability - design variations to provide different access times and data flow rates.

5.1.3 Manpower and Money

The manpower requirements are summarized under the Professional, Technical, and Utilized requirements for each major development task. The detailed breakdowns from which the summary was derived are attached in Appendix 7.5 (for engineering distribution only).

50 MILLION CHARACTER FILE

MANPOWER REQUIREMENTS BY SUB-ASSEMBLY

		57	1958				1959				1960				1961		
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
I Access - Hydraulic Actuator and Power Unit	P	1	2	2	2	2	2	2	2	2½	2½	2½	1	½			
	T	1	1	1	2	2	2	3	3	3	3	3					
	U	1	2	2	3	4	4	4	4	4	5	5					
II Access - Carriage, Arms, Structure	P	1	2	2	2	2	2	2	2	2½	2½	2½	1	½			
	T		1	1	2	2	2	2	2	2	2	2					
	U	1	1	2	3	3	4	4	5	5	5	5	1				
III Disk Array	P	1	1	2	3	3	3	3	3	4	4	4	2	1			
	T	1	1	1	2	2	3	3	3	4	4	4					
	U	1	2	3	4	4	7	7	7	7	7	7					
IV Access - Control Unit	P	1	2	2	2	2	2	2	3	3½	3½	3½	2	1			
	T	1	1	1	2	2	3	3	3	3	3	3					
	U		1	1	2	2	3	3	3	3	3	3					
V Heads and Disk - <u>Magnetics</u>	P	2	2	3	3	3	3	3	3	3½	3½	3½	2	1			
	T	2	2	2	3	3	3	3	3	3	3	3					
	U	1	1	2	2	2	3	3	3	3	3	3					
VI Read - Write, System Hookup	P	1	1	2	2	2	3	3	3	3½	3½	3½	2	1			
	T	1	1	1	2	2	2	2	3	3	3	3					
	U			1	2	2	3	3	3	3	3	3					
TOTALS Professional	P	7	10	13	14	14	15	15	16	19½	19½	19½	10	6			
Technical	T	6	7	7	13	13	15	16	17	18	18	18					
Unassigned	~~U~~	~~4~~	~~7~~	~~11~~	~~16~~	~~17~~	~~24~~	~~24~~	25	25	26	26					

525

17
20
27
27
91

91/4

23

460K

5.2 One Billion Character Bin File Program

5.2.1 Target Dates

December 1958	Functional Specification Complete
October 1959	Experimental Model Complete
March 1960	Prototype Model Complete
October 1960	Product Test Starts
June 1961	Initial Production

5.2.2 Key Technical Problems

1. Strip Selection and Drive - simplicity, reliability.
2. Storage Media - development of a durable, economical, magnetic coating on steel strips.
3. Rapid, accurate, mechanical positioning and registration and movement of strips. relative to read/write heads.
4. Magnetics - achieving on the order of 50 tracks/inch at 1000 bits/inch - skew-signal detection.
5. Tape - Head wear.
6. Configuration - access mechanism, length, width, cartridge removability.

5.2.3 Manpower and Money

As attached on following page. The billion file development effort is predicated upon drawing from the technological foundations that experience in the disk development program will provide.

ONE BILLION CHARACTER FILE

MANPOWER REQUIREMENTS BY SUB-ASSEMBLY

		1958				1959				1960				1961			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
I Magnetics - Strip and Head	P	1	2	2	2	2	2	2	2	2	2	3	3	3	3	2	1
	T	1	2	2	2	2	2	2	2	2	2	3	3	3	3	-	-
	U	1	1	1	1	2	2	2	3	4	4	4	4	4	4		
II Strip Selector and Drives	P	1	2	2	2	2	2	3	3	3	3	3	3	3	3	2	1
	T	1	1	1	1	2	2	2	2	3	3	3	3	3	3		
	U	1	2	3	3	3	3	3	3	5	5	5	6	7	7		
III Bin, Strip, Structure - Mechanical	P	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1
	T	1	1	1	1	2	3	3	3	3	3	3	3	3	3		
	U	1	2	2	2	3	3	4	5	6	6	5	6	7	7		
IV Control Unit and Read - Write	P	1	2	3	3	3	3	4	4	4	4	4	4	4	3½	2	1
	T	1	2	2	2	3	3	3	4	4	4	4	4	4	4		
	U	1	1	1	2	2	2	3	4	6	6	6	6	6	6		
	P																
	T																
	U																
	P																
	T																
	U																
TOTALS Professional	P	4	7	9	9	9	9	11	11	11	11	12	12	12	11½	8	4
Technical	T	4	6	6	6	9	10	10	11	12	12	13	13	13	13		
Unassigned	U	4	6	7	8	10	10	12	15	21	21	20	22	24	24		

5.3 One Million Character Fast Access Storage Program

5.3.1 Target Dates

October 1958	Functional Specifications Complete
March 1959	Experimental Model Complete
October 1959	Prototype Model Complete
January 1960	Product Test Starts
July 1960	Initial Production

5.3.2 Key Technical Problems

1. Configuration with minimum number of heads.
2. Head switching.
3. Very fast access time.
4. Signal detection - of high density information.

5.3.3 Manpower and Money

As attached on following page.

ONE MILLION CHARACTER FILE
HIGH SPEED RANDOM ACCESS
PRELIMINARY MANPOWER REQUIREMENTS BY SUB-ASSEMBLY

		1958				1959				1960				1961			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
I Magnetics - Head and Surface	P	1	1	1	1	1	2	2	2	2	2	1	1				
	T			1	1	1	1	1	1	1	1						
	U			1	1	1	1	1	2	2	2						
II Mechanical - Access and Disk or Drum	P	1	1	1	1	1	1	1	2	2	2	1					
	T		1	1	1	1	1	1	1	1	1						
	U		1	1	1	2	2	2	3	3	3						
III Circuitry - Read - Write	P		1	1	1	1	1	1	1	1	1	1					
	T						1	1	1	1	1						
	U							2	2	2	2						
	P																
	T																
	U																
	P																
	T																
	U																
	P																
	T																
	U																
TOTALS Professional	P	2	3	3	3	3	4	4	5	5	5	3	1				
Technical	T		1	2	2	2	3	3	3	3	3						
Unassigned	U		1	2	2	3	3	5	7	7	7						

6. Recommended Research

The three Product Development programs recommended in this report will secure for IBM a commanding lead in the area of Large Capacity Low Cost memory units. The characteristics proposed for these devices are such as to utilize the latest technology in magnetic recording and mechanical positioning. We must recognize that while these developments are being pursued there needs to be a continued research program to form the basis for the Product Developments which will follow those proposed in this report.

Based on the study made for this report research is particularly recommended in the following areas to underwrite future developments in the Large Capacity memory area.

1. <u>Rapid, accurate, high resolution mechanical positioning</u>. There appears to be no fundamental work in this area which will allow one to have an appreciation for the ultimate limits that can be achieved. It would appear that current and future work in Large Capacity Memory applications will depend heavily upon the state of the art in mechanical positioning. Observation of the devices and techniques known today would indicate that there are fundamental limitations to what can be achieved. In particular it would appear that one can trade speed for accuracy and resolution and vice versa according to some, as yet unknown, relationship. A fundamental understanding of possible relationships in this area would be invaluable in planning future developments and would undoubtedly save much effort that will probably be dissipated in pursuit of goals that are difficult or impossible to achieve.

2. <u>Non magnetic recording phenomena</u>. As was stated earlier in this section, recording techniques other than magnetic have been proposed from time to time; however, at this time none appear to be developed to the point where they could be considered for utilization in a Product Development. Of particular interest in the large capacity memory area are techniques that offer promise of densities well above those which appear to be achievable with magnetic recording. The photographic area seems particularly appropriate here. The next frontier beyond large capacity coded data storage could well be that of image or facsimile storage. In this area the parallel

transfer and reproducing techniques available in photographic systems will probably be fundamental to the potential devices. Random Access Facility will be required for this type of storage as well as it is for coded storage and hence research in this direction would be well directed.

3. Advanced Signal Detection Systems.

There is probably much that could be done in moving toward higher recording densities if systems were developed to take advantage of all the information content of a recovered signal from a memory system rather than to simply test signal amplitude as is done in most recording systems today. The slope sensing systems being used on the 650 drum and the tractor tape developments are probably only the first steps in this direction. An exhaustive examination in this area would appear to be a fruitful research that could in the future expand our performance possibilities in large capacity memories.

4. Non Mechanical Memories.

This area has received considerable attention of late and a corporate technical committee has been formed to improve communications upon this subject. Certainly research in this area is appropriate and offers the greatest possibility of a major breakthrough in access time capabilities.

7. APPENDIX

TABLE OF CONTENTS

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July 29, 1957

Memorandum to: Dr. E.R. Piore

Subject: Large Scale Data Processing
File Maintenance - Random Access Memory

The Data Processing Division is facing a very critical competitive situation in large volume applications involving file maintenance. This is exemplified by the recent loss to competition of several orders in the life insurance industry. We are currently losing out to Bizmac and Datamatic.

A still more menacing future threat to our entire business in this area is represented by the NCR 304. It appears that this machine will outperform our equipment in practically all applications where file maintenance is an important factor. Not only will this equipment outperform ours, but it will do so at a price considerably below anything that we now have to ffer.

Our Division is taking emergency steps to meet the present and anticipated future situations as best we can. These steps consist of faster tape operation and a separate off-line special purpose file maintenance machine. These actions will hold the line only temporarily until competitors improve their tape operation also.

We all agree, and we are sure that our customers feel the same, that the ultimate solution to the problem is the use of large scale random access memory at a low per unit record cost.

I am sure that Engineering Research has devoted considerable effort to the principles of random access memory. The purpose of this memorandum is to tell you that we believe time is running out.

We urgently request that Engineering Research give this matter serious consideration and advise this Division in the near future of any research projects which you believe have progressed to the point where they can become a basis of a development program which will provide us the ultimate solution.

L.A. La Motte

LHL:WCG:lt

cc: Messrs. R.H. Garretson
G.E. Jones
W.W. McDowell
R.L. Palmer
W.W. Simmons
M.B. Smith

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September 12, 1957

MEMORANDUM FOR: Mr. L. H. LaMotte

Subject: Large Scale Data Processing
File Maintenance - Random Access Memory

This is in reply to your memorandum of July 29 requesting information on random access memory.

The first enclosure contains a summary of work currently underway in Research that has a definite time scale attached to it. The second enclosure contains work on drums that may be applicable to random access memory but it is too early in the exploratory development stage to assign definite dates for evaluation.

I have not covered any serial memory devices, such as tapes, that may be applicable to insurance problems, nor did we have time to give consideration to the systems problem to determine possible other logical ways of dealing with the insurance industry's problem other than with large random access memory devices.

I am enclosing in addition three studies that may be useful to your staff:

"Large Scale Data Processing and File Maintenance in the Life Insurance Industry" prepared by R.W. Porter, San Jose Research Laboratory. I would urge that you disregard San Jose Research's estimate of manufacturing costs and use these costs only as Research's feeling for the relative complexity of these devices, since Research has no adequate means of estimating costs.

A report on SCRAM prepared by Lewis Lipschutz. This is the most complete report issued to date on this from the Research Center.

"A Study of Possible Connection of SCRAM to 700 Series Equipment" by A.S. Goble of Product Planning.

It may be appropriate that a person from Product Development be appointed that would have the responsibility of deciding with Research which large scale storage (one billion) should be selected. After the selection is made, then a plan can be evolved for greater emphasis in Research and a more rapid transition to Product Development.

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We will keep you informed on this general area, and I would appreciate your letting me know if there is anything else we can do immediately on this problem.

/s/ E.R. Piore
E.R. Piore

ERP:L
Attachments (5)

cc: Messrs. W.W. McDowell
R.H. Garretson
G.E. Jones
R.L. Palmer
W.W. Simmons
M.B. Smith
R.B. Johnson
J. M. Norton

9/17 Copies to Messrs. Schubert, Stevens, Troy, Marcy

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RESEARCH GOALS FOR FUTURE DRUMS

Research Location	Drum L	Drum Dia.	Longit. Density	Track Density	Storage Volume	RPM	Access Time	Application
San Jose	3"	1"	2000 bits/"	200 tracks/"	2×10^6 bits	60,000	1-20 ms	Low cost buffer and logic
Spring Street	12"	5"	2000 bits/"	200 tracks/"	40×10^6 bits	6000	10-100 ms	Random Access storage

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RANDOM ACCESS MEMORY DEVICES IN RESEARCH

Devices	Storage Principle	Storage Volume	Average Access Time	Stage of Research
Advanced RAMAC	Magnetic disks	Equal to or less than 100 million characters	Equal to or less than 76 ms	Techniques turned over to Prod. Dev. September 1957
DAP	Rectangular file of non-erasable photographic strips	Equal to or less than one billion characters	250 ms	Ready now for evaluation by Research and Prod. Dev.
Increased Density DAP	Rectangular file of non-erasable photo strips and document storage	More than one billion characters	Less than 100 ms	Ready for evaluation early 1960's
Photo document storage	Rectangular file of non-erasable photo strips	Less than 10 million pages	Less than one second	Project Walnut. Techniques available to SEPD July 1959
SCRAM	Circular file of short magnetic strips	Less than 20 billion characters	125 ms	Technical feasibility of components early 1959
RBSF	Roct. file of short magnetic strips (may be compatible to DAP)	Less than one billion characters	250 ms	Technical feasibility before 1960.

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C O P Y

September 12, 1957

Memorandum to Mr. R.L. Palmer
Mr. M.B. Smith

Subject: <u>Future Competitive Battles</u>

Every indication that we get is that the next major competitive battle in the Data Processing field will be in the area of large scale Random Access Memory. We are continually beseiged with reports that NCR, Bizmac, General Electric, Sperry Rand, and so forth are engineering tremendous memories at low prices.

The manufacturer who can do this the quickest will be in a very advantageous position. Our answer to the problem, at the moment, seems to be in multiple units of disc memory. I believe we should be pioneering other approaches which will allow less maintenance and less cost, as I have serious doubts that discs in the billion area will be economical.

G.E. Jones

EGJ:JG

cc: Mr. R.T. Samuel
Mr. W.W. Simmons

PRODUCT DEVELOPMENT LABORATORY
SAN JOSE
SEPTEMBER 27, 1957

MEMORANDUM TO: Mr. R. L. Palmer

SUBJECT: Large Capacity Low Cost Memory Study

REFERENCES: Memoranda on reference subject:

1. L. H. LaMotte to E. R. Piore 7/29/57
2. E. R. Piore to L. H. LaMotte 9/12/57
3. G. E. Jones to R. L. Palmer, M. B. Smith 9/12/57
4. R. L. Palmer to G. E. Jones 9/20/57
5. M. B. Smith to W. W. Simmons 9/24/57

As you know, it has been proposed that Product Development activities upon a 1/2 to 1 billion character capacity Random Access Memory be initiated in early 1959 with release projected for late 1962. The above references would indicate that competitive pressure in this area requires a more immediate and accelerated program. Mr. Stevens has asked that I forward, for your consideration, a procedure for establishing the required program.

I propose that an Engineering team consisting of myself, Mr. Gibson, and Mr. Noyes in conjunction with Mr. Wood (WHQ Product Planning) review our situation and recommend an immediate program in this area. In order to arrive at the proper decision such a study should incorporate the following:

1. A review and consolidation of our competitive position in this area.

2. A consolidation of the requirements picture for Large Capacity Low Cost Memory.

3. A study of the devices existent and proposed that are applicable to this area.

I would estimate that this study phase can be completed in three weeks and a recommendation for a program in this area could be made to Division Management at that time.

The attached sheet lists the organizations that would be contacted and the type information to be obtained from each.

J W Haanstra
J. W. Haanstra

JWH:mf
Attachment
cc: Messrs: G. E. Jones, W. W. Simmons, M. B. Smith, L. D. Stevens
L. C. Wood

Sources of Information for Consideration
in a Recommended Program on Large
Capacity Low Cost Memory Development

1. WHQ Data Processing Division

   1.1 Sales Department
   1.2 Product Planning
   1.3 Business Machines Analysis
   1.4 Market Analysis

   Determine competitive position, applications requirements and sales potential.

2. Poughkeepsie Product Development

   2.1 Product Planning
   2.2 Engineering Planning

   Determine 700 series requirements and competitive position.

   2.3 Magnetic Recording Development Activities

   Determine present and projected magnetic densities.

3. Endicott Product Development

   3.1 Product Planning
   3.2 Engineering Planning

   Determine 600 series requirements and competitive position.
   Review CRAM Status.

4. San Jose Product Development

   4.1 Product Planning
   4.2 Product Development

   Determine 300 series requirements and competitive position.
   Determine area of application for disk memories and the present and projected magnetic densities.

5. Corporate Research

   5.1 Poughkeepsie - Ossining
   5.2 San Jose

   Review Research activities and proposals for Random Access Memory Devices.
   Review Research present and projected magnetic densities.
   Review non-magnetic storage techniques.

6. Military Products Division

   Review requirements and Engineering status of Large Capacity Low Cost Memories.

7. Special Engineering Products Division

   Review SEPD information on competitive position and requirements for Large Capacity Low Cost Memory.

JWH:mf

C O P Y

MEMORANDUM TO: L.C. Wood

October 15, 1957

SUBJECT: Large Random Access Memory

In response to your request of October 11th, we are submitting some of the major comments and opinions of the Special Industry Department Managers and District Data Processing Representatives concerning the need for large random access memory.

The comments were gathered by our analysts in the EDPM field survey program we conducted in August, 1957.

H.E. Schmit - Manager Manufacturing Control Department and "unofficial" representative of Dept. 01 - General Industry.
"Need random access storate in the hundreds of millions for storage of bills of material, inventory records, labor specifications, etc. - Storage must be arranged for fast access. Input and output speeds will depend on speed of large storage. Large random memory eliminates the need for faster tape and processing. Fifty per cent of all the 705's in Dept. 01 - General Industry would order if price is right." Sixty-one of all 705's sold to date are in Dept. 01. This department normally represents 40% of IBM's business.

I.S. Homans - Manager Life Insurance Department
"Need random access storage in multiples of one hundred million characters up to at least one billion characters. The basic policy record requires 300 million to 400 million characters for every million policies outstanding. There are approximately 20,000 - 30,000 references per day per million policies. Ninety per cent of all 705 customers would order if price is not out of line." Eighteen of the 705's sold thus far are in the Life Insurance Industry.

C.H. Mahan - Manager Fire & Casualty Insurance Department
"The success of our large scale EDPM systems in the Fire & Casualty Insurance companies will be dependent upon our ability to develop more economical large capacity random access interrogation units - each unit to handle 100 million characters. Some of the larger companies will necessarily need more than one such unit as their requirements might run over 800 million characters. With all the effort and the increased cost of developing high speed magnetic tape units, the companies who have and will install this type equipment will not be able to interrogate on a random access basis, source data stored in the master tape files. I believe we are spending too much time on developing high speed tape units for file maintenance and still we are not able to interrogate the master file for source information which is necessary for reference purposes." Sixteen of the 705's sold thus far are in the Fire & Casualty Insurance Industry.

R.M. James, Jr. - Former Manager State Government Department
"Ten prospects for Motor Vehicle Registration with requirement for 100 million to 500 million characters of inexpensive random access storage."

W.J. Hollenkamp - Manager Communications Department
"Need at least 60 million characters of random access storage for Cable Pair Assignment application. Possible sale of five (5) such systems: Two (2) to New York Telephone, one to General Telephone - California, one to Pacific Telephone, and one to Illinois Bell."

C.C. Smith - Manager Banking and Brokerage Department
"Need large disk storage for eight (8) Type 705 accounts - two Savings banks for posting and inquiry of savings accounts, four commercial banks for central credit reference files, and two Commercial banks for installment loan posting and inquiry."

G.F. Trexler - Manager Public Utility Department
"Need very large random access storage for Customer records, Material and Supplies Records, Personnel Records, and Stockholders Records. Seventy-five percent of 705 accounts would order." Eight of the 705"s sold to date are in the Public Utility industry.

C.G. Thompson - Manager Transportation Department
"Need large random access memory on the 705 for Car Records and Freight Revenue, and Passenger Reservations applications. At this stage without knowing cost and speed it is very difficult to make any definite forecast."

J.D. Shaver - Program Manager - Air Force
"Need Random Access Memory of up to 200 million digits for Weapon System Inventory application for up to 6 Air Material Command Accounts. Need 1 to 50 milliseconds access time."

J. Stinson - Program Manager - Army
"Need up to 75 million characters of random access memory for 12 Army supply depots." Federal Catalog application has 3 million 250-300 character items with a 190 activity ratio and is potential for large random access if priced favorably.

R. Hinchcliffe - Program Manager - Navy
"Five hundred million characters of random access storage in increments of 100 million characters needed in Supply application for 6 locations. Twenty-five thousand transactions per day handled with 6-50 inquiry stations will eliminate 75% of the people in these accounts."

All seventeen District Data Processing representatives contacted indicated a real need for very large economical random access storage and generally speaking felt that its development had more potential and represented a better answer to today's data processing problems than higher performance magnetic tapes. However, concern was expressed about the cost of inactive storage on random access as compared to magnetic tape.

We feel that the next decade offers a market potential of 200-400 random access files of 200 million characters each and 1000 - 2000 files of 50 million characters each. This potential can only be captured if a range of access speeds are offered

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on these files that can be adapted to varying application requirements and if total storage and processing costs can be kept in line with costs of present day techniques of data processing, storage, and inquiry handling.

/s/ F.L. McManus
F.L. McManus

FLM/mml
cc: J. Hanastra-San Jose
C. Earley - San Jose
B.L. Sarahan - WHQ
H.T. Ware, Jr. - WHQ

10/21/57 - TN

MACHINE: 50 x 10^6 Disk File

SUB-ASSEMBLY: Access - Hydraulic Actuator and Power Unit

		57	1958				1959				1960				1961		
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
a. Experimental design, model, test.	P	1	2	2	1												
	T	1	1	1	1												
	U	1	2	2	1												
b. Product design, model, test.	P				1	2	1	1									
	T				1	2	2	1									
	U				2	4	3	3									
c. Engineering Test and design modification	P						1	1	1	1	1	1					
	T							2	1	1	1	1					
	U						1	1	1	1	1	1					
d. Production drawings, specifications, tool analysis	P								1	1	1	1					
	T								2	2	2	2					
	U								3	3	4	4					
e. Product Test	P									½	½	½					
	T																
	U																
f. Pilot production support and release	P												1	½			
	T																
	U																
	P	1	2	2	2	2	2	2	2	2½	2½	2½	1	½			
	T	1	1	1	2	2	2	3	3	3	3	3					
	U	1	2	2	3	4	4	4	4	4	5	5					

10/21/57 - TN

MACHINE: 50×10^6 Disk File

SUB-ASSEMBLY: Access - Carriage, Arms, Structure

		57	1958				1959				1960				1961		
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
a. Experimental design, model, test.	P	1	2	2	1												
	T		1	1	1												
	U	1	1	2	2												
b. Product design, model, test.	P				1	2	1	1									
	T				1	2	2	2									
	U				1	3	3	3									
c. Engineering Test and design modification	P						1	1	1	1	1	1					
	T								1	1	1	1					
	U						1	1	2	2	2	2					
d. Production drawings, specifications, tool analysis	P								1	1	1	1					
	T								1	1	1	1					
	U								3	3	3	3					
e. Product Test	P									1/2	1/2	1/2					
	T																
	U																
f. Pilot production support and release	P												1	1/2			
	T																
	U																
	P	1	2	2	2	2	2	2	2	2½	2½	2½	1	½			
	T		1	1	2	2	2	2	2	2	2	2					
	U	1	1	2	3	3	4	4	5	5	5	5					

MACHINE: 50 x 10^6 Disk File

SUB-ASSEMBLY: Disk Array

		57	1958				1959				1960				1961		
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
a. Experimental design, model, test.	P	1	1	2	2												
	T	1	1	1	1												
	U	1	2	3	2												
b. Product design, model, test.	P				1	3	2	2									
	T				1	2	2	1									
	U				2	4	6	6									
c. Engineering Test and design modification	P						1	1	1	1	1	1					
	T						1	2	2	2	2	2					
	U						1	1	1	1	1	1					
d. Production drawings, specifications, tool analysis	P								2	2	2	2					
	T								1	2	2	2					
	U								6	6	6	6					
e. Product Test	P									1	1	1					
	T																
	U																
f. Pilot production support and release	P												2	1			
	T																
	U																
	P	1	1	2	3	3	3	3	3	4	4	4	2	1			
	T	1	1	1	2	2	3	3	3	4	4	4					
	U	1	2	3	4	4	7	7	7	7	7	7					

Drive
Disk Mounting
Structure

Controls
Compressor (?)
No Covers

MACHINE: 50 x 10^6 File

SUB-ASSEMBLY: Access - Control Unit

		'57	1958				1959				1960				1961		
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
a. Experimental design, model, test.	P	1	2	2	1												
	T	1	1	1	1												
	U		1	1	1												
b. Product design, model, test.	P				1	2	1	1									
	T				1	2	2	2									
	U				1	2	2	2									
c. Engineering Test and design modification	P						1	1	2	2	2	2					
	T						1	1	2	2	2	2					
	U						1	1	1	1	1	1					
d. Production drawings, specifications, tool analysis	P								1	1	1	1					
	T								1	1	1	1					
	U								2	2	2	2					
e. Product Test	P									1/2	1/2	1/2					
	T																
	U																
f. Pilot production support and release	P												2	1			
	T																
	U																
Address Register, Checking Features, Interlocks, Power Supply (Read-Write Supply, also), Packaging, Customer Engineering Panel	P	1	2	2	2	2	2	2	3	3½	3½	3½	2	1			
	T	1	1	1	2	2	3	3	3	3	3	3					
	U		1	1	2	2	3	3	3	3	3	3					

Address Register
Checking Features
Interlocks
Power Supply (Read-Write Supply, also)

Packaging
Customer Engineering
Panel

V

10/21/57 - TN

MACHINE: 50 x 10^6 File

SUB-ASSEMBLY: Heads and Disk: Magnetics

		57	1958				1959				1960				1961		
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
a. Experimental design, model, test.	P	2	2	3	1												
	T	2	2	2	2												
	U	1	1	2	1												
b. Product design, model, test.	P				2	3	2	2									
	T				1	3	2	2									
	U				1	2	2	2									
c. Engineering Test and design modification	P						1	1	2	2	1	1					
	T						1	1	3	3	3	3					
	U						1	1	1	1	1	1					
d. Production drawings, specifications, tool analysis	P								1	1	2	2					
	T																
	U								2	2	2	2					
e. Product Test	P									½	½	½					
	T																
	U																
f. Pilot production support and release	P												2	1			
	T																
	U																
	P	2	2	3	3	3	3	3	3	3½	3½	3½	2	1			
	T	2	2	2	3	3	3	3	3	3	3	3					
	U	1	1	2	2	2	3	3	3	3	3	3					

I

10/21/57 - TN

MACHINE: 1 Billibin File

SUB-ASSEMBLY: Magnetics - Strip and Head

		1958				1959				1960				1961			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
a. Experimental design, model, test.	P	1	2	2	2	1											
	T	1	2	2	2	1											
	U	1	1	1	1	1											
b. Product design, model, test.	P					1	2	2	2	1	1						
	T					1	2	2	2	1	1						
	U					1	2	2	3	3	3						
c. Engineering Test and design modification	P									1	1	1	1/2	1/2	1/2		
	T									1	1	2	2	2	2		
	U									1	1	1	1	1	1		
d. Production drawings, specifications, tool analysis	P											2	2	2	2		
	T											1	1	1	1		
	U											3	3	3	3		
e. Product Test	P												1/2	1/2	1/2		
	T																
	U															2	1
f. Pilot production support and release	P																
	T																
	U																
	P	1	2	2	2	2	2	2	2	2	2	3	3	3	3	2	1
	T	1	2	2	2	2	2	2	2	2	2	3	3	3	3		
	U	1	1	1	1	2	2	2	3	4	4	4	4	4	4		

II

10/21/57 - TN

MACHINE: 1 Billibin File

SUB-ASSEMBLY: Strip Selector and Drives

		1958				1959				1960				1961			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
a. Experimental design, model, test.	P	1	2	2	2	1											
	T	1	1	1	1	1											
	U	1	2	3	3	1											
b. Product design, model, test.	P					1	2	3	3	2	2						
	T					1	2	2	2	2	2						
	U					2	3	3	3	4	4						
c. Engineering Test and design modification	P									1	1	1	1/2	1/2	1/2		
	T									1	1	1	1	1	1		
	U									1	1	1	1	1	1		
d. Production drawings, specifications, tool analysis	P											2	2	2	2		
	T											2	2	2	2		
	U											4	4	6	6		
e. Product Test	P												1/2	1/2	1/2		
	T																
	U																
f. Pilot production support and release	P															2	1
	T																
	U																
Strip Selector (Picker-Head) Strip Drive (Pinch-Roll) X. Y. Drive (Piston Adders) Power Unit (Hydraulic)	P	1	2	2	2	2	2	3	3	3	3	3	3	3	3	2	1
	T	1	1	1	1	2	2	2	2	3	3	3	3	3	3		
	U	1	2	3	3	3	3	3	3	5	5	5	6	7	7		

MACHINE: 1 Billibin File

SUB-ASSEMBLY: Bin, Strip, Structure - Mechanical

		1958				1959				1960				1961			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
a. Experimental design, model, test.	P	1	1	2	2	1											
	T	1	1	1	1	1											
	U	1	2	2	2	2											
b. Product design, model, test.	P					1	2	2	2	1	1						
	T					1	3	3	3	2	2						
	U					1	3	4	5	5	5						
c. Engineering Test and design modification	P									1	1	1	1/2	1/2	1/2		
	T									1	1	1	1	1	1		
	U									1	1	1	1	1	1		
d. Production drawings, specifications, tool analysis	P											1	1	1	1		
	T											2	2	2	2		
	U											4	5	6	6		
e. Product Test	P												1/2	1/2	1/2		
	T																
	U																
f. Pilot production support and release	P															2	1
	T																
	U																
	P	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1
	T	1	1	1	1	2	3	3	3	3	3	3	3	3	3		
	U	1	2	2	2	3	3	4	5	6	6	5	6	7	7		

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MACHINE: 1 Billibin File

SUB-ASSEMBLY: Control Unit and Read - Write

		1958				1959				1960				1961			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
a. Experimental design, model, test.	P	1	2	3	3	2											
	T	1	2	2	2	2											
	U	1	1	1	2	1											
b. Product design, model, test.	P					1	3	4	4	3	3						
	T					1	3	3	4	3	3						
	U					1	2	3	4	5	5						
c. Engineering Test and design modification	P									1	1	2	1	1	1		
	T									1	1	2	2	2	2		
	U									1	1	1	1	1	1		
d. Production drawings, specifications, tool analysis	P											2	2	2	2		
	T											2	2	2	2		
	U											5	5	5	5		
e. Product Test	P												1	1	½		
	T																
	U																
f. Pilot production support and release	P															2	1
	T																
	U																
Address Register Read - Write Amplifier Power Supply Packaging Cables Customer Engineering Panel	P	1	2	3	3	3	3	4	4	4	4	4	4	4	3½	2	1
	T	1	2	2	2	3	3	3	4	4	4	4	4	4	4		
	U	1	1	1	2	2	2	3	4	6	6	6	6	6	6		