STORAGE UNITS

A STORAGE unit is a device which is capable of receiving, retaining and reproducing information.

The human mind has a storage unit because it is capable of receiving information from any of the five senses, remembering or storing that information, and later reproducing it in any of several ways. Thus, the details of a painting or the theme of a musical composition can be recalled from memory at a later time.

IBM uses a number of schemes and devices to store information. One of the most simple and inexpensive storage medium is the IBM card. However, to fulfill the function of a storage device, two other devices must be used with the card. Information received by a punching mechanism is translated and retained in the form of holes punched in the card. The card retains the information indefinitely. When the information is to be reproduced or transmitted to some other device, the card must pass a sensing device. The punch, card and sensing unit are thus combined to form a memory unit.

IBM storage units may be electro-mechanical, electro-magnetic or electronic. Several of the devices which have been studied in previous chapters may also be classified as storage units. For example, the zone unit, studied in the Type 402 printing unit is a storage unit because it stores zone information until it is to be placed in the type bar. Electro-mechanical counters may be used as a storage unit, and the electronic counter can be used as a storage unit with a few changes in the normal counter circuit.

Relay Storage

Electro-magnetic relays are often used as a storage device. Figure 267 shows the circuits necessary to store information in relays using the binary system. An impulse resulting from a card brush energizes one or more of the four relays shown. The relays are numbered according to their value and are controlled by cams. The relays are picked by a digit so that their combined values equal the value of the digit.

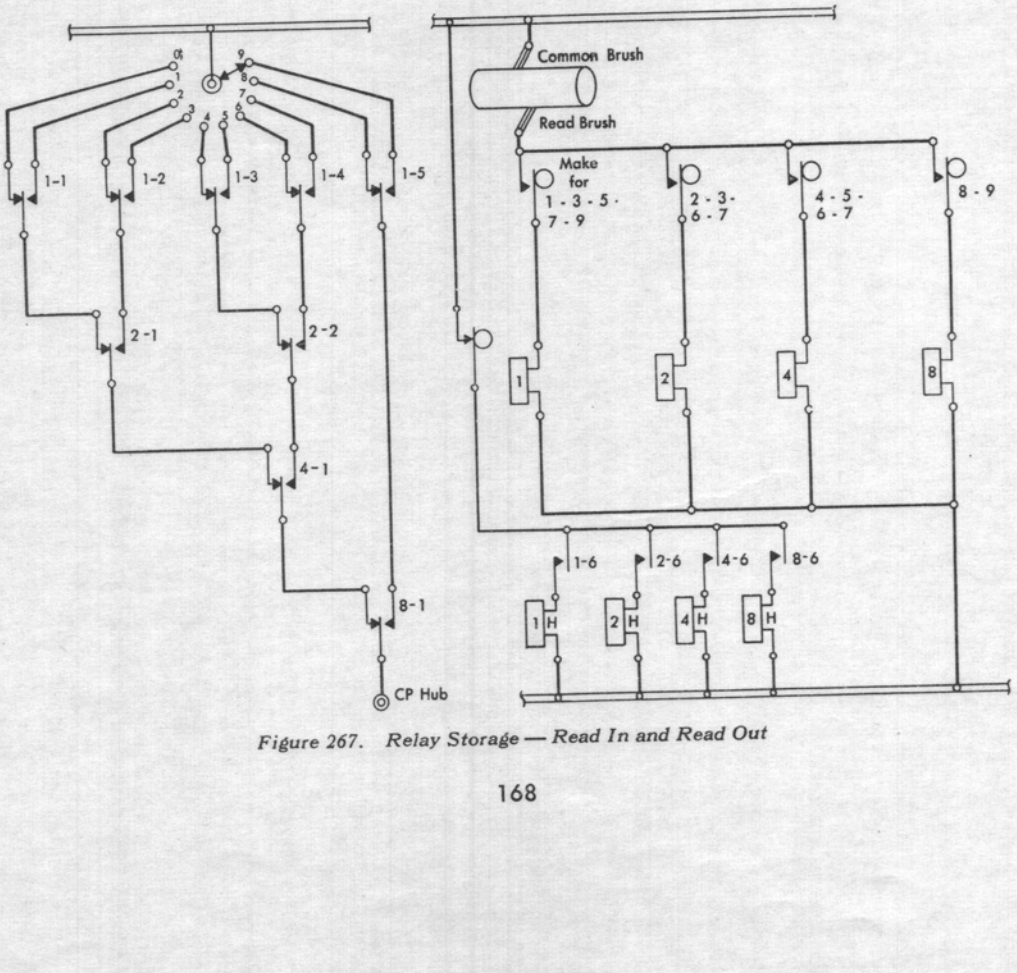

Figure 267. Relay Storage — Read In and Read Out

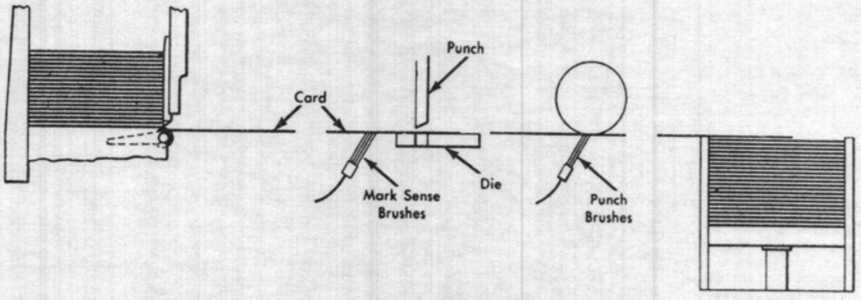

Figure 268. Mark Sense Feed Schematic

The relay contact network permits the stored information to be read out. The emitter sends out impulses 0 through 9, but only one impulse will reach the control panel hub. The selection of this impulse will depend on which relay or relays are energized. If none of the relays has been energized, the zero impulse passes through all of the normally closed points to reach the output hub.

Mark Sense Delay Unit

A storage unit is used on the IBM machines in which conductive marks are sensed to cause holes to be punched. When the mark is sensed, the card is not in the proper punching position. The storage unit retains the information while the card advances to the desired position, and then the unit furnishes an impulse to cause punching. Because the information is always stored for the same length of time, this unit is called a *delay* unit.

A feed which has brushes for sensing marks is shown in Figure 268. Figure 269 shows the relationship between the position of the mark and the punching position for a particular digit. Figure 270 shows that the card must move two cycle points after the mark is sensed before it is in position to punch the information. This requires that the delay unit store the information for two cycle points and then impulse the punch magnet.

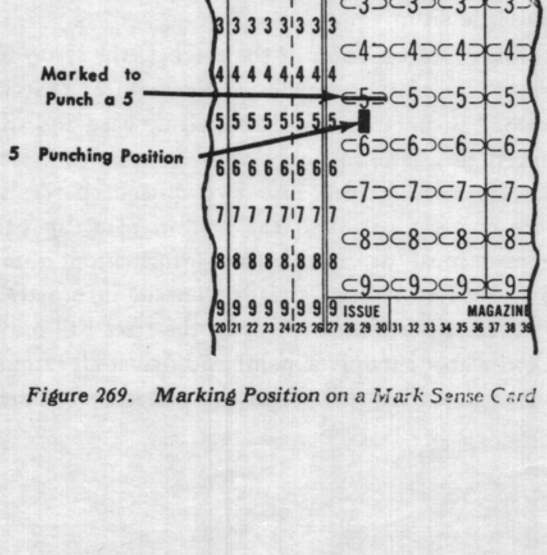

Figure 269. Marking Position on a Mark Sense Card

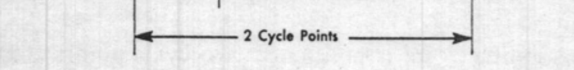

Figure 270. Cycle Point Relationship of Mark Sensing and Punching Mechanism

A basic mark sense delay unit is shown in Figure 271 with the circuit essentials. The sensing circuits have been previously studied, so a block is used to represent the electron tube and related circuits in this figure.

The unit consists of 10 control sensing magnets located radially on a stationary plate, a drum unit, which consists of a latch ring and 30 armature contact pawls, and 10 contact cams. The drum unit

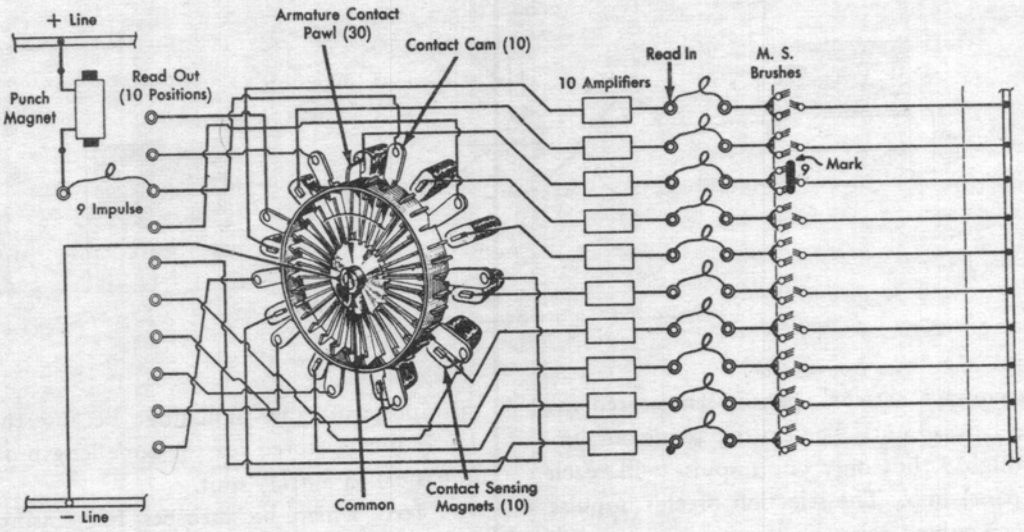

Figure 271. Mark Sense Delay Unit

rotates when the machine is running, but it is geared to make 7/15 of a revolution per machine cycle. The drum unit is divided into 30 parts by the armature contact pawls, so at the given rate of revolution 14 armature pawls will pass any given sensing magnet during each machine cycle. The machine is a 14 cycle point machine so an armature pawl will pass each magnet each cycle point.

The drum unit is timed so that when a mark is sensed, an armature latch will be directly in front of the magnet core. If a mark is sensed, it will impulse the magnet to which it is wired. When the armature is pulled toward the magnet, it unlatches and springs up, to project further from the drum unit (Figure 271).

A contact cam is positioned two cycle points from each magnet. Any armature that is tripped off by a mark being sensed will come in contact with a contact cam two cycle points later. As the drum unit rotates and the armature touches the contact cam, a circuit is completed from one side of the line to the hub of the drum unit, through the armature to the contact cam, and out to the delay unit read out hub. A punch magnet will be impulsed from the read out hub through control panel wiring. As the drum unit continues to turn, the contact cam presses the armature contact pawl down so that it is relatched.

There are ten positions per delay unit so one delay unit is required for each ten positions of mark sensing. Because the card capacity is 27 columns of mark sensing, three delay units would be required for the 27 positions.

Type 602A Storage Unit

The essentials of a single position storage unit of this type are shown in Figure 272. They consist of a magnet, armature, setup ratchet, setup or reset bail, 11 read out contact bars, and a column contact.

The setup bail pivots about the shaft on which the setup ratchets are mounted. It is cam operated and has an oscillating motion like that of a pendulum.

The setup bail and ratchet shown in the figure are in the extreme downward position which is the normal and latched position of the setup bail. The setup ratchet has nothing set up in it when it is down against the setup bail.

To enter information in the ratchet, the setup bail must operate for one cycle. This requires that the setup bail be unlatched and rotated upward and then returned to a latched position.

The cycle is divided into two distinct parts; the restore or reset part and the read-in or setup part. The unit must be reset before information is read into it because it may already contain information. On the reset portion of the cycle the reset bail moves clockwise about its pivot point and drives all ratchets so that the 9 tooth is beyond the armature as shown

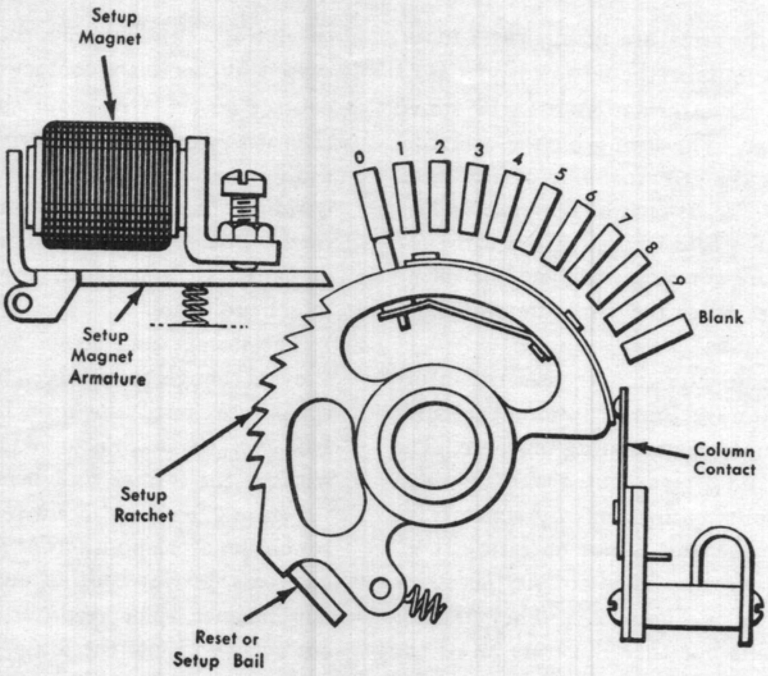

Figure 272. 602A Type Storage Unit — Single Position

in Figure 273. This figure also shows that the contact plunger moves beyond the 9 contact bar. A blank contact bar has been added to prevent the contact plunger from popping up and preventing the ratchet from following the setup bail downward.

The setup bail and ratchets then move downward for the setup portion of the cycle. As the setup bail moves downward, the ratchets follow under spring tension. The ratchet teeth are moving past the setup magnet armature in a counterclockwise direction. If the setup magnet is energized during this time, the armature will engage a tooth on the ratchet and stop it. Timing is very important during setup so that the proper tooth is engaged by the armature.

Figure 274 shows the ratchet stopped, as a result

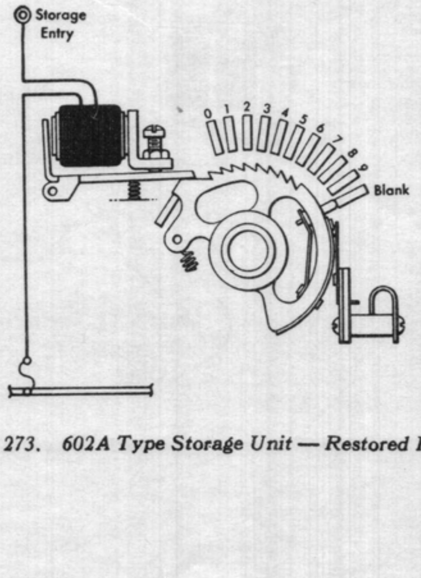

Figure 273. 602A Type Storage Unit — Restored Position

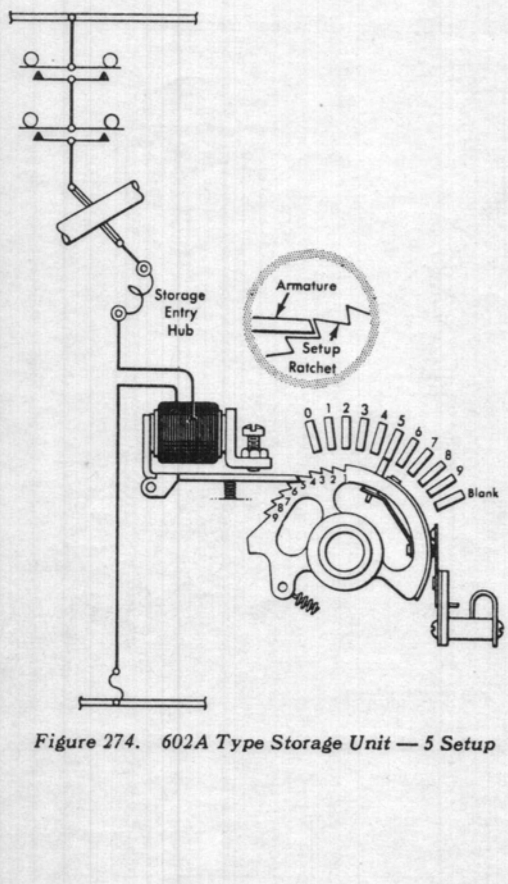

Figure 274. 602A Type Storage Unit — 5 Setup

of a 5 impulse, with the armature against the 5 tooth. The impulse used to impulse the setup magnet is of short duration, but the information is to be stored in the unit until reset. The spring on the armature is attempting to lift the armature out of the tooth of the ratchet. However, as seen in the inset of Figure 274, the armature is held in the tooth because the tooth and armature are cut on a slant and the spring tension of the ratchet holds the armature and tooth engaged.

It is desirable at some later time to read the information out of the storage unit to some other unit such as a punching unit, accumulating unit, etc. The Type 602A storage unit reads out the digit value and is a static read-out mechanism. By static read-out it is meant that the unit is not operating, i. e., the ratchets are not moving. The circuits necessary for read-out are shown in Figure 275. They are not the Type 602A circuits but they illustrate all of the principles involved in read-out.

The impulses from the emitter are timed so that they are available at the proper time with relation to the index. All impulses from the emitter are directed to the corresponding read-out contact bars. However, in any one position, such as the one shown in Figure 275, only one impulse will get through to the storage exit hub. In the case shown, the 5 impulse will pass to the contact plunger which is making contact on the 5 read out contact bar. The impulse then passes through the spring strap and rivet to the sliding contact surface on which the column contact is riding. The column contact completes the circuit to the storage exit hub. The storage exit hub could be wired to a counter, another storage unit, or a punch unit, etc.

The storage unit shown will continue to store the 5 even though it has been read out, possibly more than once, until the unit is instructed to read in. However, the machine may take any number of cycles without the storage unit being instructed to read in.

Figure 276 shows an entire 602A type storage unit. It consists of 12 positions of storage, 11 read-out contact bars, a reset bail, an operating cam and a latch trip magnet. The read-out contact bars have been cut away to show the setup ratchets. The latch trip magnet determines when the reset bail will follow the operating cam to reset and read in the unit. The unit will reset and read in when the latch trip magnet is impulsed, this is controlled by the operator from the control panel. This allows great flexibility in selecting the cycle or cycles on which read in is to take place.

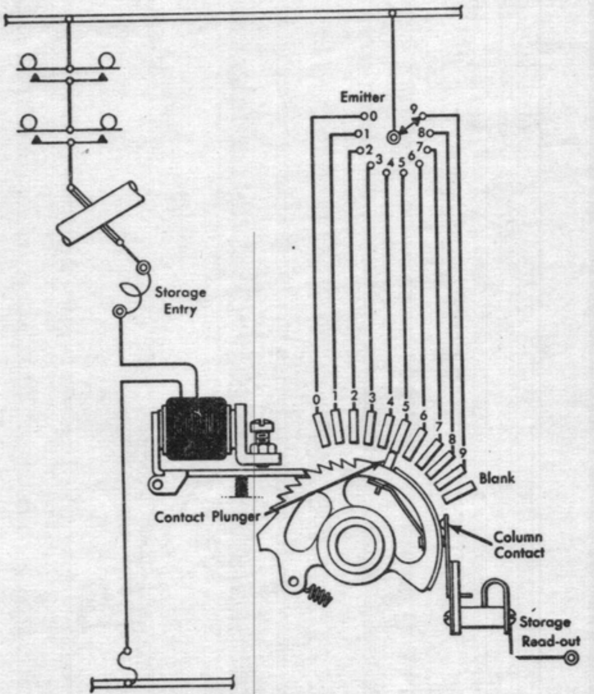

Figure 275. 602A Type Storage Unit — Read Out Circuit

Type 77 Storage Unit

The Type 77 storage unit is, in many respects, very similar to the Type 602A storage unit. The similarity exists in the method of restoring (resetting) and setting up (reading in). Figure 277 shows the similarity which exists, but does not show the whole unit.

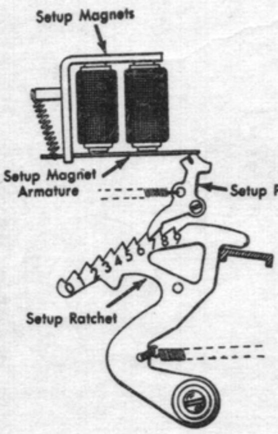

Figure 277. Type 77 Storage — Setup Magnet and Ratchet

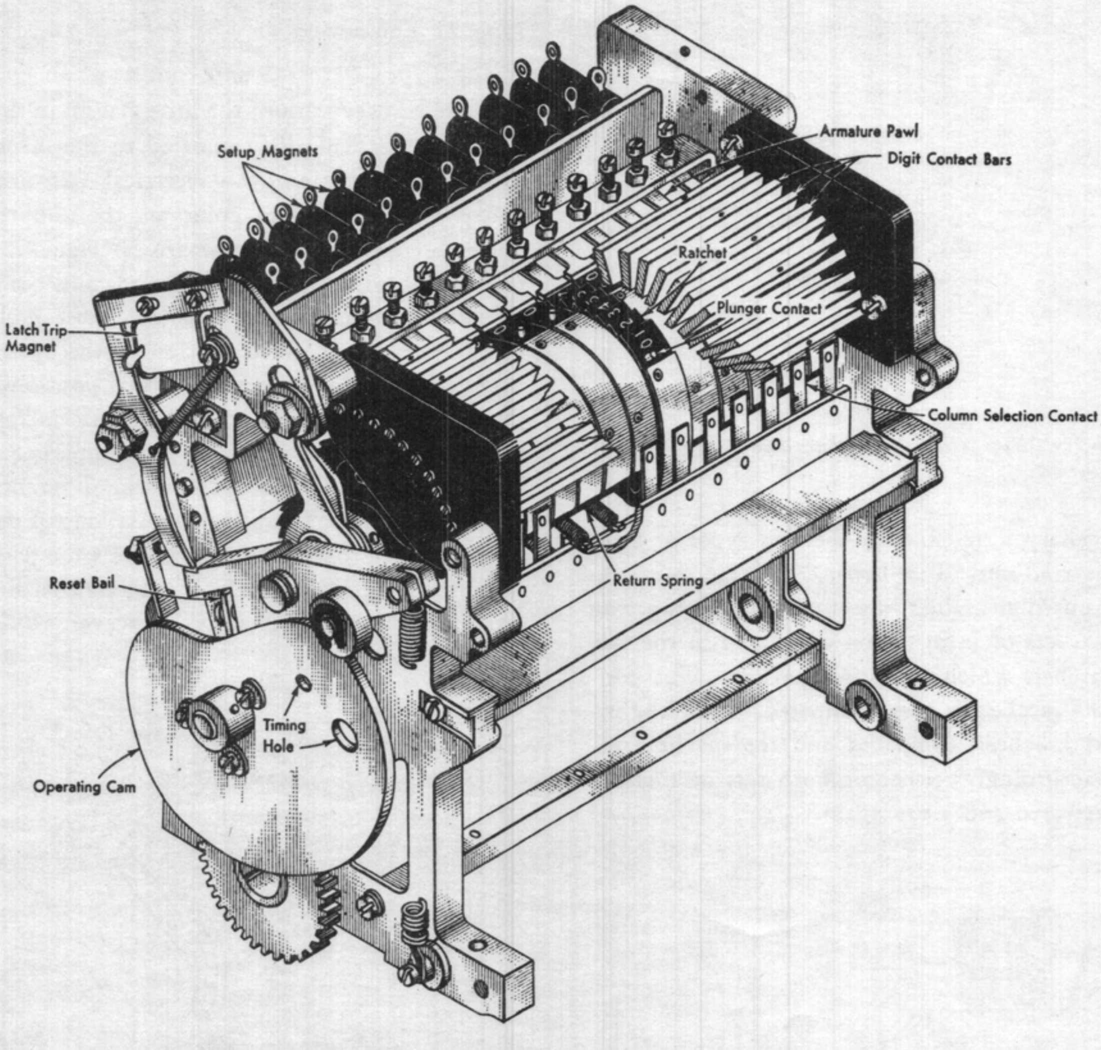

Figure 276. Entire 602A Type Storage Unit — 12 Positions

The restoring bail (setup bail) is under the control of a magnet as in the 602A unit and will only operate when impulsed to read in. On the read-in cycle the unit is restored. The position shown contains a seven. To restore or clear the seven, the setup pawl must be relatched on the armature and the ratchet moved so that the pawl is beyond the nine. The level of the ratchet beyond the nine is higher than the level of any other part except the zero tooth. When the ratchet is driven beyond the nine on the restoring portion of the cycle, the setup pawl rides up the surface of the ratchet. This high level cams the setup pawl so that the pawl clears the armature and is relatched. Figure 278 shows the pawl being relatched on the armature. Figure 279 shows the ratchet following the setup bail on the setup portion of the cycle. The unit is shown at the time the setup pawl is released to set up a five.

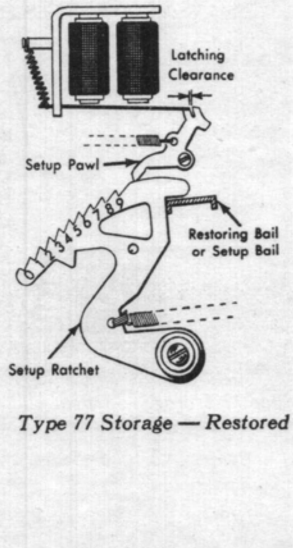

Figure 278. Type 77 Storage — Restored Position

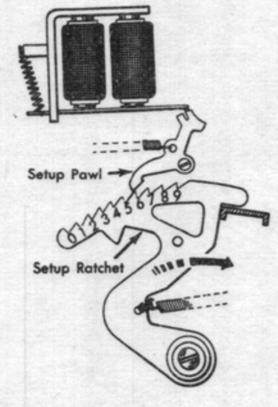

Figure 279. Type 77 Storage — Impulsed to Setup a 5

The primary differences in the two types of units are in the read-out. The Type 77 storage unit does not read out digit values but is used as a comparing unit. Two sets of information are stored in the two sets of ratchets which comprise one unit. The position of the ratchets is then compared. Once the information has been compared and the machine instructed accordingly, either or both sets of ratchets may be restored and setup again.

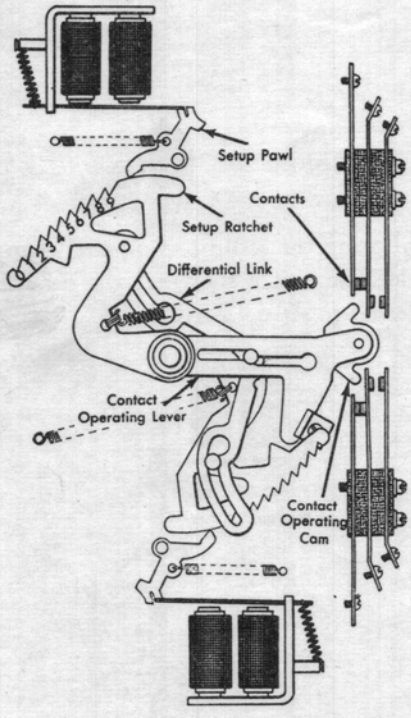

Figure 280. Type 77 Storage — Upper and Lower Section — Single Position

Type 77 Comparing

The Type 77 storage unit consists of an upper section and a lower section; the information in the upper section is mechanically compared to the information in the lower section. An electrical test impulse is sent through a series of points on the unit to determine the result of the comparison. Figure 280 is a single position showing both sections and the contact points. The two sections are in a reset position in preparation for the read portion of the cycle. Note that both contacts are in the normal position because there is no difference of ratchet position in the upper and lower sections. The key to comparing the information in the two sections is the differential link and differential link guide plate. As long as the setup ratchets move together or are in the same position in relation to the setup pawls, the differential link stud acts merely as a pivot point. However, if either of

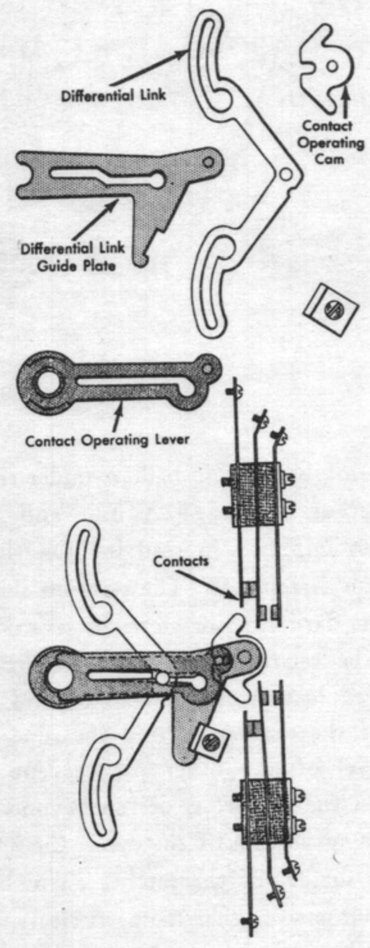

Figure 281. Differential Link — Guide Plate-Support Bail — Contact Operating Lever-Cam

the ratchets are stopped while the other is moving, the differential link stud will slide in the slot of the differential link guide plate. The slot in the guide plate is designed with two levels as illustrated in Figure 281. The differential link stud and differential link will be moved upward or downward depending on the direction the stud is moved from the center. Note that the differential link guide plate is held stationary. The differential link stud also extends through the contact operating lever. The slot in the contact operating lever is a straight slot, and if the differential link stud is moved upward or downward, the contact operating lever is moved in the same direction. The contact operating lever is free to pivot about the shaft under the control of the differential link stud.

A contact operating cam is mounted on a stud on the end of the differential link guide plate. The contact operating cam is free to pivot on this stud under the control of the stud on the contact operating lever.

The Type 77 storage and comparing mechanism is capable of recognizing only three conditions: one, that a number is equal to another number; two, that a number is higher than another; three, that a number is lower than another number. Figure 282 illustrates the three possible conditions. It will be assumed for this illustration that it is desirable to know how the digit in the upper or top section compares with the information in the lower or bottom section.

The example on the left shows the conditions which exist when the information in the top section is equal to that in the bottom section. Note that the differential link stud is in the center of the slot in the differential link guide plate and that the contacts remain in the normal position.

The figure in the center shows the conditions which exist when the top section is low in relation to the bottom section. Note that the differential link stud has moved toward the contacts and that the bottom set of points has transferred.

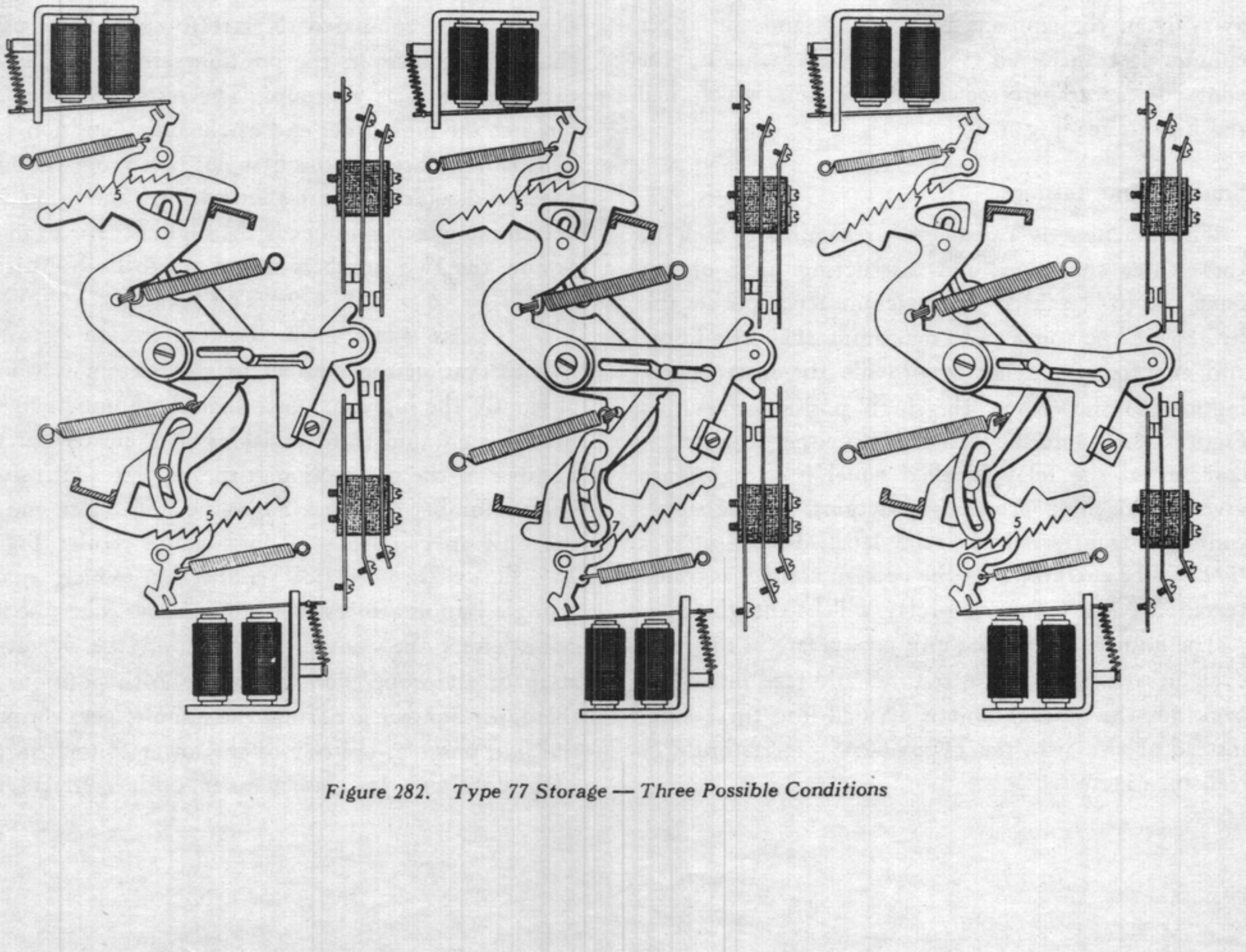

Figure 282. Type 77 Storage — Three Possible Conditions

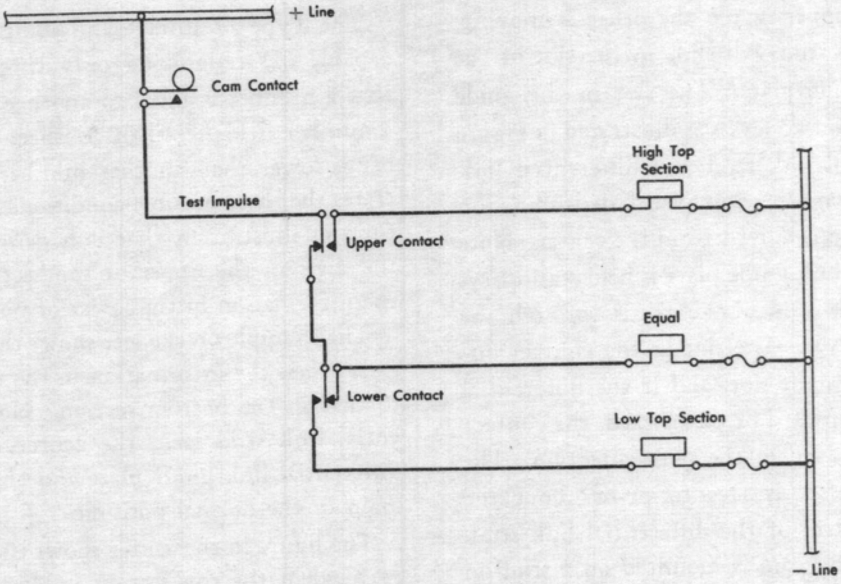

Figure 283. Test Circuits — Single Position

The figure on the right shows the conditions which exist when the top section is high in relation to the bottom section. The differential link stud has moved away from the contacts in this case, and the upper contact is transferred. Note that in each case the contact was transferred in the section which had the highest reading in it.

Storage Unit Testing

The machine is capable of recognizing each of these three conditions and instructing itself on the next step to be taken. The machine accomplishes this by testing the contacts to determine their condition, and energizing a relay to provide the instructions. Figure 283 shows how the single position shown in Figure 282 could be tested. If neither contact is transferred the relay labelled equal is energized to give the machine proper instructions. If the upper contact is transferred, the relay labelled *high top section* will be energized. If the bottom contact is transferred, the *low top section* relay will be energized.

The impulse to test the unit occurs late in the same cycle in which the unit is restored and read into. The cycle for this storage unit is divided into three parts instead of two as in the Type 602A: (1) restore, (2) read-in, (3) test.

The entire unit consists of two sections, one upper and one lower. Each section consists of 16 single positions. Figure 284 shows the entire unit. Sixteen digits can be compared to sixteen other digits using this unit. However, the positions are not tested individually but as a group. The test impulse is entered at the high order end of the unit (position 16). This is done because the first position from the high order end which indicates an unequal condition will determine which number is the highest. For example assume the two numbers below are to be compared:

6 5 3 8 4 9	Top section
6 5 4 7 1 0	Bottom section

By observation the number in the bottom section is obviously the highest. Note that the numbers in the first, second, and third positions all indicate that the number in the top section is the highest. Therefore, if the number is tested from the low order end of the unit an erroneous reading would result. Figure 285 shows the electrical connection which enable a single impulse to test the entire unit. The test impulse enters the contact network on the operating strap of the upper contact in the 16th position. If the upper contact is normal the impulse goes through the N/C point to the O/P of the lower contact in the 16th position. In this manner both contacts are

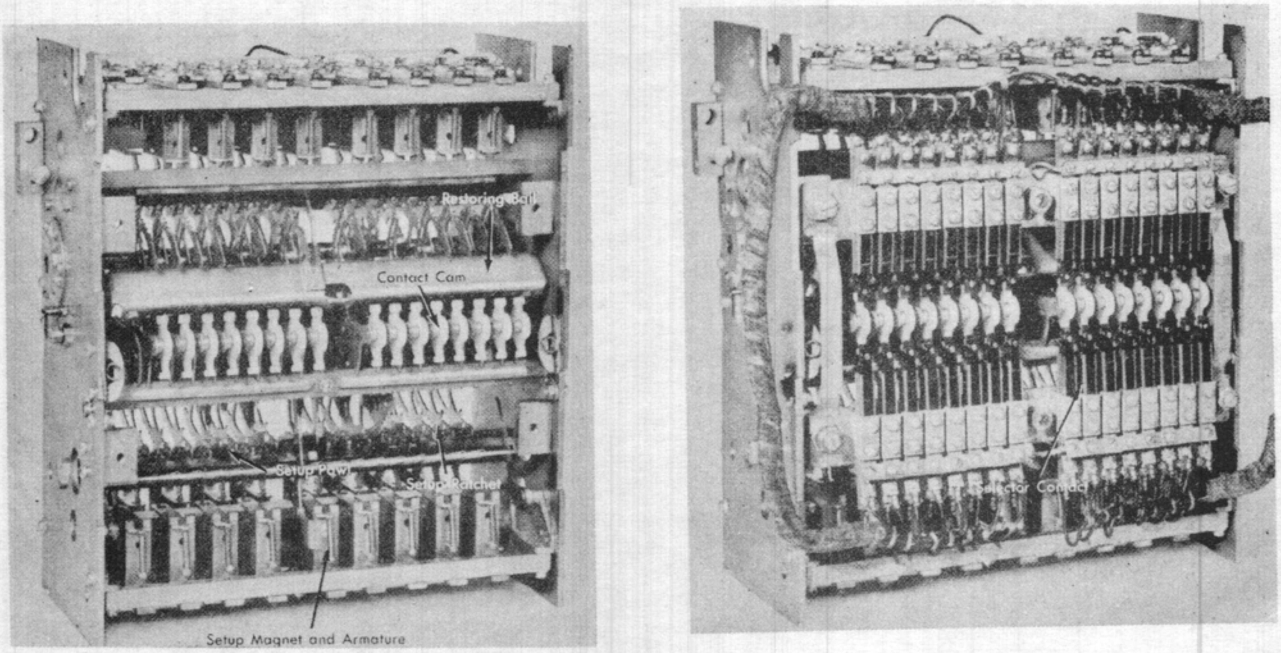

Figure 284. Entire Type 77 Storage Unit — 16 Positions

checked in each position before the next position is checked. If both contacts are normal, indicating an equal reading in that position, the impulse is passed on to the next position to be tested. The impulse passes through all of the N/C points to energize the equal relay if none of the points are transferred. However, as soon as the first transferred point is encountered, the impulse is immediately shunted around the remaining points to energize the proper relay. The N/O points of the upper contacts are all jumpered together and connected to the relay labeled *high top section.* If the first transferred point is an upper contact, the *high top section* relay is energized to inform the machine that the reading in the top section is high. Similarly if the first transferred point is a lower point, the *low top section* relay is energized.

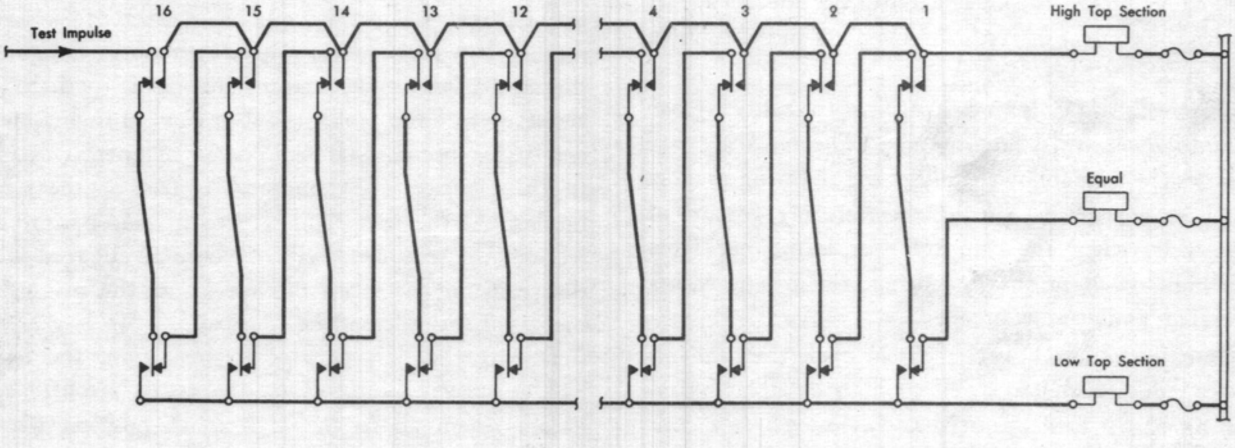

Figure 285. Test Circuits for Complete Unit

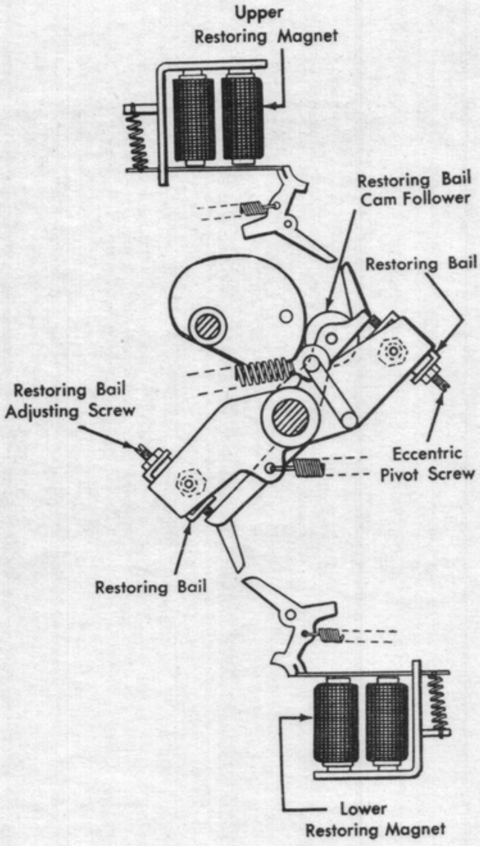

Figure 286. Restoring Mechanisms

On the next cycle it may be desired to compare other information to the information already in one section of the unit. In this case, the information in the other section is cleared and the new information read into it. It may be desirable to compare two new sets of information; in which case both sections are cleared and read into. The restoring and setup are under the control of restoring magnets and are shown in Figure 286.

The restoring bails are held against the restoring bail cam follower by spring tension. The restoring bail follows the cam follower only if the restoring magnet has been energized. During the restoring portion of the cycle, when the cam follower is moving from the high dwell to the low dwell, the bail is spring operated and cam controlled.

During the setup portion of the cycle the cam follower rides from low dwell to high dwell. The restoring bail is cam operated and is moved at a constant speed for selection. At the end of the setup portion of the cycle, any restoring bail which is operating will be relatched on the restoring pawl.

Type 407 Storage Unit (Figure 287)

This machine is capable of storing 64 positions of numerical information for an indefinite peoriod of time. The mechanical operation is similar to that of the sequence and selector units on the Collator. The storage section is divided into two separate units, each capable of storing 32 positions. Each unit is divided into two sections, an upper section and a lower section. Each section operates identically. Each position consists of a magnet, armature, stop pawl, setup ratchet and contact, and emitter contact assembly (Figure 288). The setup ratchet has twelve teeth and a stop or blank position into which the stop pawl may become engaged. Beyond the 9 tooth of the setup ratchet is a high tooth. This tooth operates against the stop pawl at the extreme operating position of the setup bail and pivots the stop pawl in such a manner that it becomes latched on the magnet armature. In this position the stop pawl is free of the setup ratchet. As the setup bail returns in the opposite direction, the stop pawl will not become engaged with the teeth on the setup ratchet unless the magnet is energized and releases the stop pawl.

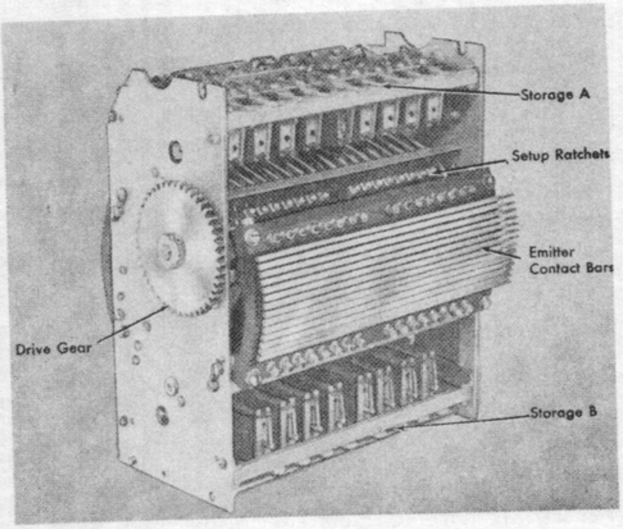

Figure 287. Storage Unit

During the first part of its operation, the setup bail operates against all of the setup ratchets and restores them all to the high tooth position which

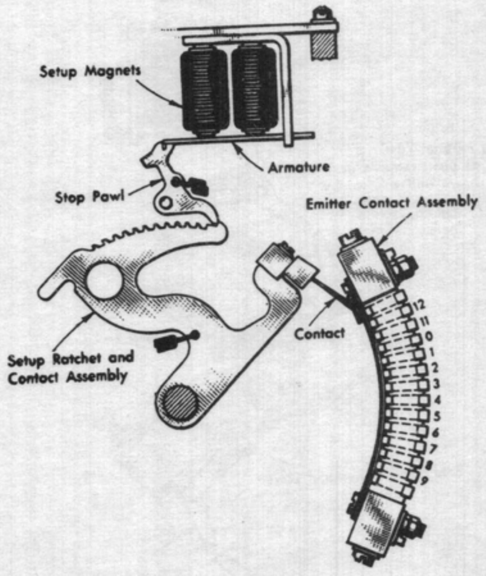

Figure 288. Storage Unit — Setup Ratchet and Emitter Contact

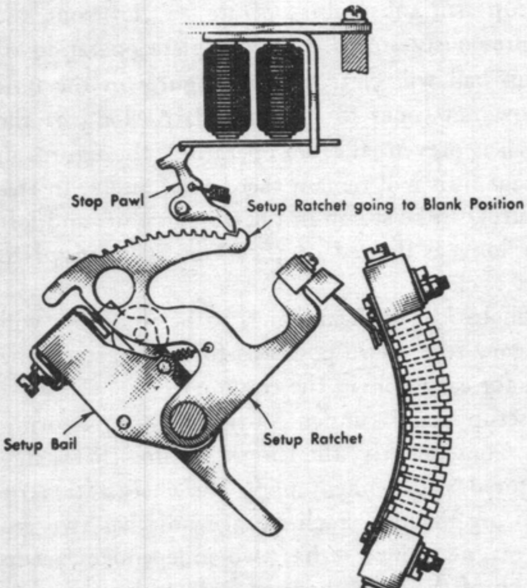

Figure 289. Setup Ratchet at Blank Position

causes all stop pawls to be latched. As the setup bail returns, the setup ratchets will follow the bail since the setup ratchets are held against the bail with individual springs. As long as the stop pawls remain latched (setup magnet de-energized) the setup ratchets will continue to follow the setup bail and will go to the blank position if the stop pawl is not unlatched before the end of the operation (Figure 289). However, when a setup magnet becomes energized, the stop pawl is released and becomes engaged with the setup ratchet. Since the setup ratchet is following the setup bail only because of spring tension, the stop pawl stops the movement of the setup ratchet and holds it in the position as determined by the tooth that the stop pawl engages (Figure 290). The tooth that the stop pawl engages is dependent upon the time that the setup magnet becomes energized. The quicker the magnet is energized after the setup bail starts back to normal, the higher will be the value set up in the unit.

As shown in Figure 290, the setup bail must be operating to insert a figure into the unit to be stored.

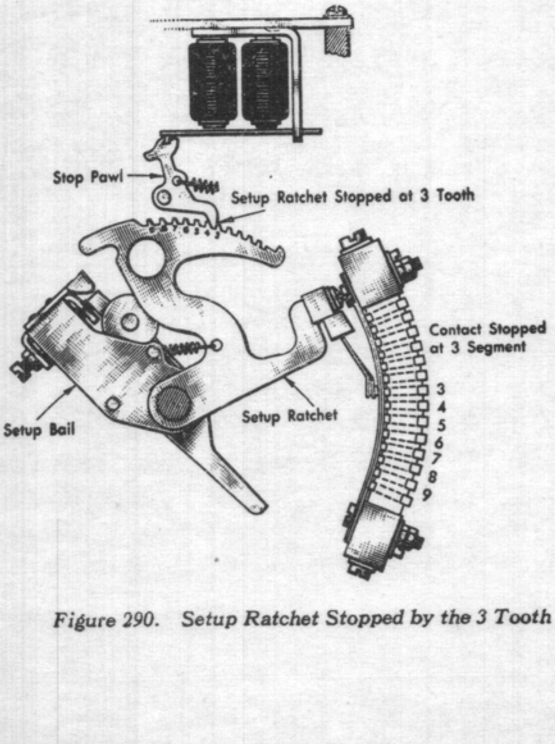

Figure 290. Setup Ratchet Stopped by the 3 Tooth

The setup bail must also operate to clear out the figure previously stored. One complete operation of the setup bail will clear out any figures in the unit and allow new ones to be inserted. As long as the setup bail is prevented from operating, the figures in the storage unit will remain there indefinitely. In this way figures can be stored in the storage units and left there as long as desired or they can be removed in the next cycle.

If alphabetical information is to be stored, it will be necessary to use two positions for each letter (one position for each hole in the column).

The setup bail is under control of the restoring magnet. Consequently, the length of time that a figure is stored is dependent upon the energization of the restoring magnet. Each storage unit has two restoring magnets since it has two independent setup bails. Each of these two bails is operated by the same cam, cam follower and arm assembly, but is further controlled by its individual restoring magnet located in the center of the section. For each time the restoring magnet is energized, the setup bail is free to operate one cycle. The setup bail cam operates each machine cycle but, unless the restoring magnet is energized, the setup bail is held in a latched position and does not operate with the cam follower (Figure 291).

As the setup ratchet moves from one position to another, the contacts which are attached to the ratchet ride over bars of the emitter contact assembly (Figure 292) with values corresponding to the holes in the card. When the setup ratchet is stopped by the stop pawl, the contact rests on the bar corresponding to

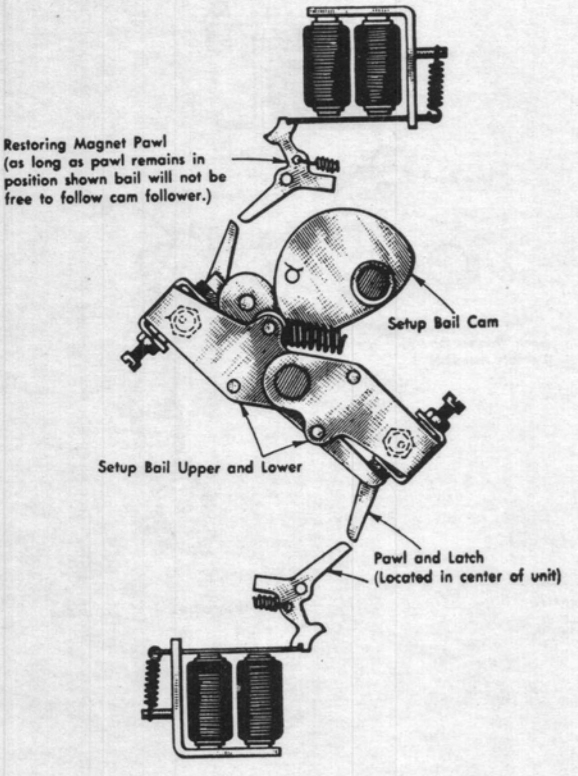

Figure 291. Setup Bail and Cam

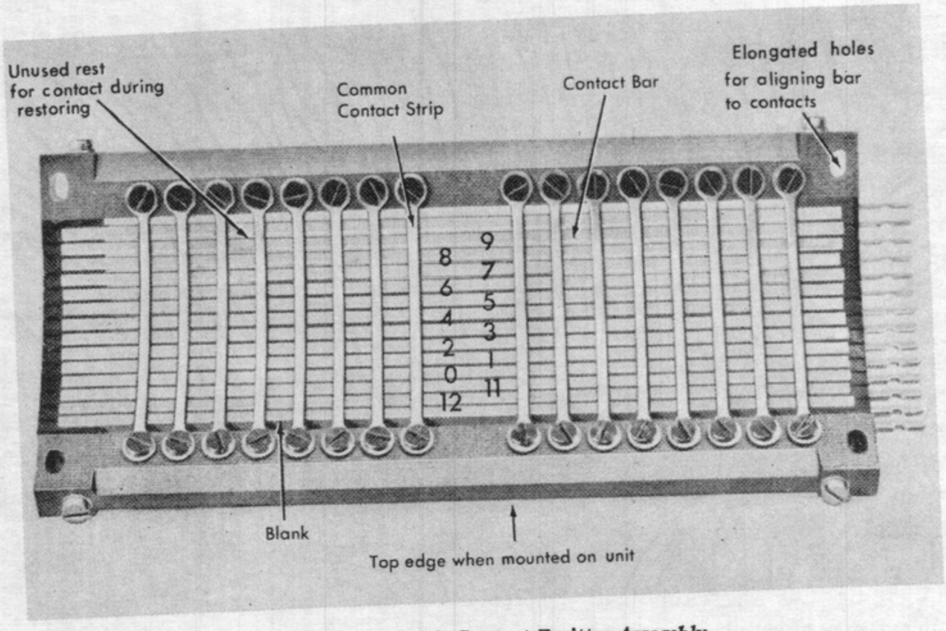

Figure 292. Storage Unit Contact Emitter Assembly

the tooth that the stop pawl engaged. The figure inserted can be used as many cycles as desired, and at the end of that time the figure can be removed and a new figure inserted.

To insure that the setup magnet armatures are not held against the magnet core, a positive knockoff operates each cycle that the setup bail operates. When the setup bail reaches its fully operated position, and the stop pawls are fully restored, the sides of the setup bail operate against two arms which are connected to the magnet armature knockoff bail by means of eccentric studs. This operates the magnet armature knockoff bail and forces the magnet armatures away from the cores (Figure 293).

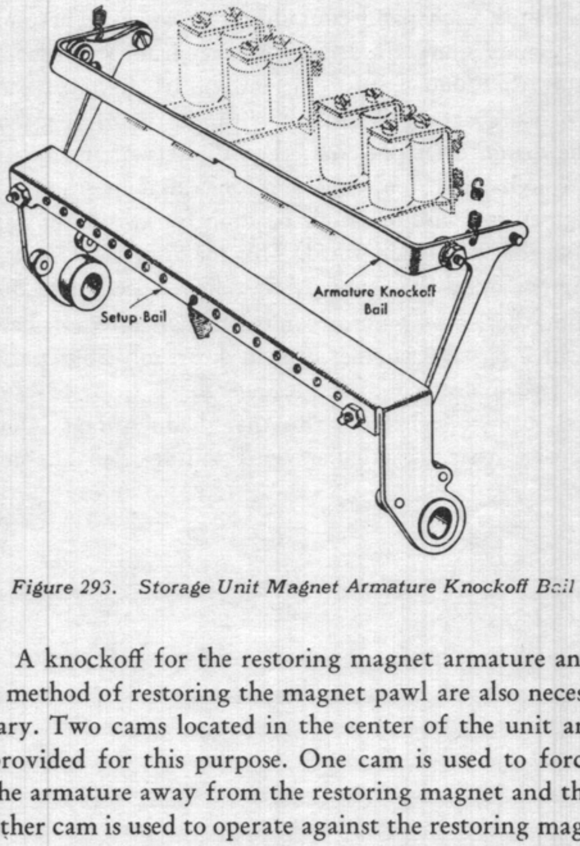

Figure 293. Storage Unit Magnet Armature Knockoff Bail

A knockoff for the restoring magnet armature and a method of restoring the magnet pawl are also necessary. Two cams located in the center of the unit are provided for this purpose. One cam is used to force the armature away from the restoring magnet and the other cam is used to operate against the restoring magnet pawl to fully restore it. Each cam is used for both the upper and lower section. Refer to Figure 294 for linkage.

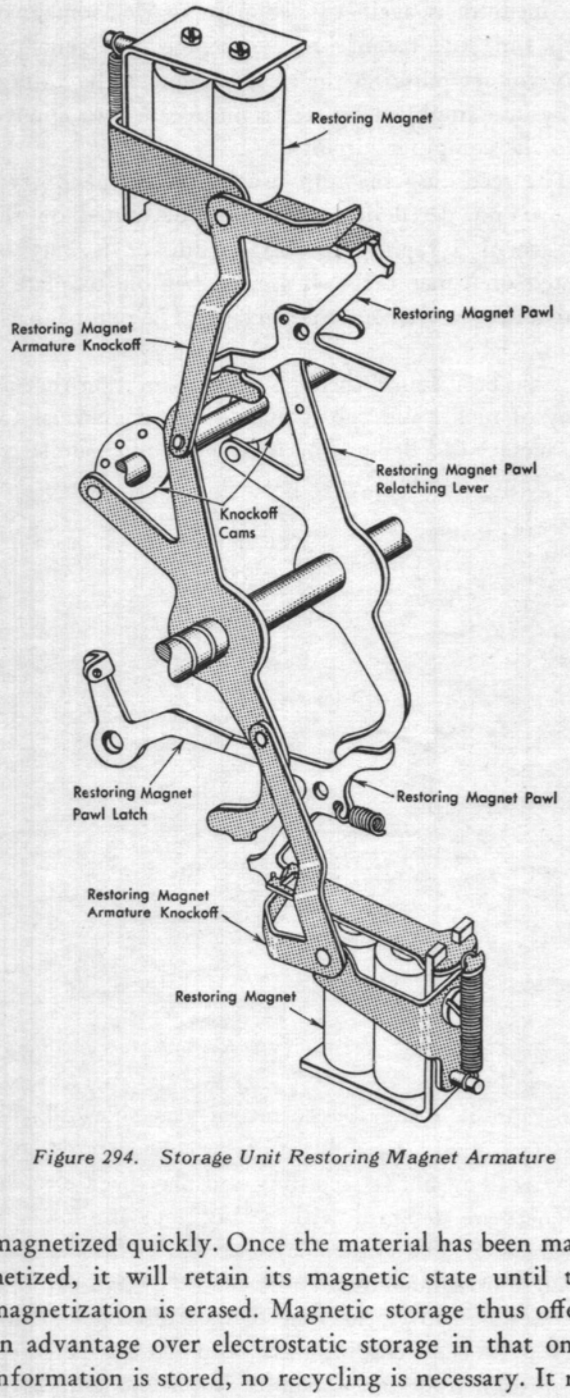

Figure 294. Storage Unit Restoring Magnet Armature

Magnetic Drum Storage

Another device offering good possibilities for rapid storage and transfer of numbers in electronic calculators is the electromagnet. Use is made of that fact that a magnetic material can be magnetized and demagnetized quickly. Once the material has been magnetized, it will retain its magnetic state until the magnetization is erased. Magnetic storage thus offers an advantage over electrostatic storage in that once information is stored, no recycling is necessary. It retains information even if the power to the calculator is interrupted.

The magnetic recording process is quite simple. The magnetic material, or medium, is carried past an electromagnet. When the electromagnet is energized, it causes the medium to become magnetized. Thus, it is possible to record pulses corresponding to coded numbers on the magnetic medium. To read the pulses, the medium is again carried past an electromagnet. This time the magnetism of the medium generates tiny voltage pulses in the electromagnet. The voltage pulses are amplified by electronic means and entered into the computer circuits.

The recording medium usually takes one of two forms: powdered iron oxide may be coated on the surface of a rapidly rotating drum, or it may be coated on paper tapes. It is also possible to plate a magnetic material on the surface of a nonmagnetic drum.

It has been found through experimentation that an alloy of nickel and cobalt makes a good material for the surface of a drum. This material is quite similar to that found in alnico magnets.

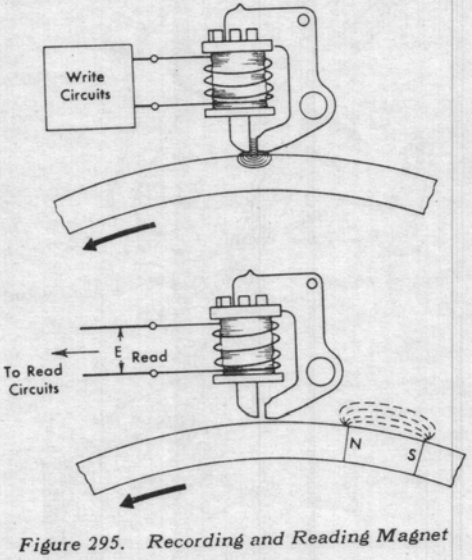

Figure 295. Recording and Reading Magnet

Because it is desirable to record very short signals, the electromagnetic field must be concentrated in a very small area. The recording and play-back electromagnets are designed with a tiny gap, as shown in Figure 295. The electromagnetic lines of force pass through iron much more easily than they pass through air. Consequently, the flux field is distorted at the air gap. As the recording medium passes the field concentration, it becomes magnetized. If no current is flowing in the coil of the electromagnet, no field will exist in the air gap and no magnetization of the medium will take place.

These magnetized areas of the drum surface may be visualized as tiny bar magnets imbedded in the surface. They will be polarized either north-south or south-north, depending on whether they represent a value of one or zero.

Once the spots have been recorded on the drum, it is a comparatively simply matter to read back the information to the machine. This read back takes advantage of the fact that when a coil is cut by a magnetic field there is a voltage developed in the coil.

The polarity of magnetization and the corresponding output pulses are shown in Figure 296. The amplitude of the output signal is between the limits of 220 and 320 millivolts. In order for these output pulses to operate the logical circuits of a machine, they must be amplified and changed to a square wave shape.

In the Type 650 Magnetic Drum Data Processing Machine, the drum has a maximum capacity of 2000 words of storage with each word containing ten digits and a sign. The words are arranged around the drum in bands, each band containing 50 words. There are 40 bands along the length of the drum in order to store the 2000 words. The individual digits of each word are arranged serially within a word space on the drum, digit one first, then digit two, and on up through digit ten. There is one digit position for sign storage and one digit position for switching purposes between each word. This makes a total of 600 digits around the drum. With a drum speed of 12,500 rpm, there are 8 microseconds per digit interval. Each digit interval is further broken down into four pulses of two microseconds duration each.

It can be seen from this that drum storage is cyclical in that a particular word will be available only

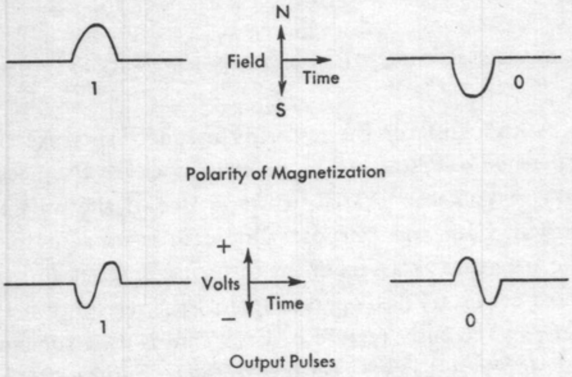

Figure 296. Magnetic Drum Storage Patterns

at the read heads once each drum revolution. The average access time for any word in storage is 2.4 milliseconds; however, the maximum access time may be as high as 4.8 milliseconds. The access time for electrostatic storage is in the order of a few microseconds.

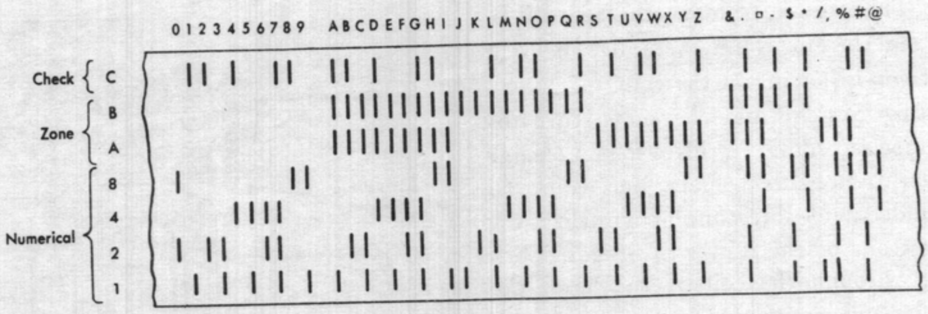

Figure 297. Character Coding on Magnetic Tape

In a calculator using both magnetic drum and electrostatic storage, the latter would be used for storing data needed immediately. Magnetic drum storage would be used to store data where a delay in access time would not slow down the calculation.

Magnetic Tape Storage

One very important member of the IBM family of storage devices is the magnetic tape. Tape storage provides a compact storage medium and a means of rapid processing of information. The equivalent of about 24,000 80-column cards can be stored on one reel of tape 10½ inches in diameter. The tape also has the advantage of being used over and over. Old information is erased just prior to the recording of new data on the tape. The magnetic tape also offers the user the benefit of variable-size unit records which corresponds in function to a card of variable length. The record may vary in size from one or two characters up to several thousand characters. The size of the unit record is not limited by the tape but by the capacity of other units within the Data Processing Machine.

The tape used is an acetate tape with a metallic oxide coating on one side. It is ½ inch wide and may be up to 2400 feet in length. Information is stored in binary form on the tape, utilizing 7 locations or tracks across the tape.

The 7 tracks or bit positions are divided into three groups. They are the numerical portion of a character that uses 4 positions, the zone portion which uses 2 positions, and the check bit position.

There is an internal check on the transmission of data that requires that the sum of the bits for any character must be even. Thus, if the sum for a character should come out to be an odd value, a check bit is added to make it even. Figure 297 shows examples of the code.

The four positions in the numerical portion represent the numbers in binary form 1-2-4-8. The numerical and zone portions are combined to form characters using the same codes as used on IBM punched cards for alphabetic information. The code here for the zones is an A and B bit for a 12 zone, a B bit only for the eleven zone, an A bit only for the zero zone. The numerical characters have neither A nor B bits.

To illustrate the process of recording information on the tape, refer to Figure 298.

The magnetic circuit consists of the read/write head, the air gap and the oxide coating on the tape. The head is made of mu metal. This material allows magnetic flux to pass through it freely and is said to have a high permeability. The mu metal head has a high permeability but will not retain magnetism; so it is said to have a low retentivity. The oxide coating on the tape has a low permeability but a high retentivity in comparison to the rest of the circuit.

When a current is passed through the coil of the write head, a flux path is set up as shown by the arrows. Notice that this flux path links the oxide coating on the tape. When current is applied to the coil, the magnetic particles of the oxide coating are re-oriented by the influence of the electromagnetic field in such a manner that the flux pattern of each magnetic par-

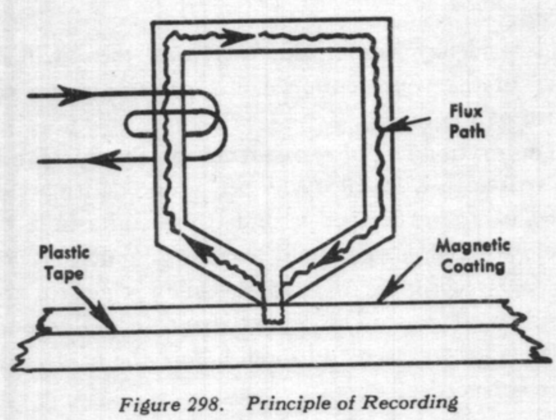

Figure 298. Principle of Recording

ticle is additive. The spot on the magnetic tape will be lengthened because the tape is moving under the head at the time current is flowing in the coil.

Data Processing Systems use the non-return-to-zero system of tape recording. In this system a change in the flux pattern represents a binary one value. To more clearly understand this concept visualize the tape moving past one of the read/write heads. With current flowing through the coil of the head, the magnetic particles will be oriented in a certain direction. Now, at a certain instant the current in the write coil is reversed. This causes a complete reversal of the polarity of the flux within the tape. It is this change in polarity of the flux that is the indication of a binary one on the tape. A binary zero is whenever the magnetic flux pattern is in a quiescent state as a function of time. In other words it is the transition of the state of flux that determines a binary one. Figure 299 shows a correlation between flux pattern and binary information.

The determination of a binary one is simple in principle. The reading circuits make use of the fundamental fact that there is a voltage induced in a coil whenever there is a time rate of change in the flux that links the turns of the coil. A binary one is sensed by the sampling of the voltage induced in the read coil by the transition in flux. A zero is the absence of a voltage pulse at a specified time in the reading cycle.

It must be remembered that there are seven read

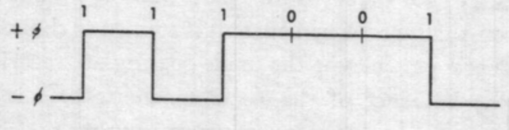

Figure 299. Relation between Flux Pattern and Binary Information

heads (side by side); and, therefore, there will be seven of the aforementioned flux patterns across the width of the tape.

The maximum pulse frequency of the current in the write coil is 15 kilocycles per second. With a tape speed of 75 inches per second, this results in a bit spacing of 200 bits per inch. There is a ¾ inch spacing between records on the tape to allow time to stop and start the tape. This allows about 10 milliseconds for the tape to reach full speed before the next character is recorded.

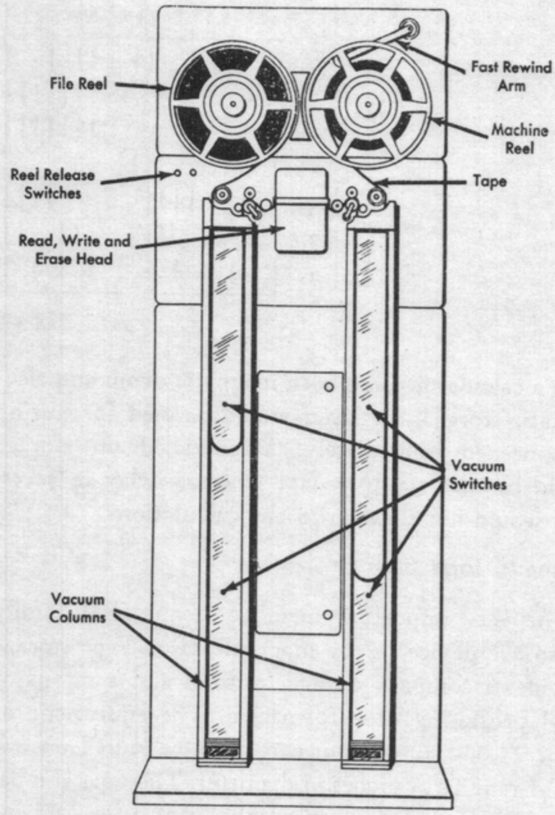

Figure 300. Tape Unit

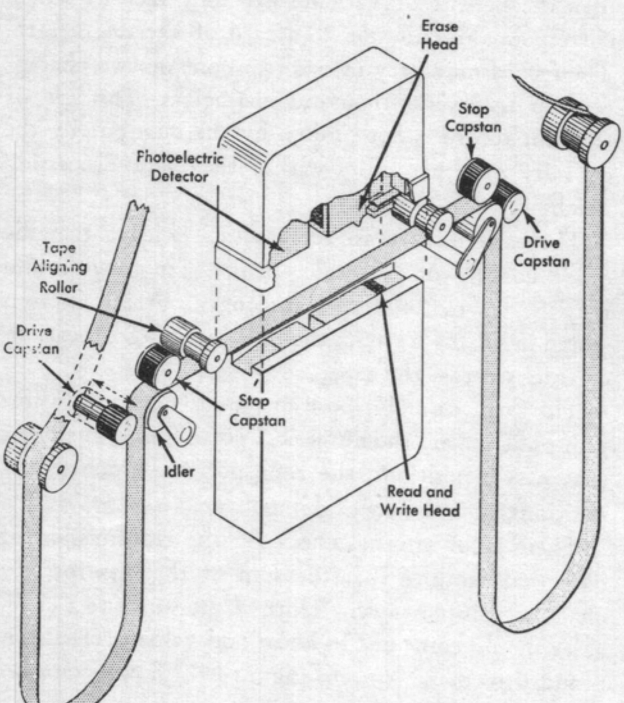

Figure 301. Tape-Feed Mechanism

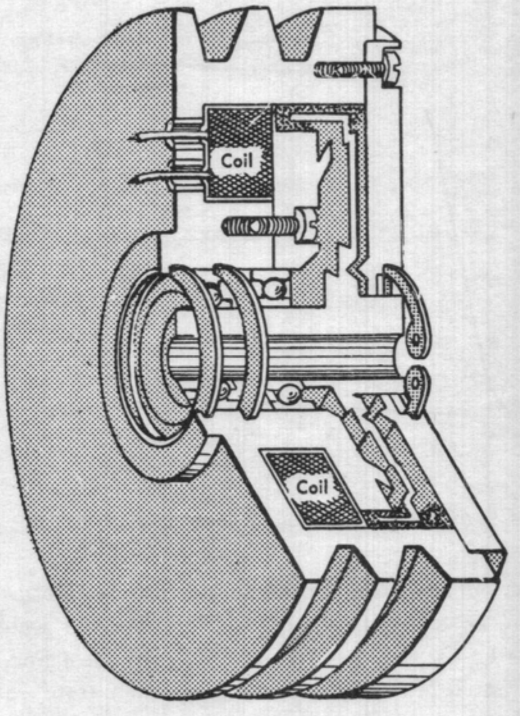

Figure 302. Magnetic Clutch

It is interesting to examine the mechanical arrangement for moving the tape. Figure 300 shows a front view of the tape unit and the path of the tape through the machine. Figure 301 shows a closeup of the tape feed mechanism. The drive capstans are rubber covered and run continuously. The idlers are controlled by an electromagnet so that they can hold pressure against the right or left capstan in order to feed the tape in the proper direction. The idlers are mechanically connected so that they can apply pressure to only one capstan at a time. This eliminates the danger of tape breakage in the event of a mechanical failure.

The reels of tape are controlled by magnetic clutches (Figure 302). These clutches consist of a bell-shaped member that is fastened to the shaft. This member is enclosed by a pulley that has a coil mounted in it. There is a mixture of powdered iron and graphite filling the space between the driven and the driving member. When the coil is magnetized, the flux passing through the mixture will solidify the iron and graphite and thus transmit motion through the clutch.

The inductance of the coil prevents the current from building up rapidly in the coil. Because the flux, and thus the torque, is proportional to current, this causes a gradual increase in torque applied to the reels. This is desirable because if the shock of a quick start were applied to the reels, the tape might slip or break on the reels. Notice the design of the parts is such that the iron powder will be contained in the outer cavity. Any that falls to the center will be returned to the magnetic gap by centrifugal force.

In order to allow rapid stopping and starting of the tape, there is a loop of slack between the drive capstans and the tape reels. It is necessary that the loop be maintained, and, further, the size of the loop should be controlled. To accomplish this control, two vacuum columns are used, one for each loop as shown in Figure 300. The tape forms the top of the vacuum column and is thereby held down in the column by atmospheric pressure. There are two pressure sensitive switches in each column. These are used to control the reel clutches and thereby maintain the proper amount of tape in each column.

When it is necessary to rewind the tape on the left-hand reel, the tape is pulled out of the vacuum columns and fed directly through the machine and wound on the left reel. It requires about one minute to rewind a reel of tape. This is an average speed of 500 inches per second. On a rewind operation, the machine runs at this high speed until it gets near the end of the tape. It then slows down to its normal speed of 75 inches per second until it finds the load point or beginning of the tape. This load point is simply a reflective substance on the tape that is detected photoelectrically.

Magnetic Core Storage

Another storage medium offering great promise at the present time is the ferrite core storage device. The core itself is a small ring made of ferromagnetic material. These rings are quite small, .080 inch in diameter and .025 inch thick. The property of the material that gives it the ability to be used as a storage medium is that it has a high retentivity. A desirable quality is for the core material to have a practically square hysteresis loop. This is shown in Figure 303. It is possible for the flux within the core to be in one of two stable states, either point A or point B on the hysteresis loop. In each case the core has a residual flux, either in the positive direction or in the negative direction. Because the core has two stable states, it can be used as binary indicating device. It is said to be storing a one value when the residual flux is at point A, and

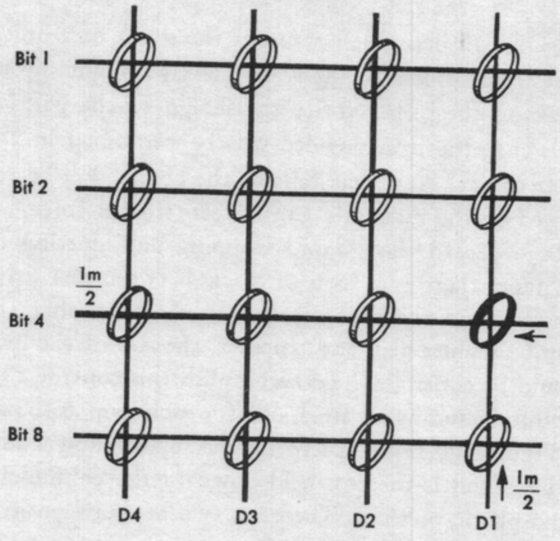

Figure 303. Typical Array of Cores

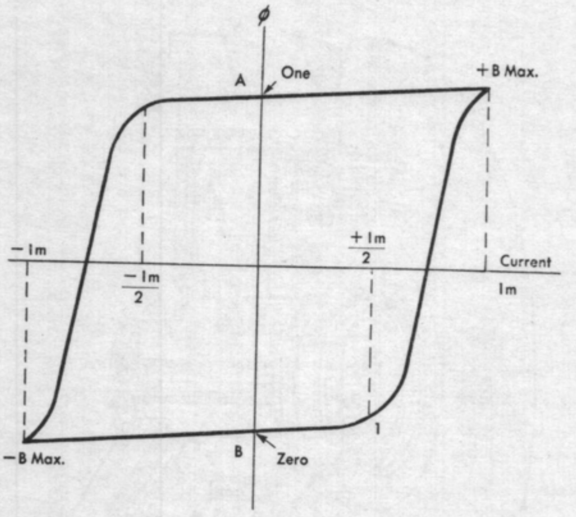

Figure 304. Hysteresis Loop of a Ferrite Core

a zero value when the residual flux is at point B.

To control the status of the cores, they are grouped in an array of rows and columns as shown in Figure 303. Each row represents a bit in storage, and each column, the digits within a word. Using this array, it is possible to store one four-digit word.

To change the magnetism of the cores, it is necessary to cause a current flow through the wires that link the cores. From the hysteresis loop of Figure 304, it can be seen that a magnetizing current of $+I_m$ will switch the magnetism of the core from point B, a binary zero, to point A, a binary one.

If a current of $+I_{m/2}$ were applied, the flux would only change from point B a small amount to point 1 on the loop. After this current is dissipated, the flux will return to its original value at point B. It requires the application of a full I_m value of current in order to switch the flux from residual value in one direction to the residual value in the other direction.

Assume that all cores in Figure 303 are set to point B on their hysteresis loop. Now to store a binary one in any position, the proper row and column must be energized. To write, a current of $+I_m$ must flow through the wires in only one core. To write in the bit 4 position of digit 1, a current of $+I_{m/2}$ is caused to flow in the digit 1 line, and a current of $+I_{m/2}$, in the bit 4 line. This causes a current of $+I_m$ at the core located where these wires cross. This current causes this particular core to switch from point B on the loop to point A (Figure 304). Because of the high retentivity of the material, the core will hold this condition indefinitely. Notice that the other cores on the digit 1 line received a current of $+I_{m/2}$ as did the other cores on the bit 4 line. This current is not sufficient to change their state, so they will remain in their binary zero status.

To read this information out of the array, it is necessary to have a third wire laced through the cores. This wire is called a sense wire and is shown in Figure 305.

With a one stored in the bit 4 position of digit 1, the magnetism of that core must be reversed in order to read out of the array. When the status of the core is reversed, the change in magnetic flux will induce a voltage pulse in the sense wire that can be used as an output from the storage unit.

To change the flux, it is necessary to move the core from point A to point B on its hysteresis loop. This is done by sending a current of $-I_{m/2}$ on the bit 4 line and the digit 1 line. The coincidence of these currents gives a total current of $-I_m$ at the core to change its status. As it changes, the output pulse will appear on the sense wire. This output pulse is in the order of 60-80 millivolts and consequently must be amplified before it can be used in any type of machine circuit.

If a certain core had contained a binary zero when it was called upon to read out, the output pulse would be very small. Consider the core at the bit 1 location of digit 2. With a current of $-I_{m/2}$ on the digit 2 line and $-I_{m/2}$ on the bit 1 line, that core is subjected to a total current of −Im. In this instance the core was in the zero status or at point B on the hysteresis loop.

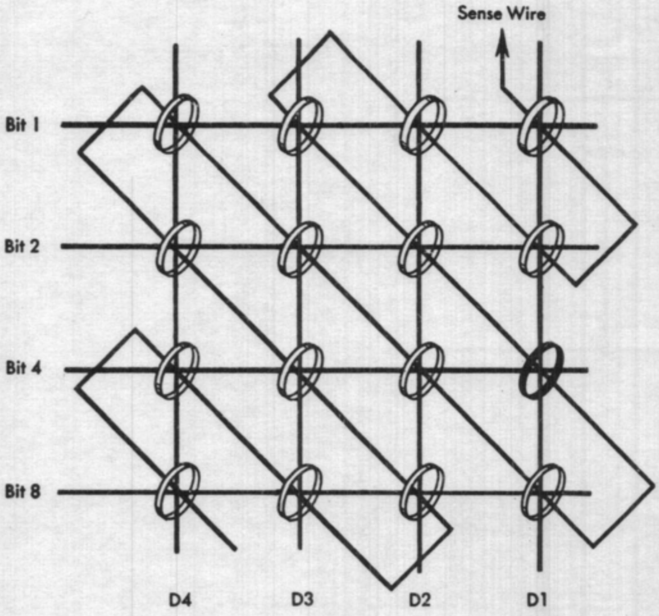

Figure 305. Core Matrix with Sense Winding

With a current of $-I_m$, the flux will change only a small amount as it goes from point B to the point labeled $-B_{max}$. This small change will induce only a very small output pulse. The machine circuits are designed to discriminate between these two pulses.

Due to the nature of the read-out system used, the information that was stored in the array is destroyed. In a practical machine using this type of storage, some type of regeneration must be provided. This is done by causing a read-in following each readout of the unit in order to retain a given bit of information.

This system of storage using magnetic cores has some definite advantages over some other storage devices. They are capable of high-speed operation, offer quick random access to storage addresses, and take up little room within a machine. They also have the ability to retain information after the machine has been turned off.

Basic Capacitor Storage Cell

In addition to the aforementioned storage devices offering high-speed operation, it is also possible to store information in a capacitor storage unit.

The basic capacitor storage unit is shown in Figure 306 and consists of a capacitor and two diodes. In Figure 306 the controlling tubes T1, T2 and T3 are shown for clarity.

The principle used is that when the condenser is discharged there is a binary one stored, and when the condenser is charged there is a binary zero stored in the unit. It is necessary only to have some method of charging or discharging the capacitor, and for detecting the charged or discharged condition of the capacitor.

Follow the operation of reading out a binary one and storing a binary zero. Consider that the condenser is discharged and that the potential at points A, C, and D is −35 volts and point B is +150 volts.

At the beginning of the readout operation, point A is raised to +10 volts by Tube T1. With A more positive than C, electrons will flow through diode D1, and point C will rise to +10 volts. The voltage at point D will rise momentarily and then drop off as the capacitor charges as shown by the curve for Point D.

The read-in gate causes point B to drop from +150 to +10 volts; but because C is also at +10 volts, no conduction occurs between B and C; so the capacitor is not discharged. After the RI gate, the capacitor has been left in a charged state. A binary one has been read out and a binary zero has been stored.

Assume now the unit contains a binary one and it is desirable to read out the one and to store the one back in the unit.

The readout pulse is applied to point A, raising A to + 10 volts. This causes a current flow through D1 and raises point C to +10 volts. When point C rises, the capacitor will charge, and the output pulse at point D will be as shown by the curve. Up to this point, the operation was the same as the first case.

When the RI gate is applied at point B, there is also a pulse applied at point E. This produces from the cathode follower a pedestal output at point D.

At the time the RI gate is applied, point B will go from +150 volts to +10 volts; and the pedestal at point D will rise from −35 volts to +10 volts and cause point C to rise 45 volts, from +10 volts to a new value of +55 volts. Point C is now more positive than B; so D2 conducts and C_s will discharge through D2 while it is on top of the pedestal pulse, point D and C are lowered to a value of −35 volts. Upon completion of the above operation, the capacitor has been left in a discharged state. A one was read out and a one has been left in the unit.

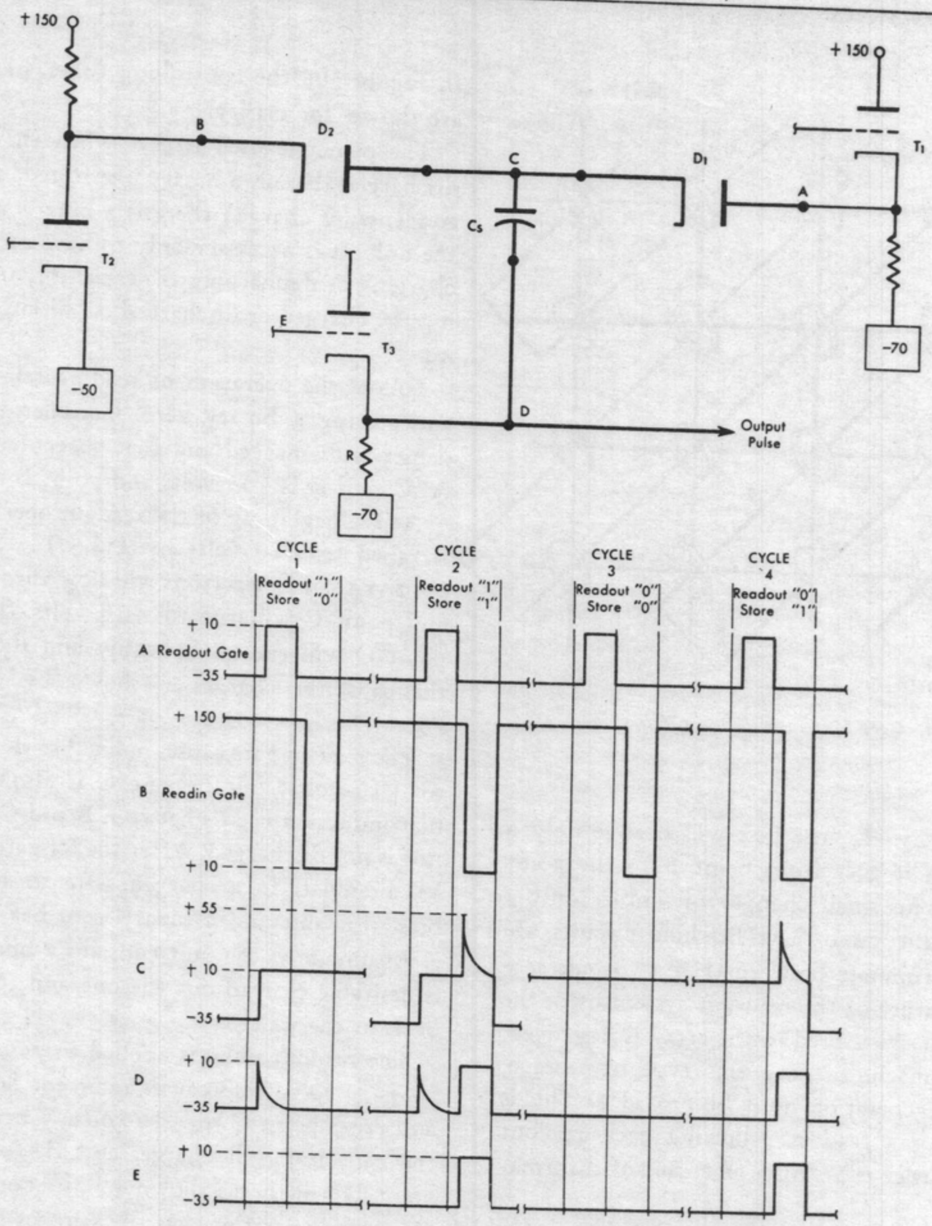

Figure 306. Basic Capacitor Storage Cell

The curves for cycle 3 and cycle 4 show the operation for reading out a binary zero and storing a zero, and reading out a binary zero and storing a one. Note that in cycle 3 the capacitor was charged when the readout gate was applied so there was no output pulse at point D. Because there was no pedestal in this cycle, the capacitor was not discharged and, therefore, left with a binary zero store.

Cycle 4 shows the readout of a zero and storing a one. The capacitor was charged at the beginning of the cycle and discharged at the end. In this cycle the pedestal was applied with the RI gate, thus raising point C to +55 volts and allowing the capacitor to discharge through tube D2. After the termination of the pedestal, points D and C are lowered to −35 volts.

Because of the nature of a capacitor, it will not hold a charge indefinitely; so that in order to retain information over a period of time, it must be "regenerated." This is done by applying a RI and RO gate at periodic intervals and controlling the pedestal. This is done by taking the output pulse that is obtained when a one is regenerated and allowing it to actuate the RI control circuits to provide a pedestal pulse. When a zero is regenerated, no output is available and so no pedestal is available.

In order to read in new information, the read-in circuits and, therefore, the pedestal are controlled by the incoming information.