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Functional Units

2266135-1

** from the Preface **

"Each machine type is different in its construction, capacity and application; yet many basic units of the machines are common in their construction and in the operations which they perform."

"By studying these mechanisms individually before being introduced to the completely assembled machine, the student is able to reduce his learning responsibilities to a series of small problems."

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Functional Units

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PREFACE

IBM ACCOUNTING MACHINES can be classified to perform the following five functions: punching, arranging, accumulating, printing and calculating.

Each machine type is different in its construction, capacity and application; yet many basic units of the machines are common in their construction and in the operations which they perform. When the customer or prospective customer points out a need for a new machine to perform a new accounting operation, a design engineer is assigned to the project of developing such a machine. The engineer's knowledge of the basic units enables him to visualize quickly the overall design of the machine.

Because each unit is capable of performing some particular operation, such as moving the card, punching the card, reading the card, accumulating information or printing information, these may be studied as functional units by the student customer engineer.

The final machine design is a result of assembling the basic units which perform the mechanical work, connecting and controlling them by means of electrical circuits.

This manual is written with the objective of introducing the new customer engineer to the functional principles incorporated in the IBM machines and acquainting him with the terminology which is peculiar to the accounting machine industry.

By studying these mechanisms individually before being introduced to the completely assembled machine, the student is able to reduce his learning responsibilities to a series of small problems. Once the student has learned the need and the application he immediately can appreciate how the machine performs the required operations. He knows what units should be found in the machine and, in general, how they work.

Because of this advanced background, he is able to learn the circuitry of the machine more rapidly, and he has a greater appreciation of the need for care in making adjustments to the machine.

Through functional unit training, a better trained customer engineer is sent to the field with greater knowledge of his equipment.

CARD FEEDING AND SENSING

THE IBM card has been called the operating unit of IBM machines. All information pertaining to a particular transaction is placed in this card in the form of punched holes. IBM cards are 7 3/8" wide, 3 1/4" high, and 0.0065" thick. There are 12 vertical punching positions, and 80 columns of punching possible. Figure 1 shows the IBM card and the code punching used to store alphabetical and numerical information in the card.

Figure 2 shows an original document which gives a man's number and the number of hours he has worked in a given pay period. This information is representative of a customer's transaction. It is to be processed by accounting machines, and this necessitates its conversion to punched-hole form.

The information is to be classified and punched in a predetermined field in a card. A field, as shown by Figure 3, is a group of columns reserved for certain information. The size of a field may vary from one column to as many as are needed to contain the information. When the card is designed, the fields are laid out to contain a sufficient number of columns for the information to be punched.

After the customer has punched the information into cards, the cards can be arranged and classified by other machines, a check or a printed report showing the desired information can be prepared automatically as shown in Figure 4.

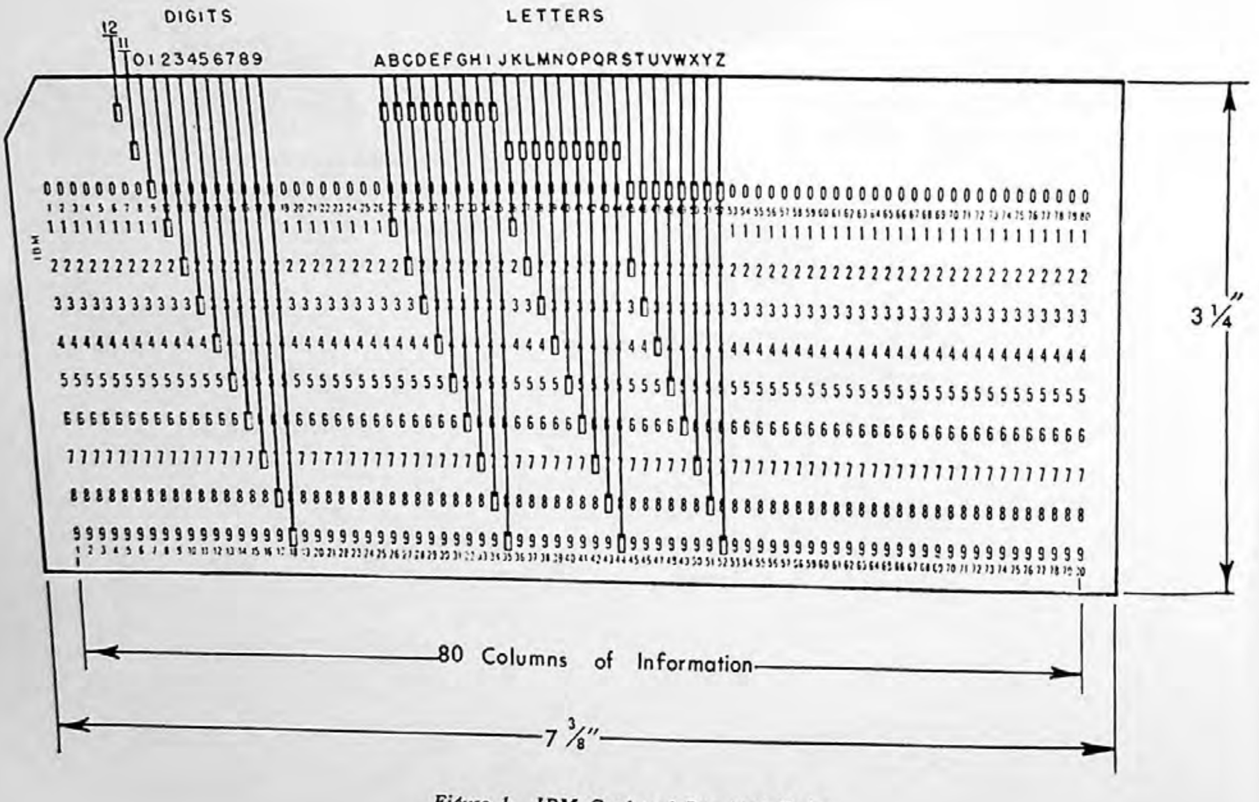


Figure 1. IBM Card and Punching Codes

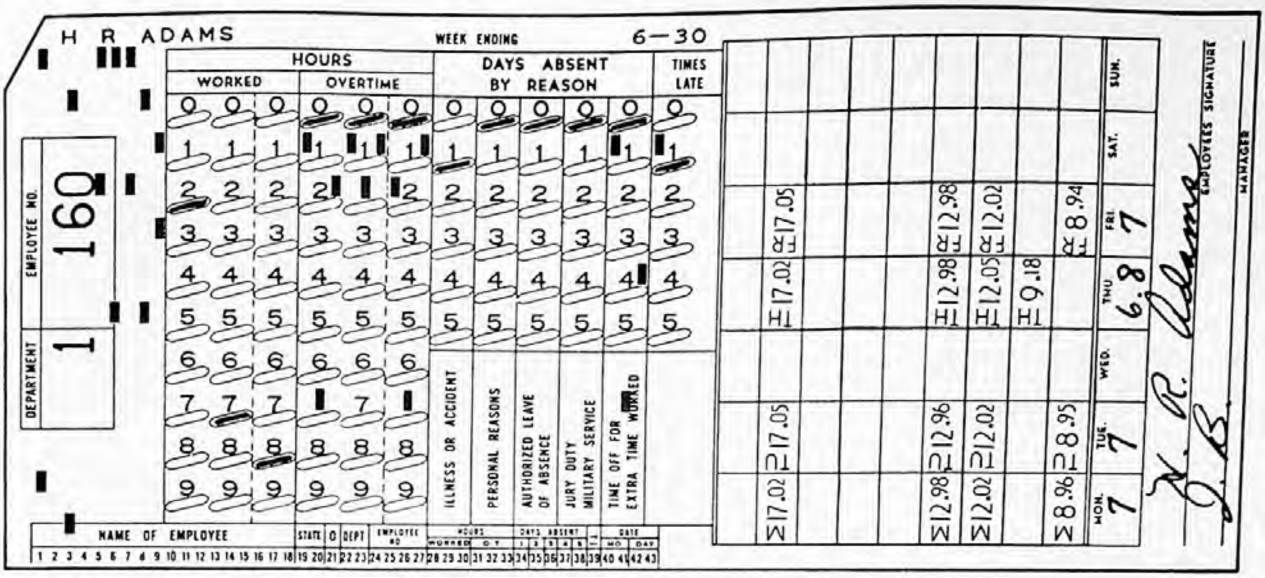


Figure 2. Time Card

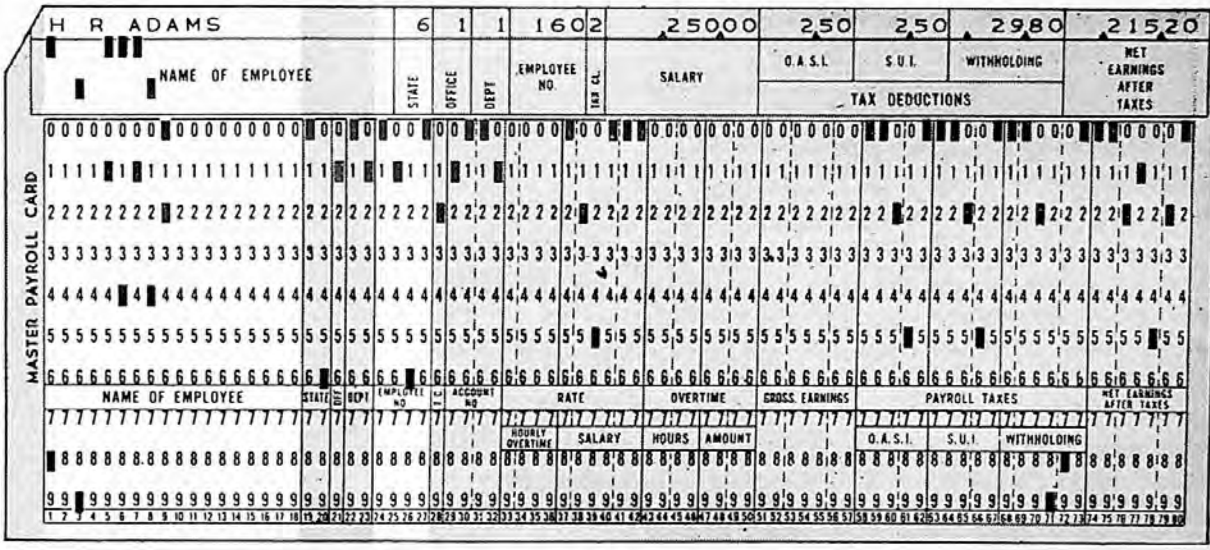


Figure 3. Earnings Card Showing Two Fields

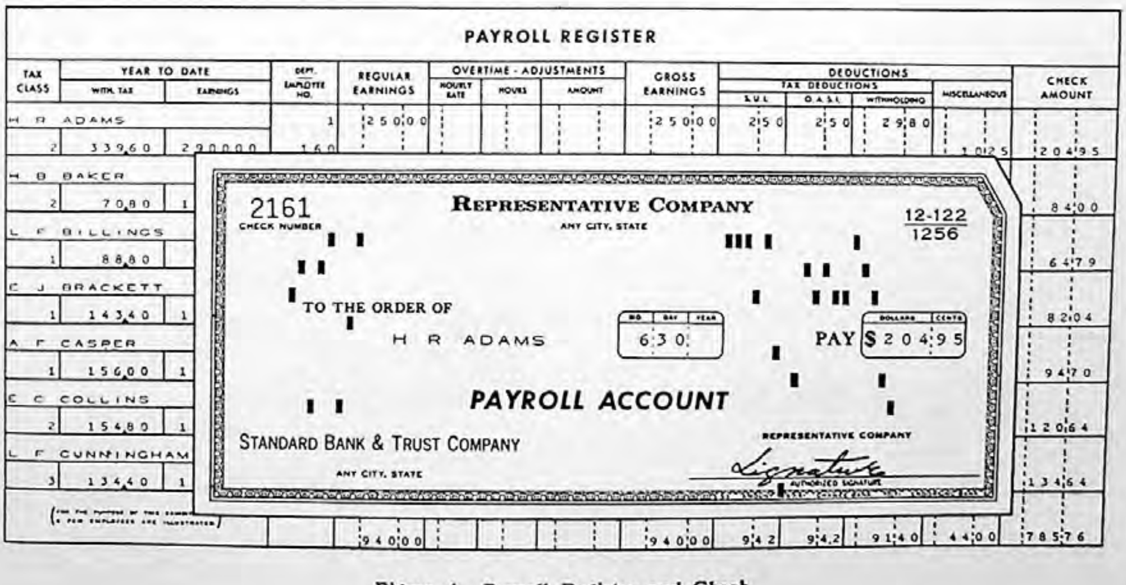


Figure 4. Payroll Register and Check

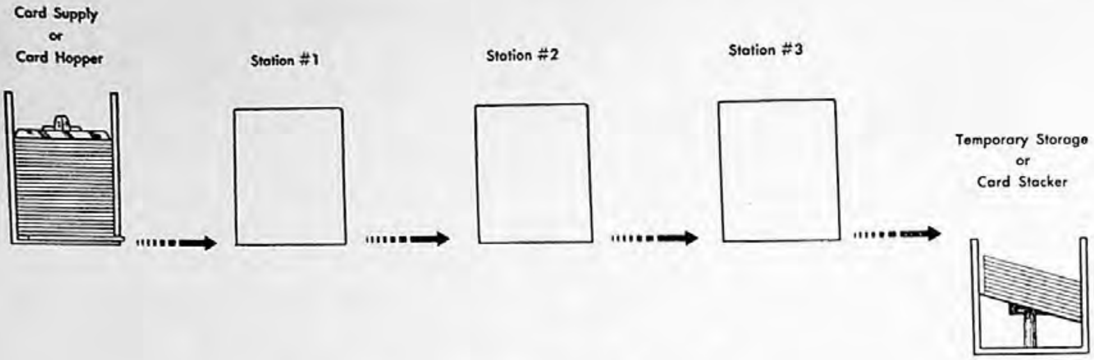


Figure 5. Components of a Card Feed

CARD FEED UNIT

BEFORE information can be punched, sensed, or printed, the card must be moved to a punching or sensing station of a machine. A means for moving the card is provided by a card feed unit, which will also contain operating assemblies, such as punching or sensing stations. The card feed unit, therefore, becomes the first functional unit to be studied.

In addition to this primary objective of the card feed unit, it must also perform the following: contain a supply of cards for the machine, draw from that supply one card at a time, and stack the cards in a temporary storage place after they have passed the operating assembly. Figure 5 is a schematic of a card feed unit showing the functions it must perform.

Figure 6 shows a feed unit used to feed cards past a punching station, one column at a time. The supply of cards is contained in a hopper until they are fed into the machine. A card is fed from the bottom of the hopper into the machine with column one entering the machine first. The card is moved rapidly and smoothly until it has been placed under the control of the card feeder right and card retainer. The card is then moved one column at a time past the punching station. The punching mechanism punches the desired hole or holes, and the card is moved to the next column; the desired information is punched in this column, and the card is moved one more column. This is known as a column-by-column type of feed unit as suggested by its operation. As soon as column 80 has moved past the punching station, the card is placed in the stacker by means of an eject mechanism.

After the cards have been punched, they may be removed from the stacker by an operator and arranged by machine in the desired order. The cards may then be placed in the hopper of a feed unit similar to the one shown in Figure 7. This feed also feeds cards from the bottom of the supply, but with either the top or bottom edge of the card entering the machine first. As the card enters the machine, it is gripped by feed rolls, and its movement through the machine from this point on is governed by feed rolls. Since the card is fed either 9 or 12-edge first, it can be assumed for the purpose of illustration that it is fed 9-edge first. In either case, however, this type of feed is referred to as digit-by-digit feeding. All 80 columns are read at one time, and holes of a like digit, such as all 9's, are read simultaneously. As the card movement continues, the 9 holes are moved beyond the sensing unit and the 8 holes move into a position to be read. This procedure continues until the entire

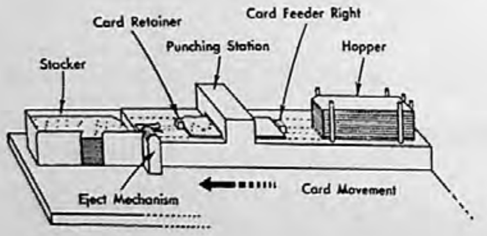


Figure 6. Column-by-Column Type of Feed

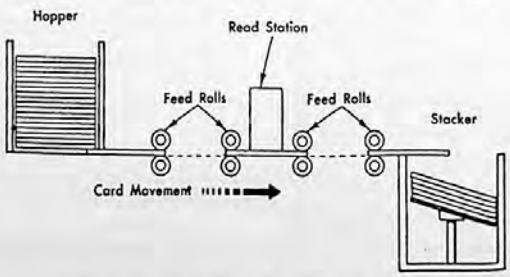


Figure 7. Digit-by-Digit Type of Feed

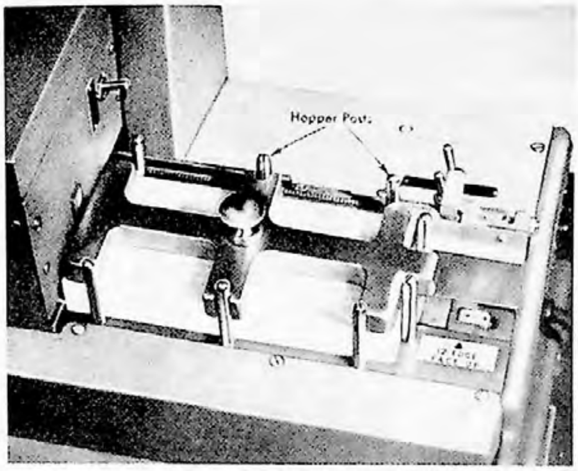


Figure 8. Hopper Used on Type 31 Card Punch

card has been read, but the card will continue to move until it reaches the stacker.

Many details of both types of feed units, column-by-column and digit-by-digit, and the principles of many adjustments will now be given in order to provide a more complete understanding of feeding mechanisms.

Card Feed Knife

When the cards are located in the feed hopper, it is necessary that only one card be picked and sent through the machine. The device used for picking the card is a card feed knife located in the feed hopper, shown in Figure 8. The feed knife moving in one direction engages the edge of a card, moving it into the machine. The feed knife then returns preparatory to picking the next card. The feed knife projection above the card surface of the feed knife block must be such that it will engage one card only. To insure proper feeding the projection must not be greater than the thickness of one card, or it would attempt to move two cards into the machine. However, the projection should be as great as is practical to prevent the knife from slipping under the card. The thickness of the card is .0065″, and the proper projection for the type of feed knife shown in Figure 9 is .004″ to .0055″.

Feed Throat

While the feed knife itself will engage the edge of one card only, the friction between cards will cause more than one card to be fed if some means is not provided to prevent it. The device used to overcome this is a throat, placed at the point where the cards attempt to enter the machine, which permits the passage of one card only. A throat of the type shown in Figure 10 consists of a throat knife and throat

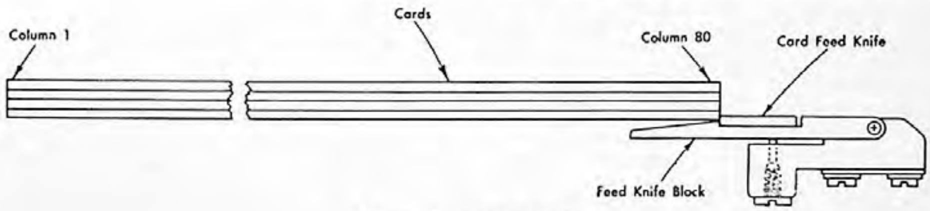


Figure 9. Feed Knife

COLUMN-BY-COLUMN FEED

FIGURE 8 shows a card hopper used with the column-by-column type feed just described. It consists of eight hopper posts which hold the cards in a position to be fed.

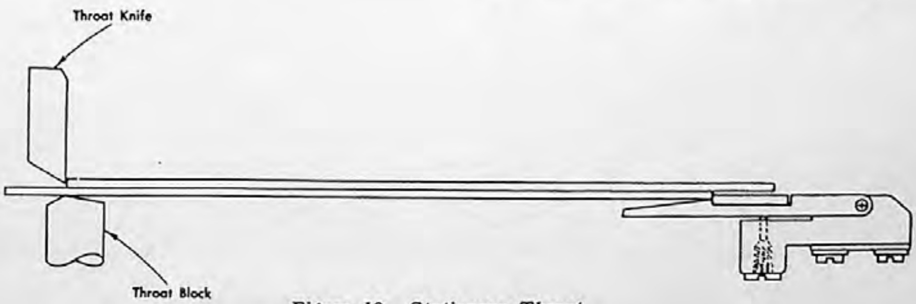


Figure 10. Stationary Throat

block. The throat block is adjustable so that the high part of the block is directly beneath the throat knife which is necessary to insure proper and consistent feeding. The throat knife is also adjustable to provide the proper clearance between the throat knife and throat block to permit one card to pass freely but not permit two cards to pass. The clearance between the throat knife and throat block should be .008″.

Feed Rack

When a card has been fed into the machine completely, it will be under the control of a feed rack. The card is held in position by means of a card feeder right and card retainer (Figure 11). The card feeder right actually positions the card, while the card retainer holds the card against the card feeder right under slight spring tension. The rack is under spring tension in the direction of the arrow, but is held in position by the dog engaged in a tooth in the rack.

The rack will space or move the card one column at a time, under the control of the dog and escapement. Figure 12 shows the dog holding the rack when the dog and escapement are in their normal position. The dog and escapement pivot about studs *A* and *C*, respectively. Note the hole in the dog, for stud A is slightly elongated so that the stud does not fill the hole. In Figure 11 the dog is held against the stud by the rack under spring tension. As a hole is punched, the escapement mechanism is operated, and the dog lever pin and pin *B* move together rotating counterclockwise about stud *A*. The dog lever pin lifts the dog out of the rack, but before the dog clears the rack tooth, the escapement moves down and engages a rack tooth preventing the rack from moving. The dog continues to be lifted clear of the rack teeth, and the rack load is then borne by the escapement. The dog, under spring tension and free to move

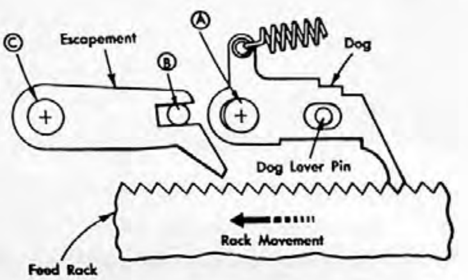


Figure 12. Dog and Escapement in Normal Position

within the limits of the hole, now moves to the right until stopped by stud *A*. Figure 13 shows the dog and escapement in the operating position. It should be noted that the dog has moved over the top of the rack tooth which it previously engaged.

As punching is completed and the punch is removed from the card, the escapement mechanism is

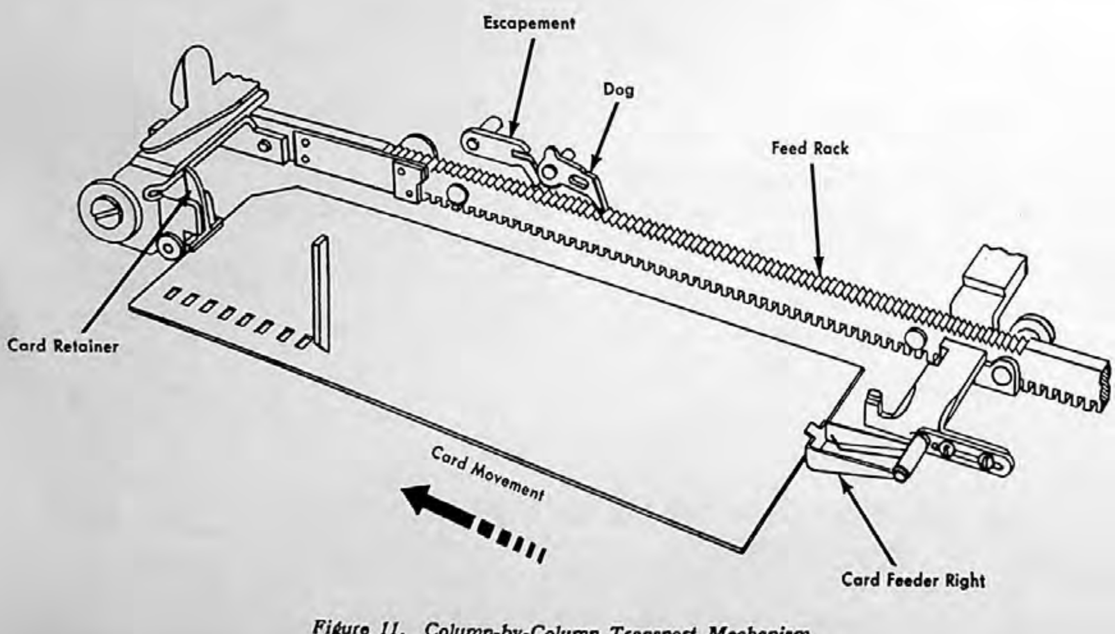


Figure 11. Column-by-Column Transport Mechanism

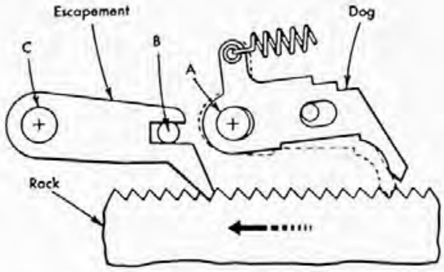


Figure 13. Dog and Escapement in Operated Position

permitted to return to normal. The dog is permitted to move down to engage a rack tooth, and the escapement is lifted from the rack. However, since the tooth on the dog now overlaps the tooth it previously engaged, it will engage the next tooth on the rack. This permits the rack to advance the card one column.

Card Stacker

It is desirable to place the cards in a stacker as soon as they have been completely punched. The ejector mechanism accomplishes this by picking the card from the card bed and placing it face down in the stacker. The eject mechanism is shown in Figure 14, and consists of a pair of card grippers, a latch for holding the gripper assembly in position to receive the card, a magnet for releasing the latch, a dash pot assembly to prevent ejecting too rapidly, and a rack and train of gears for relatching the card gripper after it has ejected a card.

The card gripper assembly is normally latched open in a position to receive the card as it spaces into the last few columns. When the card rack moves into the last column punching position, the card retainer left (Figure 14) operates against its release pin, and the card is held in position by the positive card stop. This is done to free the card and yet keep it in accurate registration for the last column punching.

After the last column has been punched, or if the card has been spaced or released beyond the last column, the last column contact is closed by the rack movement to energize the stacker magnet. The movement of the magnet armature causes the card gripper latch to release the card grippers, which close, hold-

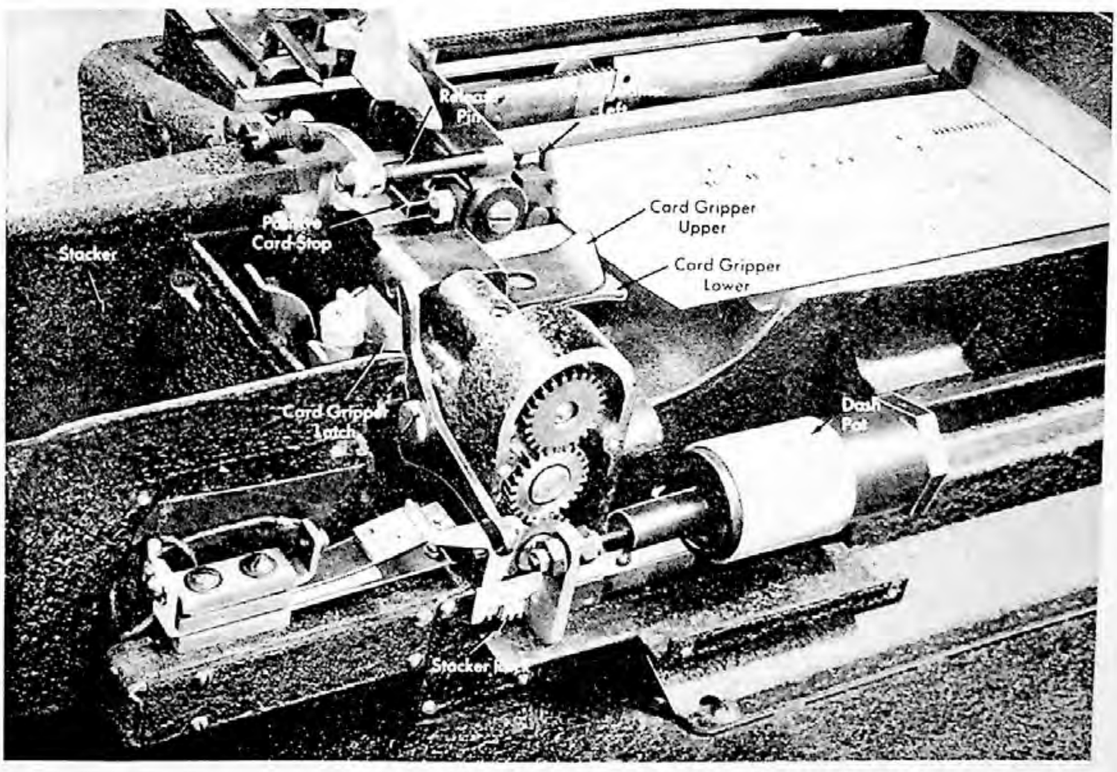


Figure 14. Card Eject Mechanism

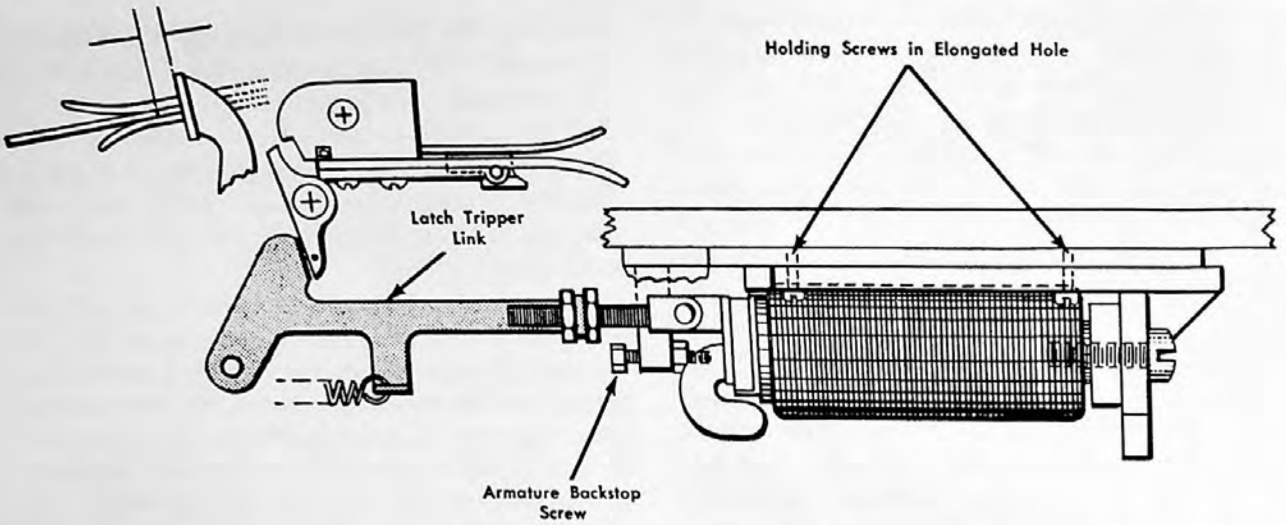


Figure 15. Eject and Stacker Mechanism

ing the card by spring action. The latch tripper link (Figure 15) also moves the stacker fingers to the right to clear the card while it is being ejected.

When the latch releases the card gripper assembly, the pressure of the spring operating against the stacker rack moves the card gripper assembly in an arc to the left until the card gripper opener stud left operates against a floating lever in the gripper assembly. This opens the card gripper jaws, releasing the card, which is guided into the card box by the return of the stacker fingers to their normal position. The explanation for the return of the stacker fingers follows.

As the stacker rack reaches the limit of its travel to the right, it operates a bell crank which closes the auto start contact. This contact completes a circuit to the trip magnet and automatically starts a new card feed cycle.

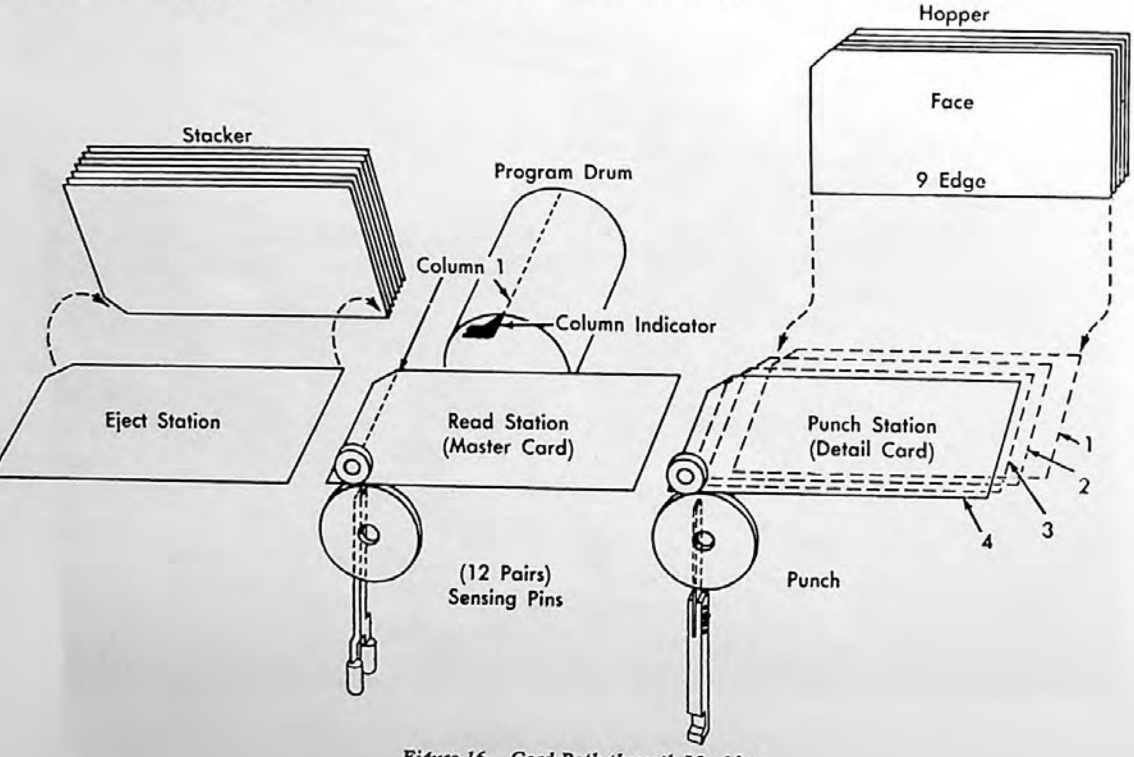


Figure 16. Card Path through Machine

As the card rack returns to the right from the last column at the beginning of the feed cycle, the stacker magnet circuit is opened by the opening of the last column contact, allowing the card gripper latch and the stacker fingers to return to their normal positions. This kicks the cards from the card grippers. As the card feed rack nears the end of its feeding stroke, it operates against the plunger in the right end of the stacker rack and through the gear train returns the card gripper assembly to its normally latched position. The latch spring pulls the latch into position, and the card grippers are again ready to receive a card.

An adjustable dash pot causes a smooth card ejection without unnecessary rebound of the card gripper assembly on the card gripper opener stud left. The dash pot consists of a piston in a cylinder which tends to compress air as the stacker rack moves to the right. A slow escape for the air provides the means of governing the ejection speed.

Card Feed Unit

Card feeding in the Types 24-26 is quite different from that in other older types of IBM punches. Under normal operating conditions two cards are in the punch station at all times. By registering the second card shortly after the first card is punched in column 80, three-fourths of the feeding time is saved. Figure 16 shows the card path from the feed hopper to stacker. On the first card feed cycle a card leaves the hopper, passes through stage 1 and ends at stage 2. On the earliest portion of the second card feed cycle, a card is aligned at position 3 and pushed to 4 preparatory to punching.

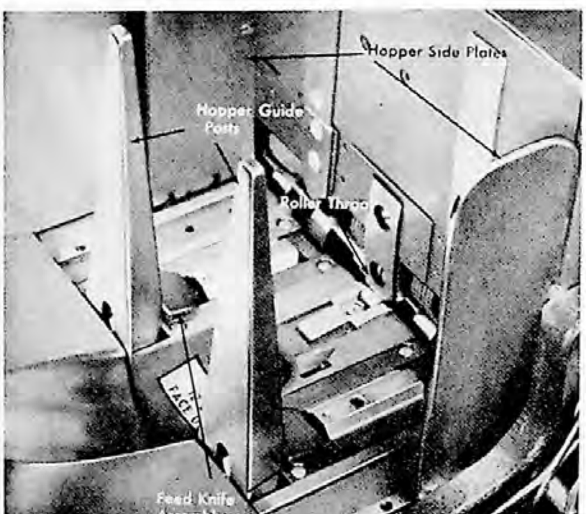


Figure 17. Feed Hopper

Attention is called to the column at which cards are registered in Figure 16. The program drum and master cards are standing in column one while the detail card is in column zero. It can be seen why lower left corner cut cards should not be used. While cards are advancing through the punching and reading stations, they are held and moved by a large feed roll underneath the card and a smaller pressure roll on top of the card. These two rolls grip the card at its bottom edge. If lower left corner cut cards were used, these feed rolls would be unable to grip the card, especially in the punching station where the card is registered in column zero.

DIGIT-BY-DIGIT FEED

FIGURE 17 shows a typical hopper used in digit-by-digit type feeds. It consists of two feed knife assemblies, one roller throat, two hopper guide posts, and two hopper side plates.

Feed Knives

The feed knives (Figure 18) are different in construction from the feed knife in the previous feed. However, in principle they operate in the same manner with an oscillating motion, and the knife will engage and feed one card only. The knife slide adjusting screw provides an adjustment to bring the knife back far enough to be sure it gets behind the card after the card is stopped by the hopper guide posts.

Feed Throat

The throat used with this type of feed knife is also slightly different in construction. Figure 19 shows a feed knife feeding a card through a roller throat into a set of feed rolls. The throat knife is very similar to the one studied, but instead of a block, a roller is used to form one side of the throat. The knife itself

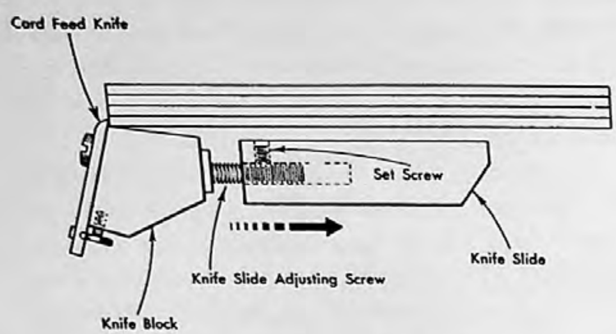


Figure 18. Feed Knife

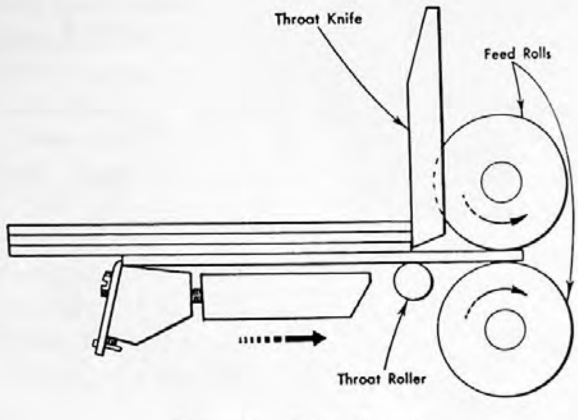


Figure 19. Roller Throat

is adjusted vertically to provide the proper throat opening which should be .010″ for this type of throat. The roller may be moved to insure that the high position of the roller is directly beneath the throat knife.

Hopper Guide Posts

The hopper guide posts form one side of the hopper and serve as a guide for the cards as they settle in the hopper to a position to be fed. They also prevent the cards from moving away from the feeding mechanism when the knife returns to pick another card.

Hopper Side Plates

The hopper side plates are adjustable from side to side by means of elongated screw holes so that the card may be shifted to cause the holes in the card to be aligned to the subsequent mechanism.

Feed Rolls

As the cards are fed from the hopper into the machine, they are placed under the control of feed rolls. Feed rolls are used to move the cards through the machine to the operating stations and on to the stacker. The first set of feed rolls gain control of the card movement before the feed knives lose control as seen in Figure 20. The feed rolls are so spaced that before one set of feed rolls loses control of a card the next set grips it. This positive control continues until the card has passed all stations and is stacked.

Feed rolls are of varying size and materials (Figure 21) to meet the requirements of the existing conditions. Rubber rolls are used where more gripping surface is required due to speed, and phenolic rolls are used where a nonconductor is required. Steel is used in most cases where no unusual requirements are made; in some cases combinations of materials are made.

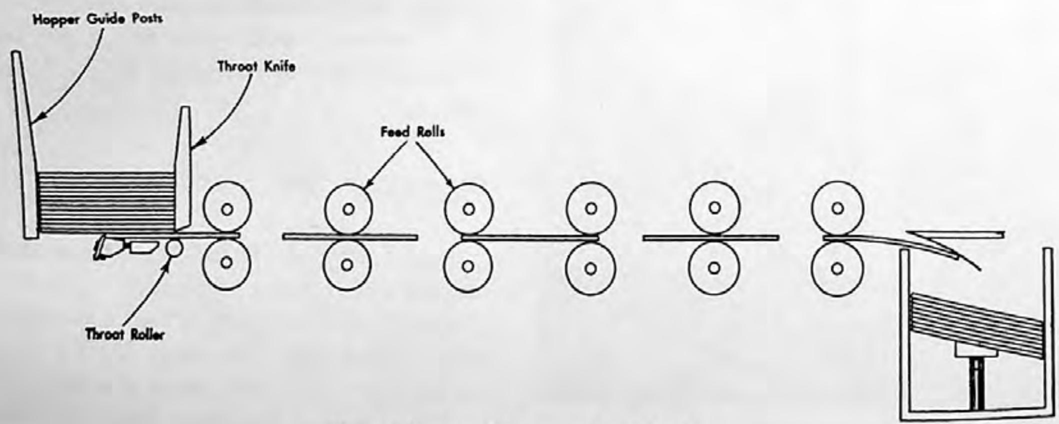


Figure 20. Card Movement by Feed Rolls

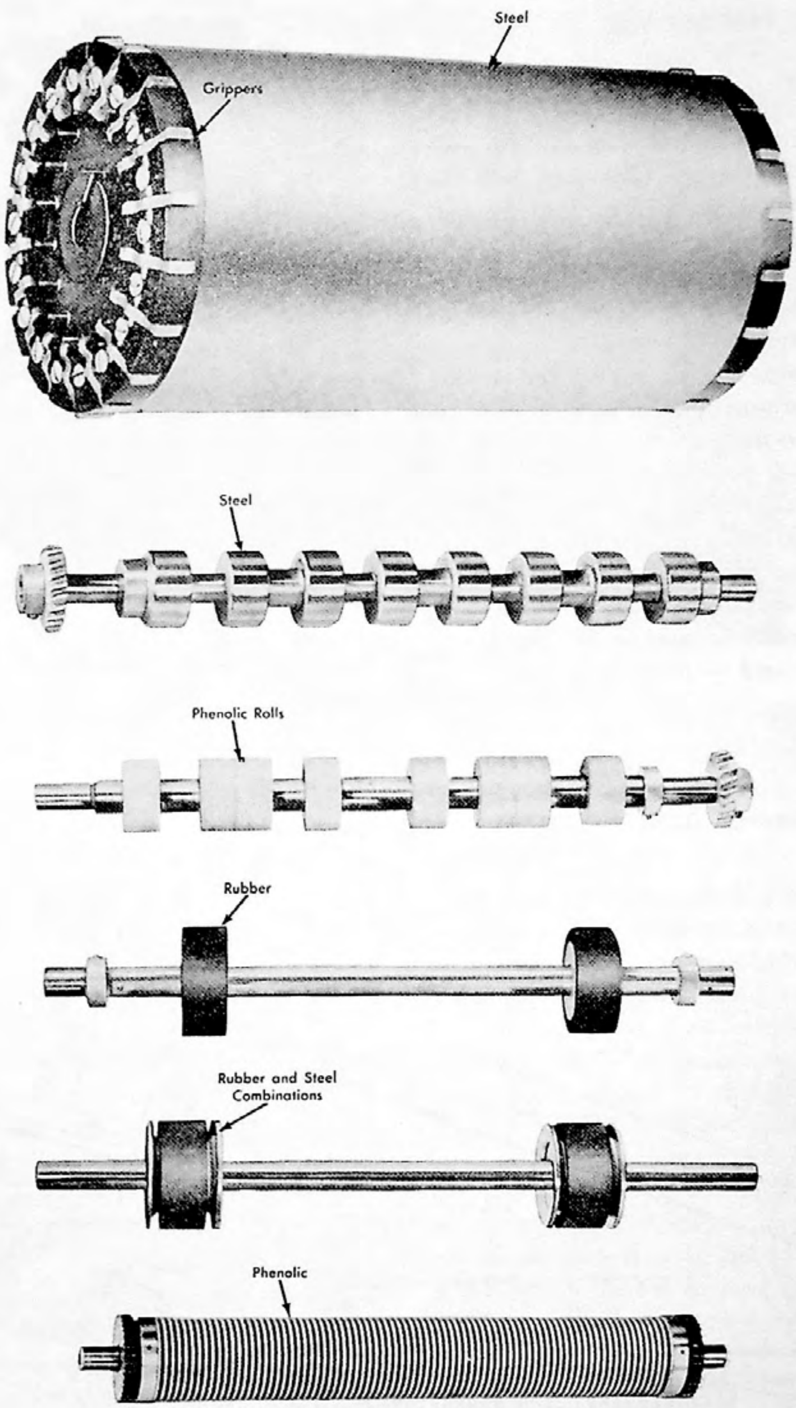


Figure 21. Types of Feed Rolls Used

STATIC READING FEED

Feed Unit of the 407

Cards are placed in the hopper (Figure 22) with the 9-edge toward the throat. They feed into the machine from the bottom, under control of the feed rolls. The hopper holds approximately 1,000 cards. Each card in turn is positioned at the first, then at the second reading stations by means of card grippers which move horizontally as indicated by the arrows in Figure 23. The cards can be held at the reading stations for any given number of cycles, after which they move around the stacker drum into the stacker, where they are held in position by a pressure plate. When the stacker becomes full, the machine stops.

The card feed unit is a static reading unit which provides for single and multiple line reading (Figure 23). With this type of card feed unit the card may be held in reading position for an indefinite number of cycles. While the card is in the reading position,

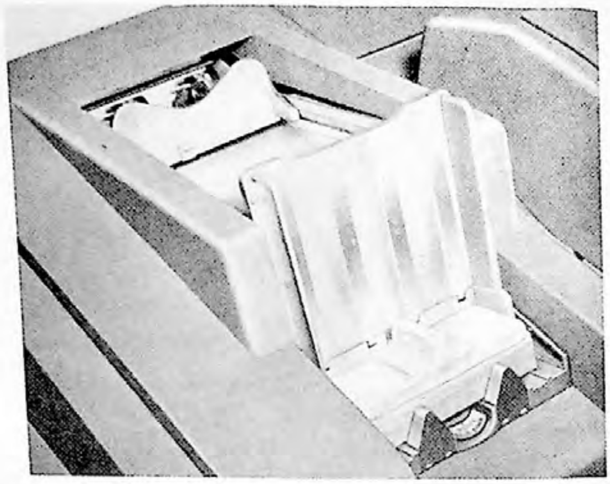


Figure 22. Hopper and Stacker

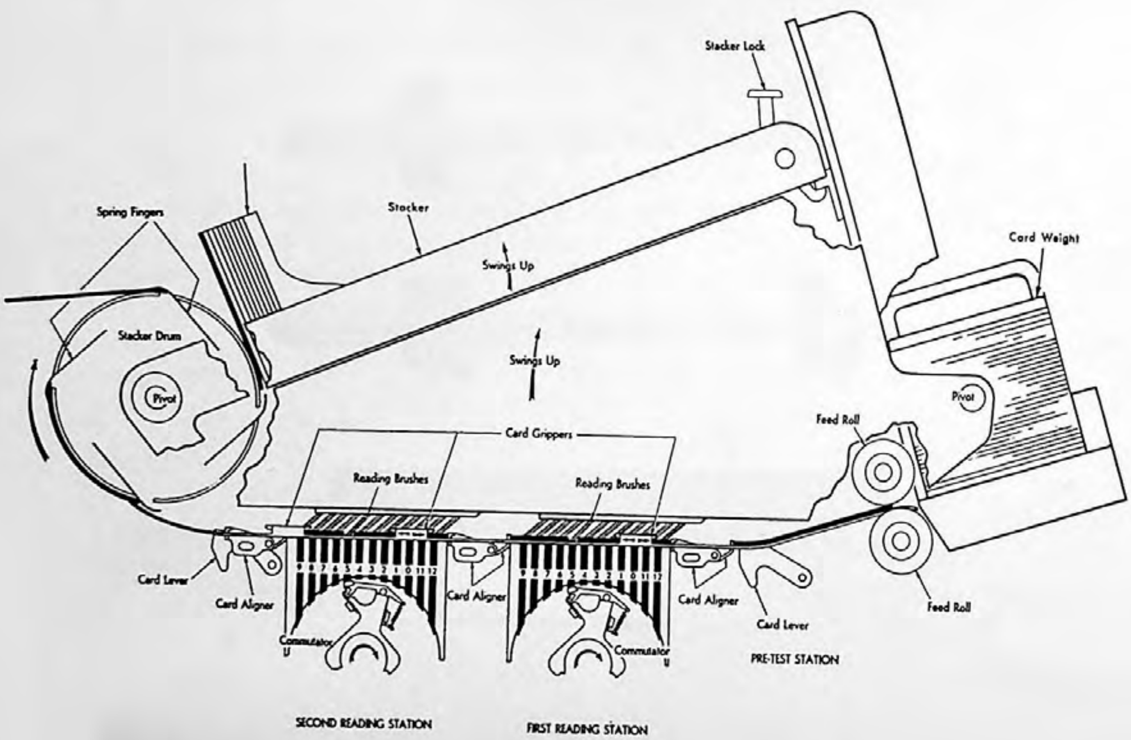


Figure 23. Feed Unit Schematic

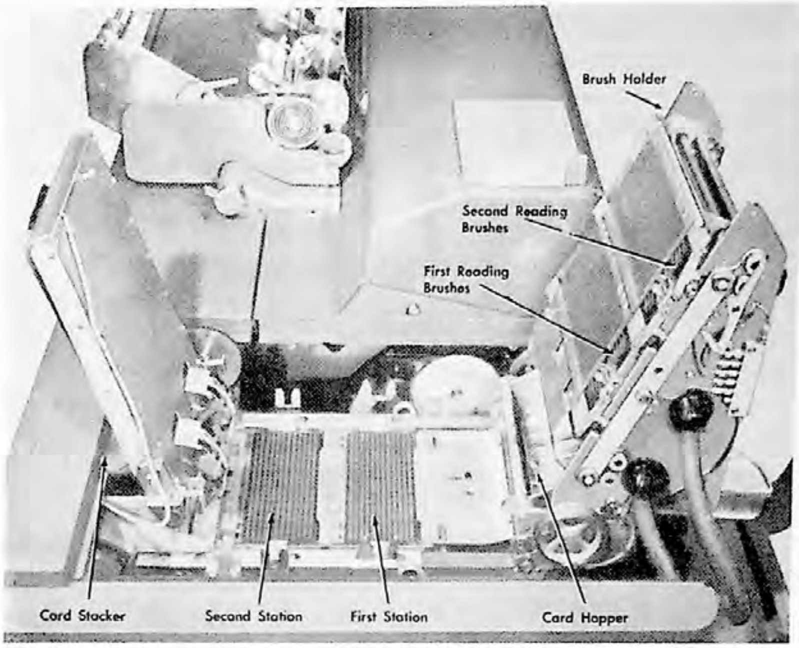


Figure 24. Feed Unit

960 brushes are in contact with the card, one brush for every possible hole in the card. A commutator assembly reads the holes as long as the card remains in position. This arrangement facilitates a method of crossfooting several amounts from a single card, as well as printing name and address on separate lines from a single card. The feed has two sets of brushes to provide a means of controlling for particular operations and for groups of cards. The card picker knives, which move the cards from the hopper, and the card grippers, which move the cards through the brush stations, are operated independently of each other. This keeps the cards in step if a card fails to feed from the hopper.

Access to the cards after they have left the hopper may be obtained by first depressing the stacker lock, then raising the stacker itself, which swings toward the back of the machine, and raising the brushes which swing toward the front of the machine. The cards may then be easily removed from the machine by hand. The brushes which normally protrude slightly below the brush separator (pressure plate) recede into the separator when it is in a raised position; this prevents any possible damage to the brushes (Figure 24).

CARD SENSING

THE MOST common method of sensing in use in present types of IBM machines is to read the holes in the card electrically by means of brushes. There are many brush types designed to read a hole under as many different conditions. However, the most common type of brush found in current machines is the three-group brush. Figure 25 shows a brush of this type which consists of a die cast ferrule which holds three groups of wire strands with six strands per group. It can also be seen from this figure that as a card passes a brush of this type, it first encounters the heel of the brush, the short strands, and as it continues to move it encounters the toe, or long strands.

When a brush encounters a hole in the card, the brush strands drop through the hole onto the contact roll. This makes an electrical connection between the brush and the contact roll. Figure 26 is a theoretical circuit which shows how the brush contact initiates action. The brush permits the circuit breaker to complete the circuit to the punch magnet. The energizing of the punch magnet results in the actuation of the punching mechanism. A three-group brush is held in place by a brush clamp screw and nut, and

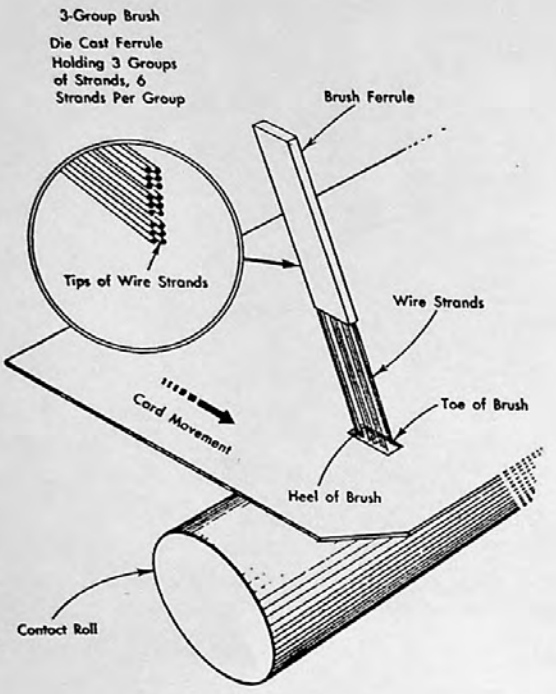


Figure 25. Brush, Card and Contact Roll

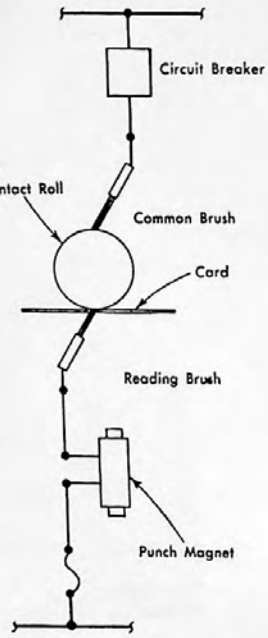


Figure 26. Theoretical Brush Sensing Circuit

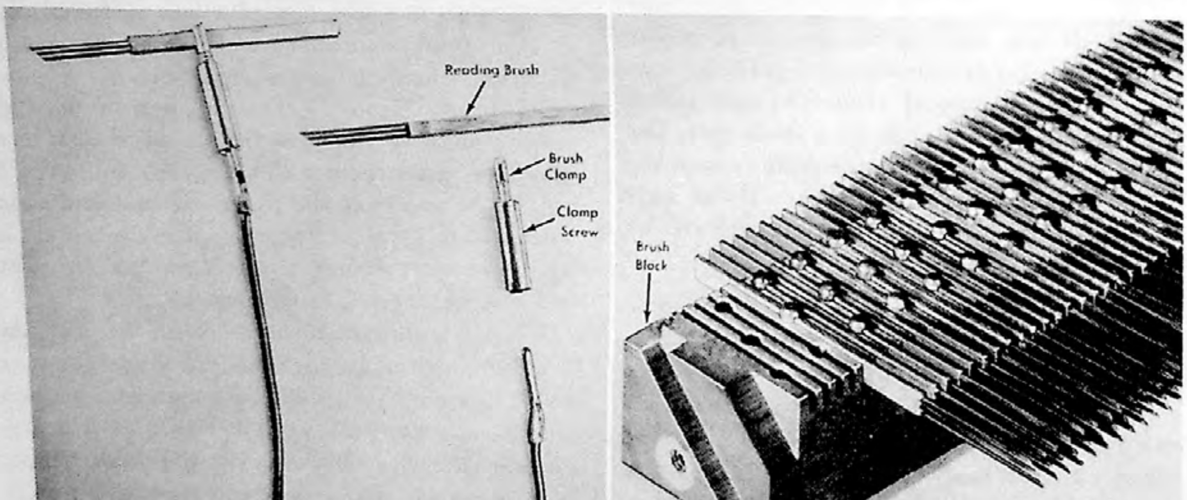


Figure 27. Brush, Brush Block, and Circuit Connections

a brush holder as seen in Figure 27. The electrical connection to the brush is made through the brush clamp screw and nut, and a wire lead which has a plug on the end, fits the hole in the nut.

In a digit-by-digit type feed, the brushes are held together by means of a brush block which contains 80 brushes. However, each brush has its own clamp screw and nut, and individual circuit connection. A card passing a set of brushes such as this can be completely read by passing the brushes only once. As each brush reads its respective column, it completes a circuit from the contact roll through the reading brush to a particular magnet or relay and on to one side of the line. However, since that circuit must also be completed to the other side of the line, regardless of which brush completed it, a connection is made by means of a common brush to the contact roll. The common brush is situated physically so that the card will never pass between it and the contact roll and a connection will always exist between the contact roll and one side of the line through the circuit breaker.

Card Reading of the 407

The complete sensing assemblies consist of 80 individual sensing bar assemblies as shown in Figure 28. These individual sensing bar assemblies consist of 12 dual groups of music wire which are cast in one mould, thus making the 12 groups common to each other. Each dual group of music wire on the individual sensing bar assembly consists of two separate wire groups for reading one hole in the card. Each one of the sensing bar assemblies is used to read one column of the card. Consequently, 80 individual sensing bar assemblies are needed for each sensing station to read all 80 columns of the card. This calls for a total of 960 dual wire groups for each sensing station. Each of the 80 individual sensing bar assemblies are insulated from each other. Consequently each column is insulated from the adjacent positions but the 12 dual wire groups of one individual assembly are common. It is still possible to get a definite value from a particular column, however, because of the *time* that the impulse is received through the sensing bar and the fact that the columns are insulated from each other.

After the card is positioned at one of the sensing stations and is held by the pressure plate, the holes in the card are read by the commutator rotor (Figure 29) which sweeps past the commutator stators. The commutator rotor is continuously turning regardless of the operation of the gripper clutch. This is necessary if one card is to be read for more than one cycle.

The commutator rotor assembly is common so that all 80 positions are "hot" at the same time. This makes it possible to have one connecting wire on one collector ring for the entire assembly. The impulses that are used are from the sensing bar hubs and correspond to the columns of the card; since the columns are insulated from each other, the impulse will be completed to the hub only when a hole is punched in

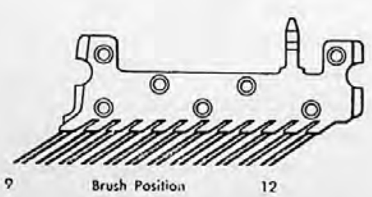


Figure 28. Sensing Bar Assembly

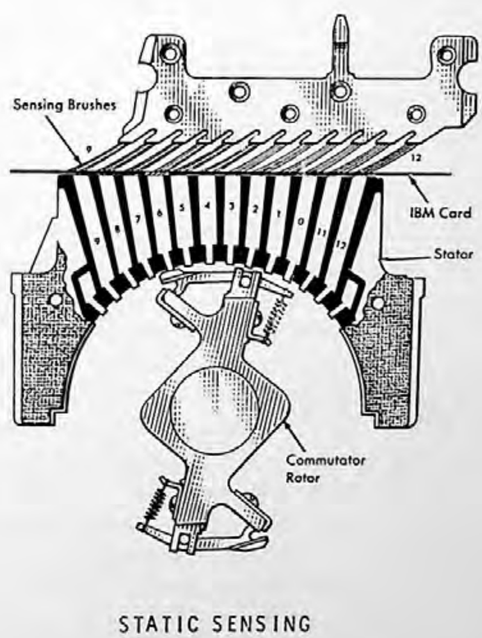


Figure 29. Static Sensing

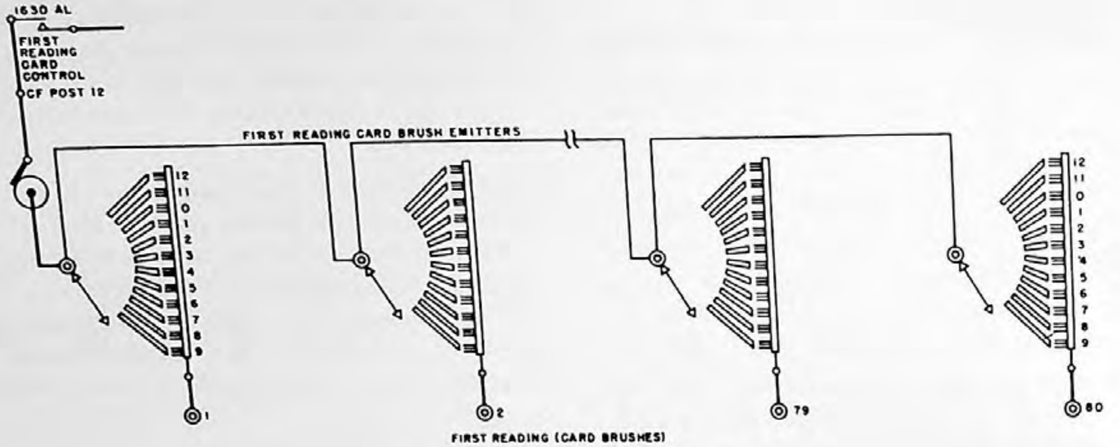


Figure 30. Reading Card Brushes

the card for that column and at a time corresponding to the value of the hole punched. Thus the cable to each sensing station consists of one wire to the commutator rotor through the collector ring and 80 wires to sensing bars, one for each column (Figure 30).

Brush Tracking

Before proper reading is assured, however, there are several conditions which must exist. First, the hole must pass the brush in alignment so that the brush will drop through the center of the hole onto the contact roll. The first column brush must drop through a hole punched in column one, and the 80th column brush must drop through a hole punched in column 80. The same is true of the other 78 brushes and their respective card columns. Figure 31 shows a feed which has two sensing stations. In each set, the brush which should read this hole is shown, and it can be seen that neither brush will properly sense the hole. These brushes were not "tracking" properly. The brush should "track" through the center of the hole in the card. Obviously, the relationship between the hole in the card and the two sets of brushes must be changed to obtain proper tracking. This can be accomplished in several ways. The hopper side plates could be shifted to cause the hole to be aligned to

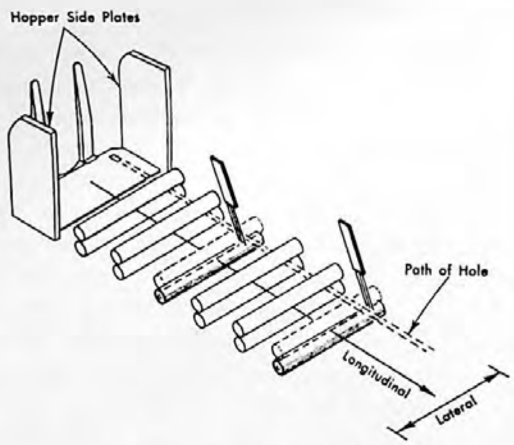


Figure 31. Brush Tracking

one set of brushes. This will also change the relationship of the other set of brushes, but they may still be tracking incorrectly. In the case shown in Figure 31 the condition on the second set would be made even worse. It is necessary to shift the second brush set itself within the brush frame to align the brush to the hole. Because the hopper side plates may have been adjusted to cause either set of brushes to track properly, both sets of brushes are adjustable laterally. There are brushes in some machines which are not adjustable laterally; this necessitates the adjustment of the hopper side plates to those brushes. Any other brush sets in the feed must then be aligned to the hole. If all but several brushes are tracking correctly, the brush ferrules should be formed with a brush bending tool to provide proper tracking of the few which are out of alignment.

Brush Tension

With the brush tracking properly, the second necessary condition is that the brush have sufficient tension to cause the brush to drop through the hole in the card and make good, firm contact against the contact roll. Figure 32 illustrates the three general conditions of brush tension: correct brush tension, too little, and too much brush tension. Brush tension is governed by the length of brush projection above the brush separators. If there is a given clearance between the brush separators and the contact roll, the greater the brush projection the greater the brush tension will be. In general, brush projection will be 1/8″ above the brush separators.

Brush Position

Still another condition to be considered is the position of the brush with respect to the centerline, or high point, of the contact roll. For the best possible contact conditions, the center of the brush should be on the high point of the contact roll. If the brushes are too far to the left or right of this point, either the heel or the toe will not be making properly and may result in burned brushes and contact roll. Figure 33 shows the brush position in relation to the contact

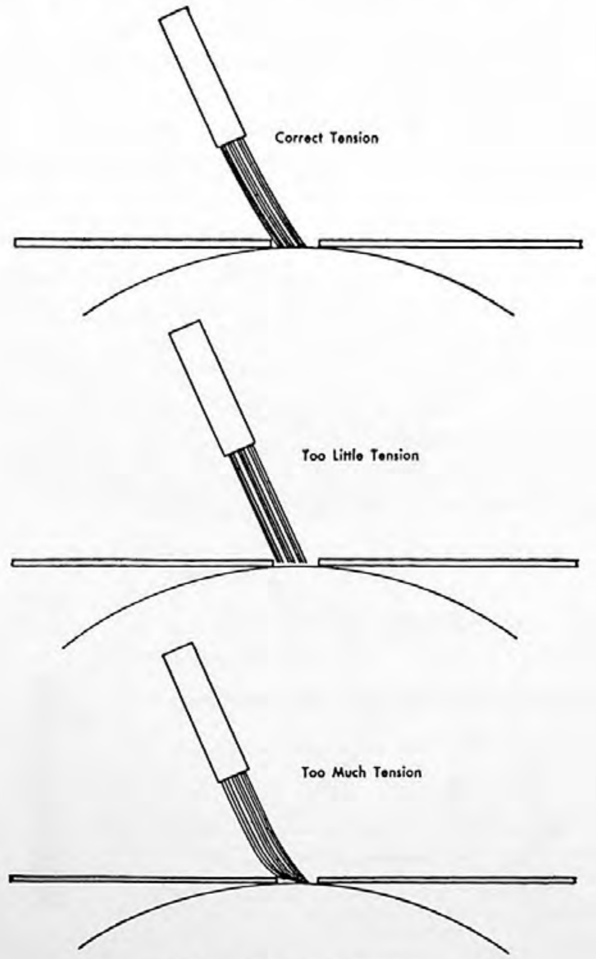


Figure 32. Brush Tension

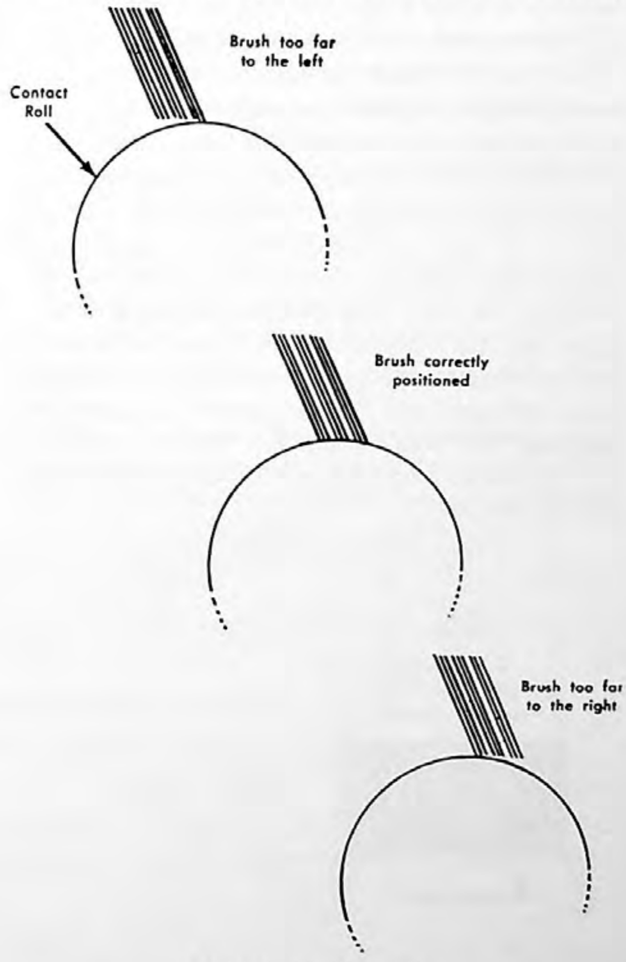


Figure 33. Brush Position

roll. The brush separators are scribed with a line to indicate the position of the heel for best contact condition.

TIMING

IF THE IMPULSE is to be recognized and used by another mechanism, the brushes must be located to read a hole at the proper time. The impulse may result in a digit being printed, punched, stored, accumulated, or compared with another. The mechanism which receives the impulse must also be timed so that it will properly recognize the impulse. For this reason all mechanisms must be timed so that they move in synchronism when operating. The timing for other mechanisms will be considered as they are studied as a functional unit. Before brush timing is discussed, the terms machine cycle, card feed cycle, cycle point, and degrees must be defined and understood.

The term revolution per minute (RPM) is a common expression used with gas engines, electric motors and many other mechanisms. In most cases the term RPM with reference to the motor itself has little meaning to the average layman. However, if the miles per hour or the rate of machine output is stated, it has a significant meaning. Similarly, in IBM machines the motor RPM has little meaning, but again if it is stated that the machine has an output of so many cards per minute the productive capacity is known. As an example, one type of punch is capable of punching 100 cards per minute. With this information the amount of production possible in a given time is easily computed.

Cycle Definition

With respect to cyles this information has another significance. It indicates that 100 times in one minute it starts and completes a sequence of operations. This sequence of operations is referred to as a cycle, and can be termed a machine cycle or a card-feed cycle. Because cards must be feeding so that punching can take place, it would be a card-feed cycle. A machine cycle is any cycle that the machine operates. It should be concluded that a machine cycle can, and does often occur without it being a card-feed cycle, but for a card-feed cycle to occur, a machine cycle must be coincident.

During a card-feed cycle, a card will move a given distance in a given machine. If there is more than one operating station, such as two sensing stations in the feed, they will usually be spaced exactly one cycle apart. Figure 34 shows this relationship. It will take exactly one cycle to move the card from the center of the contact roll of the first read brushes to the center of the contact roll of the second read brushes. If a 5 hole is read at a given time in a card-feed cycle at the first set of brushes, the same 5 hole will be read at exactly the same time at the second set of brushes but one card-feed cycle later.

Cycle Point

If the card is fed 9-edge first, the first point during the cycle when the brush could read would be when a 9 hole is under the reading brush. The second point which can be read is an 8 hole. This procedure is continued until the 12 punching position has been reached. The distance from one point, such as a 9, to the adjacent point, 8, will be one cycle point, which will correspond to the punching position.

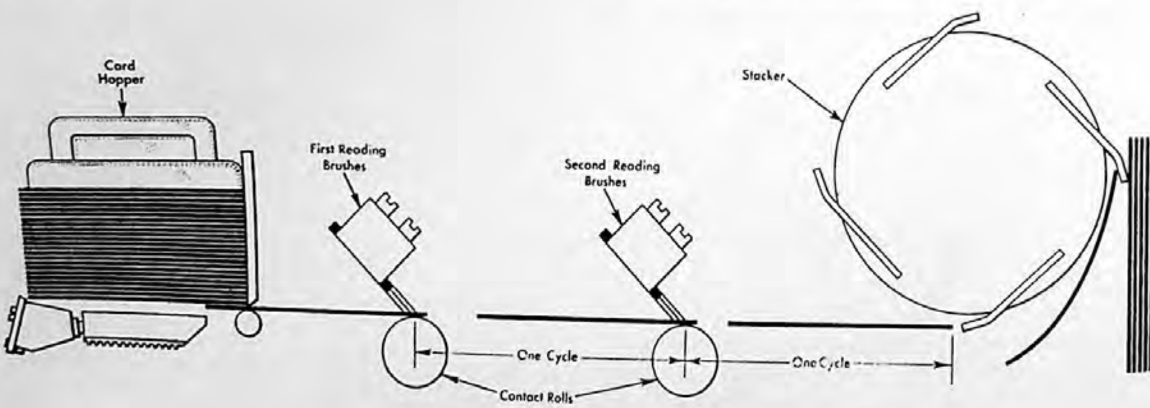


Figure 34. Cycle Relationships

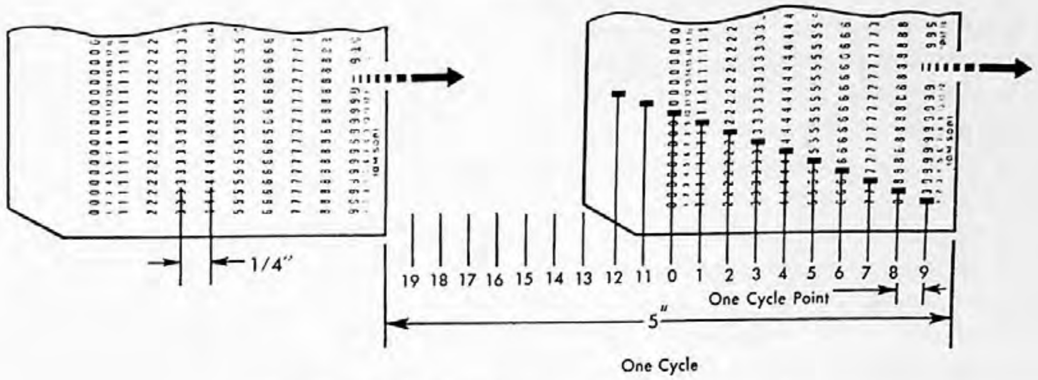


Figure 35. Cycle, Cycle Points, and Card Relationships

The distance between centers of adjacent punching positions is 1/4", which means that one cycle point must result in a 1/4" movement of the card. While there are 12 punching positions on the card, because there is 1/4" of card above and below the first and last punching position, the card is 3 1/4" from top to bottom. Because a cycle point represents 1/4" card movement, a card is equivalent to 13 cycle points. If cards were fed edge to edge, it would result in a cycle which would contain 13 cycle points. However, because some time is required to restore operating mechanisms to a normal position, a space is allowed between cards. To provide this time and space, the feed rolls are geared to move the card a distance greater than 3 1/4", and for this discussion assume it to be 5". This results in a distance of 5" between operating stations, 1 3/4" between cards, and 20 cycle points per cycle. For the 12 punching positions the cycle points will be identified with the corresponding digit. Figure 35 illustrates a 20-cycle point machine cycle and its relationship to card movement. The distance between cards, and as a result, the number of cycle points in a machine cycle, vary from one machine to another. However, the most common number of cycle points per cycle are 14, 16, and 20.

Degrees

Many mechanisms on a machine are timed to start or complete an operation at a specific time during a cycle. For this reason, an index is attached to the machine, and geared to make one revolution per machine cycle. The index is marked with graduations representing cycle points or degrees so that mechanisms can be timed to the index. An index with all 360 degrees indicated is in general use because a finer definition of timing is available. On a machine having a 20-cycle point machine cycle there will be 18 degrees per cycle point or per 1/4" movement of the card.

Figure 36 shows a timing chart which represents the machine index and timing relationships. The chart shown indicates a division both in cycle points

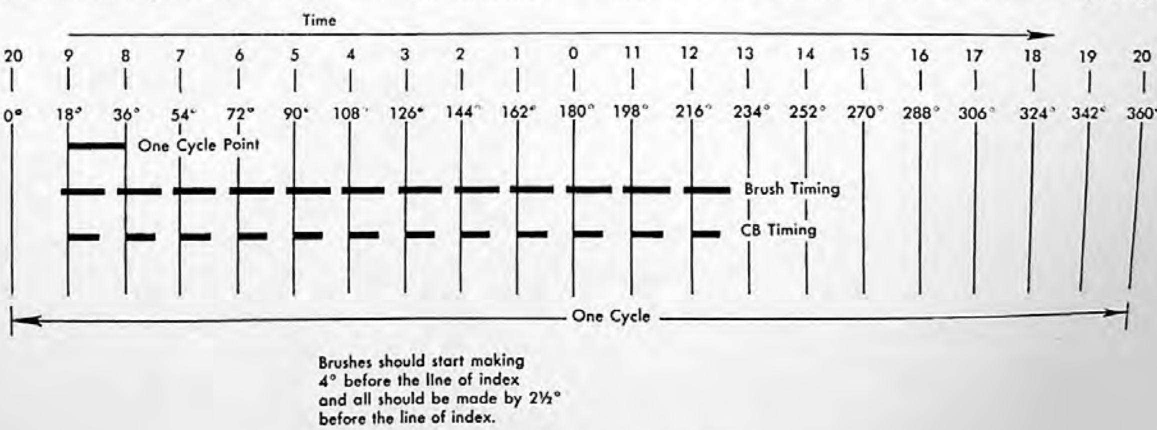


Figure 36. Machine Index and Timing

and degrees and shows one cycle. The timing relationships between the brushes and the circuit breakers are given. The heavy solid lines indicate the time that the brushes should actually be making through the hole in the card and the time that the circuit breaker is actually completing the circuit.

The actual timing of the read brushes can now be considered. It has been previously stated that the brush should make contact on the center line of the contact roll in relation to the brush holder. If this condition has been satisfied and the brushes are not making at the correct time, the hole should be changed in relation to the brush. To change the time the card reaches the brushes, it is necessary to change the time that the card is picked by the knives and fed into the machine.

Before changing the time the card is picked, a check should be made to see that the knives go back into the guide posts the proper distance. If an adjustment of this kind is necessary, it can be made by the adjusting screw or the turnbuckle shown by Figure 37. (The methods of adjustment available on

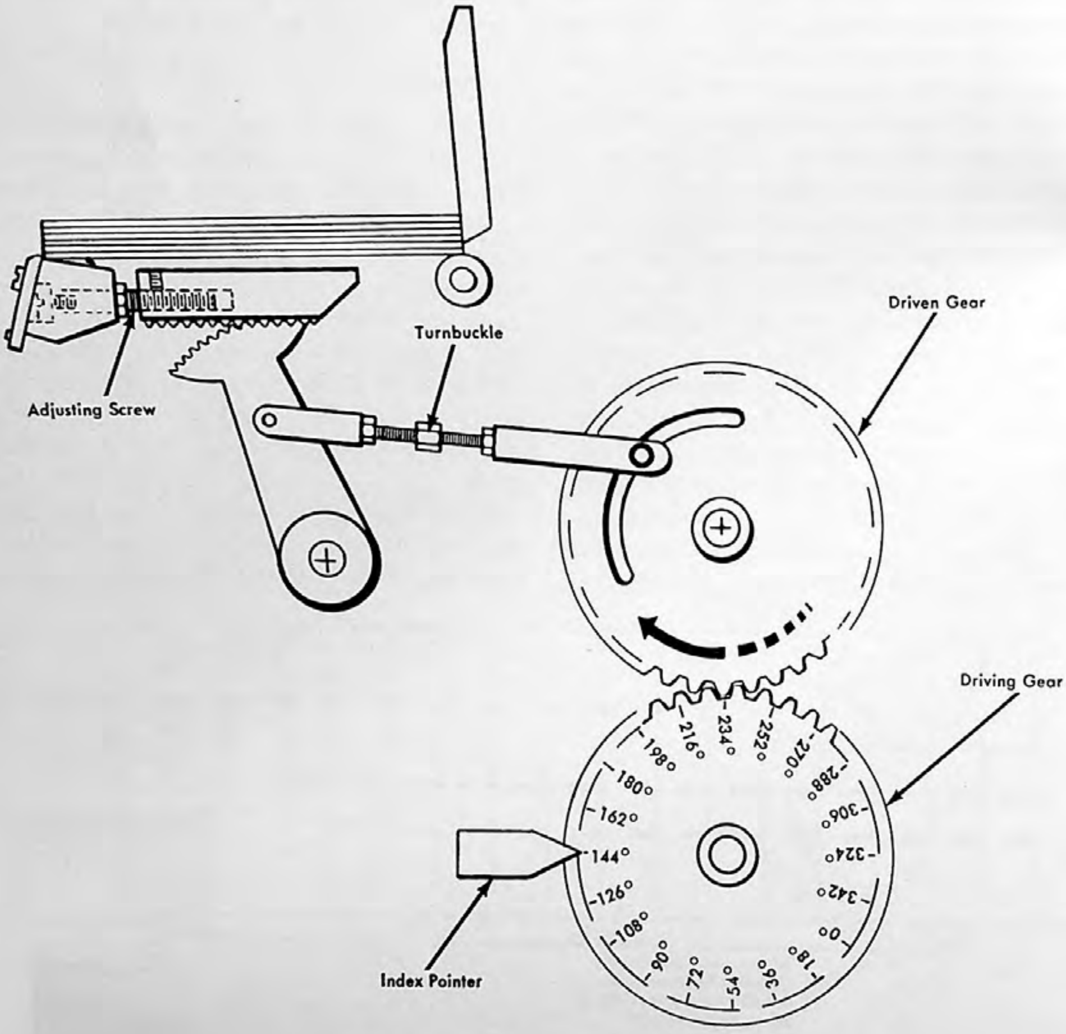


Figure 37. Methods for Timing Adjustments

this figure represent a composite of methods which exit on some machine, but no one machine has all of those shown.) This adjustment will shift the limits of knife travel and consequently the time the card is engaged by the feed knives, but does not affect the length of stroke. Because this adjustment does affect timing, it must be made first. Also at this time the cards should be checked to be sure that they are feeding straight. If the cards are feeding straight, both ends of the card will be engaged by the first set of feed rolls at the same time. One of the two adjusting screws should be adjusted to obtain this condition.

Knife Timing to Obtain Proper Reading

When all necessary adjustments have been checked or made and it is desirable to time the card movement, it can be accomplished by shifting the screw in the slot of the driven gear. This will not affect any other adjustment, the limits of feed knife travel, or length of stroke. In some cases it may be necessary to unmesh the driving and driven gear to make a change. Also, in some cases the change in time may be made with the adjusting screw if its travel into the guide posts is still within the permissible tolerance.

Where two or more sets of brushes are involved, the feed knives may be timed to cause proper reading at one brush set only. Because both sets have been set to the scribed lines, both sets should read correctly. However, if there is a variation, the second set may be shifted slightly to obtain the correct timing.

The factors necessary for proper brush sensing in flight are: brush tension, brush making on the center of the contact roll, brush tracking, and brush timing.

Stacker

After the cards have passed the reading station, or other operating station, the card is moved to a stacker. The stacker may be one of several types each of which is particularly adaptable to some machine or machines. There are three main stacker types which are listed below along with a description of each.

The *gravity type stacker* in which cards are thrown at high speed into a pocket and are permitted to settle on a spring balanced plate is one of the simplest forms. This device does not perfectly align the cards so that they may be inserted in a file drawer without jogging. However, this is not a serious disadvantage in some types of machines. The gravity type stacker

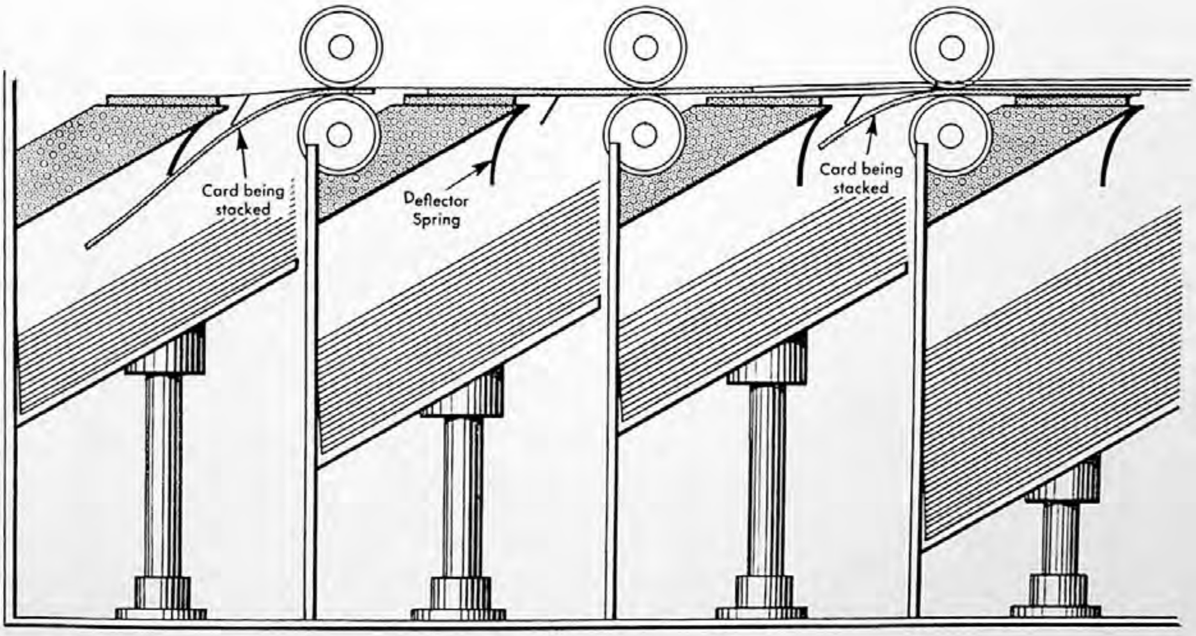


Figure 38. Gravity Type Stacker

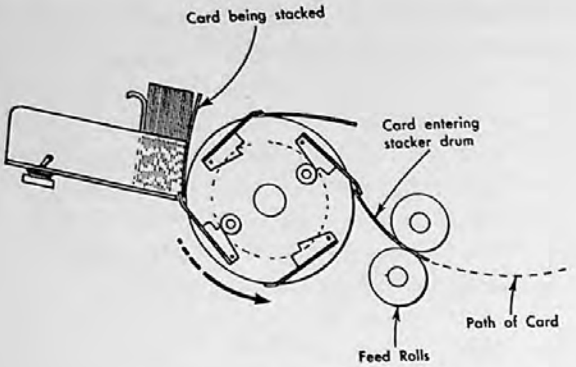


Figure 39. Drum-Type Stacker

does not operate well at low speeds because static electricity may cause the cards to adhere to one another before settling on the stacker plate.

The positive *drum-type stacker* is used on many types of machines. This drum stacker is equipped with fingers or grippers which positively engage each card as it passes from the station-to-station transport system. It deposits all cards positively and in a neat alignment on a stacker plate.

Friction-type stackers are employed in a successful manner on some machines, though they are subject to wear and subsequent misalignment of cards in stacking to a far greater degree than the drum stacker.

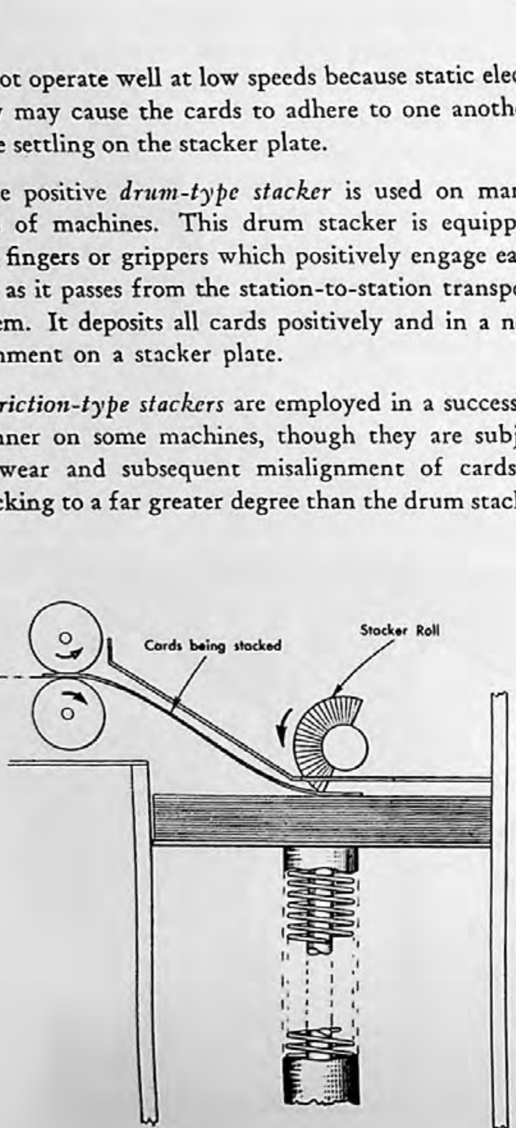


Figure 40. Friction-Type Stacker

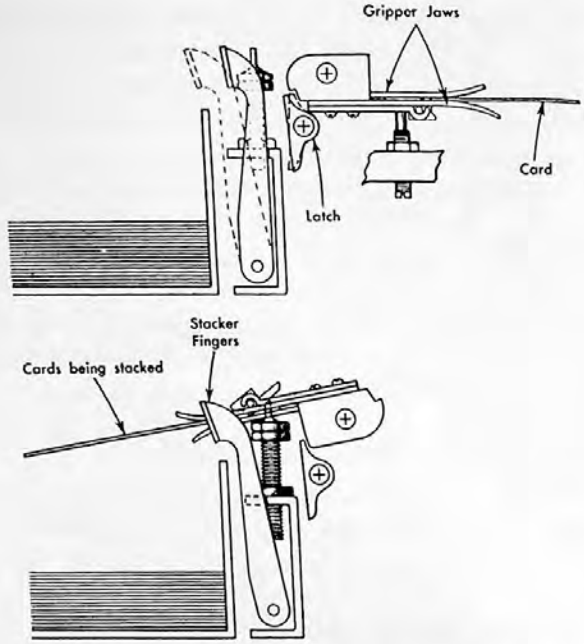


Figure 41. Combination Gripper and Gravity-Type Stacker

They were employed on some machines because space limitations did not permit the use of the more positive drum type stacker.

Radial-type stackers. As a card enters the pocket (Figure 42), the column-1 end rests on a pivot assembly, while the opposite end falls freely in an arc until stopped by spring-loaded alignment levers (see Figure 43). When approximately 5 to 10 cards accumulate at the aligners, they drop onto the oscillating card pusher that steps the cards to the front.

Card-retaining levers mounted on the pivot plate prevent the cards from falling backward into the stacker. These retaining levers are free to pivot forward to allow a card to pass, but cannot pivot backward.

As the stacker fills, the card deck is pushed outward until it activates the pocket-stop switch to stop card feeding.

Figures 38 through 43 show several stackers as they appear in a machine.

The demands of the feeding mechanisms vary from machine to machine. There are, however, four general ways in which cards may be fed from the hopper into the machine: horizontal with left edge entering the machine first; horizontal with either 9 or 12-edge first; vertical with left edge first; vertical with either

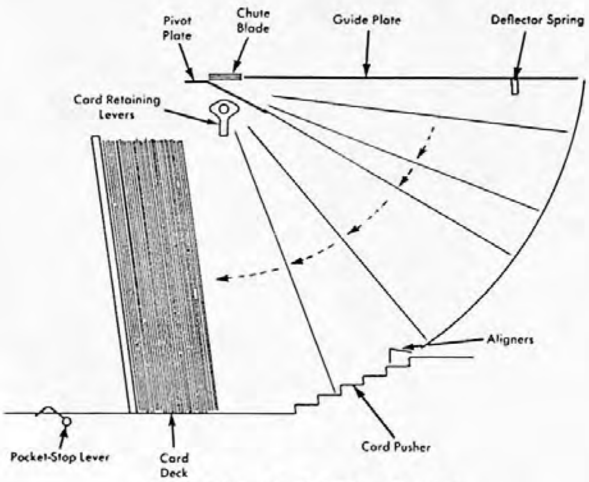


Figure 42. Radial-Type Stacker

9 or 12-edge first. Figures 44 through 47 each show a machine feed using one of the four general type feeds. Each is shown with the type of feed knife and throat used in that feed.

Several types of hoppers and feeding mechanisms, feed rolls, and stackers have been discussed and illustrated. Figures 48 through 53 show how some of these mechanisms are combined to form a card feed unit on a specific IBM machine.

In the hypothetical feed used to illustrate digit-by-digit feed only brush sensing was considered as a means of recognizing a hole. There are, however, many methods available for recognizing or sensing information. Electrical brush sensing through a hole in a card was considered first because it is the most

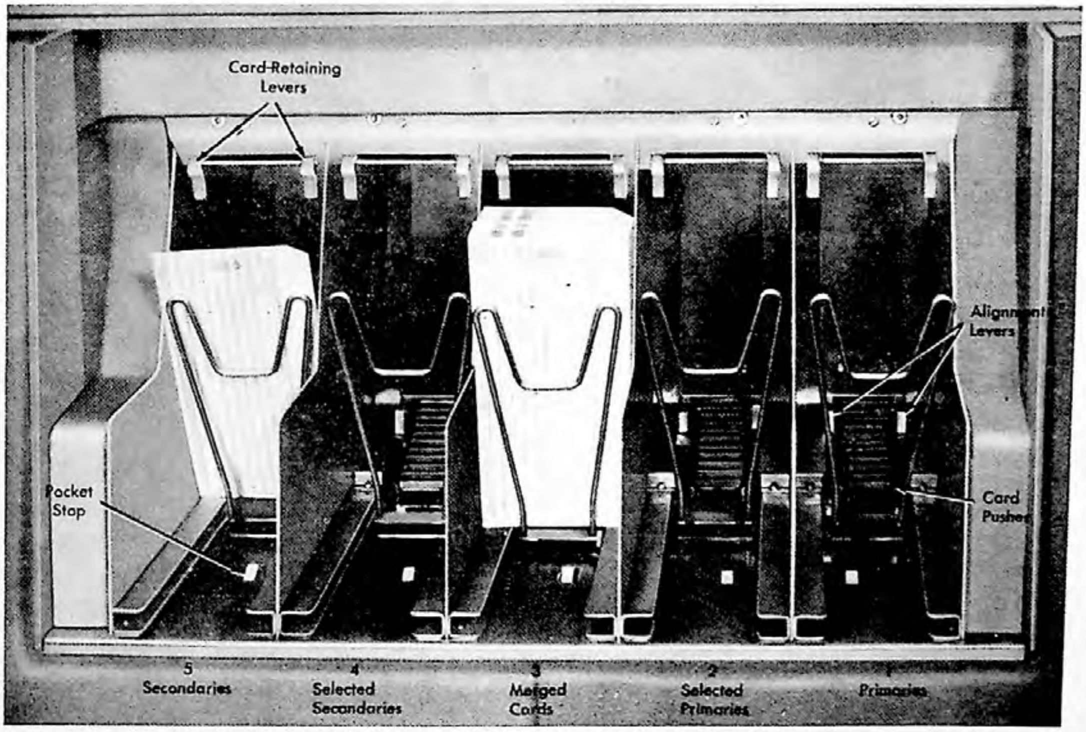


Figure 43. Radial Stackers

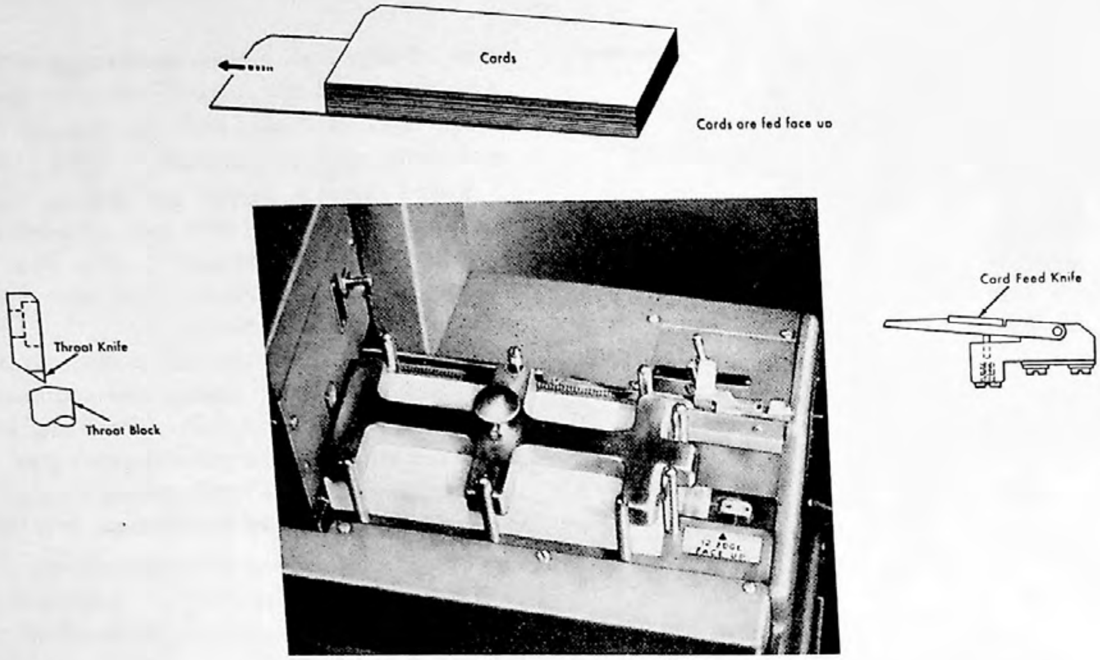


Figure 44. Horizontal Feeding — Left Edge First

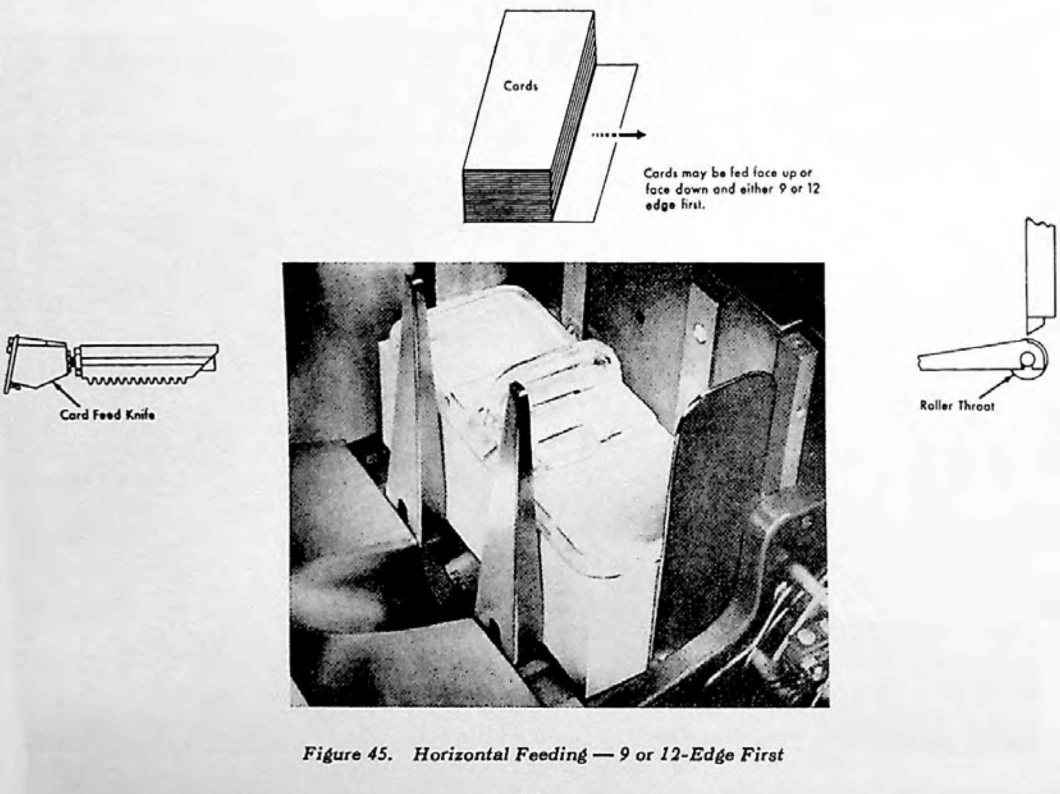


Figure 45. Horizontal Feeding — 9 or 12-Edge First

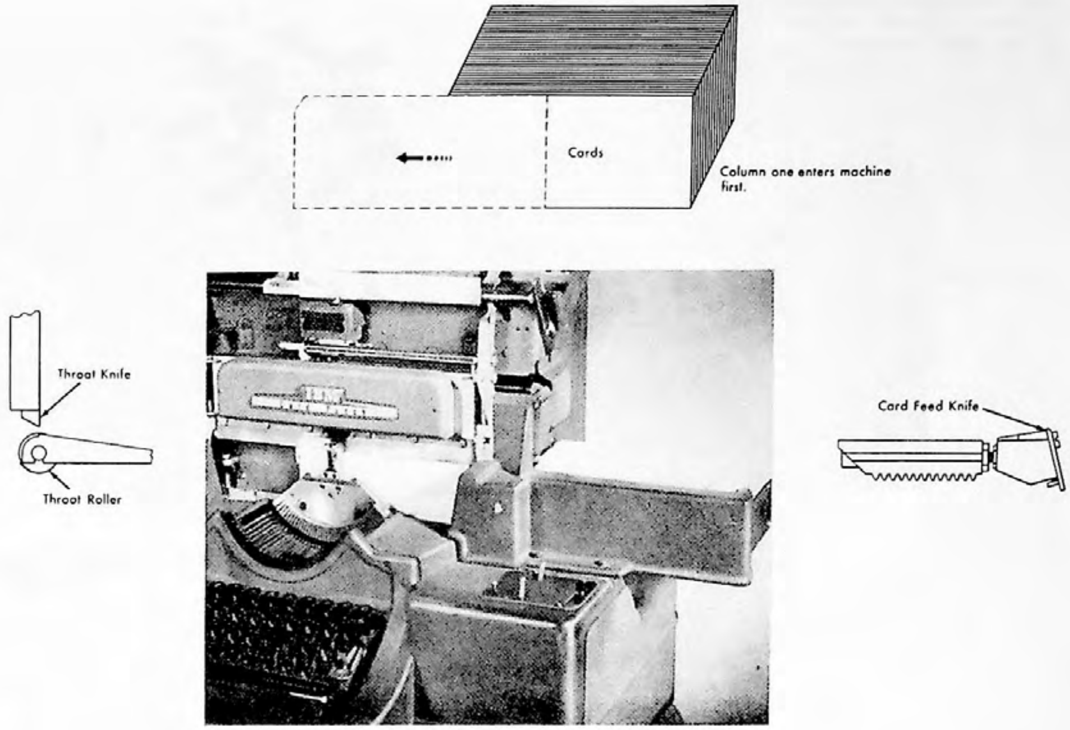


Figure 46. Vertical Feeding — Left Edge First

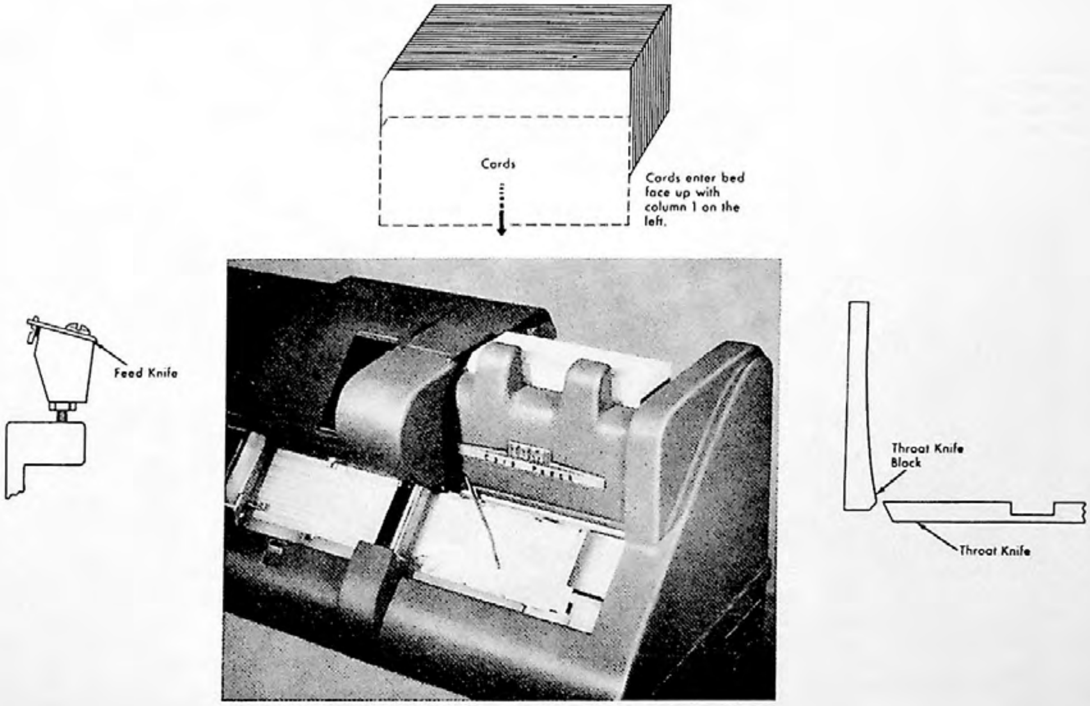


Figure 47. Vertical Feeding — 9 or 12-Edge First

Note: Cards are placed in the hoppers face down 9 edge first. A gravity type stacker is used.

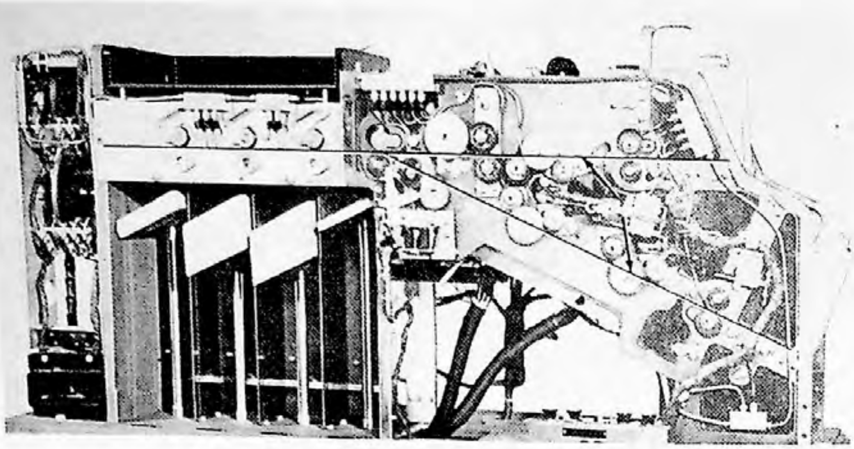


Figure 48. Card Feed Unit — Type 77 Collator

Note: Cards are placed in both hoppers face down 12 edge first. A friction type stacker is used.

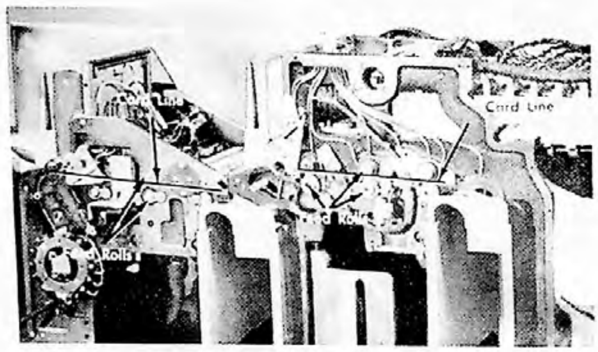


Figure 49. Card Feed Unit — Type 514 Reproducing Punch

Note: Cards are placed in the hoppers in a vertical position with the face to the front. A drum type stacker is used.

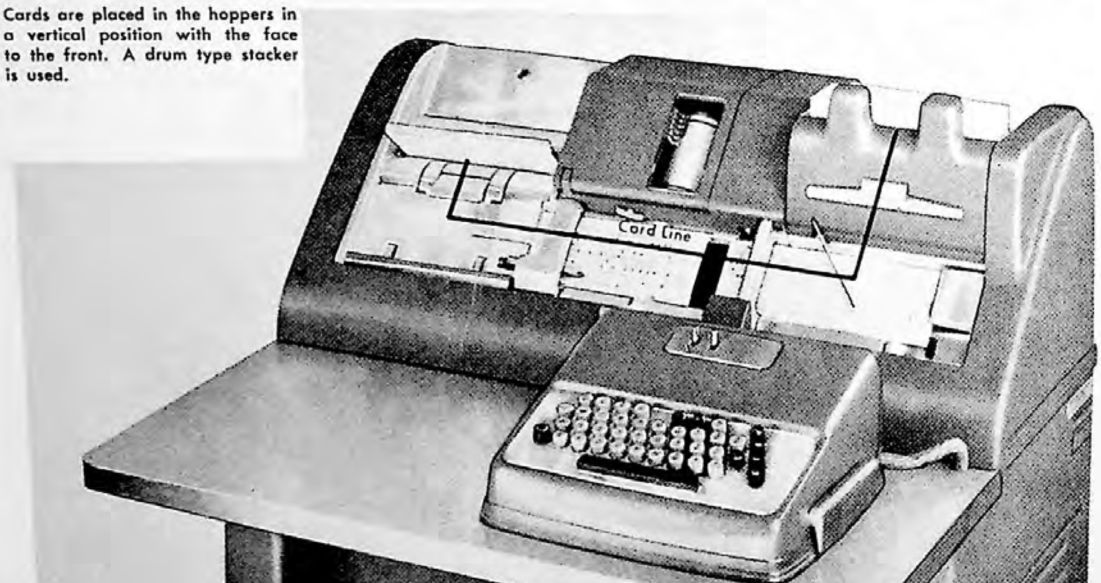


Figure 50. Card Feed Unit — Type 24 Card Punch

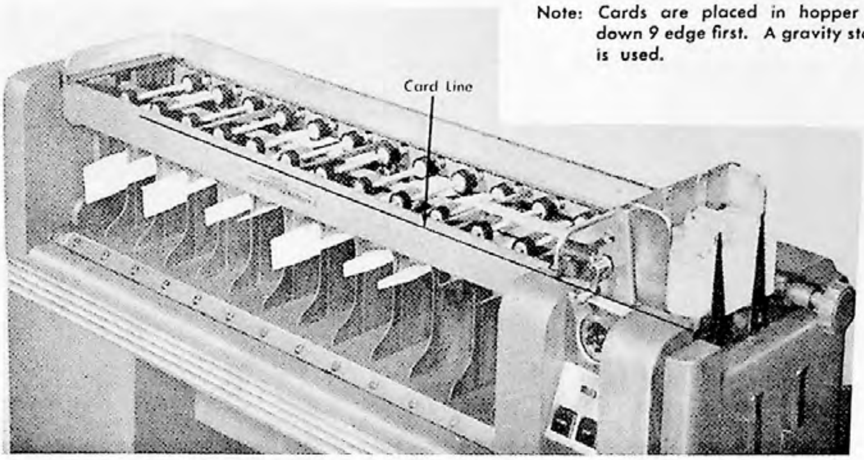


Figure 51. Card Feed Unit — Type 82 Card Sorter

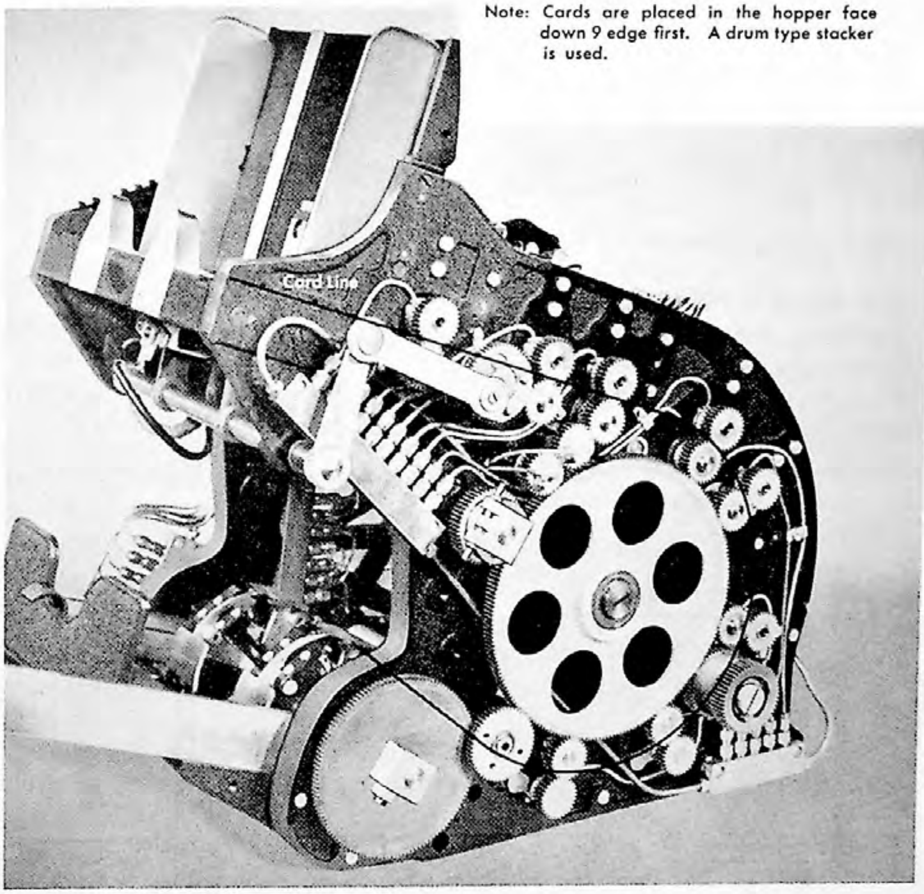
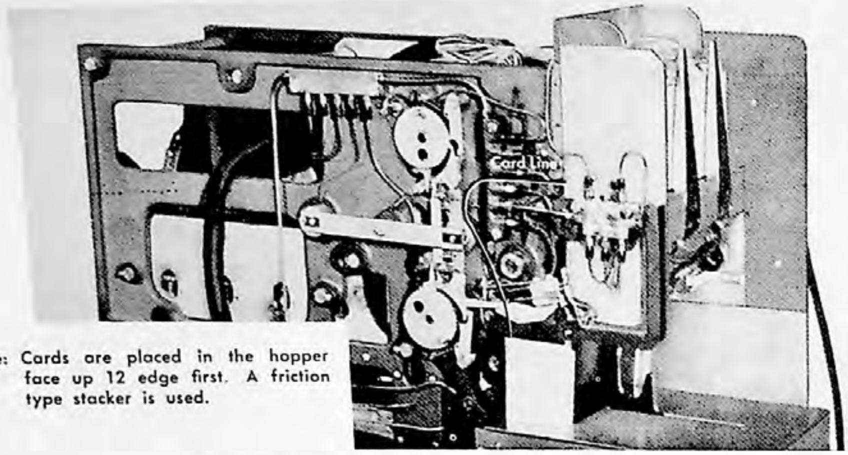


Figure 52. Card Feed Unit — Type 402 Accounting Machine



Note: Cards are placed in the hopper face up 12 edge first. A friction type stacker is used.

Figure 53. Card Feed Unit — Type 552 Card Interpreter

common method utilized in current types of IBM machines. There are two other sensing methods which, combined with the one studied, comprise the methods in common usage today. This does not imply, however, that other means are not used or will not be used; perhaps extensively, in the future. These two methods are:

1. Electrical sensing by means of pins or star wheels.
2. Electrical sensing of a mark by means of brushes.

PIN SENSING

Electrical sensing by means of pins is accomplished while the card is stationary, and is referred to as a method of static sensing. The card is sensed one column at a time with all twelve punching positions being sensed simultaneously. Since the card is to be moved intermittently column-by-column, a dog and escapement type movement is employed to control card movement.

Figure 54 shows a cross-section of a pin sensing unit which is in a normal position. The pin magnet is equal in width to a card, and it has twelve armatures, one for each punching position on the card. On the cross-section it can be seen that attached to the armature is a contact strap. A pin under spring tension is holding the armature and contact strap up away from the core of the magnet and the other side of the contact. When the pin magnet is energized, the armature is attracted to the magnet core. If there is a hole directly beneath the pin, there is no obstruction to the pin movement, and it moves down, permitting the contact to close as shown in Figure 55.

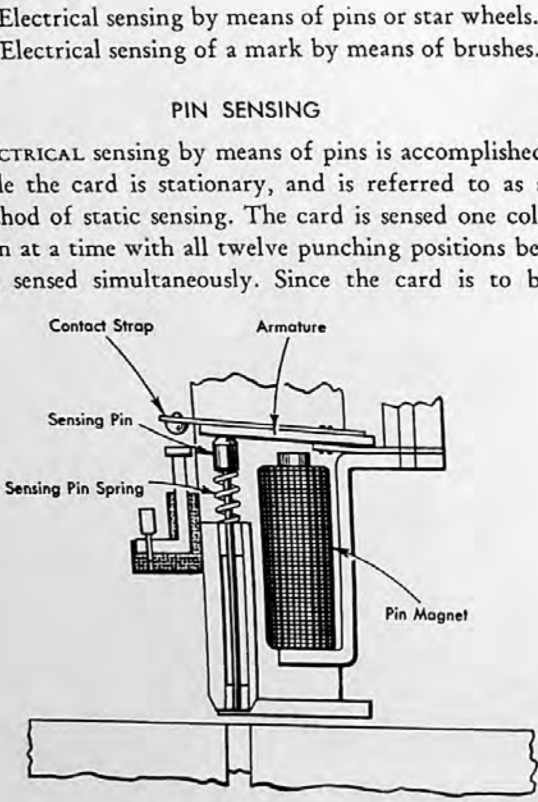


Figure 54. Pin Sensing Unit

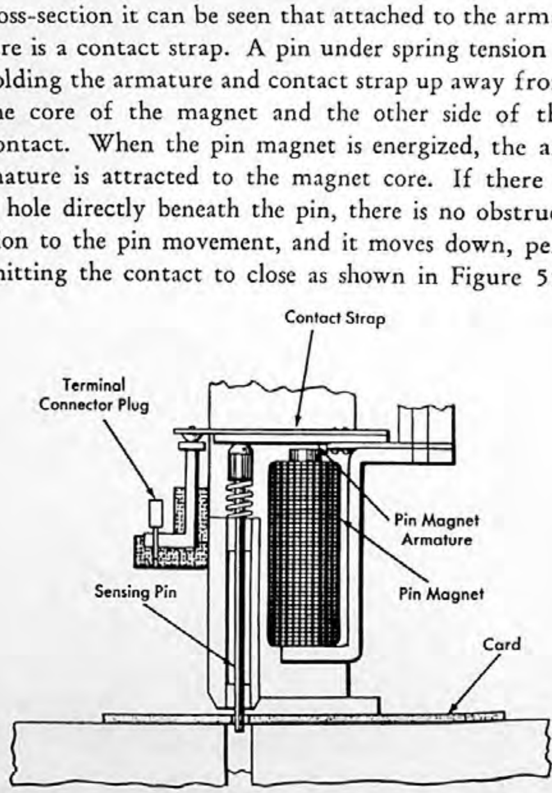


Figure 55. Pin Magnet — Energized — Hole

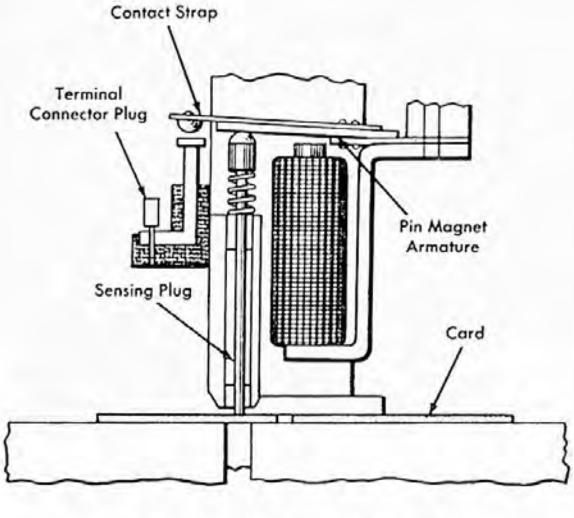


Figure 56. Pin Magnet — Energized — No Hole

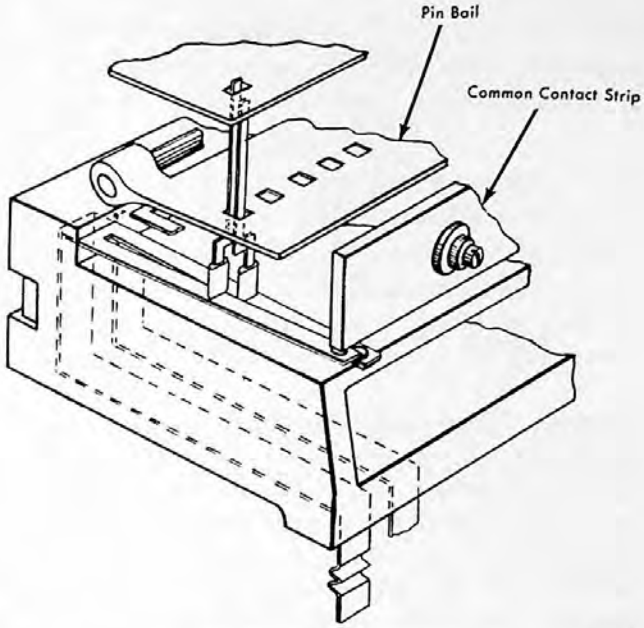


Figure 57. Dual Pin Sensing Unit

When the contact closes, it indicates that a specific hole is punched in that column. Since all twelve armatures are attracted as a result of energizing the pin magnet, all holes in a column are sensed simultaneously and all contacts above the digits punched are closed.

In all positions where no hole is encountered, the pins strike the surface of the card as shown in Figure 56. This stops the downward travel of the pins before the contacts have closed. The strength of the magnet pull on the armature is not great enough to cause the pin to puncture the card or otherwise damage it.

If a hole is sensed and a contact closes it completes a circuit to energize a relay. The relay energized will assist in instructing the machine to the next operation to be performed.

Dual Pin Sensing

Figure 57 shows another type of pin sensing unit known as a dual pin sensing unit. It is so named because it has two pins which are used to sense one hole. This unit senses all twelve punching positions column by column and has two pins for each punching position. The pins are under the control of a bail which is cam operated. The shoulders on the pins are held against the bail by the tension of the contact straps. As the bail moves up, the pins follow and if a hole in a card is above the pins, they move up until they make contact against the common contact strip. If there is no hole, the pins strike the card before the contacts have moved up far enough to make against the common contact strip. It should be noted that the contacts are constructed so that both of the contacts used to sense one hole are common and either one or both making contact will complete the circuit. Because each of the two contacts is operated by a separate pin if either one or both pins find a hole, the contact will be made. Figure 58 shows a hole being sensed by both pins.

The advantage of the dual pin sensing method is evidenced when either the holes are punched off-registration or the card being sensed is not properly

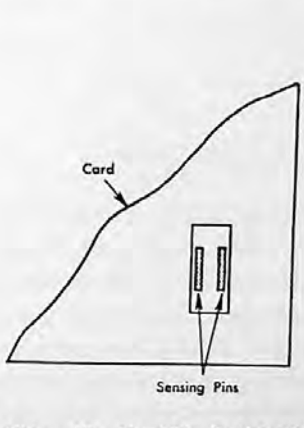


Figure 58. Dual Pin Registration

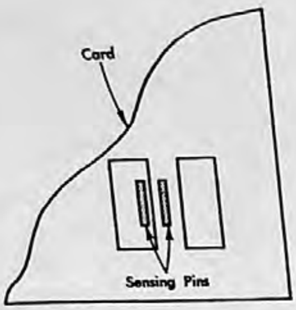


Figure 59. Dual Pins — Off Registration

registered. This method, being capable of recognizing the hole even though only one of the two pins senses the hole, will correctly sense a hole that is off-registration in either direction. Figure 59 shows a pin sensing a hole which is not properly registered. It should be seen that the distance between pins is not great enough to permit the reading of two holes simultaneously.

Star-Wheel Sensing

Another method of sensing which is similar to pin sensing is that of star-wheel sensing. This method also depends on mechanically sensing a hole and causing the closing of a contact. Star wheels may be used to sense a card in motion (flight sensing) or standing still (static sensing).

Figure 60 shows the principles involved in star-wheel sensing. During the time that the star wheel is sliding along the surface of the card the wire contacts are not making contact with the stationary contact. As soon as the star wheel encounters a hole the leading point of the star wheel glides into the hole permitting the left end of the sensing arm lever to move down. This action enables the contact wires to move up and make contact with the stationary contact. The completion of this circuit will assist in instructing the machine further.

MARK SENSING

A THIRD method of sensing is that of mark sensing. Brushes, used as the sensing device, sense a mark to initiate the punching of a hole in the card. Three brushes are used to sense the mark, and the mark must bridge at least two of the three brushes. A circuit must be completed between the center brush and either of the two outer brushes. The mark is required

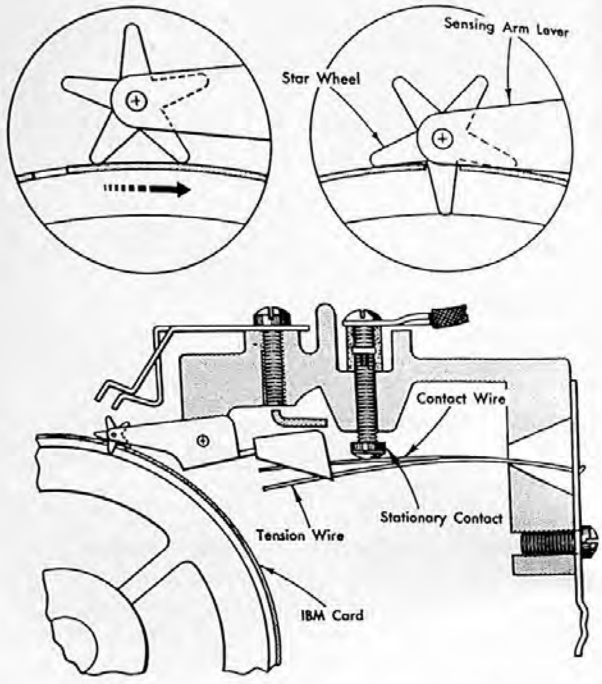


Figure 60. Star Wheel Sensing Unit

to complete a circuit which is primarily a voltage circuit and is not required to pass much current. The completion of this circuit is used to remove the negative voltage used to bias the grid of an electron tube.

Figure 61 is a schematic of a theoretical tube circuit. When a pencil mark shorts the mark sensing brushes, the control grid is driven less negative in relation to the cathode. The 40-volt negative bias is neutralized by the 110-volt positive potential. However, the 100,000 ohm resistor limits this opposing current so that the control grid is driven to zero po-

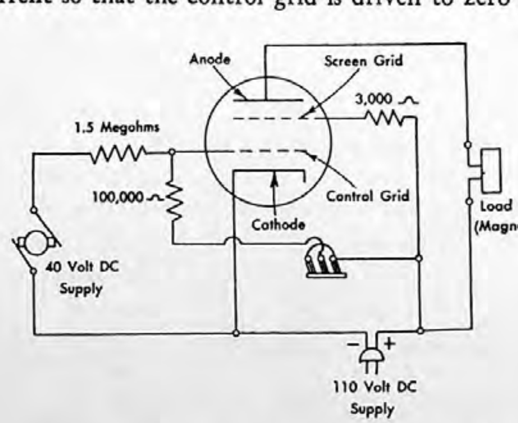


Figure 61. Theoretical Circuit for Mark Sensing

tential or only very slightly positive. When the grid reaches zero potential in relation to the cathode, maximum electron flow through the load from the 110-volt DC line will be obtained.

The 1.5 megohm resistor determines the maximum sensitivity of the tube.

The 100,000 ohm resistor becomes effective to limit the grid current when the brushes are shorted by the pencil mark.

The 3,000 ohm resistor limits the screen current to a safe operating value.

PREVENTIVE MAINTENANCE

PREVENTIVE maintenance, which includes cleaning, lubricating, and checking, is vital to good machine operation. This is especially true of units which are used a great deal such as the feed unit. The feed unit is used more than most other units and for that reason requires more attention. Particular care should be taken with preventive maintenance on the feed, since the satisfatory operation of all of the other units depends on how accurately the card is fed and read.

Cleaning

The first step in a preventive maintenance procedure is cleaning. The cleaning should start in the hopper and continue throughout the entire feed. Dirt and dust should be brushed out of the feed onto a card and put into a waste container. If a tank type vacuum cleaner, supplied to the local office with a plastic nozzle, is available, it may be used to remove dust and dirt from the feed mechanism.

Lubricating

The second step in the preventive maintenance procedure is lubricating. The automatic lubricating system should be checked; and all points which are not lubricated automatically, should be lubricated by hand. A drop of IBM 6 should be applied to each of the two roller throat bearings.

Checking

The third step in the preventive maintenance procedure is checking all parts of the feeding mechanism for wear and adjustment. The brushes in a feed require more attention than most other parts because they are subject to more wear. Therefore, the brushes should be the first item checked.

If the brushes are found to be badly worn, they should be replaced. If it is necessary to make up a new set of brushes, brush setup gage part 454090 should be used. If a brush set which was set up at the factory is to be used, tighten the individual clamps, as they may be loose due to shrinkage of the brush block.

Place the brush assembly in the holder, being very careful not to cross the brush strands or otherwise damage them.

Set the brushes to the scribed line. The brushes may now be aligned to the center of the space between the separators. If the entire set is out in the same direction, either the brush block or the separators should be shifted depending upon the provision of the machine. Individual brushes not centered between separators may be aligned by bending the ferrule with brush bending tool 450364. To facilitate observation of brush alignment, hold the brush assembly up to a light or back it up with white paper and sight along the brushes from the rear of the frame.

After the brushes have been checked, the contact roll and common brushes should also be checked. The other adjustments of the feed mechanism should be checked now in the order outlined in the machine reference manual under adjustments. This is desirable so that, where the sequence of adjustment is important, it will not be necessary to repeat an adjustment.

When checking timing, a dynamic timer should be used whenever possible. The CB's and brushes should be checked at the same time, using one dynamic timer circuit to check CB timing and the other to check brush timing. To do this, prepunch a group of cards 1-3-5-7-9 in the odd-numbered columns and 2-4-6-8 in the even-numbered columns and run all cards through the machine under power. Check brushes across the full set such as brushes 5-20-40-60-75.

If a dynamic timer is not available, time several brushes at each end and in the middle using an ohmeter and a 5 hole in the card. Run the cards through by hand.

A PUNCHING mechanism is designed to cut a hole in some material such as paper, metal, or, as in IBM machines, card stock. A common and typical punching device is a conductor's hand punch; another would be a three-hole paper punch.

There are three basic elements of any punching device: a punch, a die, and a stripper. These three elements are also present in IBM punches. The punch is the piece which is driven through the card and cuts the hole. The die serves as a base, supports the card while it is being cut, and helps to determine the shape and size of the hole. The stripper serves as a guide for the punch and as a means of stripping the card from the punch after the latter has cut the card. Figure 62 shows the components of a punching mechanism.

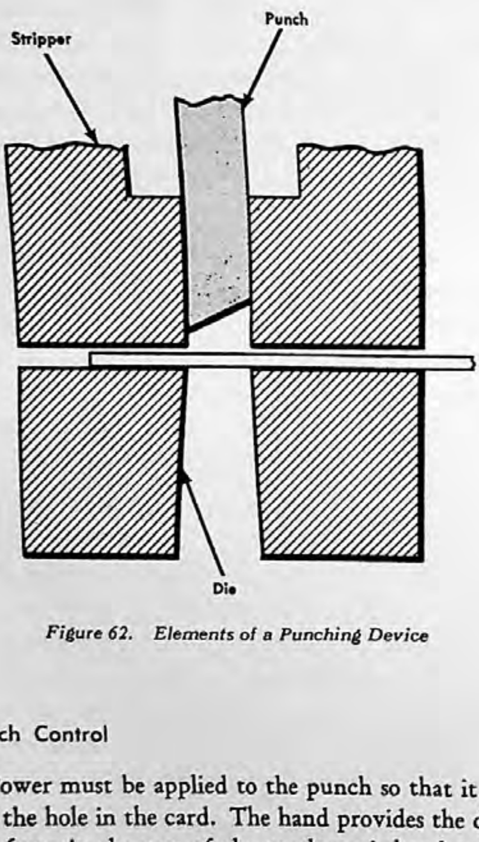


Figure 62. Elements of a Punching Device

Punch Control

Power must be applied to the punch so that it will cut the hole in the card. The hand provides the driving force in the case of the conductor's hand punch. Punches are driven automatically by a mechanical means in IBM machines. It is necessary that punching be controlled to punch the correct information at the proper time. The control may be either electrical or mechanical. The impulses which are available as a result of sensing holes in a card may control punching mechanisms. The punching mechanisms can also be controlled by an operator depressing a key on a key-driven card punch.

Punch Requirements

There are three main requirements of IBM punching mechanisms: first, the mechanism must cut clean holes in the card; second, the holes are to represent transcribed data and, third, the hole must be cut in accurate registration.

Punching Sequence

The punching of the card can occur in one of two sequences depending on the type of feed used. The cards can be punched in a column-by-column sequence which requires 12 punches, one for each punching position in a column. The cards can also be punched in a digit-by-digit sequence which requires 80 punches, one for each column.

COLUMN-BY-COLUMN PUNCHING

IN A COLUMN-BY-COLMUN punching sequence, the machine has 12 punches mounted in a row to correspond to the 12 punching positions on the card (Figure 63).

Type 31 Punch Selection

The method of selecting the proper punch is also illustrated in Figure 63. Assume that the motor plate, which is normally in a position 1/2" above the tops of the punches, has a stroke of 1/4". None of the punches will be struck by the plate when it descends; however, if an interposer 3/8" thick is moved into position over the top of any of these punches, it will depress that particular punch without disturbing the others when the plate descends (Figure 64). This interposer principle of selecting the punch to be operated is generally applied in all IBM card-punching machines in one form or another.

Type 31 Punch Operation

On some key-driven card punch machines there are 12 interposers, each individually operated by a key on the keyboard. The sketch in Figure 65 represents one such position.

As the key is depressed, it operates the bell crank to move the interposer to the left under the motor plate. When the motor plate descends, the punch corresponding to the key depressed will be forced through the card. Similarly, if any other key is depressed, its interposer moves forward to be depressed by the motor plate, and a hole will be punched in the card corresponding to the key selected. Note the felt pad through which the punches are inserted just above the stripper. This provides a means of lubricating the punches, as this pad can be kept saturated with light oil.

The motor plate is operated through a linkage by a two-coil punch magnet mounted under the base. As the key is depressed and the corresponding interposer moves forward, the interposer pushes the con-

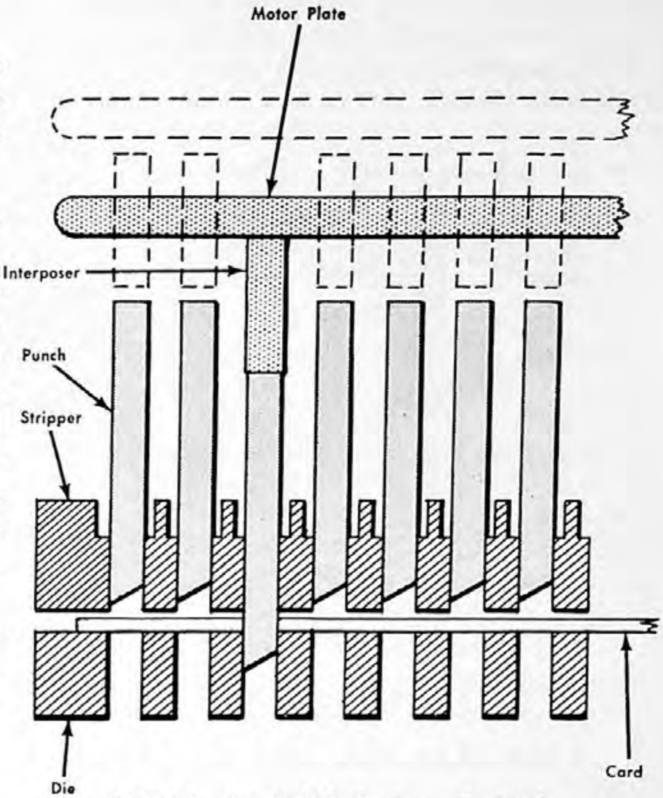


Figure 64. Punching Mechanism — Operated

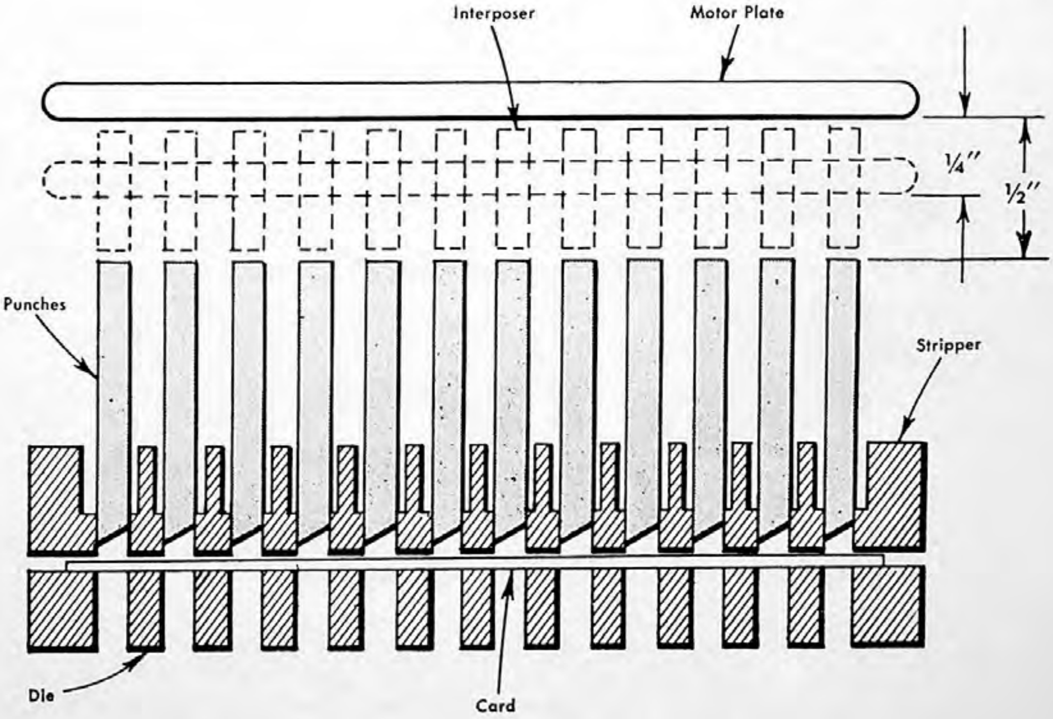


Figure 63. Punching Mechanism — Normal

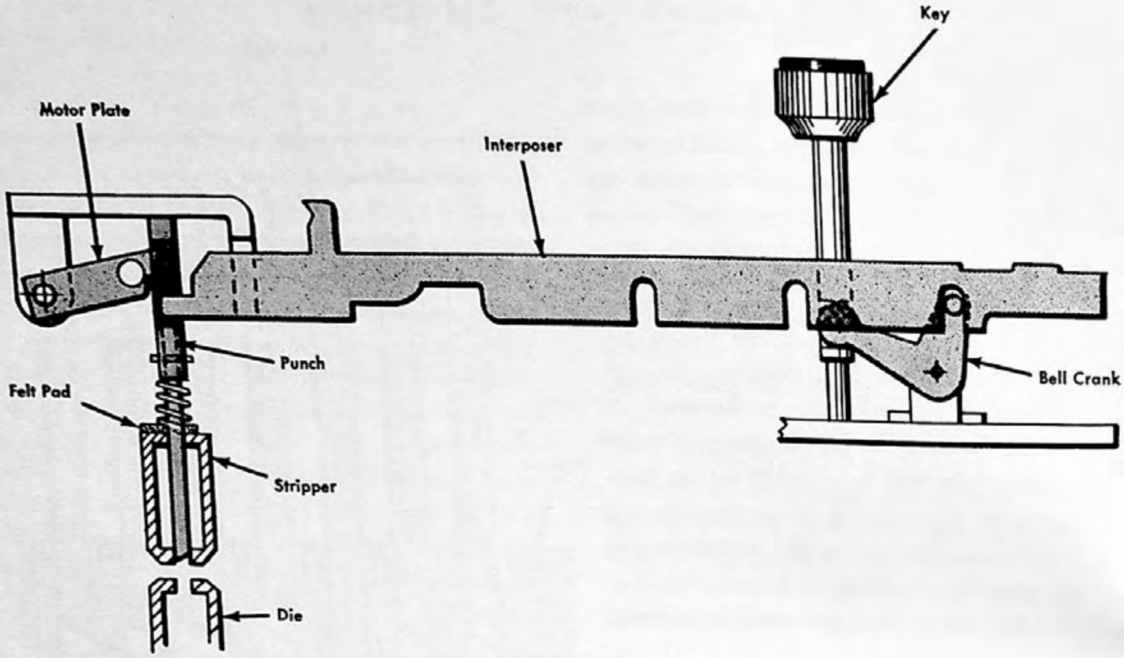


Figure 65. Interposer Operation

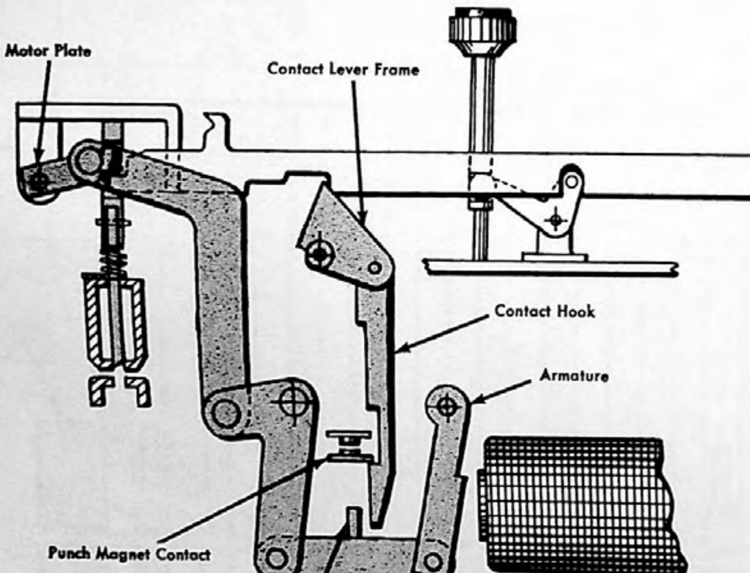


Figure 66. Punch Operating Mechanism — Normal

tact lever frame forward (Figure 66). The contact lever frame then revolves about the pivot shaft and lifts the contact hook, closing the punch magnet contact. When this contact closes, it energizes the punch magnet which attracts the armature to its cores. This movement operates through the linkage shown in Figure 66, pulling down on the motor plate which, in conjunction with the interposer drives the proper punch into the die.

When the punch magnet armature has reached the limit of its travel, the circuit breaker operates against the foot of the contact hook and allows the punch magnet contact to spring open, de-energizing the punch magnet. The armature, now released, is pulled back to its original position by the armature return spring (Figure 67). The motor plate and linkage are thereby returned to their original positions.

The punch spring pulls the punch out of the card and returns the punch to its normal position. To assure positive restoration, however, the motor plate on its upward stroke engages with the top of the punch. This insures the punch will be out of the card before the card advances to the next column. The interposer spring pulls the interposer back to its normal position and, through the bell crank, returns the key. The contact hook spring pulls the contact hook down and against the punch magnet contact; the entire mechanism is then back in its original position and ready for the next key to be depressed. This mechanism is found in the Type 16 and 31 Card Punches.

Type 31 Spacing

The spacing mechanism is also operated as a result of the punching operation. Figure 68 shows the motor plate connected to a space bar by means of a stud in a slot. As the motor plate moves down to drive the punch through the card, the space bar adjusting screw moves down against the rock shaft spindle. As the rock shaft spindle rotates, it causes the escapement to move down into the rack, and the dog is lifted out. As punching is completed and the motor plate moves up, it permits the escapement to move up out of the rack teeth, and the dog to move down to engage the next tooth in the rack. This results in a card movement of one column and puts the card in a position to receive the next punch.

Type 24 Punch Selection

The Type 24 and 26 Card Punches have still another type of punching mechanism. Figure 69 shows the essentials of the Type 24-26 punching mechanism.

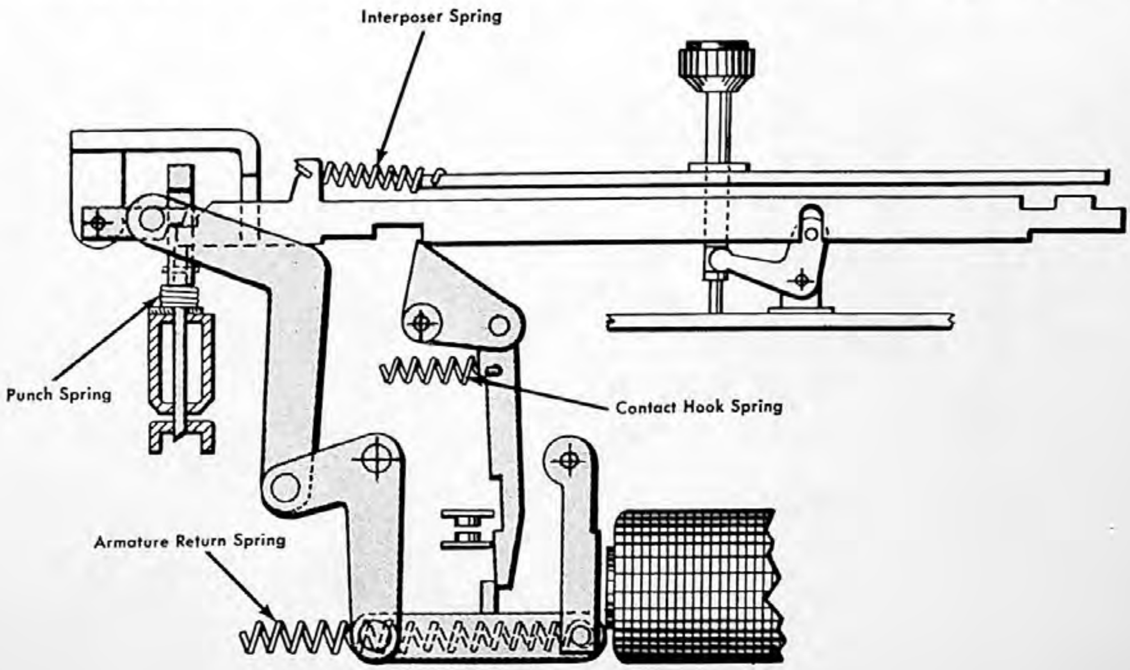


Figure 67. Punch Operating Mechanism — Operated

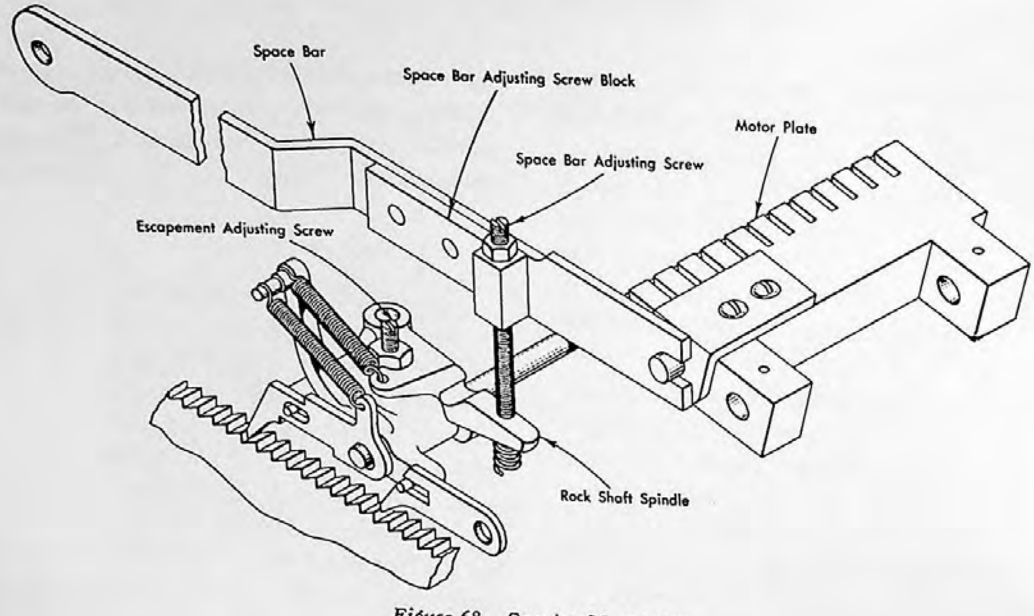


Figure 68. Spacing Mechanism

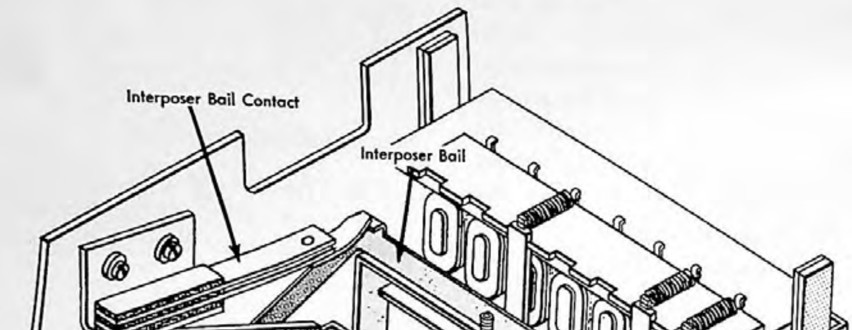


Figure 69. Type 24 Punch Mechanism

Like the Type 31 punching mechanism, this mechanism contains 12 punches (one for every punching position), 12 punch extensions, 12 punch operating arms, 12 interposers, but only *one punch bail.* Figure 70 is a side view of the punching mechanism in the normal position and with the punch clutch latched. A punch interposer magnet is energized to make the mechanism operative, and, in a manual operation, is the result of a key being depressed. The energization of this punch interposer magnet starts a train of events that leads to the punching of that particular digit or digits. It can be seen from the figure that, as a result of energizing the punch interposer magnet, the armature moves toward the magnet. This permits the interposer to rotate clockwise under spring tension up against the interposer bail which moves up and closes the bail contact. At the same time, the hook on the other end of the interposer moves under the punch bail. The closing of the bail contact results in the energization of a space magnet, moving the card one column. The action of the space magnet armature closes a contact which energizes the punch clutch magnet. The punch clutch will engage, causing the complimentary cams, which drive the punch bail, to make one revolution.

Type 24 Punch Operation

The punch bail is driven downward by one of the complimentary cams and returned to a normal position by the other. When the punch bail moves down, it pulls down the interposer that was hooked under it. The interposer pinned to the punch operating arm causes the left end of the punch operating arm to move down. Because the punch operating arm pivots about a shaft, the right end moves up. The extreme right end of the punch operating arm, which drives the punch extension, is in a slot in the punch extension. Consequently, the punch moves up. When the punch moves up into the die it cuts a hole in the card. As the cams continue to turn, the punch bail begins to move up, pulling the punch and punch extension down and out of the card. At the same time, the interposer is moved up until it strikes the notch in the armature. This stops the left end of the inter-

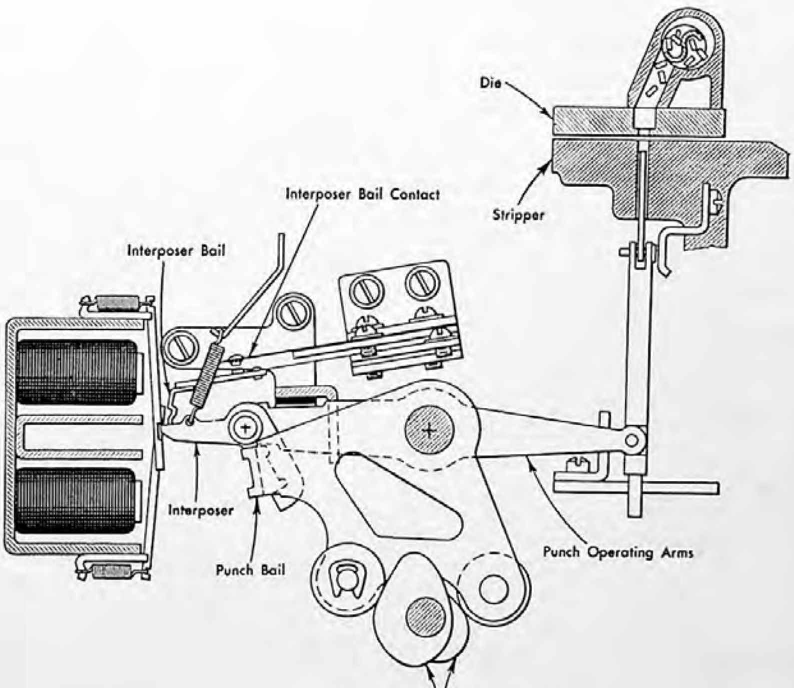


Figure 70. Type 24 Punch Mechanism

poser, but the bail continues to move up as well as the pivot point of the interposer. The right end of the interposer, therefore, will move out from under the punch bail, and the punch clutch will latch completing the punch cycle.

TYPE 24 SPACING

When a key is depressed, an interposer magnet is energized, trips the interposer bail contact, and energizes the escape magnet (Figure 71). The escape magnet armature pulls out of a tooth in the escape wheel, allowing it to rotate through force from the friction drive. At the end of the escapement armature travel, the armature pin closes the escapement contact and picks up the circuit to release the escape magnet. The time interval is short enough to drop the escape armature back in approximately the center of the next tooth of the escape wheel. Each tooth on the escape wheel causes the escapement gear train and feed rolls to advance one card column. To skip, it is necessary to hold the escape magnet energized, thus allowing the escape wheel to rotate freely at its maximum speed of 12 ms. per column over the desired number of columns. This method is also used to skip between cards.

The escape magnet contact energizes the punch clutch magnet; therefore, the escapement always occurs before punching.

DIGIT-BY-DIGIT PUNCHING

THE TYPES 513, 514, 519 are high speed punching machines, and the punching takes place in a digit-by-digit sequence with the cards feeding 12-edge first, so that the 12 is the first punching position to reach the punching station. At the punching station there are 80 punches, one for each card column. All like digits are punched simultaneously, i. e. all 12's punch, the card moves one cycle point; all 11's punch, the card moves one more cycle point; all 0's punch, etc., until the card has been completely punched with the desired data. The card must be at rest when punching occurs. The necessary intermittent motion of the card is provided by a geneva driving mechanism which will be studied later.

Type 513 Punch Selection and Operation

Figure 72 shows a schematic of the 513 punch mechanism with the magnet in a de-energized position. It has been pointed out that it must be possible for punching to take place every cycle point. The

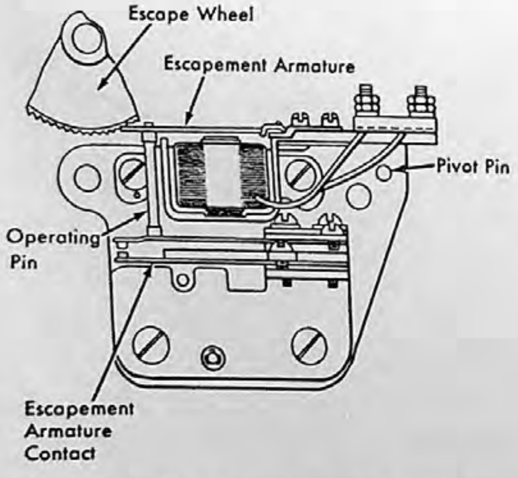


Figure 71. Escapement Magnet Assembly

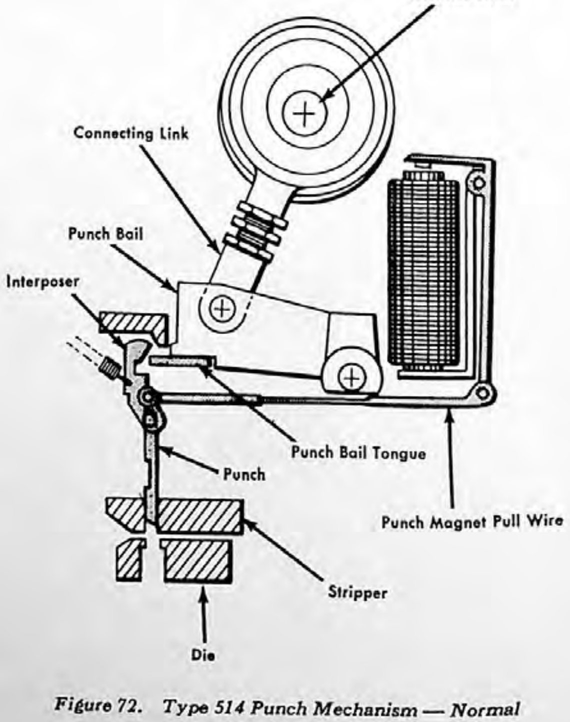


Figure 72. Type 514 Punch Mechanism — Normal

eccentric shaft is geared so that it makes one revolution for each cycle point. The eccentric shaft is connected by connecting links to the punch bail which has a reciprocating motion as a result of the rotation of the eccentric shaft. It can also be seen in the same figure that, as the eccentric shaft rotates and the punch bail and punch bail tongue move up and down, no punching takes place. If, however, the punch magnet is energized, the armature is attracted to the core and the pull wire is moved to the right. Then the interposer is pulled to the right and, as the punch bail tongue moves down during that cycle point, it engages the interposer. The interposer is driven down and, because the punch is connected to the interposer, it is driven down into the die. Figure 73 shows the punch unit with the magnet energized

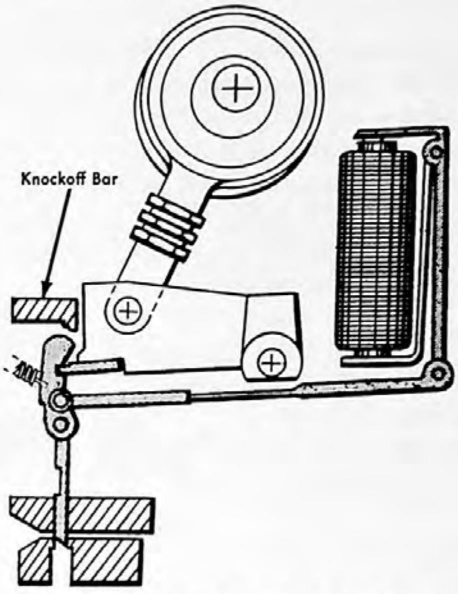


Figure 73. Type 514 Punch Mechanism — Operated

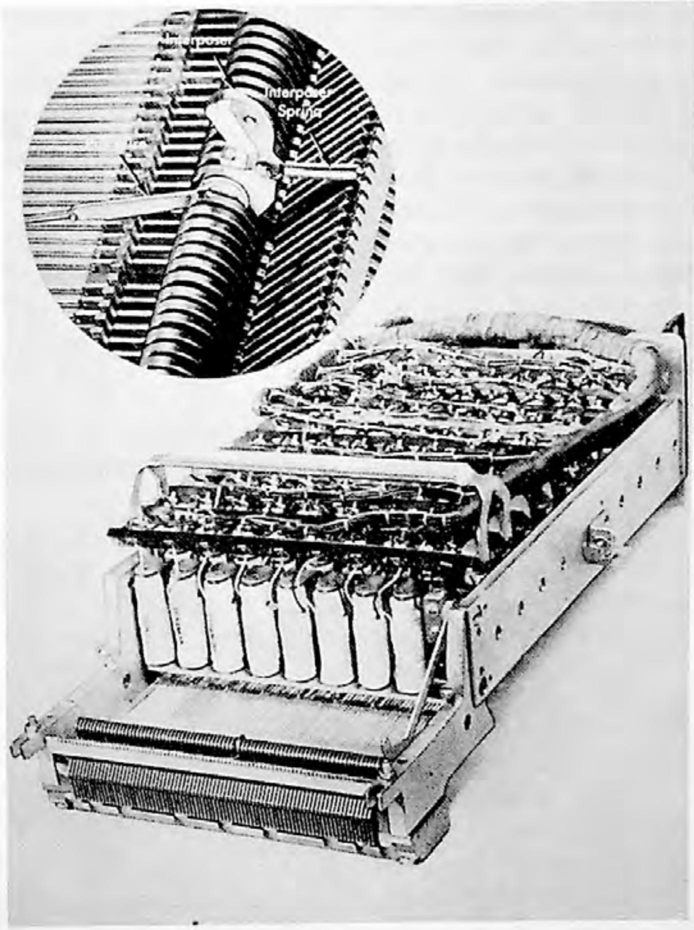


Figure 74. Type 514 Punch Magnet Unit

...n. As the interposer moves
...nch bail tongue, it strikes the knock-
...and is cammed to the left, free of the punch
...il tongue. As soon as it is free of the punch bail
...ngue, it will be moved and held to the left, in a
...mal position, by spring tension.
...ure 74 shows the punch magnet unit and the
...hows an enlarged view of an interposer and pull
...The punch magnet unit contains 80 punches
...e arranged in a row, each with its individual
... and magnet. There is only one punch bail
...s the 80 punches. The punch bail operates
...n once for every punching position of a
...nterposers which are pulled into engage-
...e punch bail tongue cause their re-
...s to be driven down through the card.
...nets are impulsed, all 80 interposers
... the punch bail and 80 holes will

...ypes of punch interposers. One
...st column, another type is used
...d yet another is used in all col-
...clusive. The interposer used
...ovided with a long stud for
...ll wire to prevent it from
...nterposer used in column 1
...o prevent the interposer
... interposers, being pro-
...nterposers, do not re-
...ign. The three types

Figure 75. Three Types of Interposers

sh...
spe...
trol...
two g...

Each o...
trical or m...
jective. This...
into the follo...

Friction driv...

1. Clutches ...
engaging two d...
woven, or molde...

2. Clutches whe...
engaging two memb...

Positive drive clutches...

1. Pawl and square ...
around the periphery of ...
a. Single-tooth ratch...
b. Multi-tooth ratchet...

2. Pawl and saw-tooth ratc...
the periphery of the ratchet).

3. Face type ratchet (te...

CLUTCH MECHANISMS

IT IS NOT always desirable to have feeding, punching, or other mechanisms operative on every machine cycle. Therefore, it is necessary to provide some means of control so that these mechanisms can be given instructions to operate. This control is generally provided by means of a clutch, many types and sizes of which are in use throughout IBM machines. A clutch is a form of connection between a driving and a driven member on the same axis. The connection must be designed so that the two members may be engaged or disengaged at any desired time. However, they may be controlled either by a manually operated device or automatically by the action of some power-driven device.

Clutch Types

The clutches used in IBM machines vary in size, ape, and principle depending on requirements of ed, load, available space, and the method of con- They can, however, be classified into one of the eneral categories shown below.

1. Friction drive clutches.
2. Positive drive clutches.

these classifications may use various elec- echanical systems for achieving their ob- may be used to further classify clutches ving subdivisions:

clutches

where frictional contact is made by scs having facings made of metal, material.

e frictional contact is made by rs by means of a helical spring.

tooth ratchet (teeth are the ratchet).

et.

het (teeth are a

FRICTION-DRIVE CLUTCHES

Friction Discs

The first type of clutch to be discussed is the friction drive clutch using friction discs for the two clutch members. Figure 76 shows a very simple, manually controlled, friction clutch. The lever is moved to the right to cause this clutch to perform its function. As the lever is moved to the right, the rotating pulley operates against the friction disc. If sufficient pressure is applied to the operating lever, it will cause the friction between the driving pulley and the friction disc to rotate the driven member. During the time necessary for sufficient friction to be created between the members, slippage will occur. This is an important factor that should be considered when using this type of clutch.

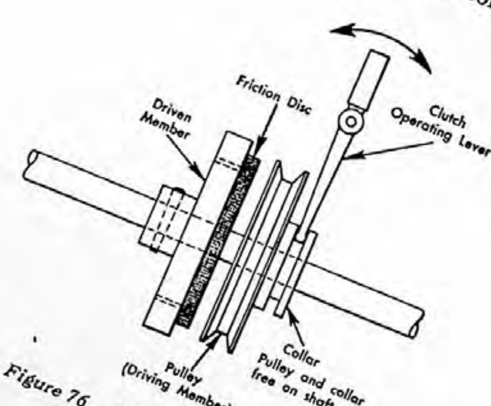


Figure 76. Basic Friction Clutch

Two Speed Clutch

The two speed clutch, which is used 402-403 Accounting Machine, is ciple to the simple clutch s there are two pulleys The two pull and th

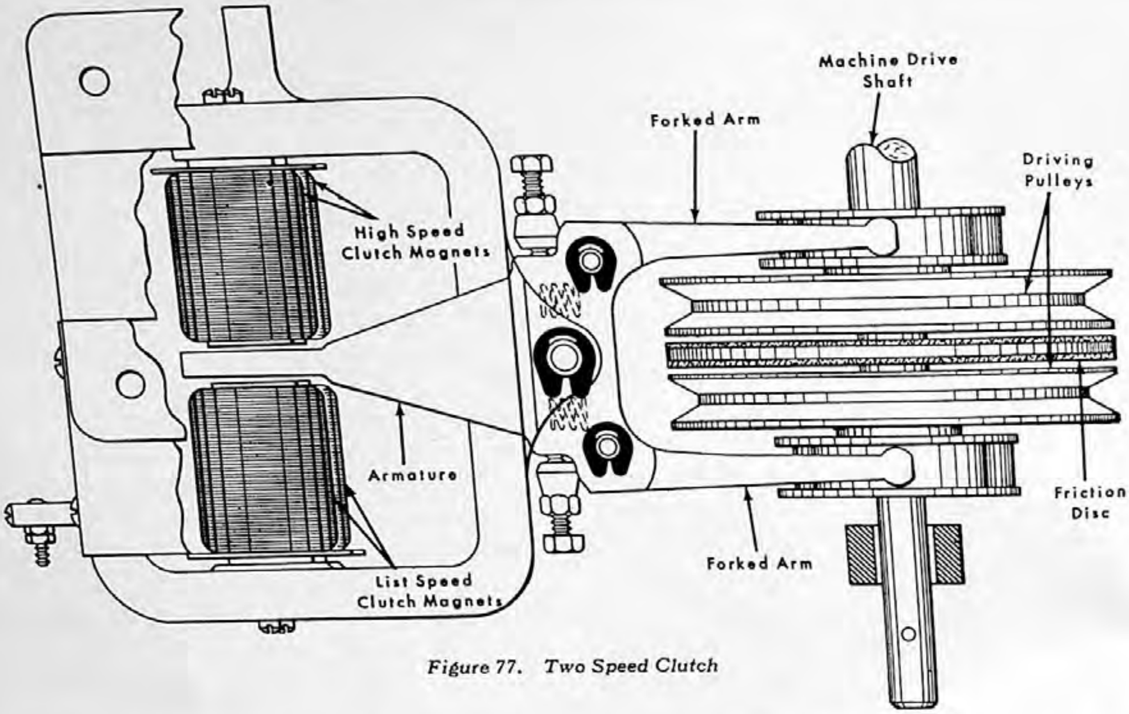


Figure 77. Two Speed Clutch

attached to the two forked arms. The forked arms are engaged in a collar on a pulley, with the collar mounted, so that the pulley is free to turn independently of the collar. The pulley is also free to turn on the shaft as well as to slide on the shaft.

If the high speed magnets are energized, they attract the armature toward the magnet cores. The armature pivots and transmits the motion to the forked arm which slides the high speed pulley over the shaft to engage the friction disc. The friction disc will then turn with the pulley and because the friction disc is pinned to the shaft it will cause the shaft to turn and drive the machine. If the list, or slow speed magnets had been energized, the other pulley would have engaged the friction disc driving the machine at list speed.

This type of clutch has two main advantages: first, the load is applied gradually without shock; second, in the case of extreme overload, slippage will occur, preventing damage to the mechanism. It is not possible, however, to obtain absolute synchronism with this clutch which limits its use in IBM machines.

Helical Spring Drive and Clutch

Another type of friction clutch used in IBM machines is the helical spring drive clutch device. Figure 78 illustrates the principle; the clutch is shown disengaged. The shaft rotates continuously and the gear is free to rotate on the shaft. A helical spring with a normal diameter slightly less than the diameter of the shaft is attached to the gear and wound about the shaft. With the armature engaging one end of the helical spring, as in the figure, if the gear is turned in the direction of the arrow the unwinding effect increases the diameter of the spring. In the figure, the spring is held unwound by the detent. Because the diameter of the spring is now larger than the shaft diameter, the spring does not grip the shaft.

To engage the clutch, the magnets are energized to pull the armature away from the end of the spring. The spring immediately tightens on the shaft. The

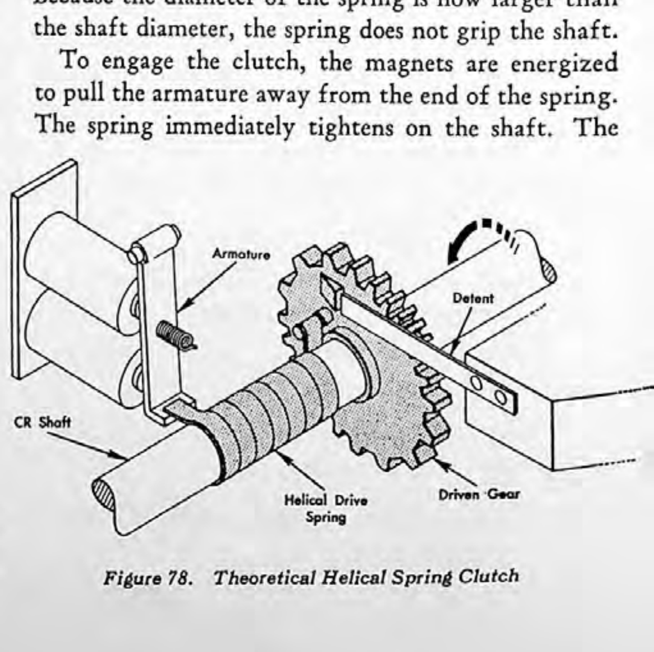


Figure 78. Theoretical Helical Spring Clutch

shaft is turning in the direction that will cause the friction between the spring and shaft to further tighten the spring. The spring is wound so tightly on the shaft that no slippage can occur between the members. Thus the shaft drives the gear to operate the mechanism which is under the control of the clutch. When the shaft, spring, and gear have made one revolution, the armature again engages and stops the left end of the spring. The momentum of the gear and the mechanism it operates causes the gear to continue to rotate far enough for the detent to drop in behind the detent stud. This increases the diameter of the spring so that it no longer grips the shaft, and the clutch is disengaged.

Type 24 Helical Spring Clutch

The principles of the helical spring clutch used on the Type 24, 26 and 56 machines are the same as those of the hypothetical clutch used for purposes of explanation. The parts of the actual clutch may be seen in Figure 79. The drive pulley and sleeve is the constantly rotating driving member and is comparable to the shaft in the figure used for illustration. However, the pulley is not attached to the shaft, but is free to rotate on it. The clutch sleeve and clutch spring operate together to provide a control and are comparable to the spring alone in the previous discussion. The remaining mechanisms, i. e. the spring collar, detent, and shaft, are connected to act as one piece and are comparable to the gear in the hypothetical clutch. The left end of the spring is on a step of the inside surface of the clutch sleeve. The sleeve also has a step in its outer periphery which will be engaged by the armature. In effect the armature is going to engage and stop the left end of the spring as in the hypothetical case (Figure 80). The right end of the spring is held by the spring collar which is clamped to the shaft and provides a means of increasing the spring diameter when the left end has been stopped by the armature. The spring permits the pulley to turn freely when the clutch is inoperative. However, when the magnet is energized and the spring is released, it clamps the pulley sleeve and the sleeve which is pinned to the shaft together. Note that the turned up ear on the right end of the spring does not drive the mechanism. It is merely the means by which the detent is able to hold the spring open when the clutch is latched.

Shoe-Type Clutch

The shoe-type clutch is a friction clutch used for high-speed, random-engaging applications, such as in the carriage. The clutch consists of a driving member called the drum, a latch wheel, a detent wheel, friction shoes and a prybar (Figure 81). The clutch is considered latched when it is disengaged; that is, the clutch latch is engaged in a tooth of the latch wheel and the detent is fully seated in the detent wheel (Figure 81).

The clutch shoes are held away from the drum, when the clutch is latched. The engaging shoe rests on the turned over ear on the prybar. This ear projects through an opening in the latch wheel. The prybar pivots on the eccentric stud on the prybar adjusting plate. The following shoe is held between the shoe stops which also project through the opening in the latch wheel.

The clutch is operated by changing the position of the prybar. The position of the prybar is controlled by the relative position of the latch wheel and detent wheel. When the clutch is unlatched, the clutch-engaging spring pulls on the bottom of the prybar. The prybar pivots around the prybar pivots stud.

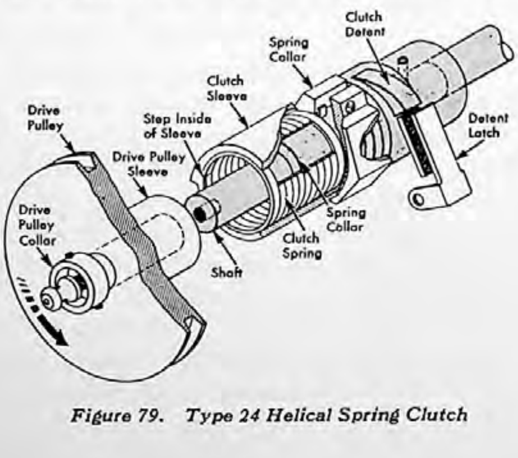


Figure 79. Type 24 Helical Spring Clutch

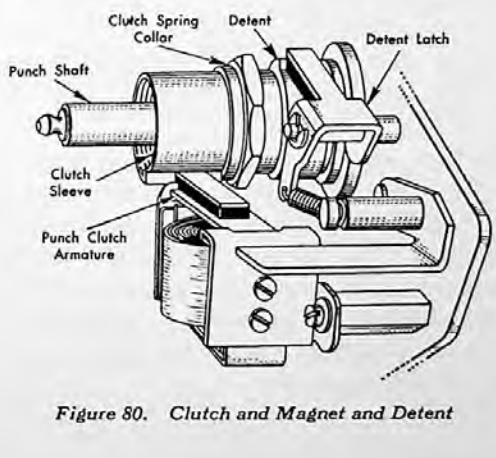


Figure 80. Clutch and Magnet and Detent

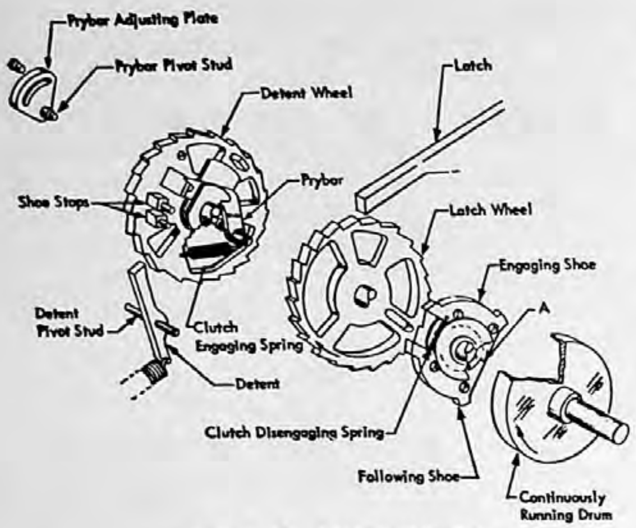


Figure 81. Shoe Type Clutch

This causes:

1. the latch wheel to move clockwise relative to the detent wheel
2. the ear on the top to move the engaging shoe outward to the right, causing it to contact the drum.

The prybar's action is transmitted to the following shoe at point A, Figure 81. Thus, the shoes are firmly engaged with the drum. The shoes operate against the shoe stops and thus transmit the motion to the detent wheel. Therefore, the detent wheel is the output member, or the driven part of the clutch.

To disengage the clutch, the magnet is de-energized and the latch is allowed to catch a tooth of the latch wheel. By stopping the latch wheel, it turns counterclockwise with respect to the detent wheel. This rotates the prybar counterclockwise about its pivot causing the clutch-engaging spring to stretch and also pulling the prybar away from the engaging shoe. This allows the clutch-disengaging spring to pull the shoes away from the drum and the clutch to disengage. There is enough overthrow in the detent wheel to let the detent seat.

When the clutch is engaged, the shoes contact the drum at four points. The shoes have an expanding action rather than simply an opening action. The inner surface of the drum is cut with large serrations. These serrations in no way insure better gripping of the clutch. Their purpose is to keep the engaging surfaces clean and prevent a possibility of the shoes tending to stick to the drum.

Figure 82 shows another view of the shoe-type clutch.

Magnetic Clutch

The next few paragraphs describe the construction and operation of the magnetic clutch. The clutch coil housing contains the coil and commutator assemblies and is pinned to the pulley drive shaft.

Clutch Construction

The coil assembly is a coil wound on a bobbin similar to a spool of thread. The terminals of the coil are connected to commutator rings which are located on the right side of the housing. The commutator rings are part of an assembly attached to the coil housing by the same screws which hold the coil assembly to the housing (Figure 83, upper right section). Insulation is placed between the commutator rings and the coil housing. Contact is made to the commutator rings and thus to the magnet coil by stationary carbon brushes similar to a motor brush.

With the commutator ring and brush arrangement, the circuit can be completed to the magnet coil regardless of the position of the idling clutch coil housing. The circuit through the magnet coil is completed from the line side through the necessary cam and relay points, to one carbon brush, through the commutator ring, magnet coil, other commutator ring, other carbon brush, and to the fuse side of the line. Depression of the start key will initially energize the magnet coil, after which a continuous hold circuit is established.

The construction of the clutch pulley assembly is shown in Figure 83, upper center section. The pulley is free to revolve about the pulley drive shaft and is fitted to two roller bearings which are placed side by side on the pulley drive shaft. The outer races of these two roller bearings are moveable to the right or left. Next to the two roller bearings on the pulley drive shaft is a ball bearing which acts as a thrust bearing for the pulley when it is away from the clutch housing assembly. This takes place when the outer races of the roller bearings move to the left with the pulley assembly against the ball bearing. Next to the ball bearing is a spacer and to the left of the spacer is another ball bearing. This latter ball bearing is the bearing point for the left end of the pulley drive shaft. This bearing fits into a casting of the machine and is held in position by bearing retaining screws. At the left of this ball bearing is a hub which is

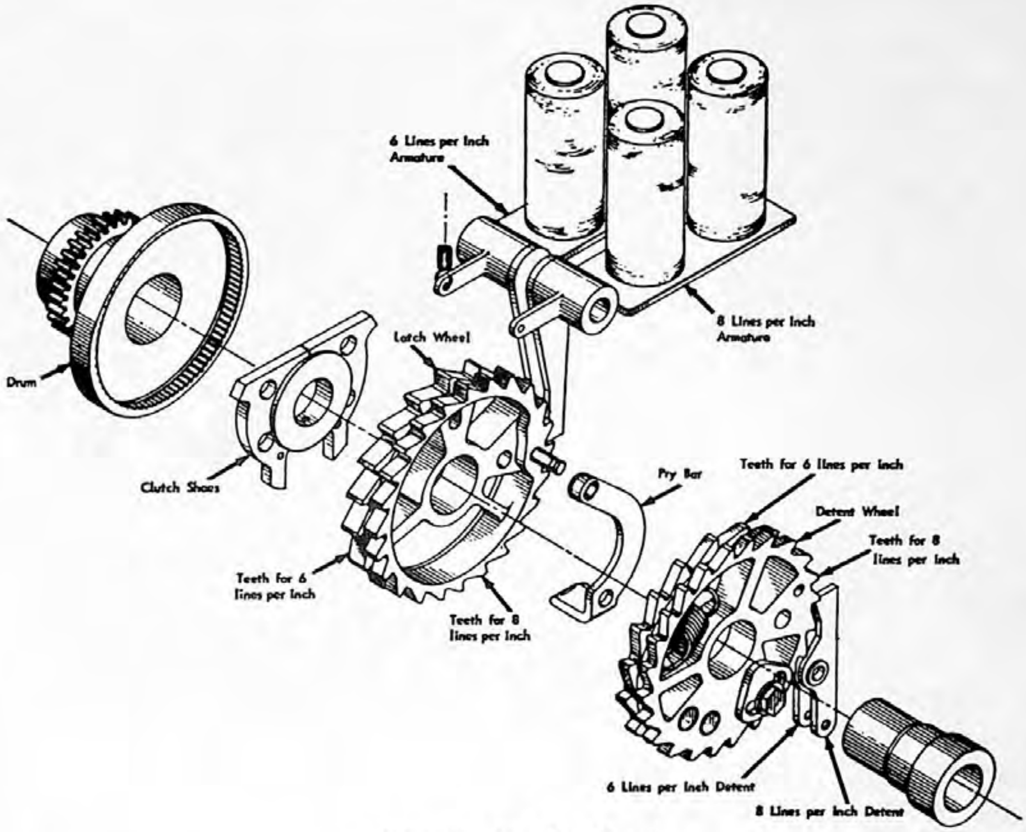


Figure 82. Shoe Type Clutch

pinned to the pulley drive shaft. This hub keeps the four bearings and spacer snugly against a shoulder of the pulley drive shaft, thus preventing any lateral movement of the bearings.

The clutch pulley of the drive clutch has a slight sliding motion because the separable roller bearings allow the pulley to move away from the clutch coil housing which is pinned to the pulley drive shaft. This makes it possible to keep the pulley drive shaft from turning by separating the clutch pulley from the clutch coil housing.

Attached to this clutch pulley by screws is the clutch armature with the same diameter as the outer diameter of the pulley. Separating the armature and pulley is a narrow gasket which prevents grease from escaping as explained in a later paragraph. This armature is attracted to the magnet when the magnet becomes energized. When the armature is attracted to the magnet core, the entire pulley assembly is moved to the right, together with the outer races of the roller bearings. This causes the clutch armature to be brought against the outer rim of the clutch housing assembly. The movement of the pulley toward the magnet core is not stopped by the magnet core but is stopped by the full circumference of the outer rim of the clutch coil housing before the armature strikes the core. When the armature is against the outer rim of the housing, there is still clearance between the magnet core and armature to keep a steady pull on the armature during machine operation. The force of the magnet is sufficient to hold the armature rigidly against the outer rim of the housing without slippage after full contact is made by the armature and housing. With the pulley firmly against the clutch housing both units will operate as one. This, in turn, causes the pulley drive shaft to turn with the pulley.

POSITIVE DRIVE CLUTCHES

Pawl and Square-Tooth Ratchet

There are two general types of clutches that fall into this category: those whose ratchet has a single tooth, and those whose ratchet has more than one tooth.

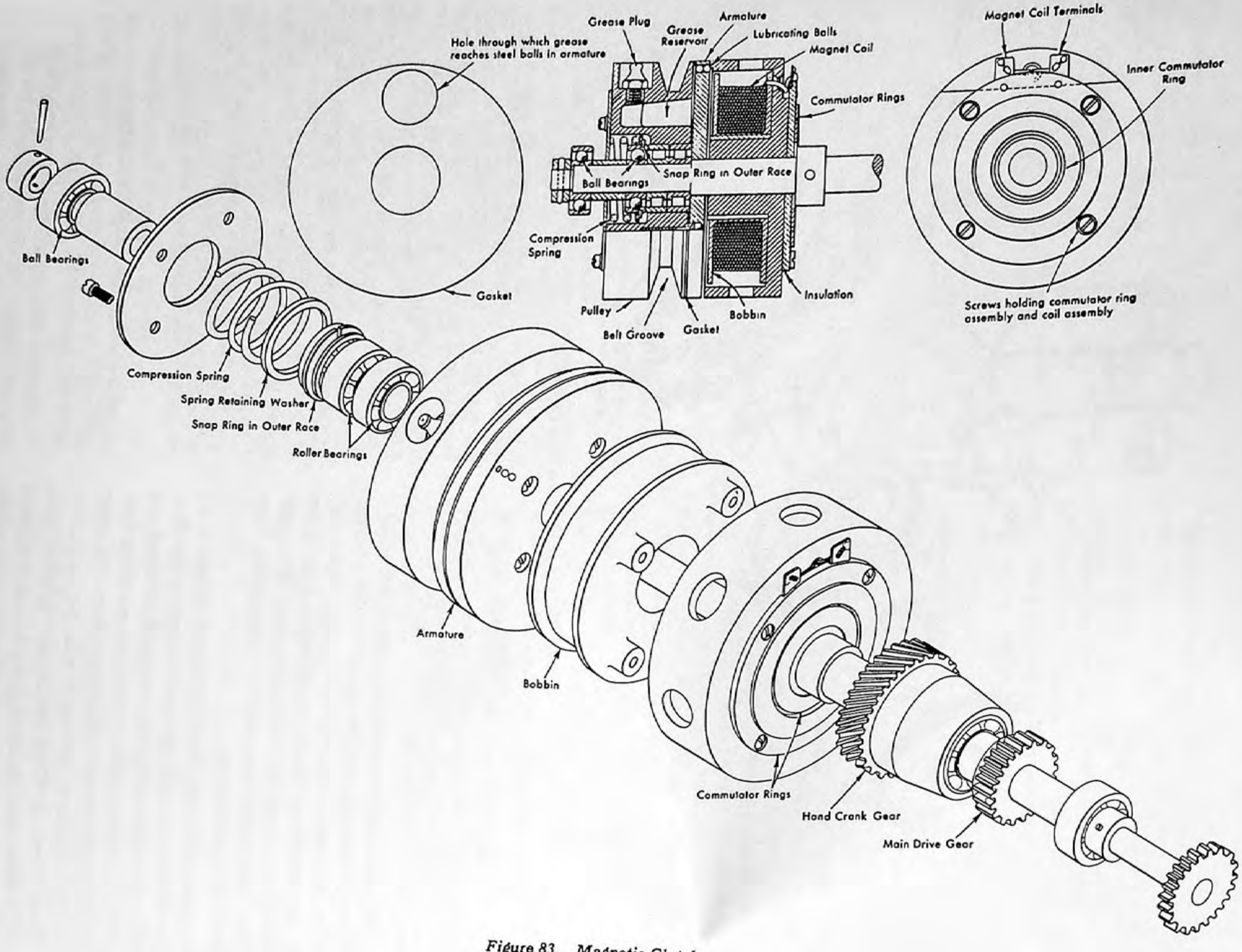


Figure 83. Magnetic Clutch

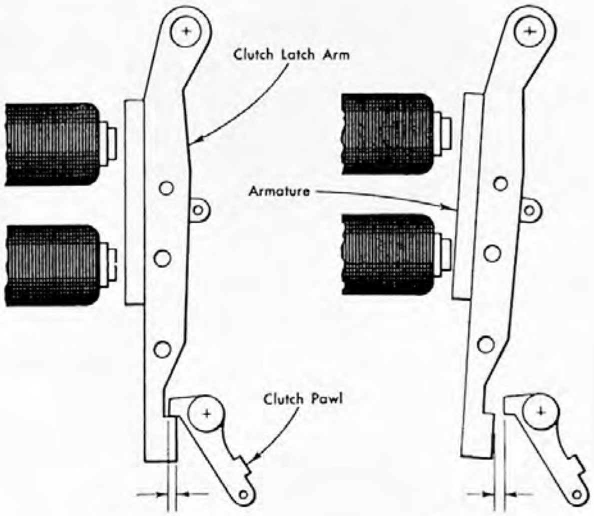


Figure 84. Clutch Pawl and Latch Relationships

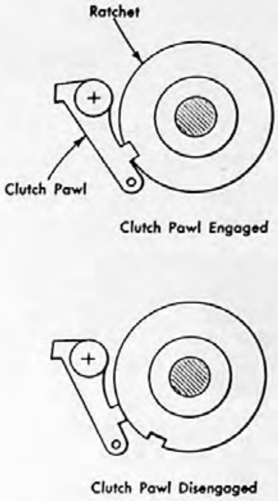


Figure 85. Clutch Pawl and Ratchet Relationships

To prevent misunderstanding of the use of terms such as latched, unlatched, engaged, and disengaged, the following explanation serves as a guide. First, it should be clear that the terms latched and unlatched refer only to the relationship of the clutch pawl to the clutch latch. Figure 84 shows the two conditions of the pawl in relation to the latch.

Latched — The clutch pawl and clutch pawl arm are held in position by the clutch latch arm.

Unlatched — The clutch pawl and clutch pawl arm are released because the armature has been attracted by the clutch magnet.

It is obvious that one of these two conditions must exist at all times.

It should also be clearly understood that the terms engaged and disengaged refer only to the relationship of the clutch pawl to the ratchet. Figure 85 shows the two conditions of the pawl in relation to the ratchet.

Engaged — The clutch pawl is engaged in the tooth of the driving ratchet.

Disengaged — The clutch pawl is not engaged in the tooth of the driving ratchet.

It is also obvious that one of these two conditions must exist at all times. It can now be concluded that at all times two conditions must exist with respect

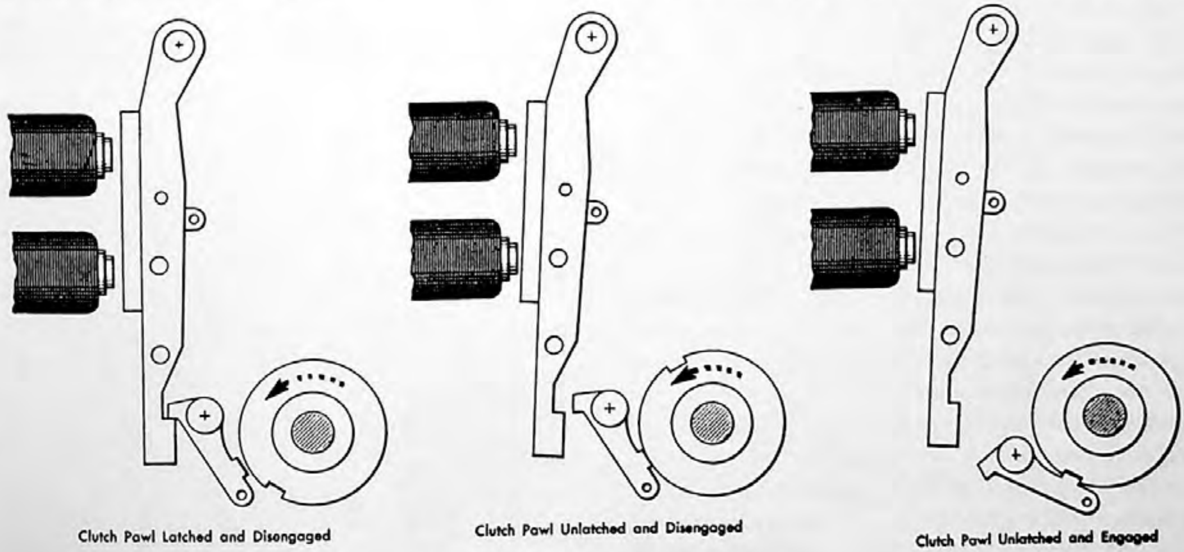


Figure 86. Combined Clutch Conditions

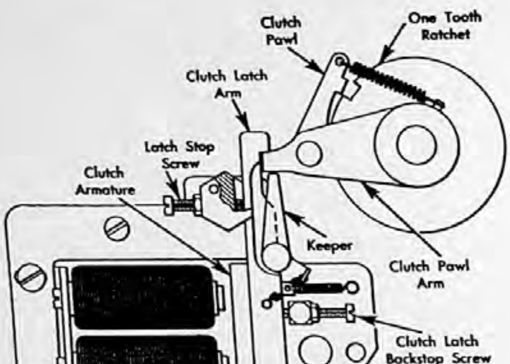


Figure 87. Pawl and Ratchet Clutch

to the clutch pawl. It is either latched or unlatched and, at the same time, it is either engaged or disengaged. If the clutch pawl is latched the pawl must be disengaged as it is impossible for the clutch to be both latched and engaged. If the clutch is unlatched, it may be either engaged or disengaged. Figure 86 shows the three possible combinations.

Single Tooth Ratchet

Figure 87 shows a typical single-tooth ratchet type clutch and the nomenclature. The principle parts of the clutch are a continuously running one-tooth ratchet, a clutch pawl, a latching mechanism composed of a clutch latch arm and keeper, and a magnet. The magnet provides a means of electrically controlling the operation of the clutch. The clutch magnet armature serves as the latching mechanism. When the magnet is energized, the armature is attracted and allows the pawl to pivot in a clockwise direction by spring tension. The pawl drops into the continuously running one-tooth ratchet and turns with it. The pawl rotates about a stud on the clutch pawl arm, and the clutch pawl arm is pinned to a shaft; thus, when the pawl turns, the shaft to which the pawl arm is pinned must also turn. Since there is but one latching point, if the clutch latch is tripped, the pawl must make one complete revolution before it can be relatched. As the pawl reaches the end of the cycle, if the clutch magnet is de-energized, the armature will be pulled by spring tension to a point where its latching surface will engage the tail of the pawl and cam it out of the one-tooth ratchet. As the pawl is cammed out of the one-tooth ratchet, the keeper ge behind the clutch pawl arm. This prevents the shaf to which the clutch pawl arm is attached, from turn ing backward. If the shaft were to turn backwar the pawl would drop against the one-tooth ratch and nip. This condition has a tendency to round o the edge of the one-tooth ratchet; as a result the pa may pull out of the ratchet part way through a cyc and cause the mechanism operated by that clutch t lose a cycle.

There are three primary adjustments to be mad on a clutch of this type.

1. Adjust the latch stop screw so that there wi be an unlatching clearance between the clutch latc and clutch pawl when the magnet is energized.
2. Adjust the clutch latch backstop screw to provide an overlap for latching up when the magnet i de-energized.
3. Shift the magnets and cores to provide a minimum clearance between the cores and the armatur when energized.

This type of clutch has two main advantages; perfect synchronism can be obtained, and it has a positive drive with no slippage. It can be engaged or disengaged at only one point in a cycle and is consequently easily synchronized with other mechanisms. For this reason it is used extensively throughout IBM machines.

Multi-Tooth Ratchet Clutch

If synchronism is not a primary consideration and yet a positive drive is needed, a multi-toothed ratchet is used so that the closest tooth will engage the pawl and consequently save time. Figure 88 shows a clutch of this type.

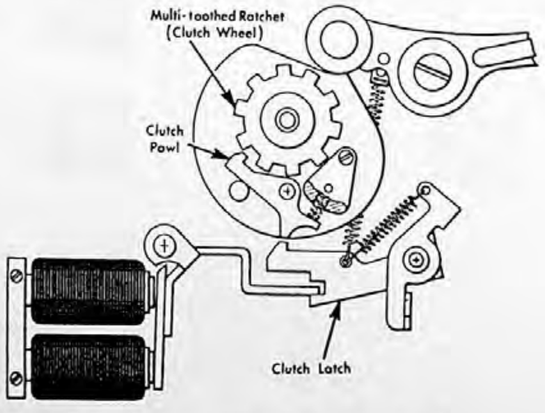


Figure 88. Multi-Tooth Ratchet Clutch

Saw-Tooth Ratchet

It may be desirable to have positive-drive where the time of engagement is not important and a square tooth ratchet is not necessary. This is true when the ratchet is not moving or is moving slowly at the time the pawl is engaged. The ratchet is then started or accelerated. This type of engagement will reduce the tendency for the driven member to lead the driving member which eliminates the need for a square tooth. Figure 89 shows a clutch of this type. Here the operation is slightly different from that of the square-tooth ratchet. The energization of the trip magnet begins a train of events that leads to the operation of the clutch. The trip magnet armature bracket operates against an ear on the feed pawl latch causing the feed pawl latch to rotate in a counter-clockwise direction. An ear on the latch is actually supporting the feed pawl and it moves under the cut-out portion of the feed pawl. The feed pawl then moves down under spring tension so that it engages a tooth on the ratchet.

At the same time that the armature bracket operates against the pawl latch, it also operates a contact that completes a circuit to the motor. The motor drives the ratchet so that when the feed pawl is engaged in the ratchet, the feed rack drive gear is operated. As the feed pawl latch, feed pawl, and drive gear revolve together in a counter-clockwise direction, the tail of the feed pawl will strike the feed pawl stop bracket before it makes a complete revolution. This action causes the feed pawl to pull out of the ratchet and, because the drive gear is under spring tension, it will now revolve in a clockwise direction to a normal rest position. Note that the drive gear is actually two pieces, which are held together by two springs. These springs are safety trip springs and are operative if some obstruction should cause the outer portion of the drive gear assembly to stop. In that event the ratchet continues to drive the pawl and the inner section of the drive gear assembly. The safety trip springs will be extended until the tail of the pawl strikes the safety trip pin. The safety trip pin, which is mounted on the outer section, disengages the pawl from the ratchet and the drive gear assembly will return to a normal position.

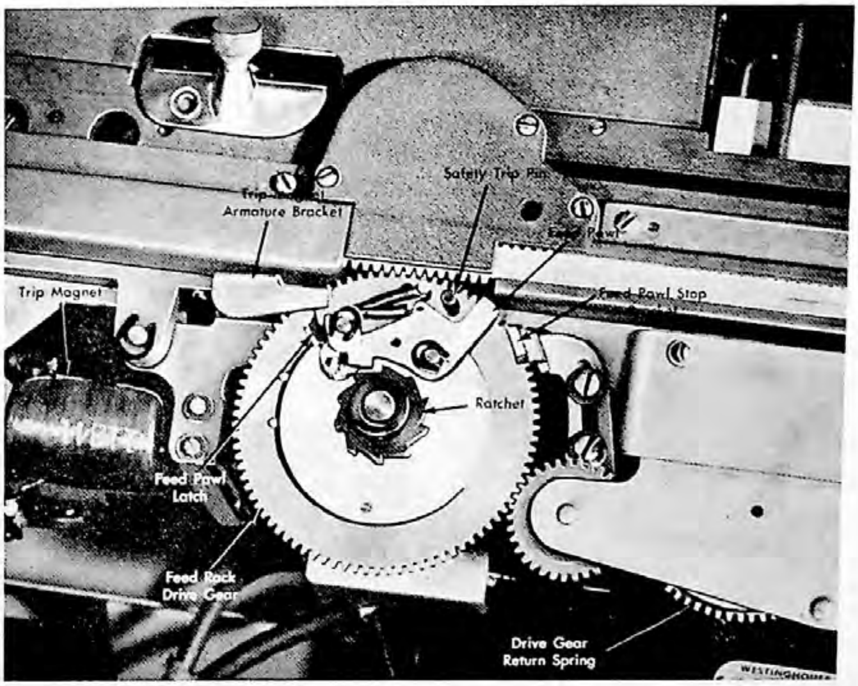


Figure 89. Saw-Tooth Ratchet Clutch

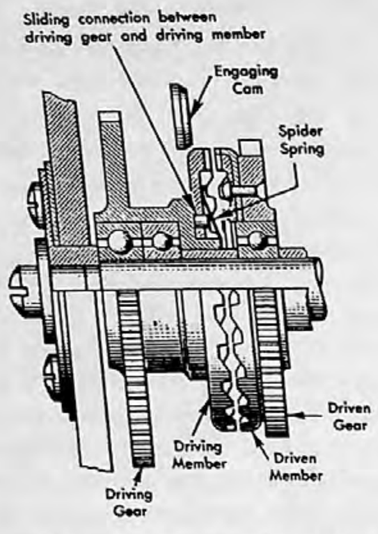


Figure 90. Face Type Ratchet Clutch

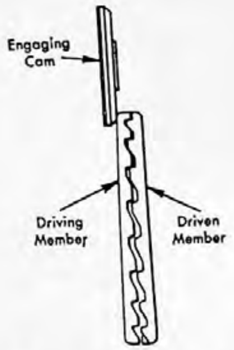


Figure 91. Face Type Ratchet Clutch — Engaged

Face Ratchet Clutch

Another type of clutch in use in IBM equipment is the face ratchet clutch (Figure 90).

It can be assumed that the driving gear is a continuously running gear and, because the driving member is turning with the driving gear, it will also be continuously running. The driving member is connected to the driving gear by means of three pins which engage three holes in the driving member. However, the driving member is free to slide to the left or right along the shaft and the three connecting pins. A spider spring is used to hold the driving member to the left, against the shoulder on the driving gear, and away from the driven member. This is the normally inoperative position (Figure 90).

When the engaging cam is moved down, the sloping surface of the engaging cam strikes the top portion of the driving member. Thus, the top portion of the driving member is moved to the right and its teeth engage the teeth of the driven member. Figure 91 shows how the clutch is engaged. The clutch teeth are fully meshed at the point where the engaging cam is operating. The driven member, connected to the driven gear, transmits motion to the gear train controlled by the driven gear.

One means of controlling the time that the clutch will be engaged is shown in Figure 92. When the magnet is energized, the armature releases the engaging cam arm and the spring causes the engaging cam to move in a counter-clockwise direction. This action permits the cam to move in against the driving member and engage the clutch.

The clutch can be disengaged by means of a cam as shown in Figure 92. The lobe on the knockoff cam which makes one revolution per cycle, disengages the clutch at the same time in the cycle regardless of the time the clutch was engaged. The clutch engaging arm is rotated clockwise far enough for the armature to relatch the clutch engaging arm.

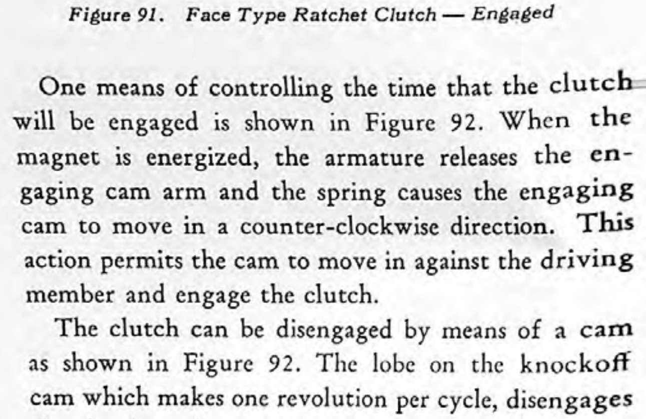


Figure 92. Engaging Cam and Controlling Mechanism

RELAYS

Reference has been made in previous sections to a need for control. Even though a clutch has mechanical control over the operation of a mechanism, the clutch itself requires electrical control. In addition to clutches there are many other mechanisms which require electrical control.

One device used to provide the necessary control is a relay. A relay is an electromagnetic device used to complete or open electrical circuits. There are many types of relays in use in present IBM machines, but one of the most common is the duo relay.

Duo Relay

The term duo, meaning two, was applied to relays when two coils were wound on one core. The relay could then take the place of two relays because a separate pick coil could be in two separate circuits, each with its own control, or a second circuit could be used to hold the relay energized. However, today the term duo-relay includes all relays which are built on the type frame shown in Figure 93. The term no longer has a meaning either as to the number of coils found on the relay or the number of points which are stacked on it. However, a duo relay does, as a general rule, provide simultaneous control over several circuits because of the number of points possible on the relay. It is available in a wide range of operating speeds, contact point combinations, and coil combinations in IBM machines.

There may be several contacts stacked on a duo relay, but each one can be classified according to type. Contacts which are closed when the relay is not energized (no outside force is acting upon them), are referred to as normally closed contacts (N/C). Those which are open are referred to as normally open (N/O). Some are transfer contacts which have both a N/C side and a N/O side. Figure 94 shows the three most common types of contacts found on a duo relay, and their electrical symbols. It also shows that an individual contact point on a relay may be referred to as the N/O point, N/C point, or operating point (O/P) to better identify the point involved.

Duo relay contacts are usually arranged in two piles. Looking at the armature end of the relay, the *A* side

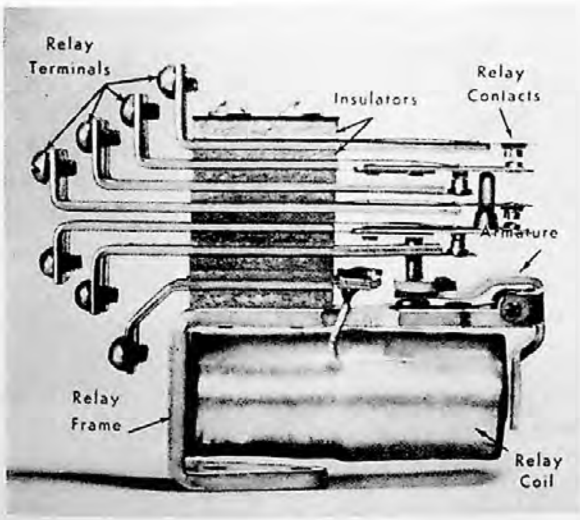


Figure 93. Duo Relay

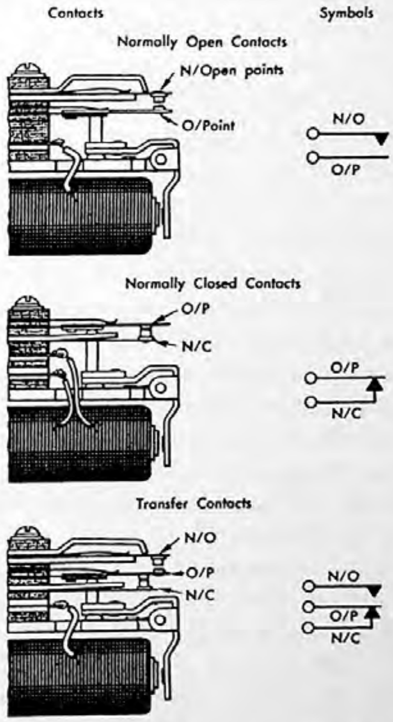


Figure 94. Duo Relay Contacts and Symbols

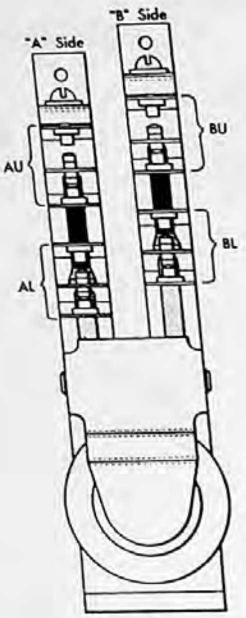


Figure 95. Duo Relay Contact Identification

is the left pile and the *B* side is the right pile on all machines except the 285 and 601. There are often two sets of contacts on one of the two sides or on both sides. To facilitate the identification of a contact, they are designated AU for *A* side upper contact, AL for *A* side lower contact, BU for *B* side upper contact, BL for *B* side lower contact as shown in Figure 95.

The relay may also have several coil combinations. It may have only one coil which, when energized, attracts the armature to transfer the relay points. Some relays are made with two coils and whenever a circuit is completed to either of these coils, the magnet is energized and the armature is attracted. One of these coils is the pickup coil, normally used for energizing the relay. The other coil is the hold coil, and is normally used for keeping the relay energized for a given period of time. The pickup coils will be referred to by the letter P and the hold coils will be designated by the letter H.

Some relays are wound with three coils, and whenever any one of these coils has a circuit completed to it, the magnet is energized and the armature is attracted. Two of these coils are normally pickup coils while the third is normally the holding coil. Such relays are used where it is necessary to energize a relay from either of two separate circuits. The pickup coils are identified in that one of the coils is known as the pickup upper (PU), and the other is the pickup lower (PL). These terms refer to the position of the terminals and not to the position of the winding on the relay as this may vary between assemblies.

All relays which use two or three coils must have these coils correctly polarized when they are connected. The wires to the coils must be connected so that the magnetic polarity of all coils is in the same direction. If the pickup and hold coils do not have the same polarity, the magnetic fields of these coils will be opposed and the relay may fail to hold. In general the *B* side of the relay coils is the common side and is connected to a fuse. Figure 96 shows the three common combinations of relay coils.

It should also be recognized that *use* is *not* the only difference between the pickup and hold coils. There is a difference in construction as well. A pickup coil is designed to pick a coil rapidly but is not generally capable of passing current for sustained periods of time without overheating and burning out. However, because the primary use of the hold coil is to hold the relay energized for longer periods of time, it is designed for this purpose. It is wound with finer wire and more turns which increases the resistance but also decreases the current. As a result, the power used, or heat generated, will be less. For this reason the coil can be energized for greater periods of time. However, relays picked through the hold coil take slightly longer to pick then if picked through the pickup coil.

Figure 97 shows a relay in both a de-energized position and an energized position. When the relay coil is energized and the armature is attracted, the armature pivots so that the end away from the core is moved upward. As it moves upward, it pushes against a pedestal which operates the contact strap of the O/P. This will either open, close, or transfer the contact depending on its type.

Wire Contact Relay

The wire contact relay is another very common type of relay found on many IBM machines. It was developed to meet the need for a compact high-speed relay for use on 40 volts D.C. The unit is available in three sizes: 4, 6 and 12 transfer contact positions. A latch type is also available. The use of transfer contacts provides a flexible capacity which eliminates the need for several different relay assemblies having various contact combinations. The relay is pluggable,

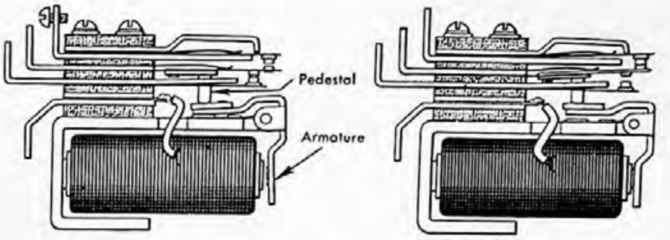


Figure 97. Duo Relay — De-Energized and Energized

employing a terminal moulding connector which permits completion of wiring before the relays are installed in a machine. The unit is readily removable for inspection or replacement and does not require removal of screws or wires.

As the name implies, this relay uses wires as the contacting surface. The wire contacts were not designed for circuit interruption, but the silver alloy now in use will stand some arcing. The wire contact numbering will be from right to left as viewed from the back of the relay. Wire relay points on a wiring diagram are labelled to indicate the relay number and the point number. For example, if the relay number is 45 and it is the third point shown, it will be labeled 45-3.

Figure 98 shows a wire relay in both a de-energized position and an energized position. When the relay coil is de-energized, the wires are making a contact connection between the upper row of terminals and the second row. The upper row terminals are always in contact with their corresponding wires and are referred to as O/P terminals. The second row terminals are in contact with the wires when the relay coil is de-energized and are called the N/C terminals. The third row terminals are in contact with the wires only when the relay coil is energized and are known as the N/O terminals.

Figure 99 shows the wire contact and coil combinations from the terminal end of the relay.

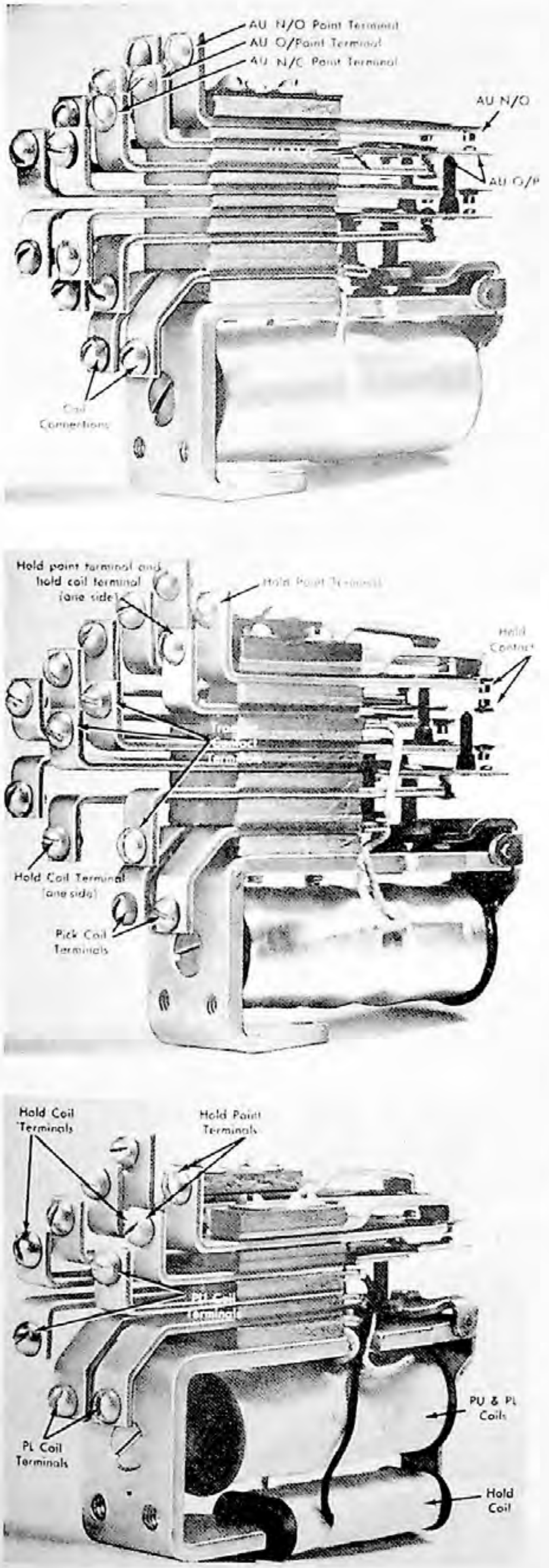


Figure 96. Duo Relay Coil Combinations

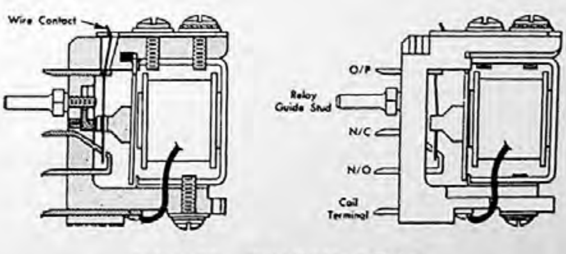


Figure 98. Wire Contact Relay

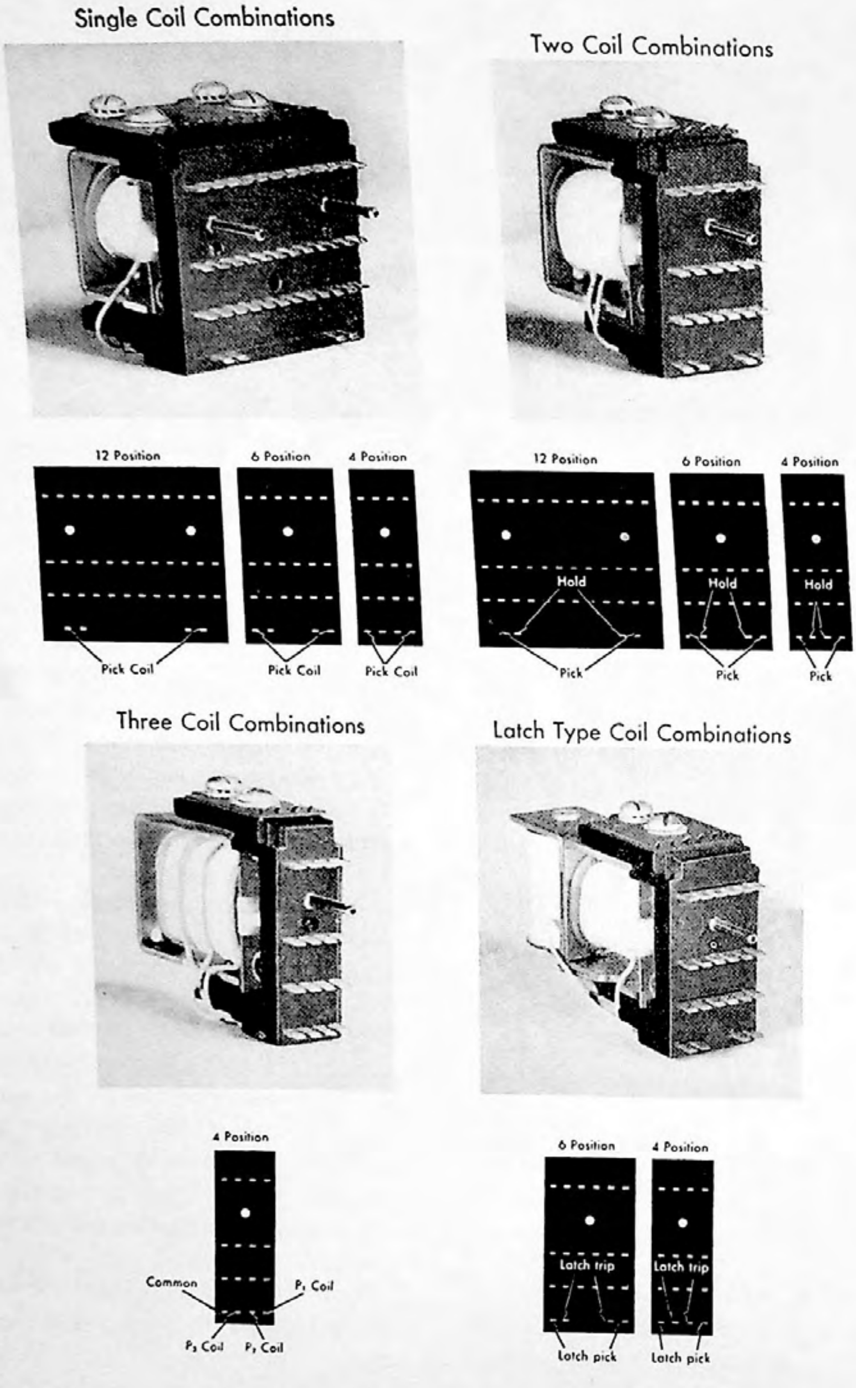


Figure 99. Wire Contact Relay Coil Combination

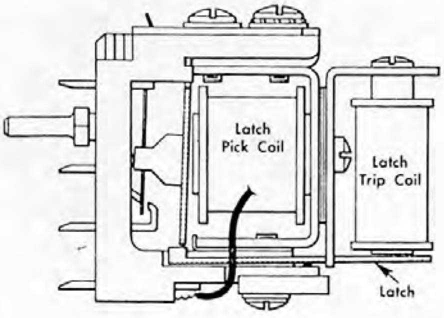


Figure 100. Wire Contact Latch Type Relay

Latch Type Wire Contact Relay

The latch type relay differs from the standard wire contact relay. It does not depend on the continued energization of a relay coil to hold the contacts transferred. Figure 100 shows a latch type relay in both normal and transferred positions. This relay has a mechanical latch that moves up to hold the armature transferred once the pickup coil has been energized. The relay will be held transferred even though the circuit to the pickup coil no longer exists. The latch must be pulled down below the end of the armature when it is desired to have the contacts return to normal. This is accomplished by means of a second coil which has for its armature the right end of the latch. When it is desired to unlatch or return the relay to normal, the latch trip coil is energized.

High Speed Relays

High speed relays are designed to be used where the pickup and dropout times of the duo and wire contact relays are not fast enough to meet machine requirements. These relays will not be studied in detail at this time, but each will be taken up later with the machine in which it is used. Figures 101 and 101A show various types of high speed relays found in IBM machines.

Permissive Make Relays

The trend to higher speed machines has created the need for a high speed multi-contact relay with contact relay with constant tension and no contact bounce. The permissive make relay was developed to meet this need. It will operate in about half the time

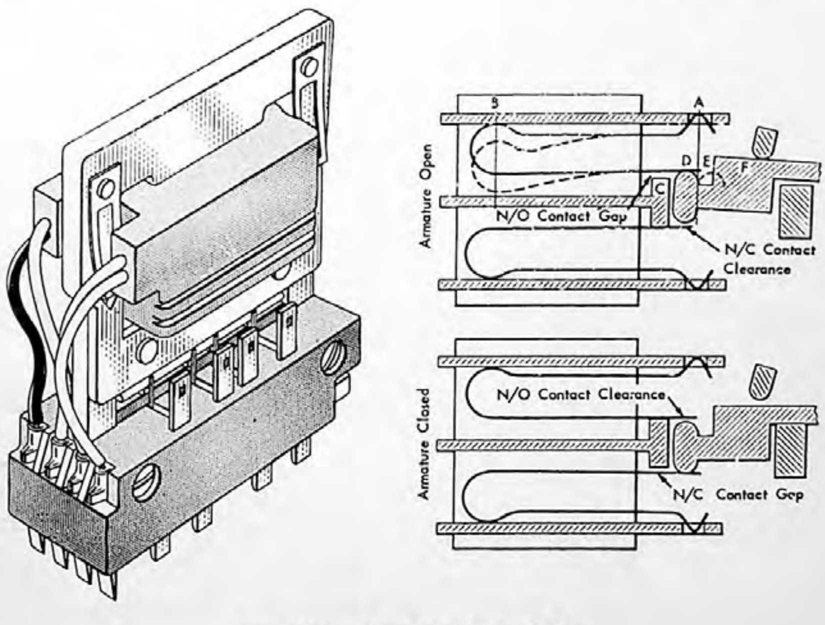
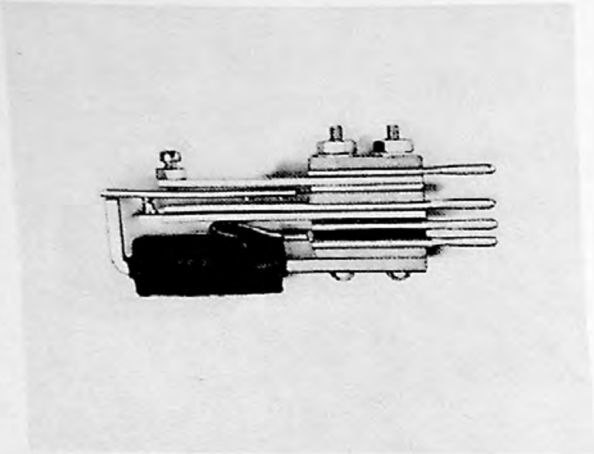
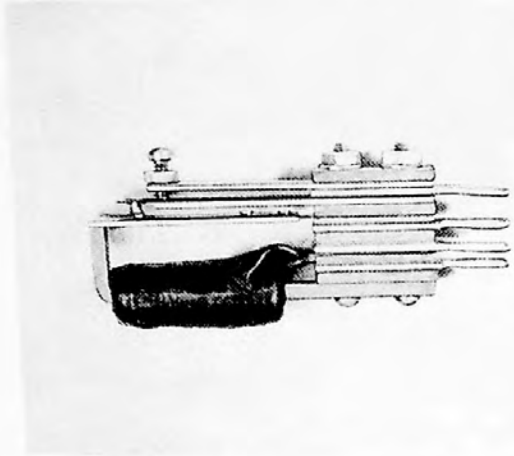


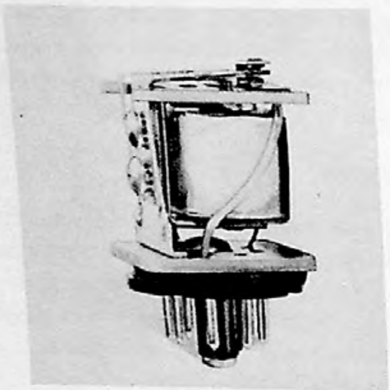
Figure 101. Permissive Make Relay

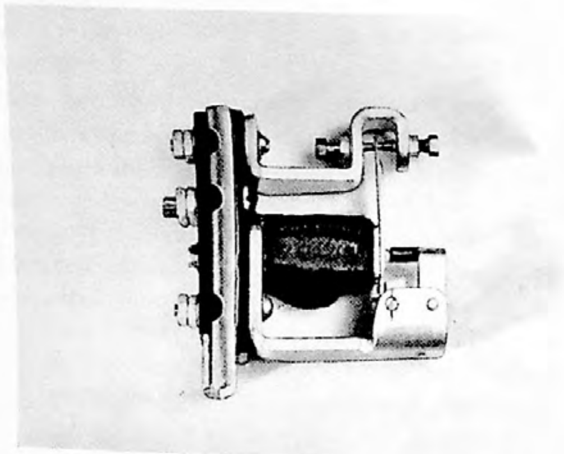


N/O High Speed Relay Used in Type 77

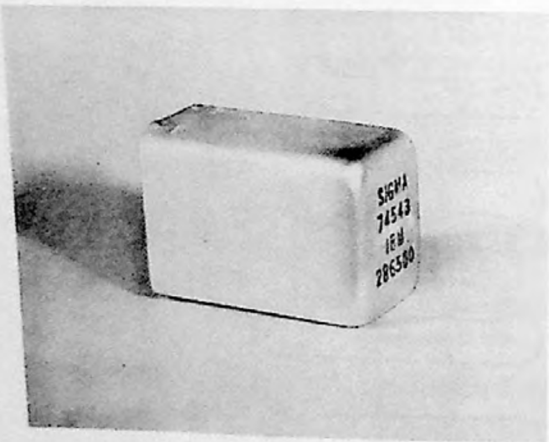


N/C High Speed Relay Used in Type 77

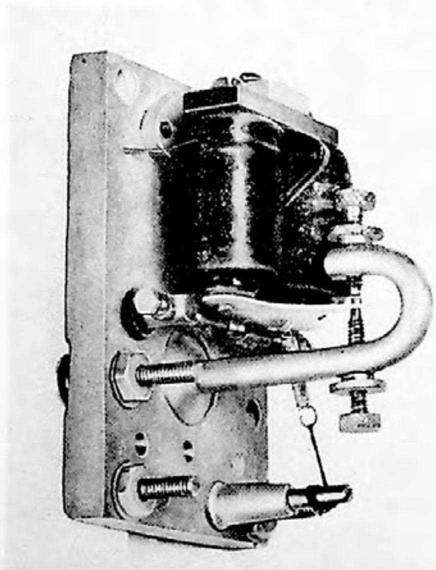




High Speed Relay Used in Type 402 Accounting Machine



High Speed Relay Used in Type 89 Collator (Cover Off.)



High Speed Relay Used in Type 80 Sorter

Figure 101A. High Speed Relays

of a wire contact relay and with contact bounce practically eliminated.

This relay is made in 4, 6, and 12 position sizes, and will add color identification to relay gates. The 4 position relay base is red, the 6 position is green, and the 12 position is blue.

The permissive make relay gets its name as the contact being closed is permitted to make by the action of the armature. Each contact position has two sets of wire contacts. One set of contacts is held open by the relay armature while the other set is permitted to make with the contact tension being dependent only on the contact wires. When the armature is attracted, the N/C contact wires are pushed away from the common contact and the wires that had been held open are dropped lightly on the common contact without bounce or oscillation. The contact tension is independent of armature travel.

CAM-OPERATED CONTACTS

Another device used to provide electrical control is a contact which is operated by a cam. The three common types of cam-operated contacts are: rocker arm, plunger, and strap or spring-blade types. The contacts may be used as master timers to provide timed impulses of a definite duration which would be available to many circuits. They may also be used in individual circuits to control the time the circuit is completed (made), the time it is opened (broken), or both.

Rocker Arm Type

Figure 102 shows the essential elements of a rocker arm type contact. A rotating cam operating against a cam roller causes the rocker arm to pivot. When the roller passes low dwells of the cam, the contact will be made. The number of times a contact makes during a cycle and the duration of the make are determined by the cut of the cam. For the cam contact illustrated, the contact will open and close twelve times in one revolution.

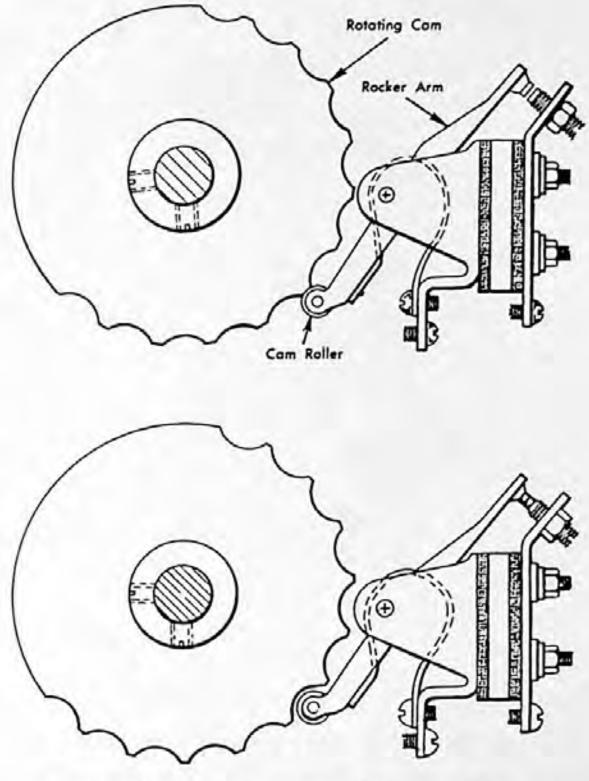


Figure 102. Cam Contact — Rocker Arm Type

Unitized Rocker Circuit Breaker

A new style rocker circuit breaker is currently being used on some IBM machines. This circuit breaker is similar in all respects of operation to the rocker arm circuit breaker, except that instead of being assembled on a bar, it is a complete unit in itself. This makes removal much easier (Figure 103).

Preventive maintenance and adjustments are the same as for the rocker arm circuit breaker.

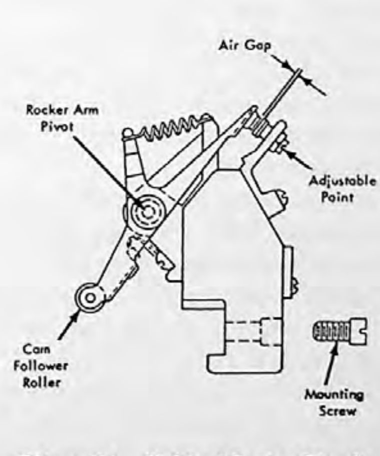


Figure 103. Unitized Rocker Circuit

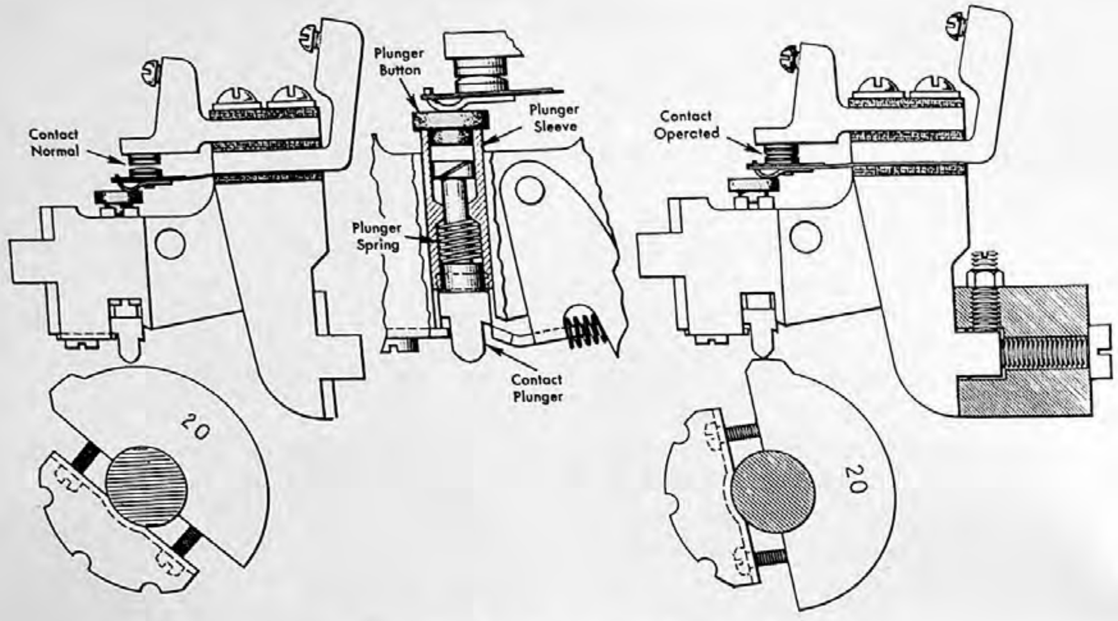


Figure 104. Cam Contact — *N/O Plunger Type*

Plunger Type

Figure 104 shows the construction detail of a plunger-type cam contact. The lobe on the cam strikes the contact plunger causing it to move upward. The plunger in turn moves against the plunger spring which applies pressure to a sloping shoulder on the plunger sleeve. The plunger sleeve and button move up together closing the contact. As the plunger continues to move up, it compresses the plunger spring. Compressing the plunger spring increases the contact tension. The plunger spring is pressing against a sloping shoulder of the sleeve, which is in two parts. The two parts are cammed out against the casting. This action creates a slight bind which tends to overcome bouncing, and also holds the contacts made for a longer period of time. As soon as the spring tension has been decreased to the point where the contact tension overcomes the friction between the sleeve and casting, the contact opens.

The cam contact shown is a normally open contact. It derives its name from the fact that unless the plunger is being acted upon by the cam, it is open. Figure 105 shows a contact that is closed unless the plunger lifts the upper point to open the contact; this is called a normally closed contact.

Using these two types of contacts, it is possible to obtain any timing duration desired, with a cam having a maximum high lobe of 180° duration. A normally open contact is used for all variations of timing up to 180°. For a duration of more than 180°, a normally closed contact is used. For example, a 20-degree cam could be used to give either a make duration of 20° or 340°. The 20 degrees are used to describe the duration of the high lobe which means that they could close a normally open contact for 20° or open a normally closed contact for 20°. There are 41 different cams ranging from 6° to 180° duration of the high lobe. In addition there are cams which are cut with lobes spaced around the entire circumference where impulses at regular intervals are required for more than half of a cycle.

Latching Plunger Type

There are two other cam contacts which operate on essentially the same basis as the plunger type. The latching plunger type shown in Figure 106 is capable of operating once for each revolution of the cam. The contacts are closed by a lobe on a latching cam which operates on the contact plunger and carries it beyond the latching point of the latch arm. As the latch and unlatching cam continue to rotate, the unlatching cam strikes the latch arm releasing the plunger.

The unlatching cam can be shifted in relation to the latching cam by loosening the set screws which lock the two together. The two clamping screws can

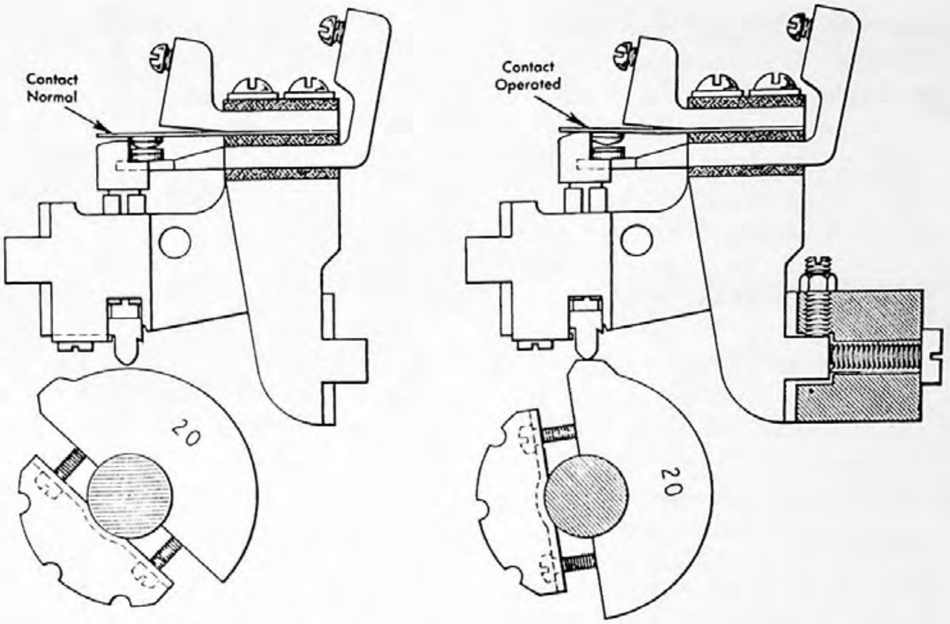


Figure 105. Cam Contact — N/C Plunger Type

be loosened and the latching cam can be rotated on the shaft. In this way any make and break condition can be obtained. The advantage of this contact and cam arrangement is that by means of the one cam assembly all possible combinations of timing may be obtained.

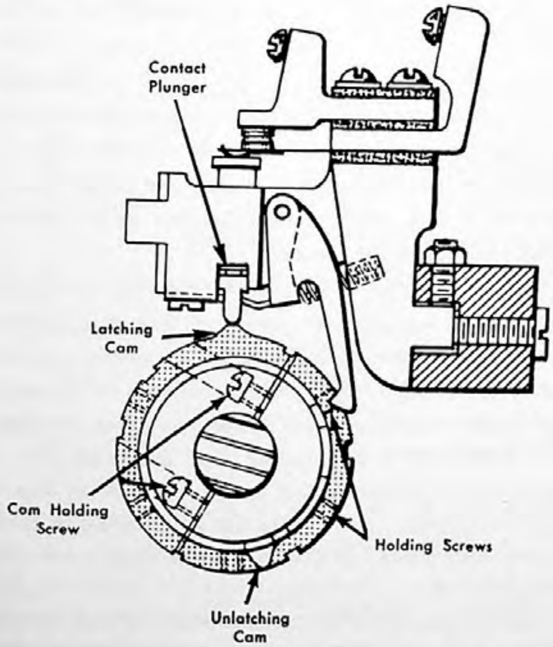


Figure 106. Cam Contact — Latch Plunger Type

High Speed Plunger Type

The other cam contact (Figure 107) is the high-speed plunger type. The laminated stationary contact and spring cam follower reduce the bouncing of the contact points at high speeds. This construction allows the cam to be used on current machines at speeds of 1200 RPM.

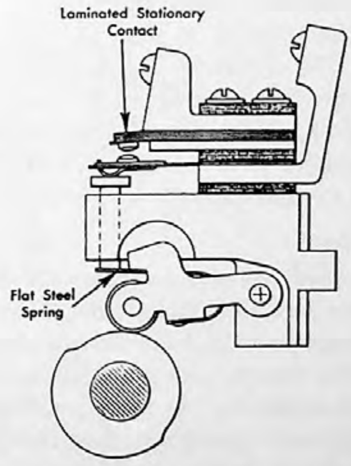


Figure 107. Cam Contact — High Speed Plunger Type

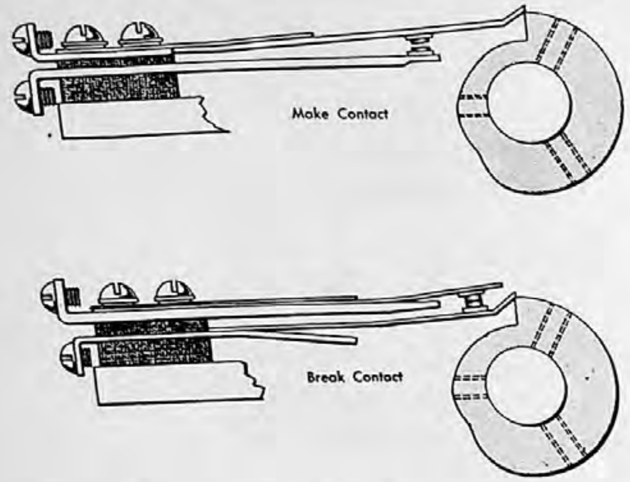


Figure 108. Cam Contact — Spring Blade Type

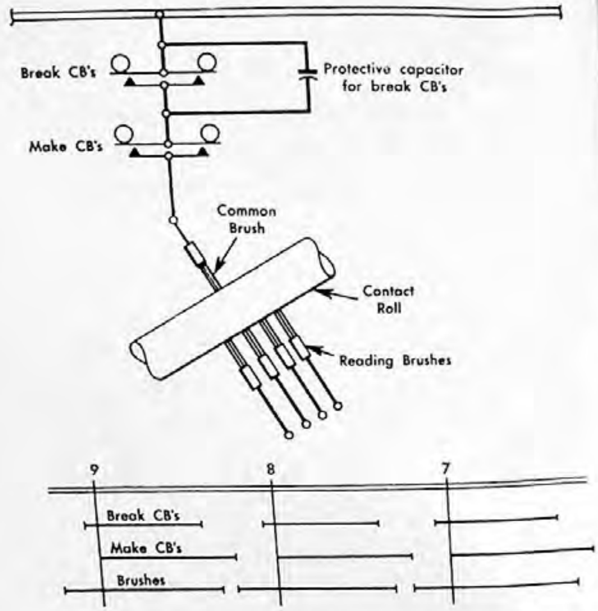


Figure 109. Cam Contacts Used for Brush Protection

Spring Blade or Strap Type

Figure 108 shows the two types, make and break, of spring blade cam contacts. The break contact points are made while the operating strap is riding on the high portion of the cam, and they open when the operating strap falls off the high portion. Conversely, the make contact points are open while the operating strap is on the high portion of the cam; the points make when the strap drops off the high portion. Break contacts are used where an accurate breaking point is necessary; make contacts are used where an accurate making point is required.

The plastic cams used to operate the contacts are stamped with a fraction indicating the size of the cam. The size is given in fourteenths or a fraction of 1/14, and it indicates the fraction of the circumference that is high. Thus, an 11/14 cam has 11/14 of its circumference high and 3/14 low. A 1/28 cam has 1/28 of its circumference high and 27/28 low. The cam is divided into fourteenths because the original design called for its use on machines employing a 14 point cycle, and at that time the cam sizes corresponded to index division. At present, the cam size has no significance in relation to index points.

Circuit Breakers

Cam operated contacts are most commonly used as circuit breakers, abbreviated CB's. The term CB is also commonly used to refer to any cam operated contact, even though cam contacts are frequently used for other purposes. In many machines they are also referred to by their controlling clutch. For example P-cams are under the control of the punch clutch in the Type 513.

The usual purpose of a CB is to provide timed impulses of a definite duration. When a circuit to a magnet is completed or broken, an arc results. Hence, if the brushes are allowed to make and break the circuit connection, arcing at the brushes would result; the brushes would soon be burned beyond use. To prevent this, CB's are provided to make and break the circuit connections. This is accomplished by connecting the CB's in series with the brushes as shown in Figure 109. As a result, no circuit can be completed unless the circuit breakers are making contact. In addition, the time during which the CB's are made is less than the duration of the brush contact through a hole so that the CB's can be set to both make and break the circuit.

Because the cut in the CB cam is not exactly accurate, two sets of cams are used; one to obtain accurate make time and the other to obtain accurate break time. With this offset timing, no circuit is completed unless both sets of cam contacts are closed. This results in a circuit duration less than that of either cam contact or the brush contact, as seen in the above figure. Two make CB's connected in parallel and two break CB's connected in parallel are used. The only reason for using two CB's in parallel is to distribute the load over more contact surface because, even though the contacts are made of tungsten, arcing will burn them.

Because the arc resulting when a circuit is broken is much greater than that caused when a circuit is made, and because the circuit is always interrupted by the same set of CB's, some additional protection is necessary. This additional protection is provided in the form of capacitors connected across the break contacts.

CAM CONTACTS AND RELAYS IN A TYPICAL CIRCUIT

FIGURE 110 is an example of how cam contacts and relays might be used to control the energization of a clutch. In this circuit the relay would be energized for one cycle only, unless the start key is held down. As a result the clutch magnet will be energized for one cycle only.

The closing of the start key contact energizes the pick coil of the duo relay. Note that the terminal on the *B* side is connected to the fuse side of the line. *This is a rule;* however, there are a few cases where it is desirable to reverse the connections. Once the relay is energized the points transfer, closing both the AU and AL points.

The AL point is the point through which the relay will be held energized by means of C1. One side of the hold coil is connected directly to the O/P of the AL contact. The other side of the coil is connected to a terminal on the *B* side. There is, however, a jumper from that terminal to the *B* side terminal of the pick coil which connects the *B* side terminal to the fuse side of the line. The N/O point of the AL contact is connected to the other side of the line through cam contact C1. Cam C1 is a normally closed cam which will be open for a very short time at the end of a cycle to de-energize relay 1. The hold circuit is established as soon as the points are transferred and is as follows: positive line, through C1, through R1AL N/O, through the hold coil, through

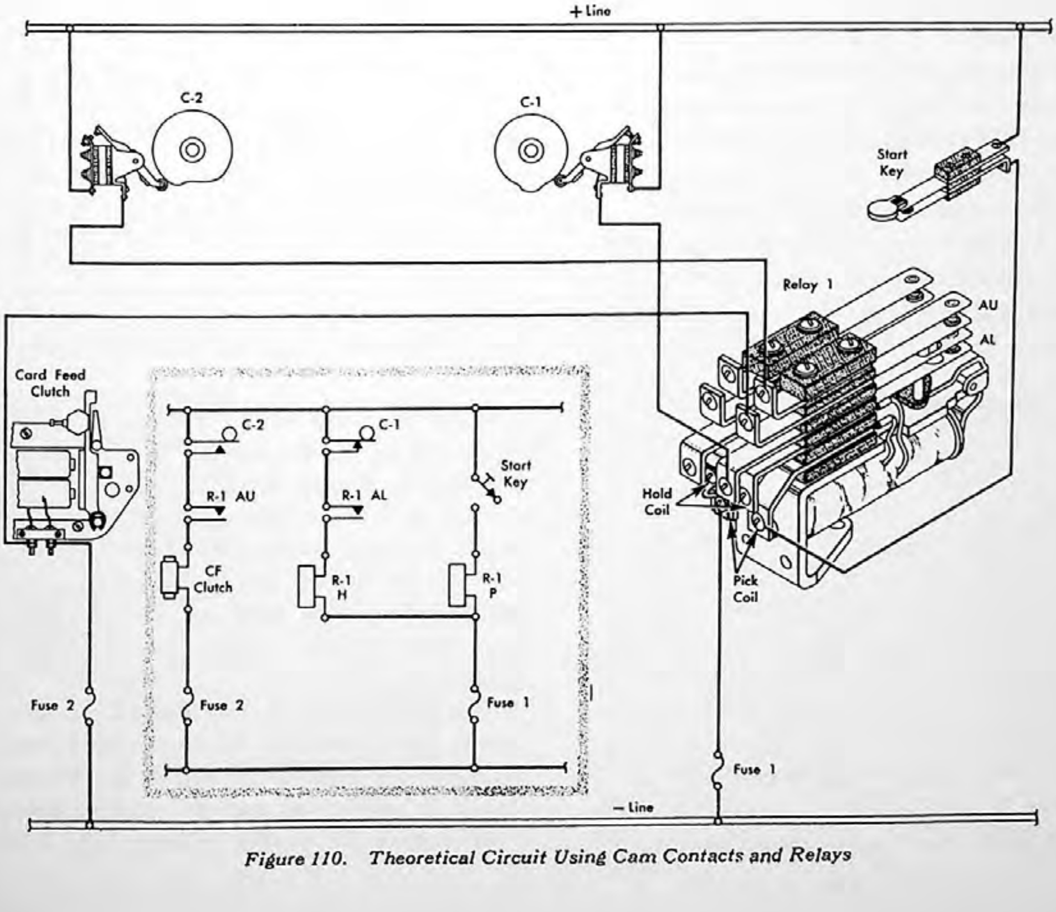


Figure 110. Theoretical Circuit Using Cam Contacts and Relays

the jumper to the pick coil (as a terminal only), to fuse #1, to negative side of the line.

It should be understood that, while a relay point is mounted on the same frame as its coil, there is not necessarily any electrical connection between the point and the coil. A relay point may be used in a circuit which is far removed from the physical location of the relay. On the wiring diagram, relay points are drawn near the units which they control.

R1AU point is an example since it energizes a clutch magnet which is physically located at some distance away from R1. C2 completes the circuit to the clutch magnet through R1AU. The R1AU point will be shown in the clutch circuit which may be located anywhere on the wiring diagram. The inset in the figure shows these circuits as they would appear on a wiring diagram schematic.

Circuit Design and Analysis

Before a circuit can either be designed or analyzed, it is necessary to know the circuit requirements or objectives. Once the objectives are known, a circuit can readily be designed or understood.

The start and run circuits for a hypothetical machine will be designed here to provide an understanding of typical IBM circuits. Instead of listing all the objectives of these circuits, they will be stated one at a time so the reason for each can be explained.

It should first be stated that the machine will be operative (feeding cards); the cams which are operating contacts will be turning, as long as the motor is running.

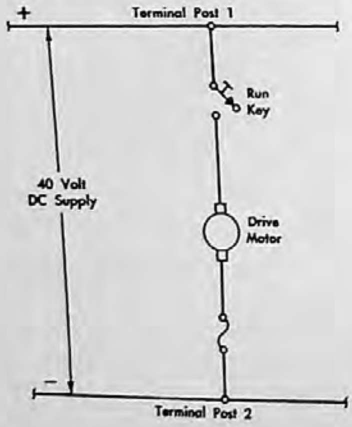


Figure 111. Key Controlled Motor Circuit

The first objective then is to provide a means of energizing the motor. A circuit could be used that would only have a motor and a key contact for components as shown in Figure 111. This circuit, however, could be operative only as long as the operator held the key contact closed, which would be an unsatisfactory condition. A circuit with a relay point in series with the motor is used so that the operation is automatic once it has been started. It is now only necessary to control the time that the relay is energized and de-energized. Figure 112 shows a circuit using a relay to control the motor. The start key is used to energize the relay, but once the relay is energized it holds continuously through its own *A* point. With this condition, it would be necessary to remove the power from the machine to stop it. If the above were the only requirements of the circuit, a switch controlled by the operator would be a more simple solution.

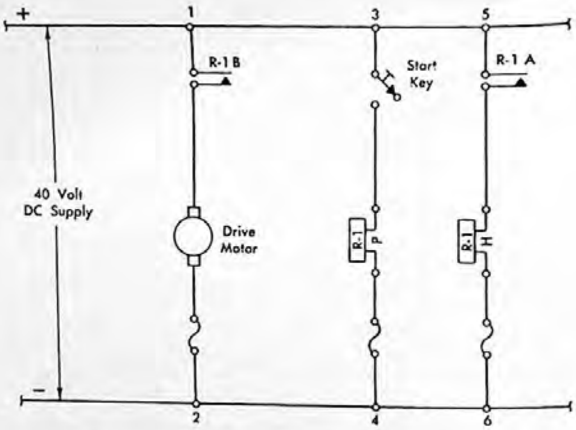


Figure 112. Relay Controlled Motor Circuit

The second condition to be satisfied is that it must be possible to stop the machine at any time the operator desires. A stop key is added in the circuit to the hold coil to provide this control. The operator might, in haste, accidentally depress both the stop and start key so, for safety, the stop key should take precedence over the start key. When stop key has been added to meet these requirements, the circuit appears as in Figure 113.

The above circuit is practical except that under certain conditions the machine should stop automatically, so that the operator is not required constantly to observe the machine. One of these conditions is when the stacker becomes full. If the ma-

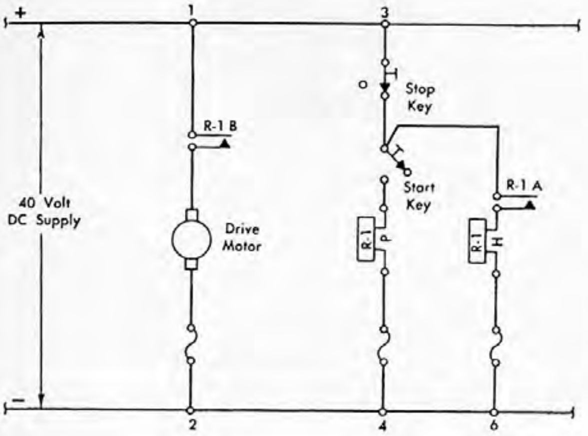


Figure 113. Stop Key Control

chine continues to run while the stacker is full, the cards will jam, destroying a number of cards and possibly damaging the machine. A contact is placed in the stacker to recognize when the stacker becomes filled. Figure 114 shows a stacker stop contact. It is placed in the existing circuit to stop the machine when the contact opens. It is placed in the circuit to hold R1 energized.

In many cases it is necessary for cards being processed to feed successively. This is required for purposes of control, which will be studied with the individual machines concerned. To accomplish this,

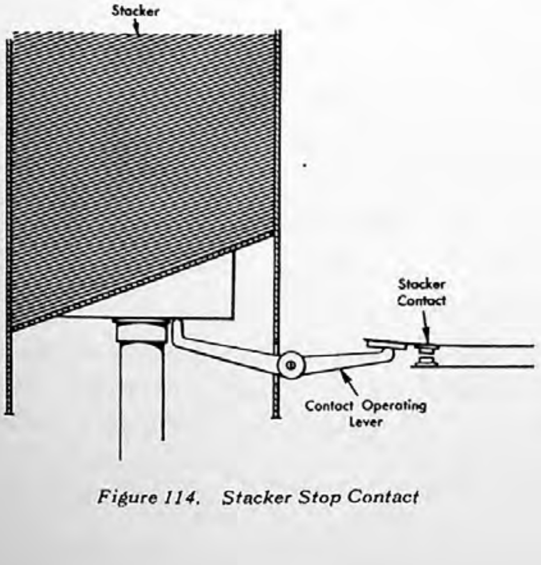


Figure 114. Stacker Stop Contact

it is necessary to stop the card feed unit from operating as soon as the hopper becomes empty. This permits the operator to place more cards in the hopper so that the succession of cards is not interrupted.

Recognition of the time the hopper becomes empty, is easily accomplished by means of another contact operated by a lever similar to the one operating the stacker stop contact. The lever is located in the hopper and is a normally open point, closed only as long as there are cards in the hopper. It is placed in the circuit which is associated with the R1 hold coil only. This is done because it is necessary for the operator to be able to energize R1 and run the cards out of the machine with the start key. Figure 115 shows how both the stacker stop and hopper contacts are added to the circuit to meet these requirements.

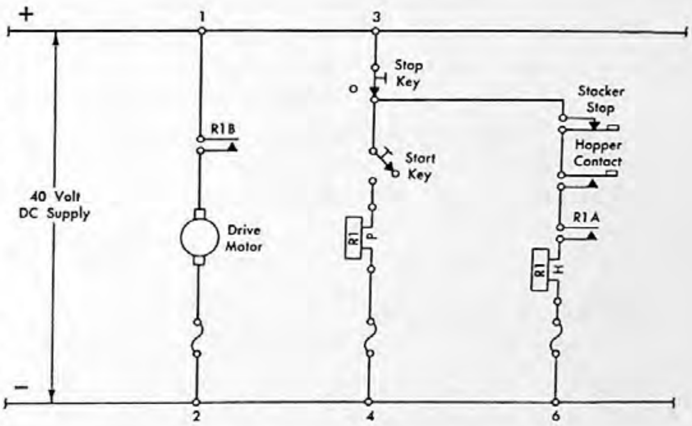


Figure 115. Circuit with Stacker Stop and Hopper Contacts

It is also necessary to recognize when cards are not feeding even though there may still be cards in the hopper. This may occur because a card failed to enter the machine from the hopper or because of a card jam. A card jam may destroy a number of cards and damage reading brushes and other machine parts. One or more card lever contacts are placed in the feed to recognize the presence or absence of a card. If the space between cards is small and the card lever is able to span that distance, the card lever contact will not open while cards are feeding. In this case the contact could be placed directly in the hold circuit for R1. However, in many cases the space is too great for the card lever to span; as a result an arrangement such as the one shown in Figure 116 is needed. The sequence chart and the explanation in the figure show

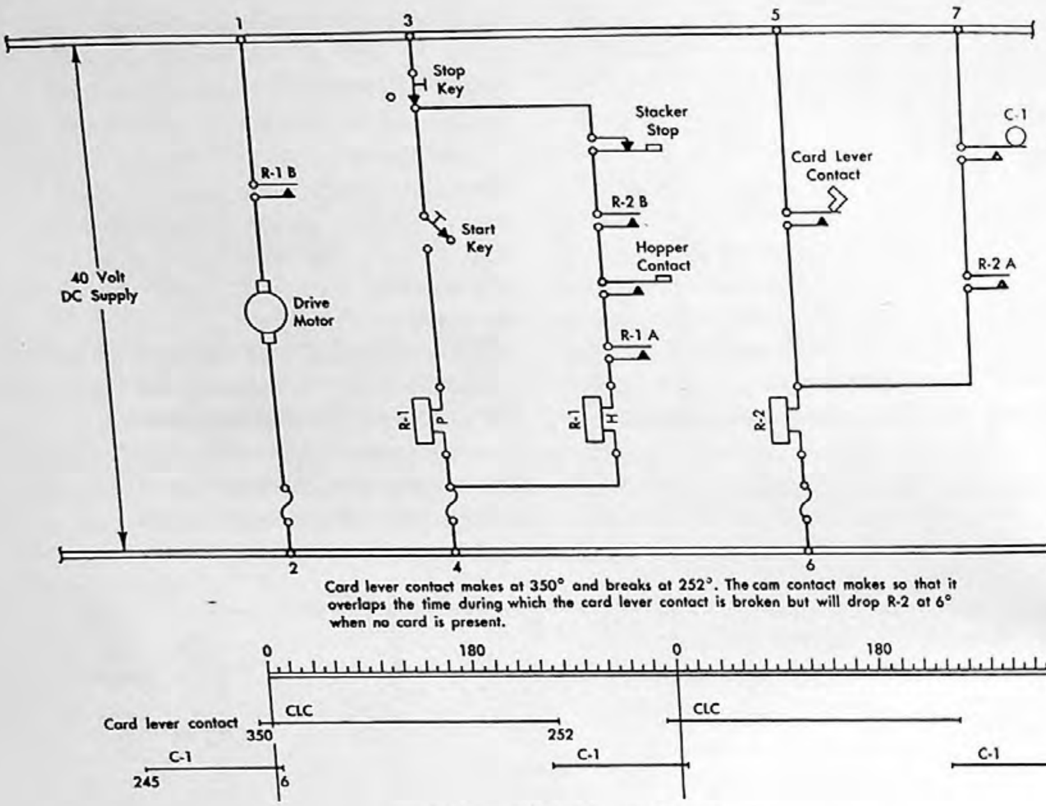


Figure 116. Completed Circuit

how R2 is held energized as long as cards are passing the card lever. If a card fails to feed or is stopped because of a jam, the card lever will not close. R2 will be de-energized, opening the hold circuit to R1, thereby stopping the machine.

If this circuit existed on a machine, to analyze it the approach would be similar to the method used in designing the circuit. It is necessary to know the requirements of the circuit before it can be designed. It is also important that the requirements be known in order to facilitate circuit analysis.

Timing Chart

There are three aids generally used to assist in circuit analysis which are: 1) timing charts, 2) sequence charts, and 3) action and function charts. Timing charts found on the wiring diagram are of two types: mechanical and electrical. They show the time that a specific action occurs during a cycle. The electrical timing chart shows the time in a cycle that each cam contact makes and breaks, also the time card lever contacts make and break. The timing chart in no way indicates the cycle in which an action occurs. Figure 117 shows a timing chart for the circuit shown in Figure 116. In this case there is only one card lever contact and one cam operated contact, but on a machine many more will be found.

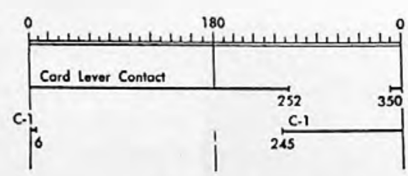


Figure 117. Timing Chart

Sequence Chart

A sequence chart can be constructed from the circuit diagram and the timing chart to show the sequence in which circuits are completed or broken. Figure 118 shows a sequence chart for the circuit described above. To draw this sequence chart it is

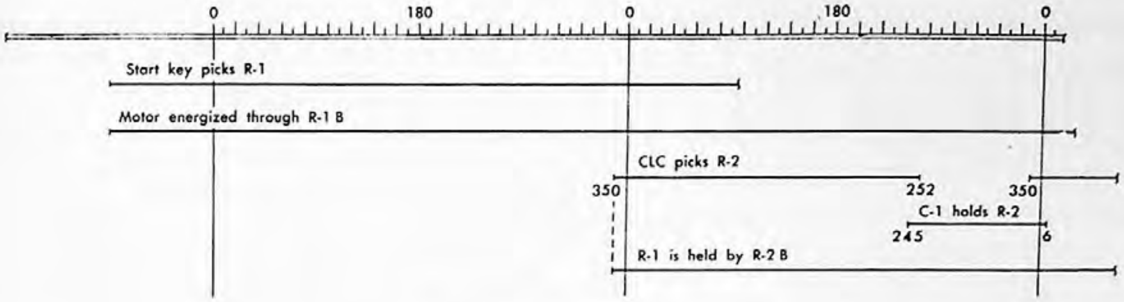


Figure 118. Sequence Chart

necessary that certain initial conditions be known. The machine is not operating and there are cards in the hopper but none elsewhere in the machine. Cards will be fed as a result of the motor operating, and the first card will close the card lever contact during the first cycle. The time that it closes can be determined from the timing chart.

To start the machine, the start key is depressed to energize relay 1. This closes the R1B point which energizes the motor. Both of those actions are indicated by the sequence chart. If the start key was released at this time, or any time before the card lever contact is closed, the machine would stop. This is because no hold for R1 can be established until R2 is picked. However, if the start key is held down until R2 is picked, a hold for R1 will be established. Observation of the circuit will show that if the hopper contact opens because there are no more cards in the hopper, or the stacker fills and opens the stacker stop contact, or the stop key is depressed, the machine will stop. It has been shown also that if a card fails to feed or cards are jammed, R2 will be de-energized, thereby stopping the machine.

To understand a machine completely, both the mechanical action and the circuit action must be kept in mind. A mechanical timing chart is provided to give the time that a mechanical action takes place.

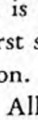
Function Charts

Function Charts furnish a pictorial outline of a circuit function in terms of the relationships required between major components, but, unlike action charts, they do not show the detailed paths of action. The purpose of the function chart is to present on one page the cause and effect of the more important elements of a given operation and serve as a guide to the understanding of the circuit as a whole. This should materially reduce service time by showing at a glance the highlights of a function without requiring the review of a relay outline or circuit description. It is believed that the function chart should be the first source of information when analyzing an operation.

All function charts begin at the top of the page and read down as time progresses. There is no fixed time scale. Since a function chart is a cause and effect relationship of the various components of a given function, the reader must always proceed to the next lower component and never in an upward direction.

SYMBOLS

There are two basic symbols used in function charts as shown in Figures 119 and 120.



A relay or other apparatus is operated.

Figure 119

A relay or other apparatus is released (returns to normal).

Figure 120

EXAMPLES SHOWING THE USE OF SYMBOLS

Simple sequential cause and effect relation. Relay 1 operates and causes the operation of relay 2 which, in turn, causes the operation of relay 3. Relay 3 then releases relay 4 (Figure 121).

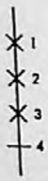


Figure 121

Multiple effects from a single cause. Relay 1 operates and causes the operation of relays 2 and 3 and the release of relay 4 (Figure 122).

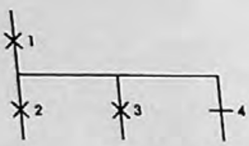


Figure 122

Multiple causes for a single effect. Both relays 1 and 2 must operate before relay 3 will operate as shown in Figure 123.

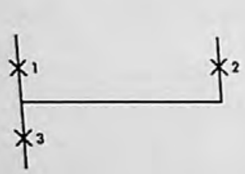


Figure 123

Multiple causes with multiple effects. Relays 1 and 2 must operate before 3 and 4 will operate as shown in Figure 124.

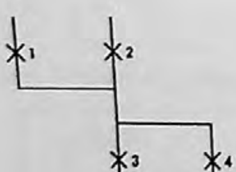


Figure 124

Alternate causes will always contain the word OR. Either relay 1, or 2, or 3 will cause operation of relay 4, as shown in Figure 125.

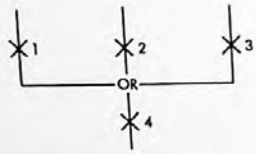


Figure 125

A bracket is used to remind the reader that an element previously energized is needed to cause further action. In the example shown, R20 and R1 are required to cause operation of R2. R1 alone can operate R3. Note that R20 does not affect relay 3 because the bracket enters below the line leading to relay 3 (Figure 126).

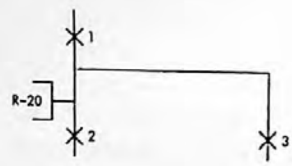


Figure 126

TYPE 26 FUNCTION CHART DESCRIPTION (FIGURE 127)

The following description of the Type 26 manual punching cycle may be helpful in becoming familiar with the charts:

If a character key is closed and relay 3 is energized, the interposer magnet will be operated. This results in the operation of an interposer, which will in turn operate (close) the interposer bail contact. Closing the interposer bail contact causes tubes 2 and 3 to operate (begin conduction).

Tube 2 causes the keyboard restoring magnet to operate; this releases the key contact and operates (opens) the restoring bail contact. Opening the restoring bail contact releases the interposer magnet.

Tube 3 operates the escape magnet which in turn operates the escape armature contact. The escape armature contact operates tube 1 which will cause relay 22 to energize. Relay 22 causes tube 3 to cut off and tube 7 to begin conducting.

Cutting off tube 3 causes the release of the escape magnet which releases the escape armature contact. The escape armature contact releases (cuts off) tube 1.

Tube 7 causes operation of the punch clutch magnet which in turn operates the punch cams and punch mechanism. The punch cams release (cut off) tube 7, which releases the punch clutch magnet.

At about the same time that the punch clutch magnet is released, the punch mechanism releases (opens) the interposer bail contacts. The bail contacts then cut off tube 2, causing the release of the keyboard restoring magnets which in turn releases (closes) the restoring bail contacts.

The last item is the release of relay 22 by the punch cams.

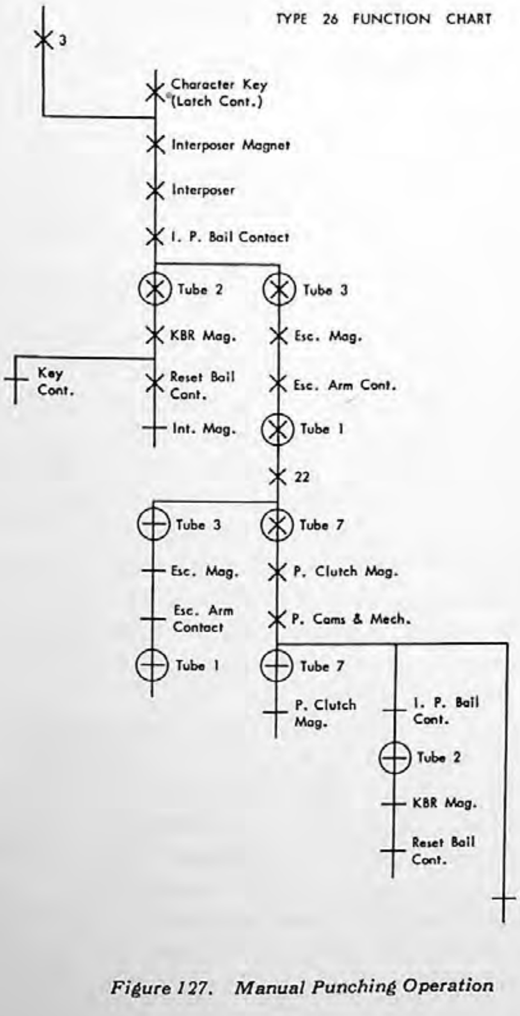


Figure 127. Manual Punching Operation

COMMUTATORS AND EMITTERS

Commutators and emitters are similar in principle; they differ primarily in the way in which they are used. An emitter is a distributing device that makes available a series of timed electrical pulses. It is electrically similar to an automotive distributor; both send timed impulses to a desired point at a specific time.

In physical construction, emitters consist of metallic inserts moulded or held in a bracket of insulating material. The inserts may be spaced about the inner circumference of a circular moulding or along the length of a flat moulding. The most common type, which will be described in this manual, is the circular type. Figure 128 shows two emitters used on different machines, but both operate on the same principle. The inserts are connected to terminals on the outer circumference to facilitate wiring.

A brush assembly rotates two or more brushes against the inner circumference of the emitter moulding. In addition to the inserts forming the spots, there is a ring around the entire inner circumference of the emitter moulding. One brush or brush set, rides on the ring while the other brush or brush set makes contact with the spots. The brushes are common; thus the ring is connected to the spot where the brush makes contact. The brushes contact only one spot at a time, so the ring is never connected to two spots simultaneously.

Digit Emitter

There are two common methods of wiring an emitter of this type. Figure 129 shows one method where the common ring is connected directly to the voltage source through CB's. The emitter is timed so that when the CB's make for a 9 impulse, the brushes will be making on the 9 spot. The CB's are in the circuit to prevent the brushes from making and breaking the electrical circuit which would destroy the brushes. As the emitter brushes rotate, the 9 spot emits a 9 impulse, the 8 spot emits an 8 impulse, etc. In this manner an emitter with twelve inserts would emit twelve impulses to twelve different wires. Any digit or combination of digits can be directed from an emitter to control an operating unit such as a punching, printing or storage unit.

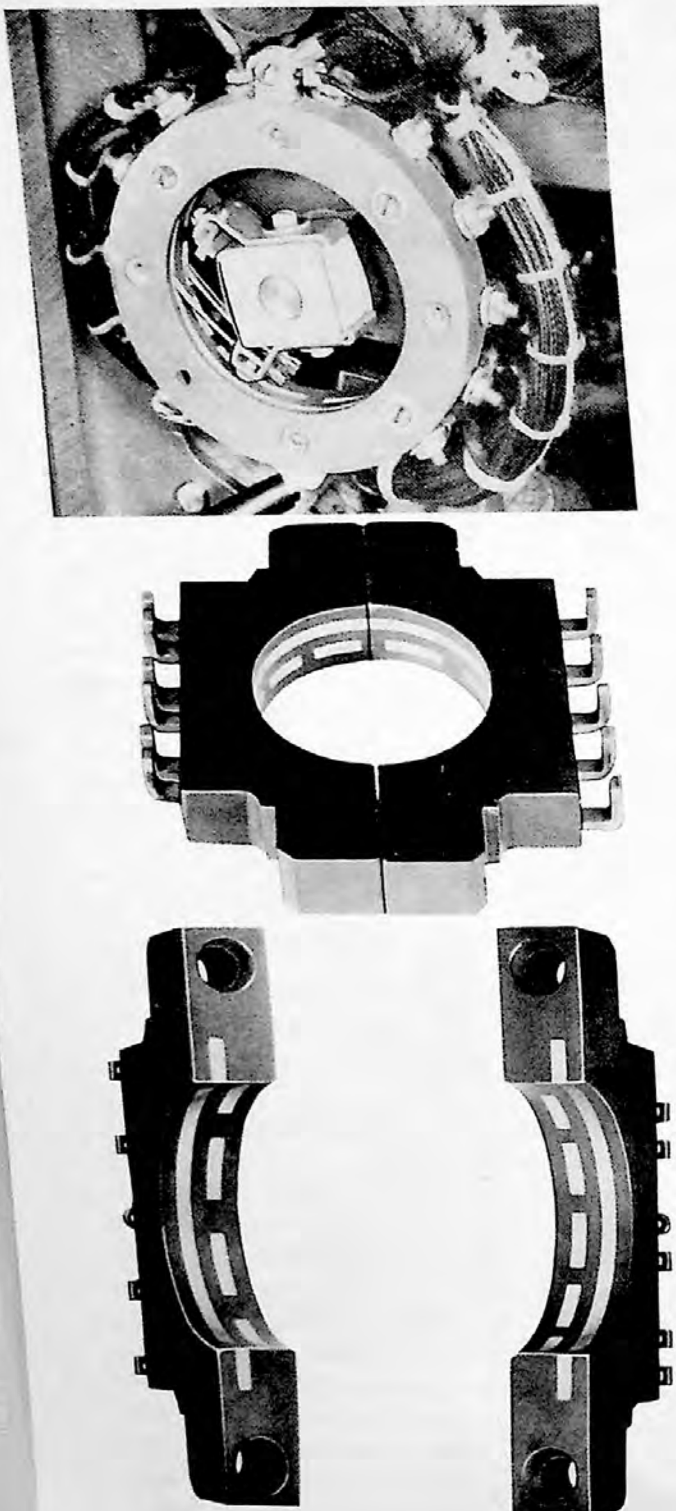


Figure 128. Emitters

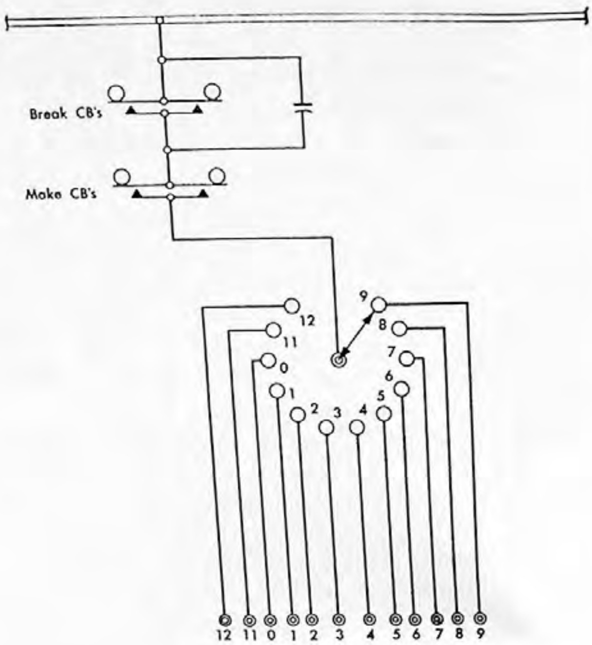


Figure 129. Emitter Circuit

Digit Selector

Figure 130 shows a second method of wiring an emitter. When an emitter is wired in this manner, it is referred to as a digit selector. The emitter is more flexible when wired in this manner. If it is desirable to have a digit emitter, the digit impulse hub can be connected to the common hub to make an emitter of the type shown in Figure 129. However, when desired, the common hub can be wired to a reading brush to select digits. The impulse desired can now be selected to perform one or more functions. For example, it might be desired to recognize a card only if it has a 5 punched in a specific column. The brush reading that column can be wired to the common hub; a wire from the 5 hub can be wired to control some mechanism. The mechanism will now operate only when the column being read is punched with a 5. It might be, however, that any one of several punches in the column is to cause some mechanism to operate with each digit controlling one mechanism. For example, a 5 punch could be wired to cause one mechanism to operate, while a 3 punch could control the operation of another mechanism, and a 7 could be wired to control still another mechanism.

The digit selector is completely flexible; any digit or combination of digits can be selected to operate any mechanism.

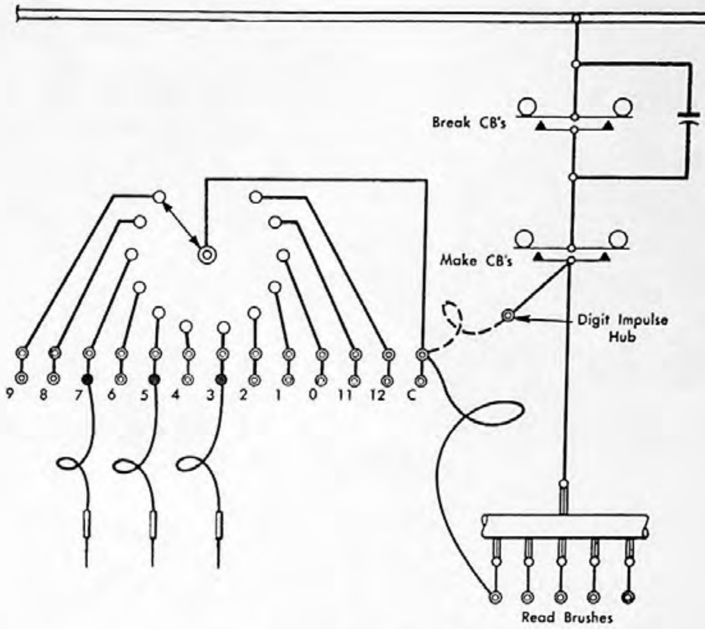


Figure 130. Digit Selector

Selection Commutator

The selection commutator is a special type of emitter. The common ring is connected to the voltage supply and the spots are all connected to one wire or circuit. As the commutator rotates, a series of timed impulses are sent out on the one wire. This is the same type of action as that of a CB. However, on the selection commutator the impulses sent out can be selected because the connections between the common ring and the spots are controlled. Figure 131 shows the selection commutator both assembled and disassembled.

On this type of emitter, the brushes are stationary and the commutator ring revolves. The two brushes ride on the outer circumference of the commutator with one brush passing over the spots and one riding over the common ring. A third brush also rides on the commutator to form a hold circuit for the energized magnet.

In the view showing the commutator disassembled, it can be seen that the spots, which the brush contacts, are extended into the center of the commutator. A switch arrangement has been designed to provide a connection from the spots in the center to the common ring. If the switches are pulled out toward the edge of the commutator, the switch contact connects that spot to the common ring. If the switch is moved to the center of the commutator, the connection is broken. It is easily seen that with this arrangement the digits to be read in a column may be selected.

Contact Emitter — Figure 132

This emitter utilizes contacts mounted around a molded block, actuated by push rods. The push rods are depressed by a roller fastened to a rotor arm, which revolves with the shaft.

The twelve contacts are all common on one side, and are connected to the common wire. As each push rod is depressed by the roller in turn, the contacts are closed, furnishing timed impulses from 12 to 9, in the same sequence as the emitter shown in Figure 128.

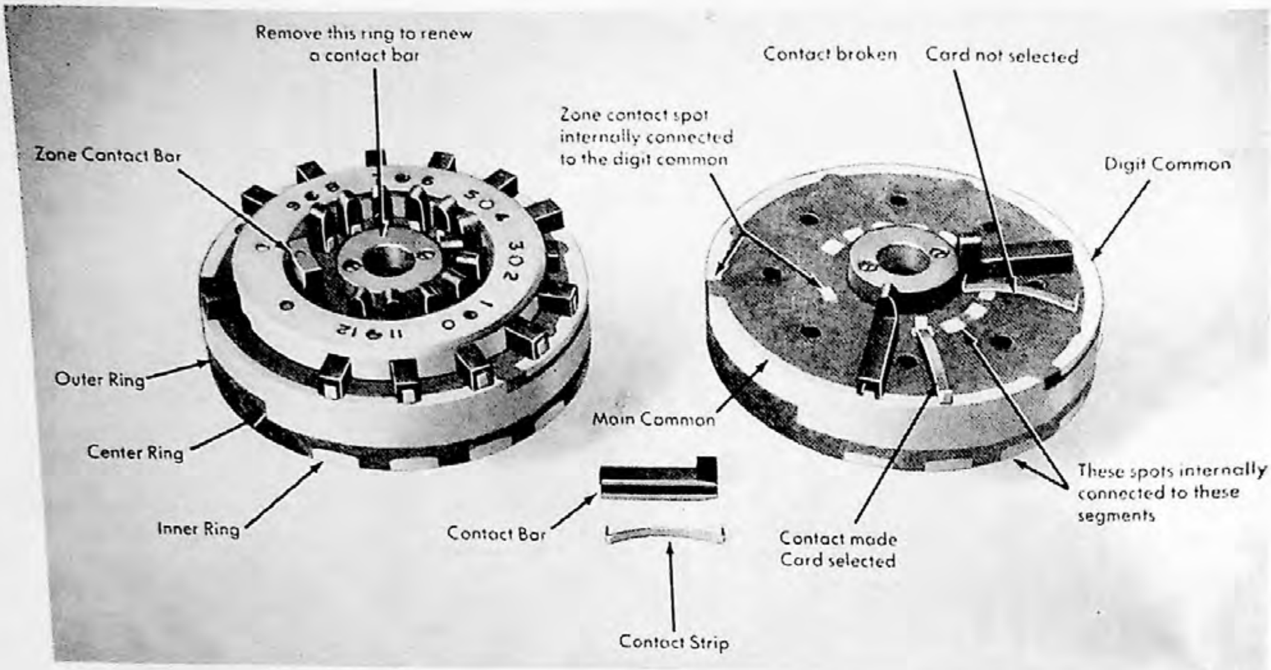


Figure 131. Selecting Commutator

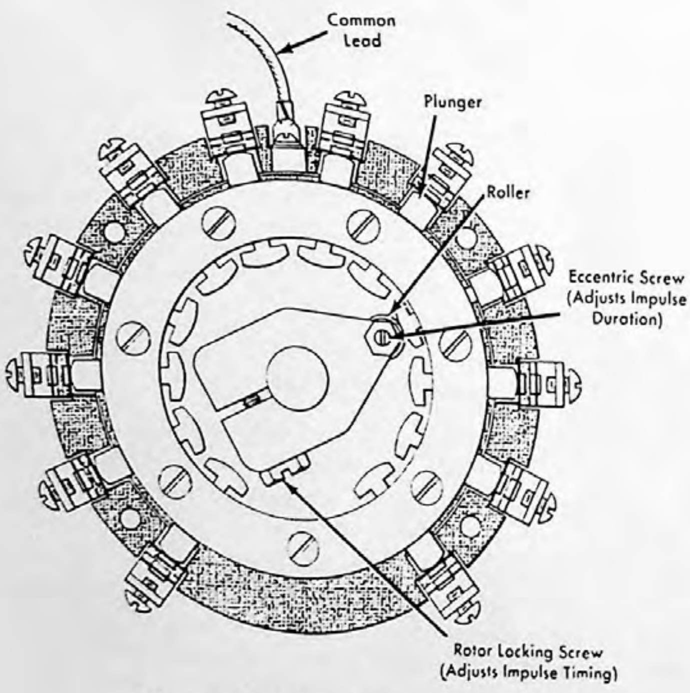


Figure 132. Contact Type Emitter

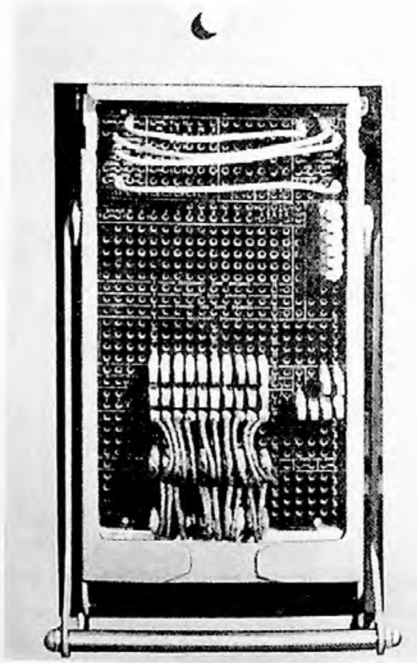


Figure 133. Control Panel

To PROVIDE FLEXIBILITY, many circuits terminate at a control panel. Figure 133 shows a single panel control panel, wired, and in a machine. The wires serve to connect two or more circuits. Figure 134 illustrates schematically how a circuit from one side of the line is connected to a circuit leading to the other side of the line by means of a control panel wire. Figure 135 shows how the control panel wire physically connects the two circuits shown in Figure 134.

Control panel hubs usually either emit or accept impulses. In general, hubs which lead to the fuse side of the line accept impulses, while hubs leading to the other side of the line emit impulses.

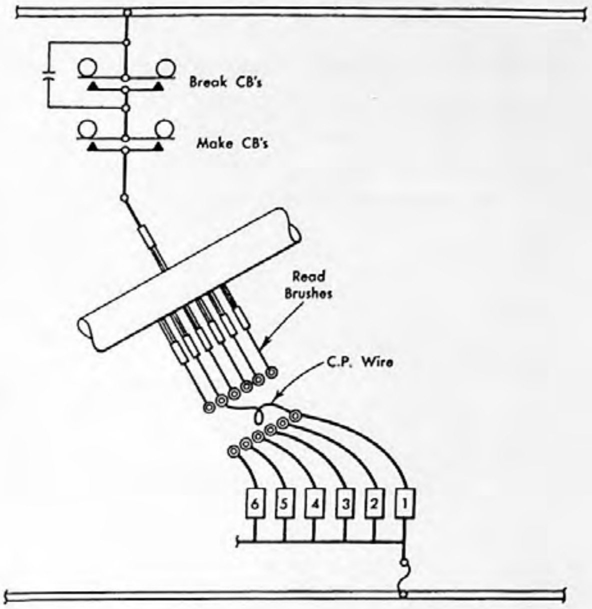


Figure 134. Circuit Completed by Control Panel Wiring

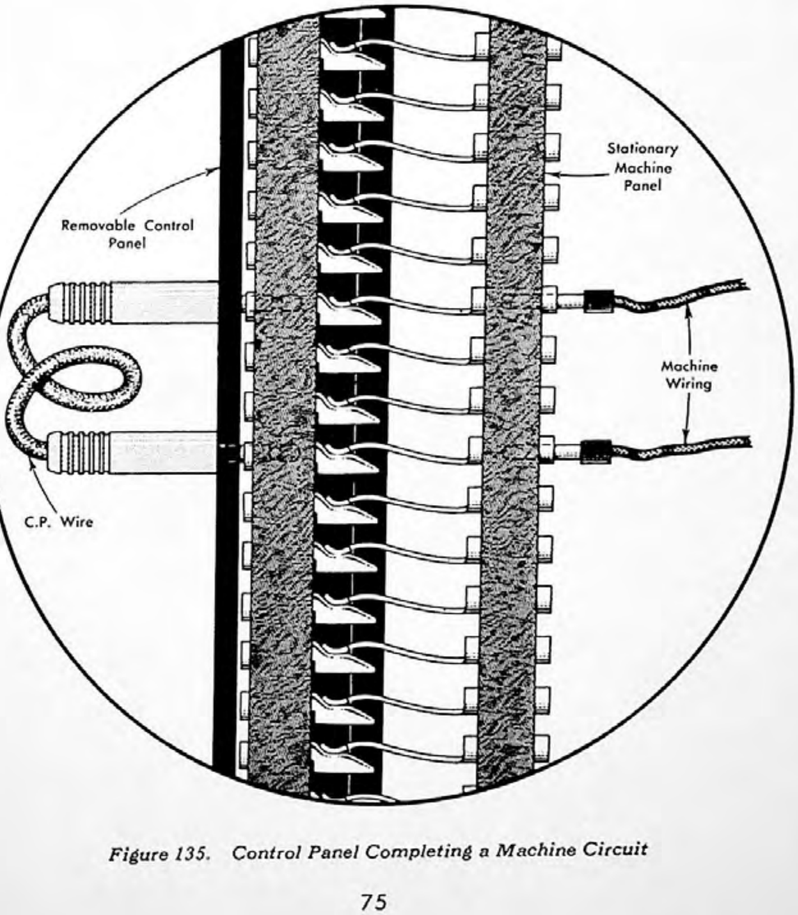


Figure 135. Control Panel Completing a Machine Circuit

Another type of panel (Figure 136) consists only of hubs into which the external wires are inserted. The wires themselves have longer and larger tips which pass through the control panel and press directly against the stationary prongs, and are known as self-contacting control panel wires (Figure 137).

Control of the machine may also be obtained by miscellaneous switches and card lever contacts. Figure 138 illustrates a few of these, and they may be operated either automatically or manually.

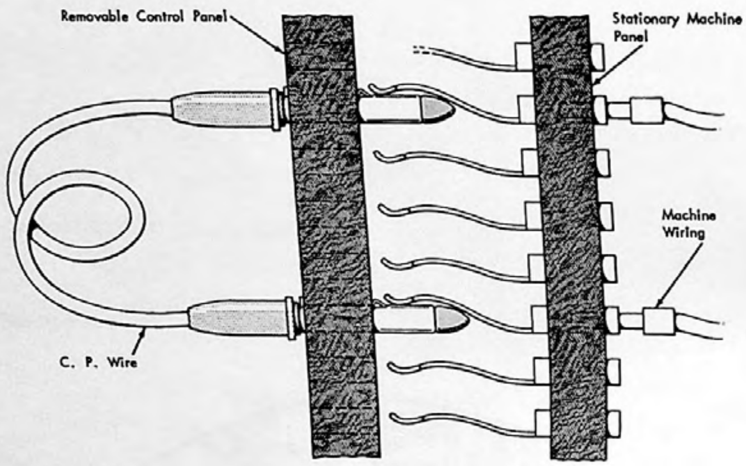


Figure 136. Self-Contacting Control Panel Completing a Machine Circuit

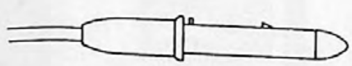


Figure 137. Self-Contacting Control Panel Wire

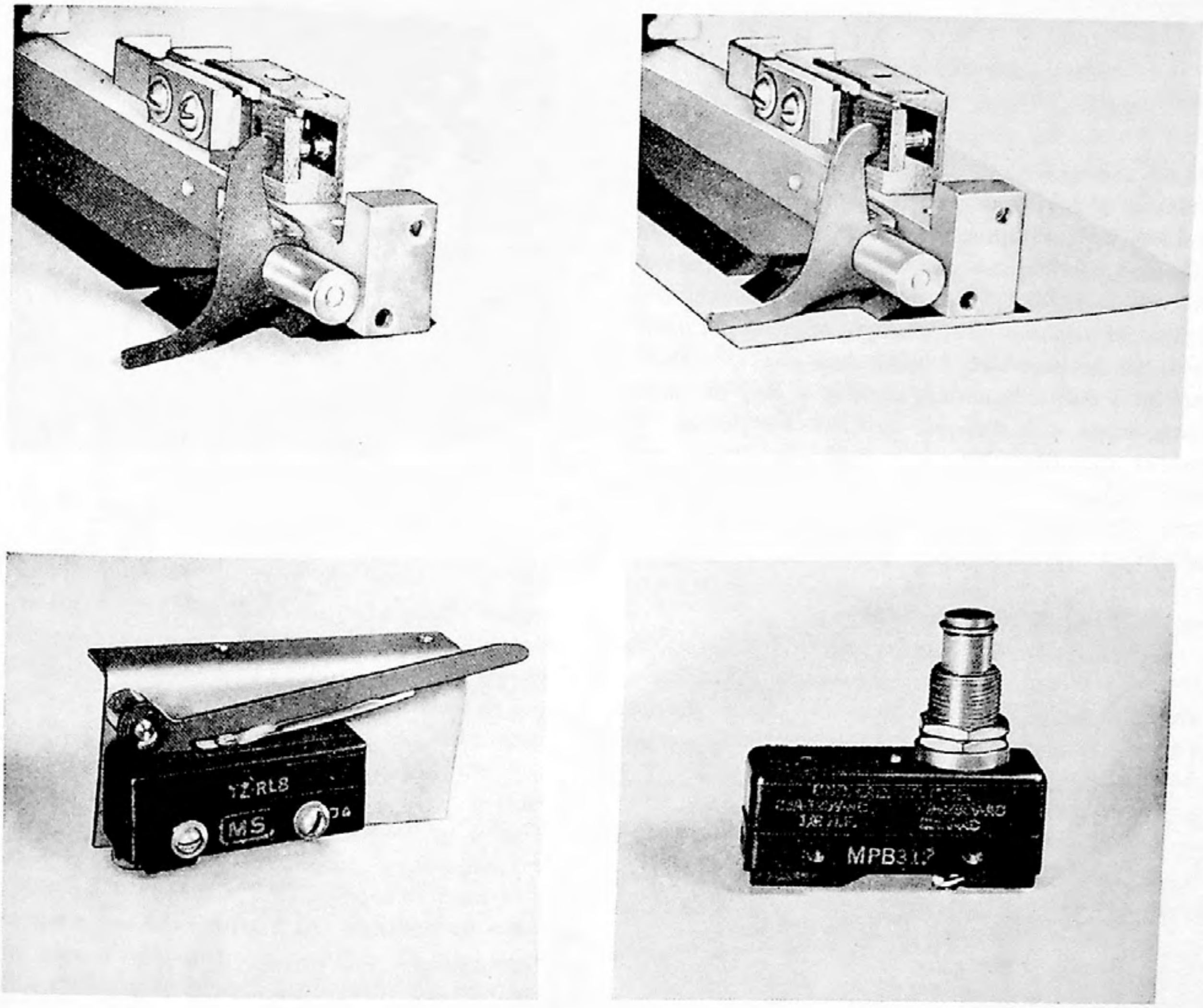


Figure 138. Miscellaneous Switches and Card Lever Contacts

ACCUMULATING MECHANISMS

AN ACCUMULATOR, by definition, is a device which is capable of performing the functions of arithmetic. In IBM, it is a common practice to refer to the individual mechanisms which make up an accumulator as counters. A counter is a device which is capable of addition. An example of a simple counter is the device which is sometimes used by a doorman at a public function, such as a play or sports event, when it is desirable to know the number of persons attending. This is a mechanical device that has a button or lever for the doorman to press. Each time he presses the button (which he will do for each person entering), it adds a one, or counts one. This type of counter will only add a one, and consequently to add a six, one must be added six times.

There are many different types of counters, operating on mechanical, electro-mechanical, electrical or electronic principles. IBM uses counters in each of these categories. However, some are in limited use because IBM counters must generally:

1. Accept an electrical impulse
2. Add digit values
3. Carry
4. Indicate the algebraic sign of the number
5. Read-out the result
6. Reset to a zero value

Principles of Addition

Many counters use a wheel to record and accumulate digit values. The number in the counter is represented by the position of the wheel in relation to a fixed reference point. Because our numbering system is based on ten, the wheel can be divided into ten equal parts, or some multiple of ten. Assume a wheel divided into ten parts, as shown in Figure 139. This will be referred to as an add wheel. To add the number four into the counter, it is necessary to rotate the add wheel 4/10 of a revolution. If the counter was previously at the zero position, its new position would represent a four. However, if it had contained a number from a previous operation; such as a two, it would now be in the position representing the sum of the two digits, six. The add wheel is designed to advance one position for every unit to be added.

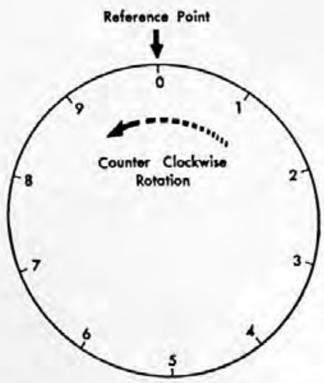


Figure 139. Add Wheel

If the number eight is placed in a counter and the number six is added to it, the sum, of course, is 14. When this operation is done manually, it is necessary to carry into the tens position from the units position. In a manual operation anytime the sum in one position is equal to, or greater than ten, the person adding must remember to carry into the next higher order position. It is also necessary for the machine to remember to carry. Considering the add wheel again, and assuming it has previously accumulated a value of eight, a six is added to it. The add wheel will advance six positions. As a result, the add wheel will move from the eight position through the nine, zero, one, two and three to the four position where it will stop. The units position now contains a four, which is correct. However, the tens counter must be instructed to add one as a result of a carry operation.

Mechanical Principles — Type 402 Counter

Before continuing the study of counter operation, a study of the counter plate, shown in Figure 140, should be made. This figure indicates the names and function of the parts which cause the counter to operate. The counter plate shown is the 402 type which has two complete counters mounted on it. The driven gear is meshed with and driven by a gear which is continuously running during the time the machine is operating. As a result, the adding wheel clutch gear and carry cam are turning continuously. The driven gear, carry cam and adding wheel clutch gear make one revolution per machine cycle.

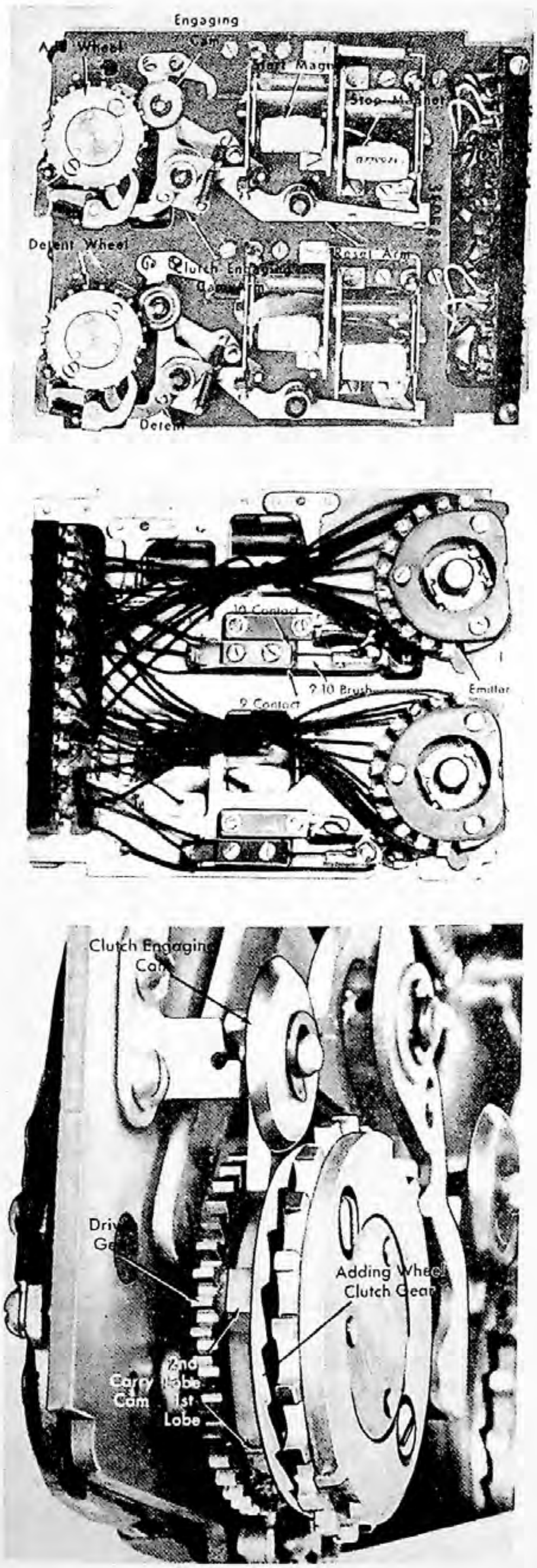


Figure 140. Type 402 Counter Plate

Counter Start

To start the adding wheel it is necessary to engage the clutch by energizing the start magnet. When the start magnet is energized, the armature is pulled away from the clutch engaging cam arm. This permits the clutch engaging cam arm to rotate under spring tension, and move the clutch engaging cam down against the adding wheel clutch gear. The adding wheel clutch gear, being free to slide on its shaft, is pressed in against the adding gear as seen in Figure 141. As the adding wheel clutch gear continues to turn, it meshes the clutch teeth and the adding wheel begins to turn.

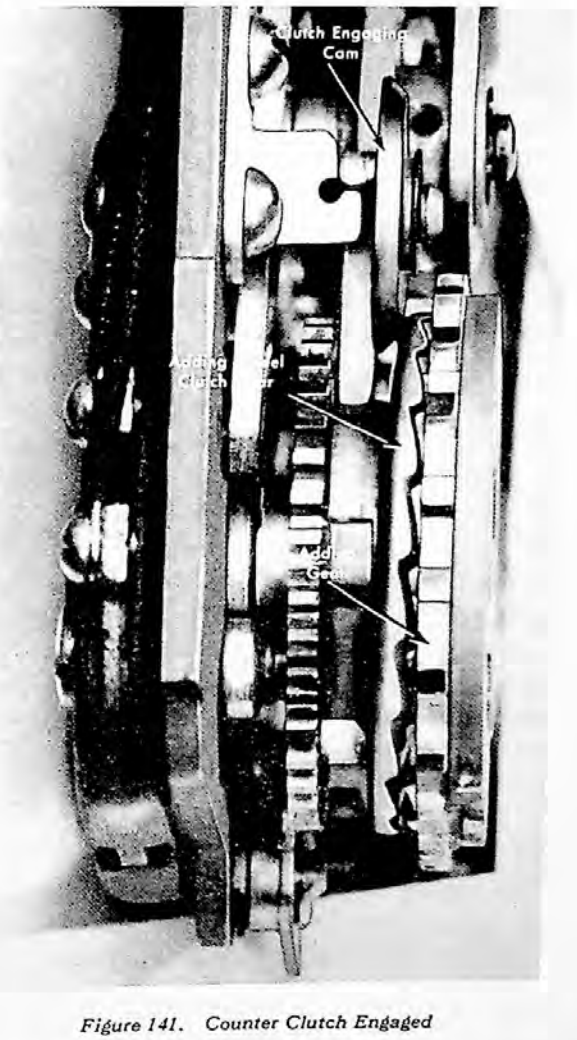


Figure 141. Counter Clutch Engaged

Counter Stop

There are two ways to stop the adding wheel. The first is mechanical, and is accomplished by either of the two lobes on the carry cam. If the clutch is still

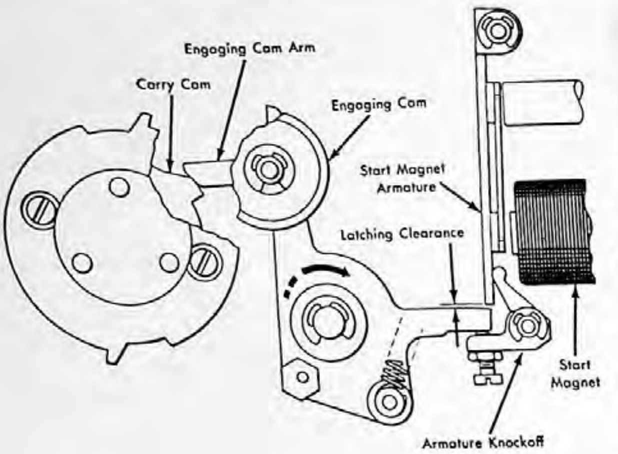


Figure 142. Carry Cam Dis-Engaging Clutch

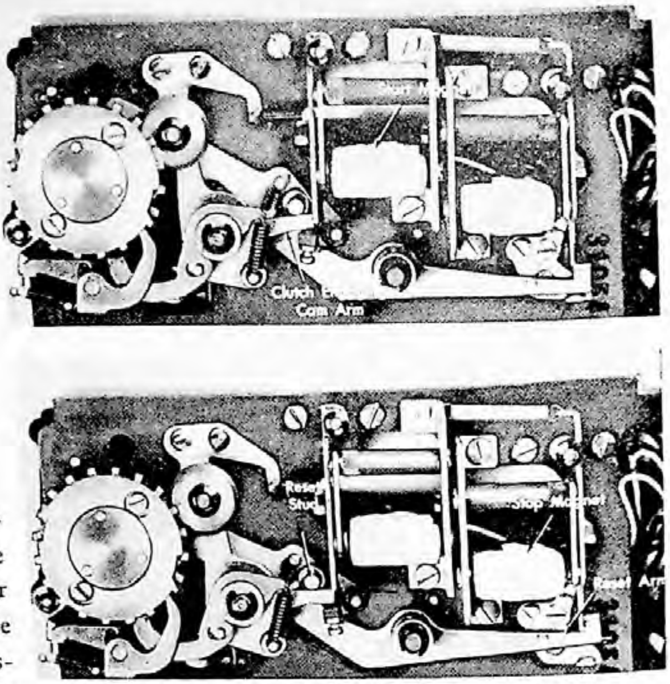


Figure 143. Stop Magnet Dis-Engaging Clutch

engaged at 183°, the first lobe of the carry cam disengages it at that time as shown in Figure 142. The second lobe disengages it at 255° if it is engaged after 183° and before 255°. The reasons for this will be explained in detail later. The second means of disengaging the clutch is by electrically energizing the stop magnet. When the stop magnet is energized, the reset arm is free to rotate in a counterclockwise direction. As it rotates, the reset stud strikes the clutch engaging cam arm, driving it in a clockwise direction. The clutch engaging cam arm is rotated far enough for the armature of the start magnet to move out over the clutch engaging cam arm and relatch it. As the clutch engaging arm rotated clockwise, it should be noted that the clutch engaging cam was pulled away from the adding wheel clutch gear, permitting the clutch to disengage by spring action. Figure 143 shows a counter, first with the clutch engaged and then disengaged as a result of energizing the stop magnet. The reset arm will be relatched on the armature by a stud on the back of the driven gear.

Add Wheel Detent

An adding wheel detent is provided to assure a positive positioning of the add wheel when the clutch is not engaged. The detent is mounted over a collar of the clutch engaging cam arm and held by a spring so that it moves with the clutch engaging cam arm. As the clutch engaging cam arm rotates counterclockwise to engage the clutch, the detent is pulled free of the detent wheel. This action frees the add wheel so that it can be rotated when the clutch teeth are meshed. When the clutch is disengaged, the detent again moves into the detent wheel to insure its being correctly positioned and held. This action can be seen by observing Figures 142 and 143.

9-10 Contact and Cam

A 9-10 contact and cam is provided to enable the counter to recognize when the amount accumulated in a counter has reached nine or more. The 9 and 10 contact cam is the outermost part of the adding wheel assembly and has three different levels. In Figure 144 the 9-10 contact arm rides the surface of the 9-10 contact cam. The majority of the cam surface consists of the intermediate level. The 9-10 contact arm controls the position of the 9-10 brush. During the time that the contact arm is riding on the intermediate level of the cam, the 9-10 brush is not making on either side of the contact assembly.

In Figure 144, the 9-10 contact arm is resting on the zero position. As the adding wheel assembly rotates counterclockwise, the position directly beneath the contact arm progresses until the contact arm drops into the low dwell. The low dwell of the cam represents the nine position and when the contact arm is in the low dwell the 9-10 brush is permitted to move, under spring tension, until it is making

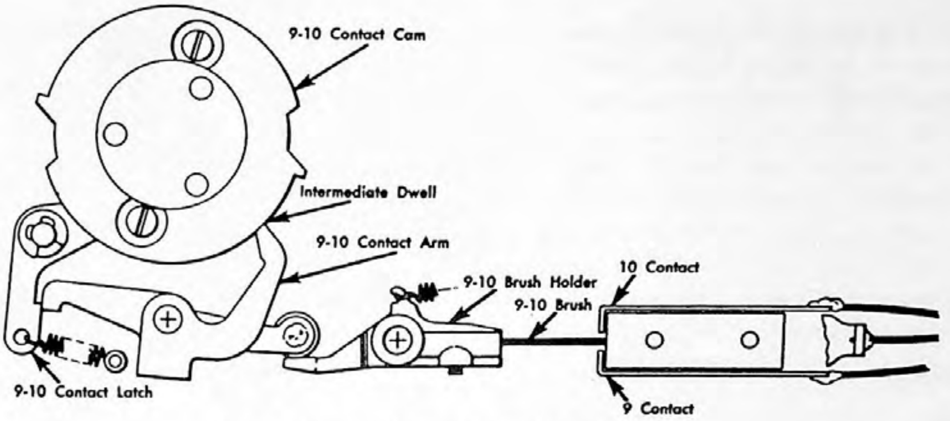


Figure 144. 9-10 Contact Cam, Arm, and Contact

contact on the 9 side of the 9-10 contact assembly as seen in Figure 145. The contact now indicates that a nine is in the counter.

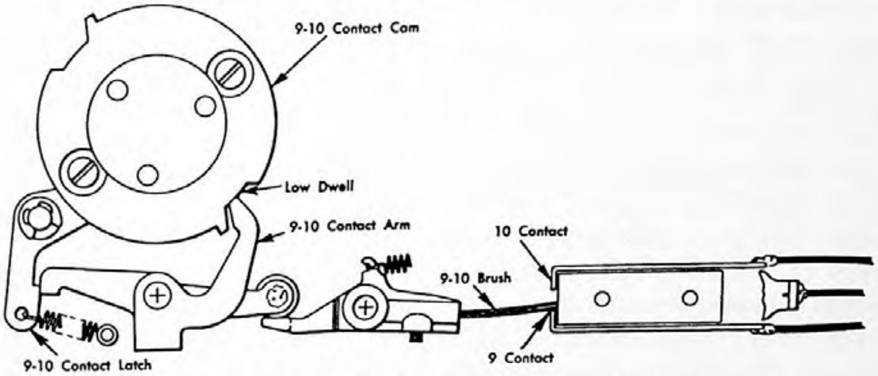


Figure 145. 9-10 Contact Arm and Contact in 9 Position

If the adding wheel continued to turn, the 9-10 contact arm would ride up on the high dwell of the contact cam. The 9-10 brush would then be cammed up so that it would make contact on the 10 side of the 9-10 contact assembly (Figure 146). The position immediately following the nine position is the zero position. It can be concluded then that the 9-10 contact will make on the 10 side whenever the adding wheel is rotated from the nine position to the zero position.

Anytime the counter moves from nine to zero, a carry is needed. The carry operation must take place after the adding operation is completed so the counter

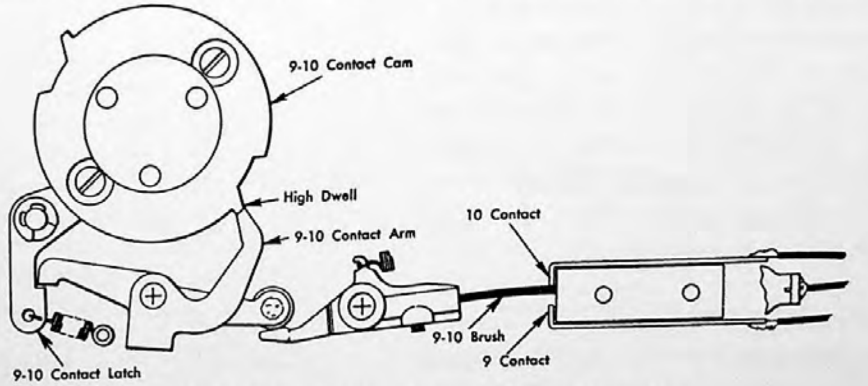


Figure 146. 9-10 Contact Arm and Contact Passing From 9 to 0

must remember if it moved from nine to zero. To enable the counter to do this, a latch is provided to hold the 9-10 brush made on the 10 side. Figure 146 shows that as the 9-10 contact arm rides up on the high dwell of the contact cam, the left end of the arm will be raised high enough for the 9-10 contact latch to move under it. The 9-10 brush will now remain made on the 10 side until after the counter has carried. A roller on the back of the driven gear will then trip the latch permitting the 9-10 contact to return to normal.

Counter Emitter

The counter emitter, on the 402 type counter, is used for summary punching and conversion operation which will be covered when the machine is studied.

Counter Chart

To facilitate the understanding of counter operation, a counter chart, shown in Figure 147, will be used. The counter chart has six positions which represent six counters. Counters in a machine are grouped into counter groups of 2, 4, 6 and 8 counters. At the top of the chart the positions are labeled. The first position on the right is the units position, the second position is the tens position etc. Either of these terms may be used to describe a specific position. The counter position will not be indicated on the following charts.

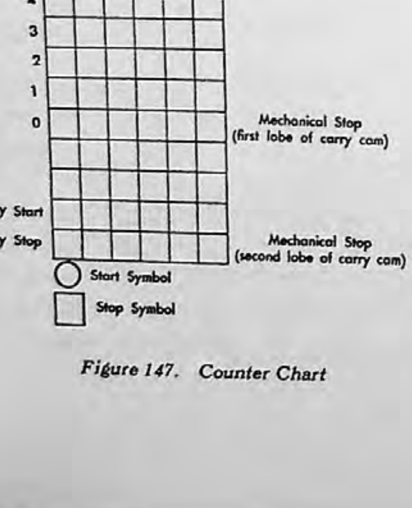


Figure 147. Counter Chart

Along the left side of the chart the numbers that can be accumulated are indicated. These numbers also represent the time that a punched hole, corresponding to the digit to be accumulated, would be read.

The times that the two lobes of the carry cam disengage the counter clutch are shown on the right-hand side of the chart.

At the bottom of the chart, symbols are shown which are used to indicate when a counter is started or stopped.

Counter Operation

To illustrate counter operation, a problem will be studied using a counter chart. The number 195 is to be accumulated in a six-position counter group. The counters are all in the zero position.

The number 195 is to be read from a card as it passes a reading station, and the impulses directed to the start magnet corresponding to the position read. The five will be sent to the units position, the nine sent to the tens position, and the one to the hundreds position. In any machine using this type counter to accumulate, the cards are always fed 9-edge first so that as a card passes the reading brushes, the nine will be the first hole read.

Figure 148 shows that all positions of the counter group are at zero before the card is read. The adding wheels are not turning because none of the clutches has been engaged. However, the driven gear is rotating. As the card advances, and the nine hole is sensed, the impulse is directed to the start magnet in

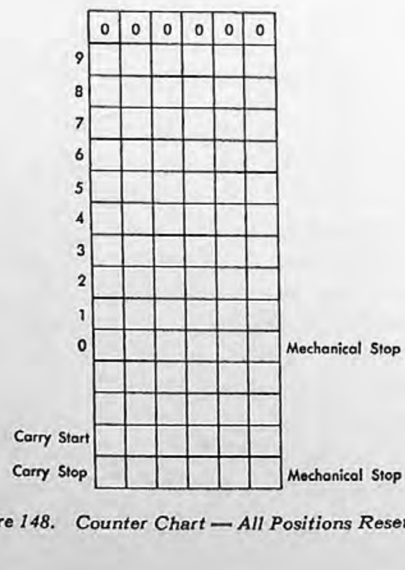


Figure 148. Counter Chart — All Positions Reset to Zero

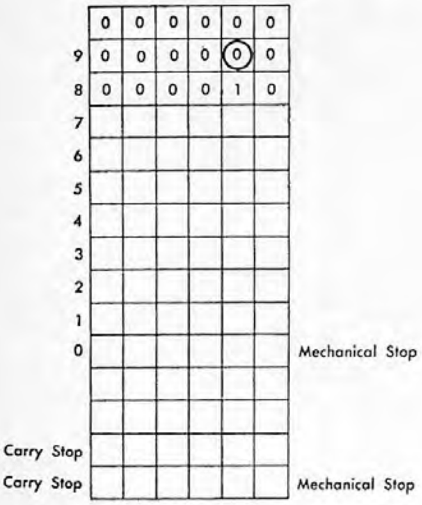


Figure 149. Counter Chart

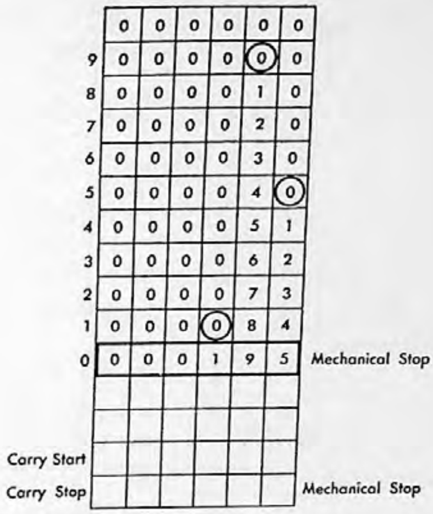


Figure 151. Counter Chart

the tens position. This is shown on the chart by a start symbol in the tens position opposite the nine (Figure 149). One cycle point later when an eight would be read, the add wheel in the tens position has advanced to the one position. None of the other counters has turned because their start magnets have not been energized. The next hole to be read is the five hole in the units position of the card. The impulse resulting from sensing the five hole energizes the start magnet in the units position (Figure 150). The add wheel of the tens position counter has advanced to the four position, and none of the others has advanced.

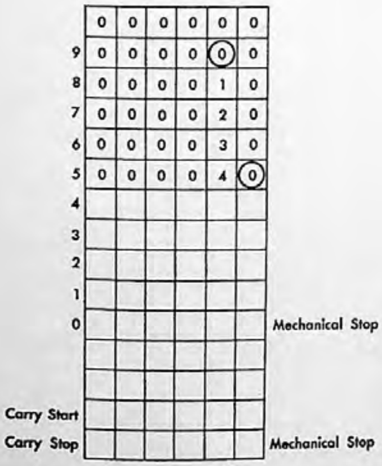


Figure 150. Counter Chart

Figure 151 shows the counter chart at zero time when all positions which have been started are stopped by the first lobe of the carry cam. The counter now contains the number 195. The counter group did not accumulate enough in any position to cause a carry so the amount shown at zero is the total amount accumulated.

The circuits required to add are shown in Figure 152. The counter chart shows that the only electrical impulses necessary were the impulses to the start magnets. The impulses result from reading a hole in the card and are available at a hub on the control panel. The wiring to the start magnet also terminates at a hub on the control panel. They are arranged this way so that any brush position may be wired to any counter position for flexibility.

The counter numbering in Figure 152 may appear to be inconsistent. However, it is consistent with the punching in the card columns to facilitate wiring. For example, if the amount to be accumulated is punched in columns 61 through 66, the units position of the amount would be punched in column 66. Column 66 would be wired to counter six, etc., which would eliminate confusion in wiring and result in a neater control panel.

Assume that a second card is now passing the brushes and that columns 61 through 66 are punched 000908. This amount is wired to be accumulated in

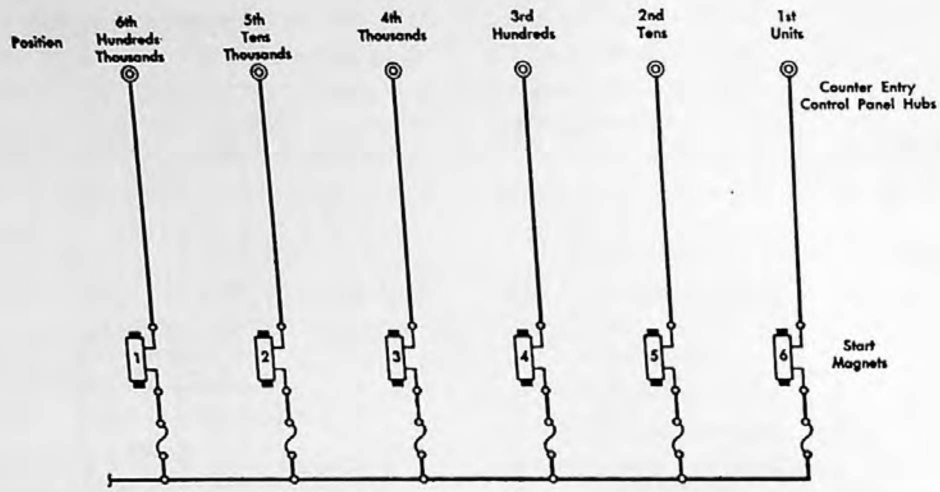


Figure 152. Circuit Necessary for Adding Only

the counter group which already contains the amount 195 from the preceding card. The chart shown in Figure 153 shows, at the top, that the amount 195 is already in the counter.

From this same figure it can be seen that the third position is started when the nine is sensed in column 64. The units position start magnet is impulsed when the eight is sensed in column 66. The important thing to note at this time is that, as the units counter advances from four time to three time, the counter add wheel advances from nine to zero. As this occurs, the 9-10 brush makes contact on the tens side and is latched in this condition. This enables the machine to remember to carry. A notation should be made on the chart to indicate this. A "t" can be placed in the square just above carry time in the column in which it occurred to represent the 9-10 contact latched on the 10 side. This will assist in the correct completion of the chart. This notation should be made as soon as the adding wheel has advanced this far.

Figure 154 shows the operation complete with the exception of the carry operation. The actual amount in the counter before carry time is 000093 with the 9-10 brushes in the 1st and 3rd positions latched on the 10 side to initiate a carry into the next higher order positions. This figure also shows a start impulse in the 2nd, 4th, 5th and 6th positions at zero time. This happens because the zero holes are sensed at this time. The start magnets actually accept these impulses and the armatures release the engaging cam

	0	0	0	1	9	5	
9	0	0	0	1	9	5	
8	0	0	0	2	9	5	
7	0	0	0	3	9	6	
6	0	0	0	4	9	7	
5	0	0	0	5	9	8	
4	0	0	0	6	9	9	
3	0	0	0	7	9	0	
2							
1							
0							Mechanical Stop
Carry Start							
Carry Stop							Mechanical Stop

Figure 153. Counter Chart

	0	0	0	1	9	5	
9	0	0	0	1	9	5	
8	0	0	0	2	9	5	
7	0	0	0	3	9	6	
6	0	0	0	4	9	7	
5	0	0	0	5	9	8	
4	0	0	0	6	9	9	
3	0	0	0	7	9	0	
2	0	0	0	8	9	1	
1	0	0	0	9	9	2	
0	0	0	0	0	9	3	Mechanical Stop
				t		t	
Carry Start							
Carry Stop							Mechanical Stop

Figure 154. Counter Chart

arms. However, before the clutches can be engaged, the first lobes of the carry cams lift the engaging cam arms back to a latched position on the start magnet armatures. It is not necessary to show these impulses at zero time.

Carry Operation

Another fundamental fact must be considered before this problem can be completed. If, manually, the number five is added to 95, it is immediately recognized that a carry into the tens position is necessary. In addition, because the carry is directed to a position which has a value of nine, it is also necessary to carry into the hundreds position. In a manual operation, the carry is made in one position and later in another position. However, in machine operation, all carrying must take place at the same time. It is, therefore, necessary that the machine recognize when a carry is made into a position which contains a nine, and not only accept the impulse, but immediately pass it on to the next higher order position.

Figure 155 shows the previous problem completed and illustrates the principles of carrying. The carry into the second position was the result of the 9-10 brush in the first position being latched on the 10 side. The carry into the 4th position was the result of the 9-10 brush being latched on the 10 side in the 3rd position. However, the impulse to carry in

	0	0	0	1	9	5	
9	0	0	0	(1)	9	5	
8	0	0	0	2	9	(5)	
7	0	0	0	3	9	6	
6	0	0	0	4	9	7	
5	0	0	0	5	9	8	
4	0	0	0	6	9	9	
3	0	0	0	7	9	0	
2	0	0	0	8	9	1	
1	0	0	0	9	9	2	
0	0	0	0	0	9	3	Mechanical Stop
	0	0	0	0	9	3	
	0	0	0	¢ 0	9	¢ 3	
Carry Start	0	0	(0)	(0)	(9)	3	
Carry Stop	0	0	1	1	0	3	Mechanical Stop

Figure 155. Counter Chart

the 3rd position was the result of the 9 in the 2nd position passing on the impulse it received from the 1st position. All counters that are started for carrying are stopped by the second lobe of the carry cam. The sum is now correct and may be checked manually.

To facilitate the understanding of the carry operation, the circuits necessary for carrying will be added to those which were necessary to merely add the amount from one card. The necessary wiring is shown in Figure 156 and the 9-10 brushes are in po-

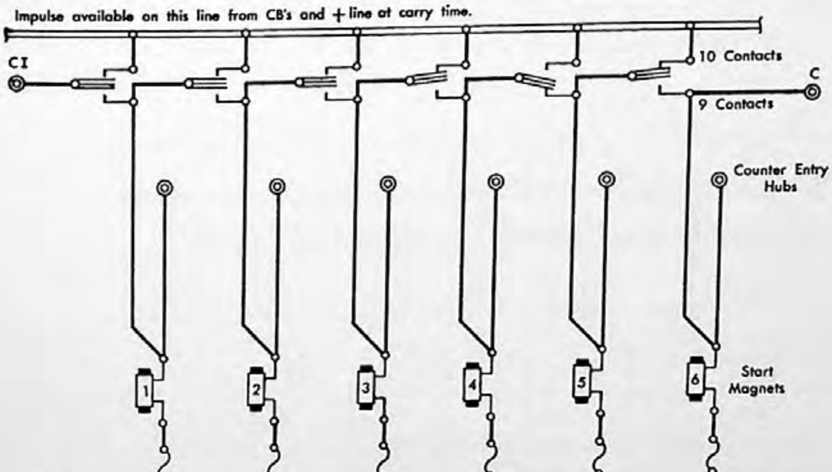


Figure 156. Circuit Necessary for Adding with Carry

sition to provide the necessary carry for the problem just completed. It will be remembered that the 9-10 brushes in the first and third positions were latched on the 10 side. The 9-10 brush of the second position was made on the nine side, because this counter contained a nine and the low dwell of the 9-10 contact cam represents the nine position.

At carry time, an impulse from the plus side of the line through a cam operated contact is available at the 10 side of all 9-10 contact assemblies. Any or all 9-10 brushes made on the ten side receive this impulse at precisely the same instant. In this case the first and third brushes accept this impulse. In the third position, the impulse travels through the brush to the 9 side of the 9-10 contact assembly in the next higher order position (Position 4). It then goes straight down to impulse the start magnet of position four (Counter #3), to the fuse and the negative side of the line.

In the first position, the impulse passes through the brush and follows a similar path to impulse the start magnet in the second position. However, at the same time, a parallel circuit is available from the 9-10 brush in the first position through the 9 side of the 9-10 contact assembly in the second position to the start magnet of the third position counter. This happens because the counter recognizes a nine in the second position by the 9-10 brush making contact on the nine side.

The nine side is only effective when a carry is made into a position which contains a nine. A brush making on the nine side does not start a carry but merely passes the impulse along, if it receives one. However, it should be noted that, if several nines are in adjacent counters and the first receives an impulse to carry, the impulse is passed on until a nine is not encountered. Figure 157 illustrates this. In this figure, the 9-10 contact is latched on the 10 side in the first position only. This will initiate a carry into the second position, but, since there is a nine in the second position, the third position will also carry. There is also a nine in the third position which causes the fourth position to carry. However, the impulse will not be passed on to the fifth position because the 9-10 brush of the fourth position is not making on the nine side. Also note that even though the 9-10 brush in the fifth position is making on the nine side there is no carry into the sixth position as a result.

Timing

The adding wheel must advance one position for every unit to be added. This requires that the adding wheel advance one position for every cycle point the clutch is engaged. To better understand the actual operation of the counter, a few timings relative to the index should be considered.

This type of counter is used only in machines having 20 cycle points per cycle. This results in each cycle point containing 18 degrees. The adding wheel must turn during 18 degrees on the index for each unit to be added. If a nine is to be accumulated in a counter, the counter must turn for $18° \times 9 = 162°$. The brushes and CB's are timed so that a nine is sensed

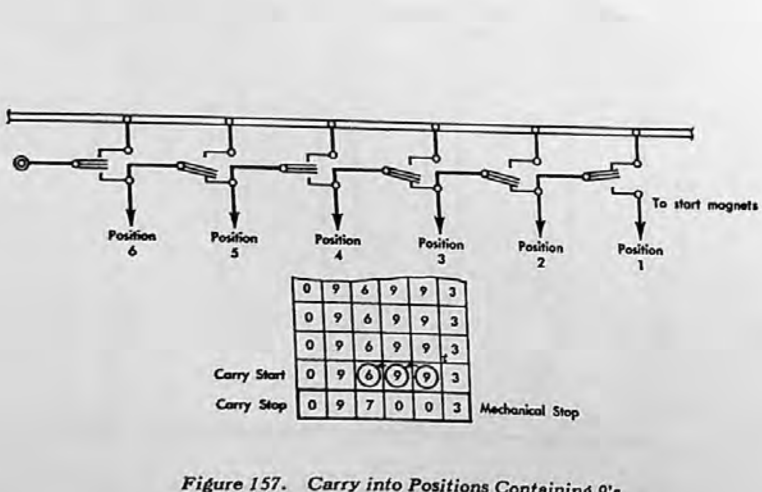


Figure 157. Carry into Positions Containing 9's

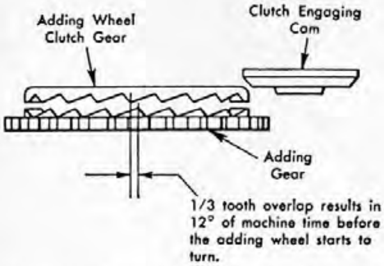


Figure 158. Counter Clutch Tooth Overlap

at 9°. The start magnet is energized at 9°, but the adding wheel does not begin to turn immediately. Figure 158 shows that when the start magnet is impulsed, and the clutch attempts to engage, the teeth are not in a position to mesh fully. This is done to allow time for the teeth on the adding wheel clutch gear to engage the next tooth on the adding gear. The teeth on the driven gear overlap the teeth on the adding wheel assembly by a third of a tooth or 6°. From this, it is easily seen that the driven gear must turn 12° before the clutch teeth mesh. Now recall that the impulse reading a 9 hole is available at 9°, that there is a 12° lag before the adding wheel starts to turn, and that the adding wheel must turn 162° to accumulate a nine. The time on the index when the adding wheel must stop is the sum of these or 9° + 12° + 162° = 183°. The first lobe of the carry cam must disengage the adding wheel clutch at that time.

Assume that an eight is to be accumulated. An 8 hole is sensed 18° later than the 9 hole so it is sensed at 27°. The adding wheel must turn 18° x 8 = 144°. Therefore, the adding wheel must be stopped at 27° + 12° + 144° =183°. The time when the adding wheel should stop can be checked in this manner for each digit, and it will be found to be 183° in each case. However, if a zero hole is sensed, the adding wheel should not advance. A zero hole is sensed at 171° and the clutch would engage 12° later at 183°, but at 183° the clutch is disengaged by the first lobe of the carry cam. This prevents the adding wheel from advancing when the start magnet is energized from a zero hole. Complete the table in Figure 159.

The start magnet is energized at 225° for the carry operation. It is only necessary to advance the adding wheel 18° or one position to carry. Therefore, the second lobe on the carry cam must disengage the clutch at 225° + 12° +18° = 255°.

PRINCIPLES OF SUBTRACTION

THE FOLLOWING is an example of manually subtracting one number from another.

$$\begin{array}{r} 46983 \\ -21692 \\ \hline 25291 \end{array}$$

Theoretically there are two possible ways of performing this operation in a counter. One is to turn the counter wheel backwards. The second is to add a figure which will advance the counter to the correct position.

The driving gear turns in only one direction, however, and the adding wheel clutch teeth are cut so that the counter wheel will only turn in one direction. The alternative is to accomplish subtraction by adding the complement of the number to be subtracted.

Figure to be added	Hole in card	CB Time (Degrees)	Start Magnet Energized (Degrees)	Add Wheel Starts (Degrees)	Add Wheel Stops (Degrees)	Add Wheel has turned (Degrees)	Add Wheel has turned (cycle point)
9	9	9	9	21	183	162	9
8							
7							
6							
5	5	81	81	93	183	90	5
4							
3							
2							
1							
0							

Figure 159. Counter Table

Subtraction — Type 405 Machine

When this counter is used in a type 405 machine, the complement of any number can be determined by subtracting that number from a figure made up of 1 followed by as many zeros as there are positions in the counter group to be used. For example, to determine the complement of 1,234 when using a 6-position counter, subtract 1,234 from 1,000,000 as follows:

```
1,000,000
    1,234
---------
  998,766
```

In other words, the complement is obtained by subtracting the first significant figure at the right from 10, and all other positions to the left from 9. The first significant digit is a complement on a ten base, while all digits to the left are complements on a nine base.

```
9999910
00123 4
-------
99876 6
```

With a figure ending in zeros (012300), the same rule applies: subtract the first significant digit at the right from 10 and all other digits from 9.

```
9991000
012 3 00
--------
987 7 00
```

Therefore, for the first significant digit of an amount to be subtracted, subtraction is accomplished by adding the difference between 10 and the digit to be subtracted. Thus:

To subtract 9, add a 1
To subtract 8, add a 2
To subtract 7, add a 3
To subtract 6, add a 4
To subtract 5, add a 5
To subtract 4, add a 6
To subtract 3, add a 7
To subtract 2, add an 8
To subtract 1, add a 9

For all positions to the left of the first significant digit, subtraction is accomplished by adding the difference between nine and the digit to be subtracted. Thus:

To subtract a 9, add a 0
To subtract an 8, add a 1
To subtract a 7, add a 2
To subtract a 6, add a 3
To subtract a 5, add a 4
To subtract a 4, add a 5
To subtract a 3, add a 6
To subtract a 2, add a 7
To subtract a 1, add an 8
To subtract a 0, add a 9

Counter Operation — Subtraction

First, it is necessary to know when and how the counter adding wheel must start and stop. Figure 160 shows how a complement is added. The number to be subtracted is 7, and if it is the first significant digit, its complement is 3. A 3, then, is the number to be added.

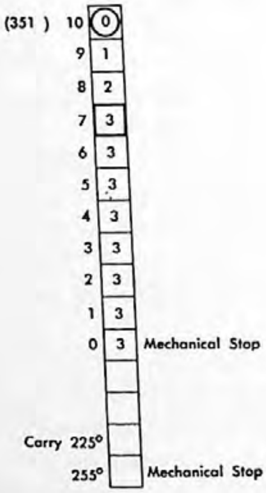


Figure 160. Subtraction in the Units Position

It should be remembered that the machine will sense a 7 hole and the impulse must result in a 3 being added. The 7 impulse would normally cause the add wheel to start and the counter to accumulate a 7. However, if the counter is started 3 cycle points earlier and stopped by means of the 7 hole being sensed, a 3 will be accumulated. The impulse, to start the counter, would have to be available one cycle point before 9 time which will be referred to as 10-time hereafter.

The index time for this impulse would be 351°, 18° before 9 time (9°). It should be recognized that, if the start magnet in the units position is impulsed at 351°, and the stop magnet is impulsed from the hole in the card, the correct complement will be added for any digit punched in the card.

In all positions to the left of the first significant digit, the number added should be based on a 9's complement. Therefore, to add the correct complement of a digit in one of these positions it would be necessary to energize the start magnet at 9-time and stop it by an impulse from a hole in the card. Note that if a 9 is to be subtracted, a zero should be added or in other words, the adding wheel should not advance. In this case the start magnet and the stop magnet receive an impulse at the same time. When this occurs, the clutch engaging cam arm will be relatched before the adding wheel can advance.

The following problem illustrates these principles. Assume two cards are fed through the machine and the amounts are accumulated in a six-position counter group. The first card is punched 006902 and is added. The second card is punched 001945 and is subtracted. This problem is done manually and the result is shown below.

+006902
−001945
+004957

The counter operation for this problem is shown in Figure 161. The information accumulated on the first cycle is added, in the manner previously described, with the impulses from the brushes starting the counters and the counters being stopped by the first lobe of the carry cams.

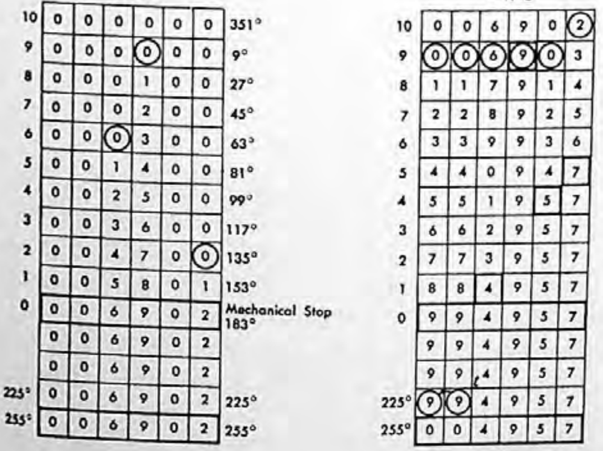


Figure 161. Counter Chart — + 6902 − 1945

The numbers sensed from the second card are subtracted by adding the complement of 1945. The impulse used to start the units position counter occurs at 351° or 10-time, and is referred to as a "hot 10" impulse. The impulse which starts all other counters in the counter group comes at 9-time (9°) and is called a "hot 9" impulse. In the columns where a digit is sensed, the resulting impulse is directed to the stop magnet to stop the adding wheel. In positions where no hole or a zero hole is sensed, the counters are stopped at zero by the first lobe of the carry cams or the zero impulse.

The carry operation takes place in a normal manner with the 9-10 brush latched on the ten side initiating a carry. Positions which receive an impulse to carry and contain a 9, also pass this impulse on to carry in the next higher order position. The high order position counter attempts to pass the carry impulse on because it contains a nine, but there is no path for current flow.

The counter circuit as shown for adding operations is not adequate for subtracting. An impulse directed to the counter from a brush should energize the start magnet in an adding operation, but energize the stop magnet during subtraction. At times it is also desirable to neither add nor subtract the information in a card. These objectives are accomplished by controlling the counter with relay points. The relays whose points are used to control the counter

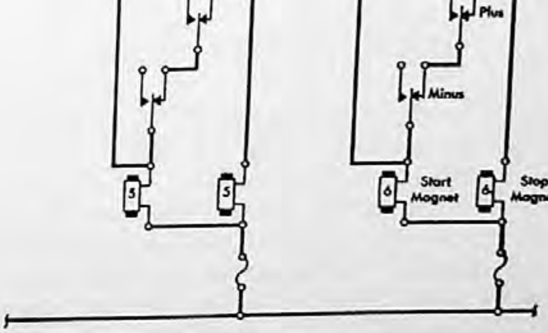


Figure 162. Counter Control Circuits

will be under the control of holes in the card which identify the information. Two relays are used, a plus relay and a minus relay. Figure 162 shows how the points of the relays are placed in the counter control circuits to instruct the counter to either add, subtract or not accept any information.

If neither the plus nor the minus relay is energized, the impulse received by the counter entry hub will not reach either the start magnet or the stop magnet. If the plus relay is energized, the impulse will be directed to the start magnet. If the minus relay is energized, the impulse will be directed to the stop magnet. A N/C minus relay point is placed in the circuit to the start magnet to open this circuit.

A means of starting the counter on a subtract operation is shown in Figure 163. The N/O minus relay point is used to provide a circuit from the start magnet in the units position counter, to a wire which is always hot at 10-time. In any position other than the units position, when the minus relay is energized, the start magnet is connected to a wire which emits a 9 impulse to start the counter.

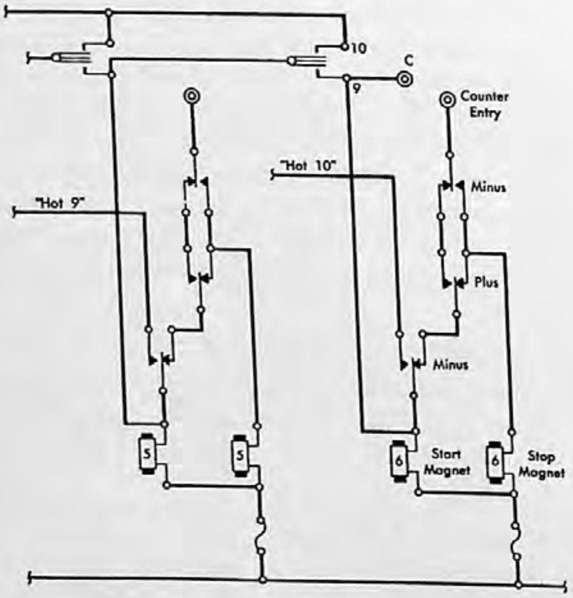


Figure 163. Counter Control Circuits

The complement of the first significant digit is based on 10 even though it does not occur in the units position. The units position is the only position which is started at 10-time for a 10's complement. However, the fact that it starts at 10-time and does not contain a significant figure signifies that the adding wheel will turn until 183°, thereby adding ten. The 9-10 brush latches and initiates a carry into the tens position. If there is a significant digit in the tens position, the additional unit added, as a result of the carry, puts it on a tens base. However, if there is no significant digit in the tens position it will have added 9. The carry into that position causes it to advance to zero and carry into the third position, thereby putting the third position on a 10's base. There will be a 10 added in every position until the first significant digit is encountered. Figure 164 illustrates, by means of a counter chart, the way in which a counter locates the first significant digit. The number 005900 is subtracted from a counter which has not had anything accumulated in it previously, and the amount accumulated should now be the complement of the number added or 994100.

	−005900					
10	0	0	0	0	0	0
9	0	0	0	0	0	1
8	1	1	1	0	1	2
7	2	2	2	0	2	3
6	3	3	3	0	3	4
5	4	4	4	0	4	5
4	5	5	4	0	5	6
3	6	6	4	0	6	7
2	7	7	4	0	7	8
1	8	8	4	0	8	9
0	9	9	4	0	9	0
	9	9	4	0	9	0
	9	9	4	0	9	c 0
225°	9	9	4	0	9	0
255°	9	9	4	1	0	0

Figure 164. Counter Chart

Sign Indication

An accumulating mechanism should indicate the algebraic sign of the amount it contains. In Figure 164 the amount was negative and the counter contained a complement figure. In the preceding counter problem shown in Figure 161, the amount accumulated was positive, and the counter contained a true figure. In this way the algebraic sign is indicated. A complement figure (a negative sign) is indicated by a nine in the high order position. To be sure that the sign is always correctly indicated, it is necessary that the counter group always have a capacity of at least one position more than the maximum amount to be accumulated. If this is done, the high order position will always contain a zero if the amount is plus, i. e., a true figure. It will always contain a nine if the amount is a negative or complement figure. As an example of the rule, if amounts are to be accumulated and the total may contain as many as four digits, a four position counter group could not be used. A four position total would require a five-position counter group. However, because counters are grouped in 2, 4, 6 and 8 position counter groups, a six or eight position counter group would be necessary.

Subtraction — Type 402 Machine

Type 402 machine uses the same counter as the Type 405 and its functions are identical. However, a subtract operation differs slightly from the Type 405 subtract operation in that a complement system based on a 9 in all positions including the units position is used.

It can be seen from the following example that if a number is subtracted from another number and the balance remains positive, the units position will be one low. The number in the counter is 862. The number to be subtracted is 495. Therefore, 999504 would be added, assuming a six-position counter. The results would be as follows:

```
0 0 0 8 6 2
9 9 9 5 0 4
-----------
9 9 9¢3 6 6
1 1 1
-----------
0 0 0 3 6 6
```

Figure 164A

The result should be 000367 so the counter is one low. As more cards are accumulated, the error will increase. This operation is not satisfactory, obviously, as the amount accumulated must be accurate.

Now recall that in an earlier example the high order position attempted to carry, but could not. This was because the nine side of the 9-10 contact was trying to pass the impulse on, but the 9-10 brush was not connected to a start magnet. However, the 9-10 brush in the high order position is connected to a control panel hub labeled CI (Figure 156). The hub CI (carry impulse) emits an impulse when the high order position attempts to carry. It should also be noted that the 9 side of the 9-10 contact in the units position counter is connected to a control panel hub, C. The C hub is a carry entry hub which accepts a carry impulse. If the CI hub is connected to the C hub by control panel wire (Figure 165) when the same two cards are run through the machine, the result is as follows:

```
0 0 0 8 6 2
9 9 9 5 0 4
-----------
9 9 9¢3 6 6
1 1 1 0 0 1
-----------
0 0 0 3 6 7
```

Figure 164B

The result is now correct because the high order position carried back into the units position. When the counter contains a true figure, this will occur every time an amount is subtracted and the total remains positive. If the amount in the counter is negative, it will occur every time an amount is subtracted or when an amount is added that will make the sign positive.

The counter wiring is the same as for the 405 with one exception. The units position start magnet

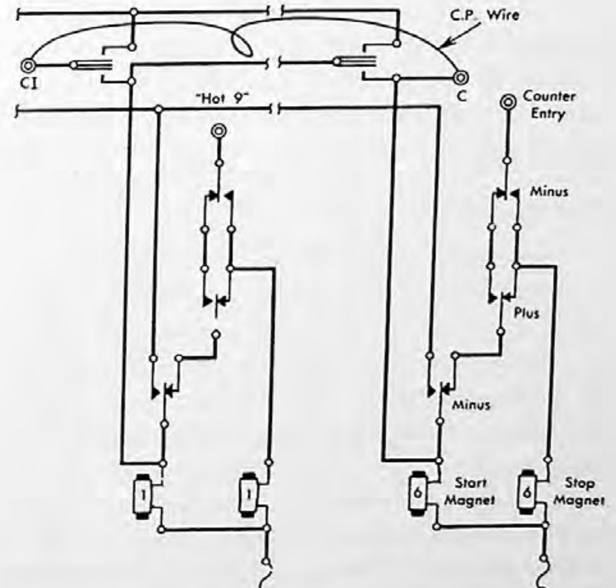


Figure 165. Counter Wiring

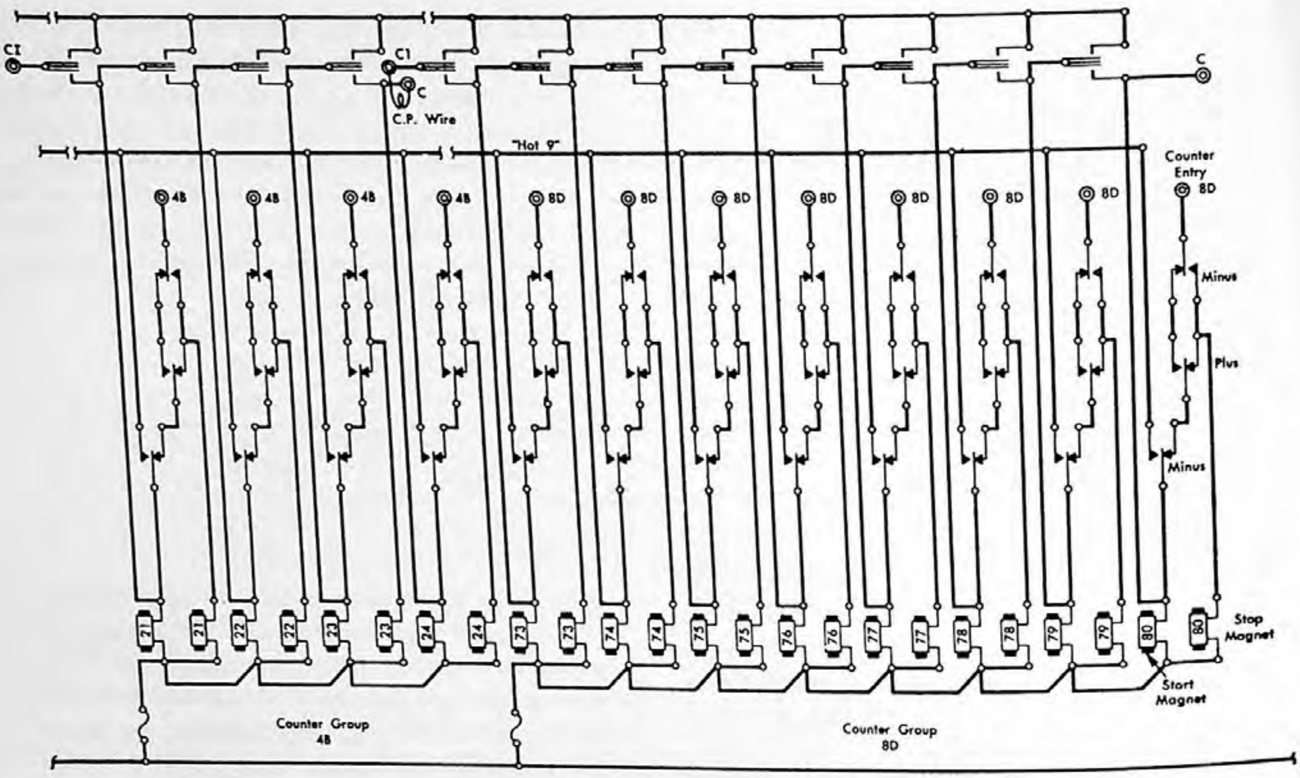


Figure 166. Counter Coupling

is connected to the "hot 9" wire when the minus relay is energized, as are the other positions. The CI and C control panel hubs must be connected by control panel wiring.

Counter Coupling

The CI and C hubs serve another purpose, that of coupling counters. For example, the largest counter group in the machine has eight positions, but assume it is necessary to accumulate a figure which contains 10 digits. Obviously a counter of greater capacity is needed. A larger counter may be obtained by coupling two or more counter groups together. If an eight and a four position counter are coupled, the resulting counter group will have 12 positions, which will be sufficient. The only requirement for coupling counters is to cause the high order position of one to carry into the units position of the other. This is accomplished by control panel wiring. The CI hub of the low order counter group is wired to the C hub of the high order counter group. Figure 166 shows two counters coupled together.

The counter groups have been labeled to facilitate description. With the control panel wiring as shown, counter 80 is the units position counter, and counter 21 is the high order position counter. However, the person wiring the control panel will determine which is the low and high order counter groups. If the control panel wire is inserted so that it will connect the CI hub of counter group 4B and the C hub of counter group 8D, then counter 24 is the units position and counter 73 the high order position counter.

Read Out and Reset

The read out and reset of the 402-405 type counter is done in one operation. As a counter reads out the information it contains, the counter adding wheel must stop at its zero position. The counter may have any number in it at the time the counter is to be cleared or reset. For this reason, the mechanical stop at 183° is not a satisfactory way to stop the adding wheel. The counters may be stopped by energizing the stop magnet when the counter adding wheel reaches zero. Recall that the 9-10 brush makes on the 10 side to recognize when the counter reaches zero. The timed impulses are available at the 10 side of the 9-10 contact so that when the 9-10 brush makes, an impulse is directed to the stop magnet and to a counter exit hub. The stop magnet will stop the counter adding wheel at zero and the counter exit hub can be wired to a print magnet or counter entry hub as desired by the operator.

The time that the impulse is available is as important as it has been in previous operations. The counter and type bars must be synchronized so that the information reading out of the counter will reach the type bar when the type bar is in a position to print the correct information. Information is also read from a card and printed, which signifies that the card movement and sensing, readout, and type bar movement must all be synchronized.

For this to be true, the adding wheel must reach zero at the time corresponding to the digit to be read out. For example, if the counter contains a nine to be read out, the adding wheel must reach zero at 9-time. The same is true of all other digits. If the counter has a nine, it must advance only one position to be at zero. The counter should be started one cycle point before 9-time or at 351° to cause it to reach zero at 9-time. A counter which contains an eight would have to advance two cycle points to reach zero. Therefore, it would have to be started at 351° or 10-time, to reach zero at 8-time. It will be found that for every digit, the counter will have to be started at 351° to reach zero at a time corresponding to the digit read out. This is illustrated by the counter chart in Figure 167.

The counter chart shows that all positions in a counter clearing on a total cycle move from 9 to zero and latch the 9-10 contact on the 10 side. It is not desirable to carry after the counters have been reset to zero, so a means must be provided to prevent it.

From a circuit standpoint the objectives to be accomplished are as follows:

1. At 10-time, start all counters in the counter group which is to read out and reset.
2. Provide a circuit to the stop magnet and counter exit hub from the 10 side of the 9-10 contact as the counter advances from nine to zero.
3. Prevent a carry during a total cycle.

10	(0)	(5)	(9)	(0)	(2)	(3)
9	1	6	0	1	3	4
8	2	7	0	2	4	5
7	3	8	0	3	5	6
6	4	9	0	4	6	7
5	5	0	0	5	7	8
4	6	0	0	6	8	9
3	7	0	0	7	9	0
2	8	0	0	8	0	0
1	9	0	0	9	0	0
0	0	0	0	0	0	0
	0	0	0	0	0	0
	t 0	t 0	t 0	t 0	t 0	t 0
225°	0	0	0	0	0	0
255°	0	0	0	0	0	0

Figure 167. Counter Chart — Readout and Reset

Figure 168 shows how these objectives are accomplished. A total relay point is added in the circuit to the start magnet. It will not affect the circuit during adding or subtracting because it will be normal, but on a total cycle, when the counter is to read out and reset, it will be transferred. The total relay N/O point now connects the start magnet to the "hot 10" impulse to start the counter at 10-time.

The 10 side of the 9-10 contact is connected to a wire which emits an impulse every cycle point for read out and resetting as well as one at 225° for carrying. When the 9-10 brush makes against the 10 side as the counter is advancing from nine to zero, an impulse is available through the brush to another total relay point which has been added. This point is transferred, and the impulse is sent through the normally open point to the counter exit hub, which is wired by a control panel wire to a print magnet, counter entry, etc. There is also a parallel circuit through the N/O total relay point, to the right and down to a N/C minus relay point as a terminal, up to and through the N/C plus relay point and down to the stop magnet. This circuit stops the counter, which has now been reset to zero.

The total relay point is transferred on a total cycle only, so that it will not interfere with normal carry operation. However, it will remain energized during the total cycle long enough to prevent a carry during the total cycle.

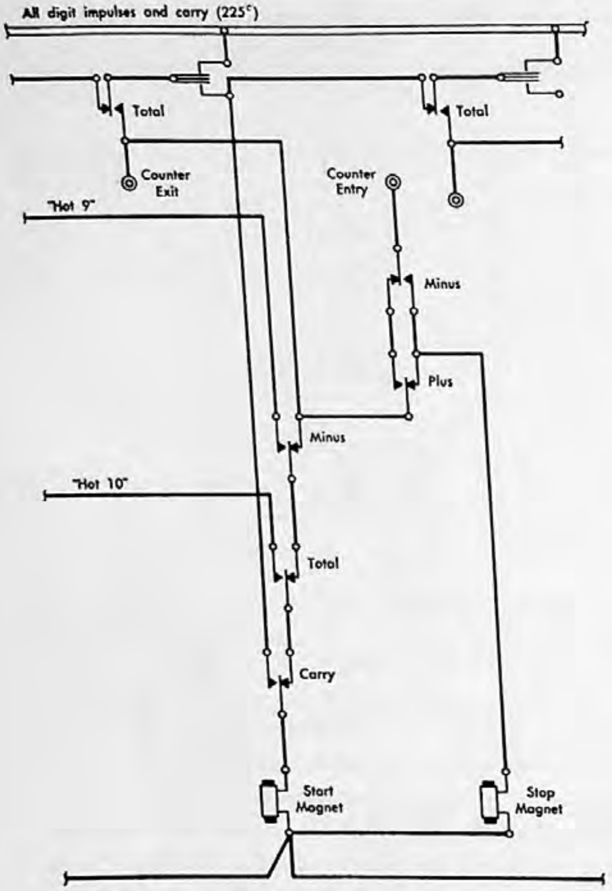


Figure 168. Control Circuits — Readout and Reset

Because the 10 side of the 9-10 contact is connected to CB's which emit all digit impulses and the carry impulse, another minor problem is presented. When the 9-10 brush makes on the 10 side of the 9-10 contact during an adding or subtracting operation, it will cause the next higher order position start magnet to be energized immediately, unless something is done to prevent it. To overcome this, a carry relay is used and its points are placed in the circuit so that a carry impulse will not reach the start magnet unless the relay is energized. The relay is controlled by a cam operated contact so that it will only be energized during carry time. It will not interfere with any other operation.

COUNTER OPERATION SUMMARY

Adding

The counter is started by an impulse to the start magnet resulting from a brush sensing a hole in a card.

The counter is stopped mechanically by the first lobe of the carry cam.

Carrying

The counter is started by an impulse to the start magnet originating from a 9-10 brush latched on the 10 side of the 9-10 contact at 225°.

The counter is stopped mechanically by the second lobe of the carry cam.

Subtracting

The counter is started automatically by an internal circuit completed to the start magnet.

The counter is stopped by an impulse to the stop magnet resulting from a brush sensing a hole in a card.

Read Out and Reset

The counter is automatically started at 351° by an internal circuit completed to the start magnet.

The counter is stopped, and the information read out, when the counter advances to zero, by an impulse to the stop magnet and counter exit hub. The impulse originates from 9-10 contact when the 9-10 brush makes contact on the 10 side.

RATCHET TYPE COUNTER

THE RATCHET type counter is another accumulating mechanism and is used in the Type 602A Calculating Punch. This counter is similar to the Type 402 counter in that it is driven by means of a continuously running drive shaft and drive gear. The counter accumulates about the same as the Type 402 counter. However, this counter may be referred to as a complement counter because it accumulates a complement figure for amounts to be added and accumulates true figures for amounts to be subtracted. This is exactly the reverse of the Type 402 counter operation, but the methods are the same, i. e., when accumulating complements both are started at 9-time and stopped by a hole in the card, etc. Consistent with the reversal of operation, this counter resets to 9 instead of zero. The start and stop magnets control a ratchet type clutch, from which it derives its name.

The ratchet type counter has no carry cam and the counter wheel and ratchet gear make one revolution for each adding operation. This eliminates the necessity for timing the counter to the machine cycle during installation.

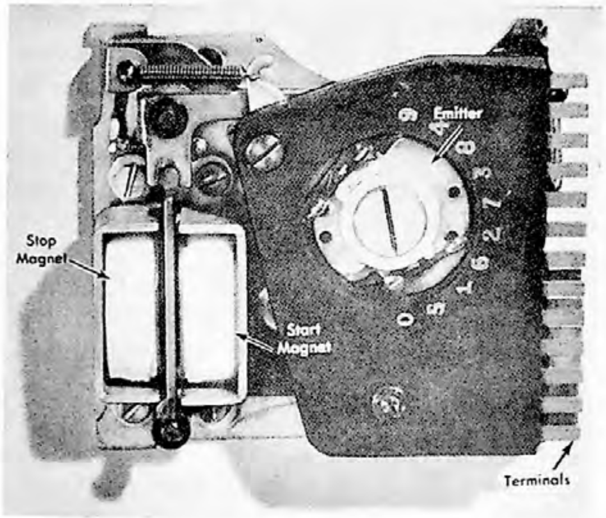


Figure 169. Ratchet Type Counter

The read out of this counter takes place through the emitter and does not require resetting to read out as the Type 402 counter does. However, it is capable of reading out and resetting in one operation which is controlled by the control panel wiring.

The ratchet type counter is pluggable, permitting removal and installation without disconnecting or connecting wires. Figure 169 shows the ratchet type counter, and from the illustration it can be seen that there is only one position per counter plate.

Mechanical Principles — Type 407 Counter

The ratchet type counter (Figure 170) used in the Type 407 is pluggable, permitting removal from the machine without disconnecting wires. This arrangement also makes it possible to wire the terminal mouldings before inserting counters. Both the ratchet

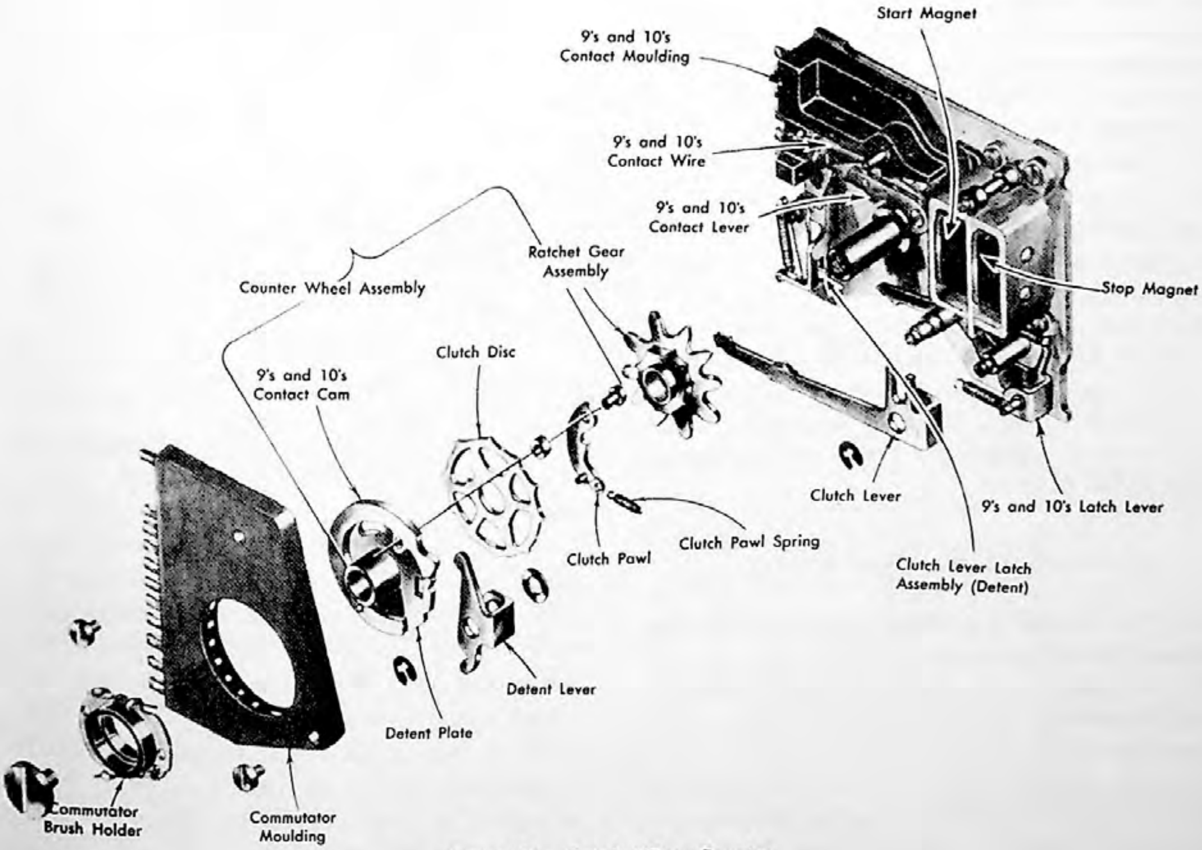


Figure 170. Ratchet Type Counter

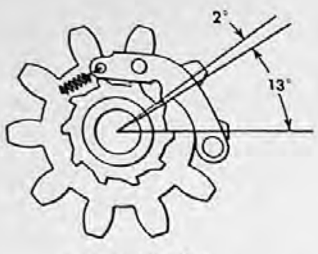


Figure 171. Counter Clutch Overlap

gear and ratchet have 10 teeth and allow one complete revolution of the counter wheel and ratchet gear for each adding operation. Since there are two adding cycles (direct entry and typewheel entry) of the counter for each machine cycle, there must be at least two complete revolutions of the ratchet gear for each machine cycle. The 407 is a 24 cycle point machine; consequently the counter drive gear has 24 teeth. Since the ratchet gear has 10 teeth and the counter drive gear has 24 teeth, the ratchet gear must make 2-2/5 revolutions for each machine cycle.

A mechanical knockoff is provided at the end of each of the two adding cycles plus a third knockoff after the carry impulse. These knockoffs are located on the counter drive gears, therefore, it is unnecessary to time the ratchet gear to the counter drive gear when the counters are inserted into the machine. The counters may be inserted into the machine at any point in the cycle; when reset, they return to their proper position.

Counters are accumulating devices used for adding or subtracting quantities normally punched in the card. They may also be used to add or subtract quantities from other counters or storage units. As the impulse is received from the card, the counter clutch becomes engaged and the counter wheel assembly begins to rotate.

COUNTER ADDING (DIRECT ENTRY)

At 155° (if adding by direct entry) the mechanical knockoff stops the counter wheel from turning. The final position of the counter depends on the distance the counter wheel turned before being stopped. Since this machine is a 24 cycle point machine, 15° represents the distance between each cycle point and each hole in the card. If 15° represents the distance between the successive readings from the card, the counter wheel must rotate 15° for each unit value to be accumulated. Thus, to add a 1, the counter wheel must turn for 15°; to add a 9, the counter wheel must turn 9x15 or 135°. At the time the start magnet receives the impulse to engage the counter clutch, the clutch pawl overlaps the ratchet assembly by 2° (Figure 171). Since there are 15° between the teeth on the ratchet, the ratchet must move 13° after the start magnet receives its impulse before the counter wheel actually starts to move. To add a 9 the impulse to the start magnet comes at 7° as noted by the timing chart. The counter wheel does not turn until 13° later or 20° on the index. As noted, in order to add 9 into the counter, the counter wheel must turn for 135°. Thus, to add a 9, the counter wheel starts turning at 20° and stops at 155°. The mechanical knockoff stops the counter wheel from turning at 155°. The mechanical knockoff starts to operate at 140° but does not actually stop the counter wheel until 155°. The mechanical knockoff operates at the same time each cycle. Thus it can be seen that, the higher the figure to be added, the sooner the counter clutch should be engaged to start the counter wheel turning since it will be stopped mechanically at 155° (Figure 172). If the start magnet becomes energized at 37°, the counter wheel starts rotating 13° later or at 50°. At 155° the counter wheel is stopped by the mechanical knockoff. Thus $155° - 50° = 105°$ of rotation of the counter wheel; $105° \div 15 = 7$ which means the counter wheel turned 7 cycle points and added 7 in the counter. In other words, if the start magnet is energized at 37°, a 7 will be added in the counter. The timing chart shows that 37° corresponds to the impulse for a 7.

As mentioned previously, this machine has two adding cycles within one machine cycle. The preceding explanation described the direct entry type of adding where the impulses to the start magnet came directly from the card brushes. The type wheel entry cycle is identical mechanically to the direct entry type. The difference in the two types is in the timing conditions. The start magnet on a type wheel entry cycle receives its impulses 150° later than it would on a direct entry cycle. Consequently the mechanical knockoff for the type wheel entry cycle is effective 150° later than for the direct entry cycle or at 305° (Figure 173).

The type wheel impulses sometimes referred to as echo impulses) are impulses coming from the print unit.

The preceding section has to do with the general operation of the counter when adding. The next section is to show *how* the counter does the adding.

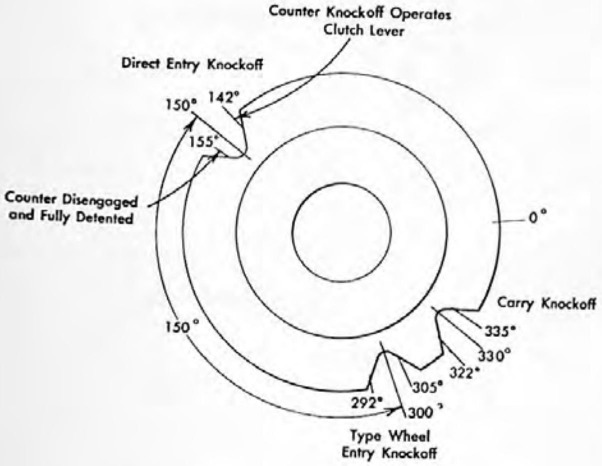


Figure 173. Counter Knockoff Cam

MECHANICAL OPERATION WHEN ADDING

A common armature operates between the start and stop magnets to actuate the clutch lever. This armature may rest in either of two positions—against the start magnet yoke or against the stop magnet yoke. When the armature is against the stop magnet yoke, the clutch disc with 10 teeth is latched on the clutch lever. When the clutch disc is latched on the clutch lever, the clutch pawl is held clear of the ratchet (Figure 174) with the result that the counter wheel assembly remains stationary. The ratchet and ratchet gear are continuously turning since the ratchet gear assembly is meshed with the counter drive gear and revolves when the counter drive gear shaft turns. However, this has no effect on the counter wheel assembly as long as the clutch pawl is held clear of the clutch ratchet.

The clutch lever is detented at its free end to insure that the armature retains its position against either the start or stop magnet and to prevent rebound when attracted to the opposite magnet. The operating time of the magnets is less than five milliseconds.

When the armature is positioned against the start magnet, the clutch lever clears the clutch disc, which in turn allows the clutch pawl to drop down and become engaged with the clutch ratchet (Figure

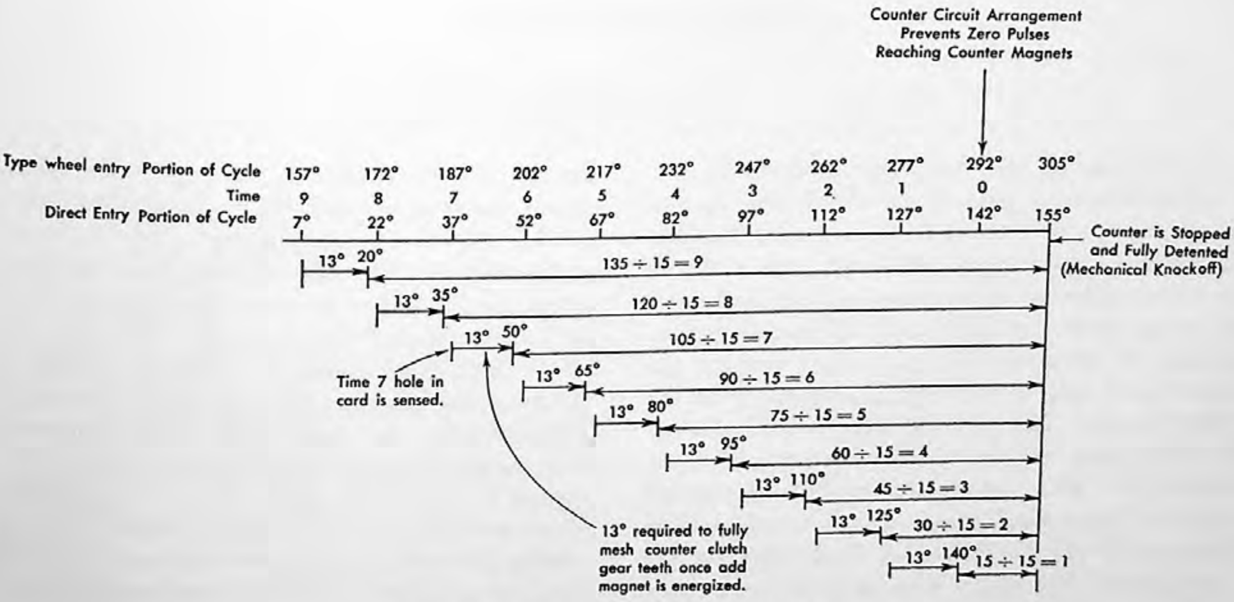


Figure 172. Counter Movement when Adding

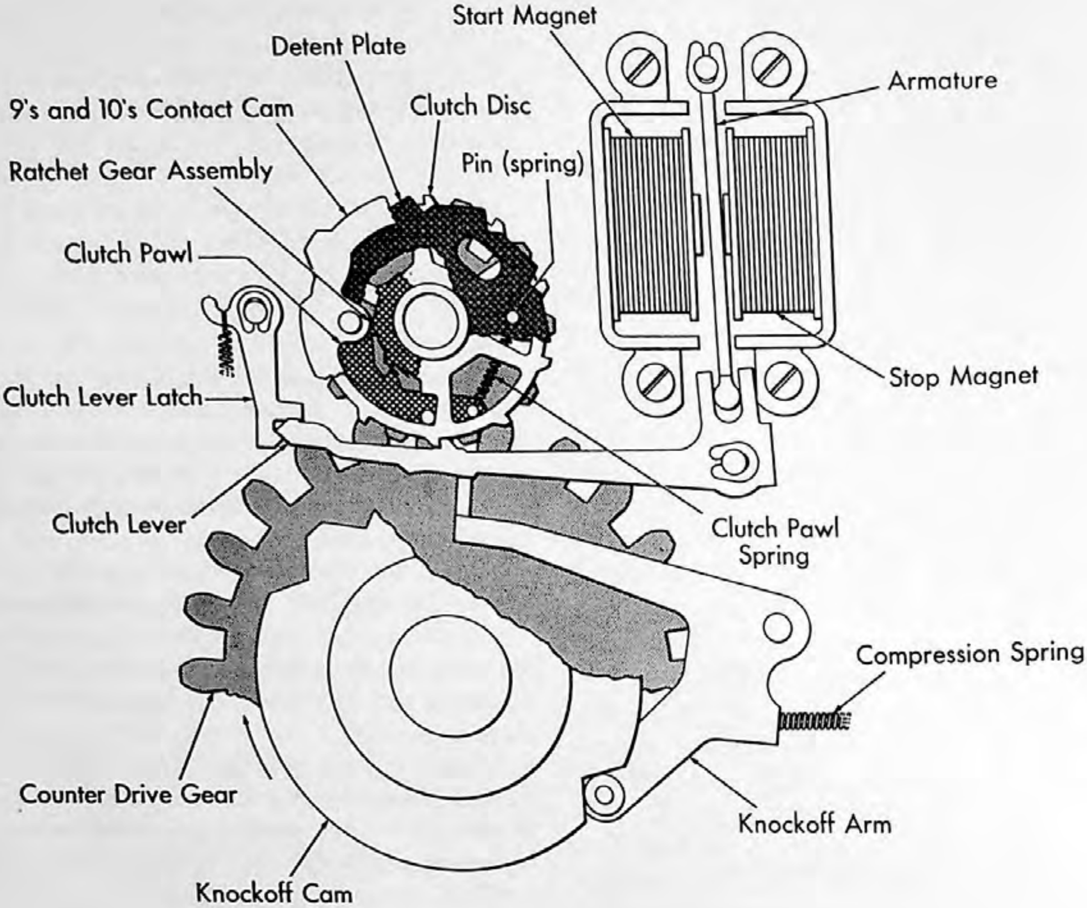


Figure 174. Clutch Pawl Disengaged

175). The stud on the clutch pawl operates against a cam surface on a spoke of the clutch disc. As the disc is allowed to move counterclockwise, the cam surface moves away from the clutch pawl stud and the clutch pawl is free to move into the ratchet by its spring action (Figure 176). Consequently the position of the clutch disc determines whether the clutch pawl will or will not be engaged with the clutch ratchet. The position of the clutch disc on the other hand is determined by the position of the clutch lever. When the clutch pawl becomes engaged with the clutch ratchet, the counter wheel assembly rotates with the clutch ratchet. This is because the clutch pawl is fastened at its pivot to the detent plate and, thus, to the counter wheel assembly. As long as the clutch pawl remains engaged with the clutch ratchet, the counter wheel will rotate with the clutch ratchet. The counter wheel is stopped by the action of the mechanical knockoff. The mechanical knockoff causes the clutch lever to move into the path of the latching surfaces of the clutch disc and stops the clutch disc. At this time the camming surface of the clutch disc operates against the stud on the clutch pawl and forces the clutch pawl out of engagement with the clutch ratchet. At this time the detent lever engages a notch in the detent plate to position the wheel assembly by heavy spring tension, thereby holding the clutch pawl clear of the ratchet teeth as the gear and ratchet assembly continues to rotate (Figure 177).

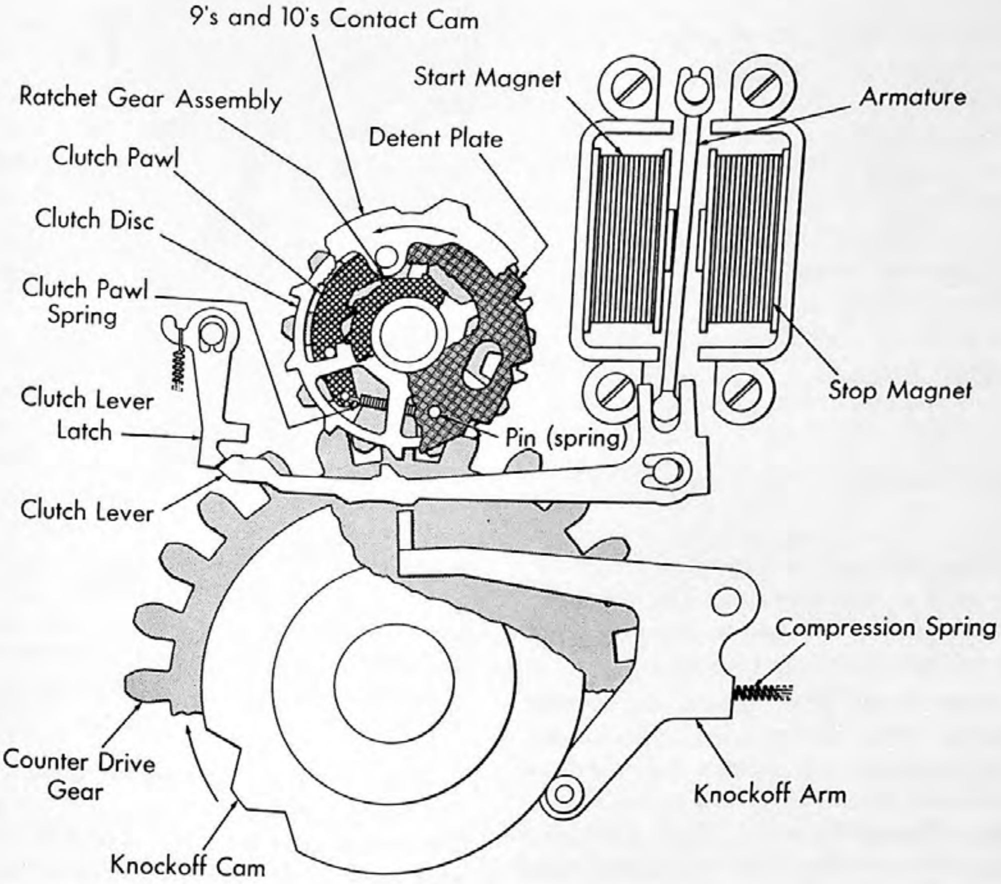


Figure 175. Clutch Pawl Engaged

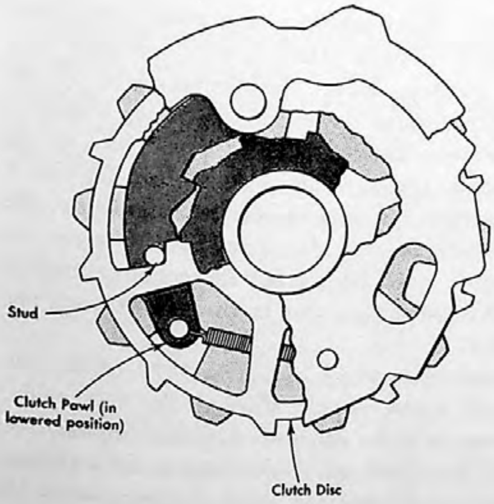


Figure 176. Operation of Clutch Disc

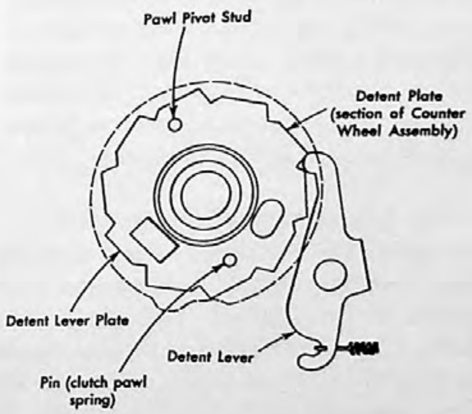


Figure 177. Counter Wheel Assembly in a Detented Position

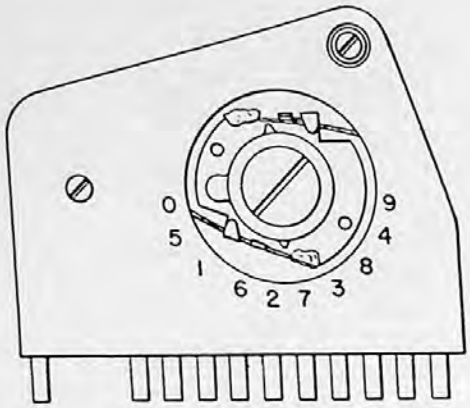


Figure 178. Counter Emitter Brushes and Moulding

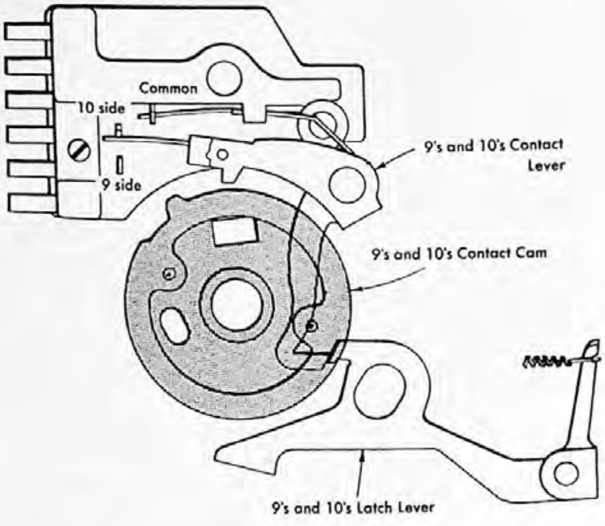


Figure 179. 9's-10's Contact in Latched Position

When addition is being performed, the counter wheel always stops at the same time. The difference in the values added results from the different times that the counter wheel may be started.

As the wheel assembly is driven, the emitter brushes advance about the moulding. The brushes are not diametrically opposite, but are displaced from this position by 18° which is one-half of the angular space between adjacent segments (Figure 178). One brush serves as the common while the counter wheel assembly moves from 0 to 4 with the second brush contacting these segments; the second brush becomes the common for digits 5 through 9 with the first brush contacting these segments.

Addition of one number to another is accomplished by advancing the wheel assembly the number of positions required by the impulse timing, regardless of the value in the counter at the time. The counter wheel is advanced by an impulse to the start magnet. It is stopped by the action of the mechanical knockoff. Individual counter plates may be grouped by wiring and groups may be combined by control panel wiring to provide sufficient capacity to handle the amounts to be entered and accumulated.

COUNTER CARRY

A carry is indicated by the counter wheel assembly when it passes from 9 to 0 (10) to close and latch the 9-10 contact on the 10's side. The 9-10 contact lever is operated by the 9-10 cam to control the contact position. The 9-10 cam plate is part of the counter wheel assembly and turns whenever the counter wheel turns. The cam is cut to permit the 9-10 contact brush to transfer to the 9's side when the wheel assembly advances to 9. A high lobe on the cam operates the lever to transfer the 9-10 contact brush to the 10's side as the counter wheel advances from 9 to 0 (10). The lower end of the contact lever latches on a latch lever to keep the 10 contact closed through carry time of the machine cycle (Figure 179). Carry time comes after all adding has been completed for the machine cycle. The carry circuit is completed at the same time regardless of which cycle (direct entry or type wheel entry) that the adding takes place. There is only one carry time for each machine cycle. The medium level of the 9-10 cam maintains the common contact wire in a neutral position between the 9-10 contacts for all digit positions except 9, and except when latched in the 10 position. A stud in the counter drive gear operates the latch lever after carry time to release the 9-10 contact lever, permitting the contact brush to assume the neutral position at the end of each machine cycle.

At carry time, which occurs at 307° of the machine cycle, a cam impulse through the 10's contact will cause one to be added in the next higher order position. The operation of the mechanical knockoff, one cycle point after the carry impulse, stops the counter wheels after 1 has been added. The presence of a 9 in a counter to the left, adjacent to one which has advanced from 9 to 0 during adding time, will extend the carry impulse to the next higher order position through the circuit arrangement. This circuit exists to all adjacent positions with 9's in the counter until it is broken by the absence of a 9 in a counter.

SUBTRACTION

Subtraction is the operation in which the value of a counter is reduced by the amount that is subtracted. If the counter wheel could be turned backwards, subtraction could be performed in this manner. Since the counter wheels cannot be turned backwards, however, some other means must be used. Subtraction is done by adding the complement of the figure to be subtracted. The following example shows that subtracting one number from a given number will give the same result as adding the complement of the number to be subtracted from the same given number: Subtract 14321 from 37834.

```
  3 7 8 3 4          9 9 9 9 9 9
 -1 4 3 2 1          0 1 4 3 2 1
 ----------          -----------
  2 3 5 1 3          9 8 5 6 7 8
                     complement of
                     number to be
                     subtracted

                         3 7 8 3 4
9's complement of    + 9 8 5 6 7 8
number to be         -------------
subtracted             0 2 3 5 1 2
                               + 1   carry-
                     -------------   back
                         2 3 5 1 3
```

This machine operates on a 9 complement basis. The 9's complement of a figure is the difference between the figure and nine. Thus subtraction is accomplished by adding the difference between nine and the figure punched in the card.

To subtract 9,	add a 0
" " 8,	" " 1
" " 7,	" " 2
" " 6,	" " 3
" " 5,	" " 4
" " 4,	" " 5
" " 3,	" " 6
" " 2,	" " 7
" " 1,	" " 8
" " 0,	" " 9

In subtraction, the electrical circuits operate differently from those for adding, in that a fixed impulse is completed to all counter start magnets to start the counter wheels turning with a "hot 9" as the card starts under the second reading brushes. At the time the second reading brush senses the hole in the card, a circuit is completed to the stop magnet. This stops the counter wheel. The sole purpose of the stop magnet is to stop the counter wheel from turning. Under this arrangement the counter wheel does not move the distance corresponding to the distance from the hole in the card to zero, as in adding, but the distance from the 9 position of the card to the hole in the card that caused the counter wheel to be stopped. For example, if a 6 is punched in the card, the counter wheel starts turning at 9 time and stops at 6 time; therefore, the counter wheel turns for 3 cycle points. The 9's complement of 6 is 3, consequently the complement of the figure to be subtracted is added.

When subtracting, all counter positions start turning at the same time but stop at different times, depending upon when the stop magnet is energized by sensing a hole in the card. Adding, on the other hand, is just the opposite. When adding, the counter wheels start turning at different times, depending on when the start magnet is energized by sensing a hole in the card, but all counter wheels stop at the same time by action of the mechanical knockoff.

The impulse to start the counter wheels turning when subtracting is called a "hot 9" since the impulse comes through automatically when a card is being subtracted at the same time that a 9 would be read from a hole in the card. If a 9 is to be subtracted, the start magnet receives the "hot 9" impulse for subtracting at the same time that the stop magnet receives its impulse from the 9 hole in the card. Consequently, the counter wheel should not move. As noted previously, to subtract 9, zero is added, therefore the counter wheel should not move. See Figure 180 for the duration of the cycle on which the counter wheel turns while subtracting various amounts.

MECHANICAL OPERATION WHEN SUBTRACTING

The mechanical operation of the counter when subtracting is quite similar to that when adding. The main difference is in the method of stopping the counter wheels from turning. In adding, the mechanical knockoff stops the counter wheel; in subtracting, the energization of the stop magnet causes the counter wheel to be stopped.

During a subtraction cycle the start magnet becomes energized at 7° by a "hot 9" impulse. As

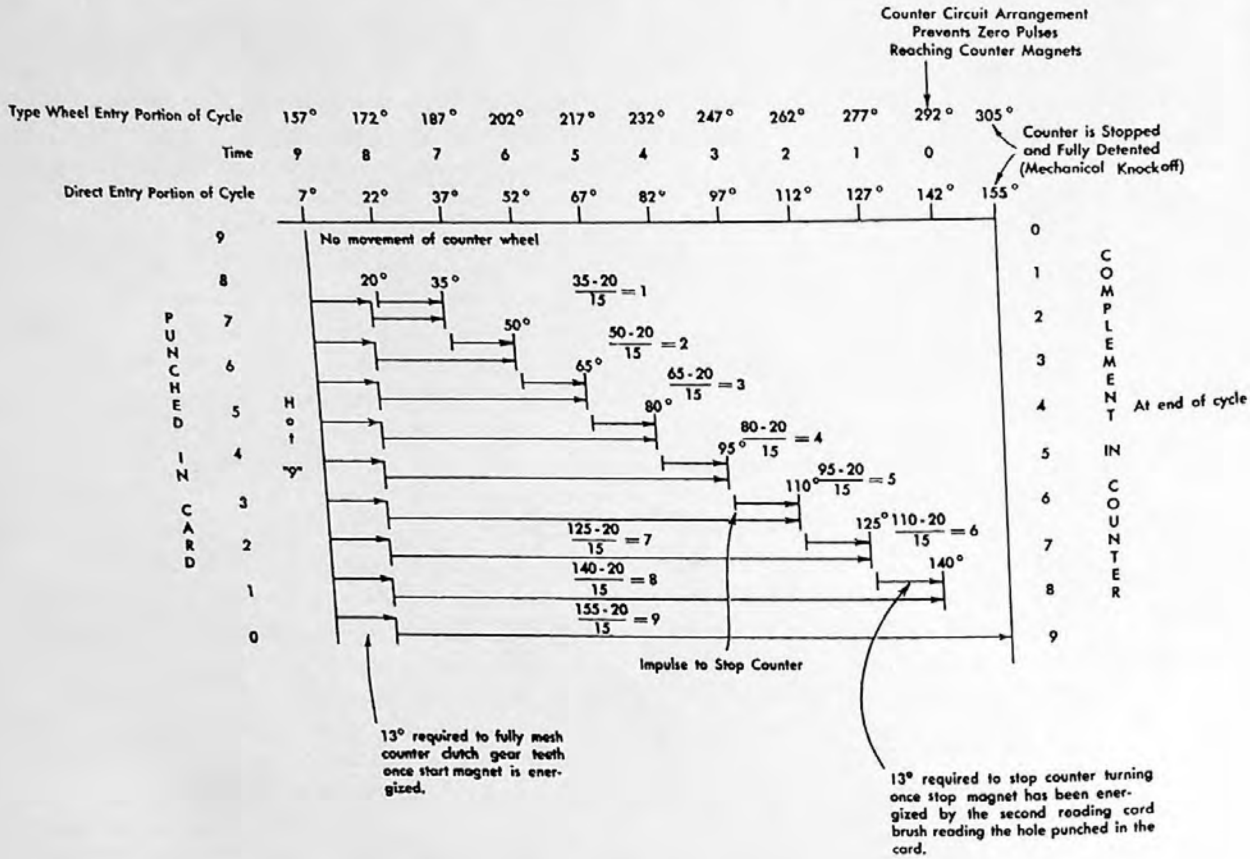


Figure 180. Counter Movement when Subtracting

when adding, this causes the clutch lever to move free of the clutch disc, which in turn allows the clutch pawl to drop into the clutch ratchet (Figure 175). All counter positions of the counter groups being subtracted receive this "hot 9" impulse and, unless a 9 is to be subtracted, all counter wheels will start turning at the same time. At the time the hole in the card is sensed, a circuit to the stop magnet, corresponding to the position read, is completed and causes the magnet armature to be attracted to the stop magnet core. The operation of the magnet armature to the stop magnet side causes the clutch lever to pivot and move into the path of the latching surfaces of the clutch disc. As the clutch disc comes up against the clutch lever, the clutch disc is stopped. The counter wheel assembly tends to continue to rotate but, as it does, the clutch pawl operates against the cam surface on the spoke of the clutch disc and rises out of the clutch ratchet; this causes the entire counter wheel assembly to stop. The detent lever operates so that the counter wheel assembly is in the proper position to keep the clutch pawl free of the ratchet and the emitter brushes positioned on the proper segment.

Figure 181 shows the timing relationships for adding and subtracting with both direct and type wheel entry impulses.

It should be noted that the advance of the clutch disc, as it is released by the clutch lever and pulled by the clutch pawl spring, insures that at least "1"

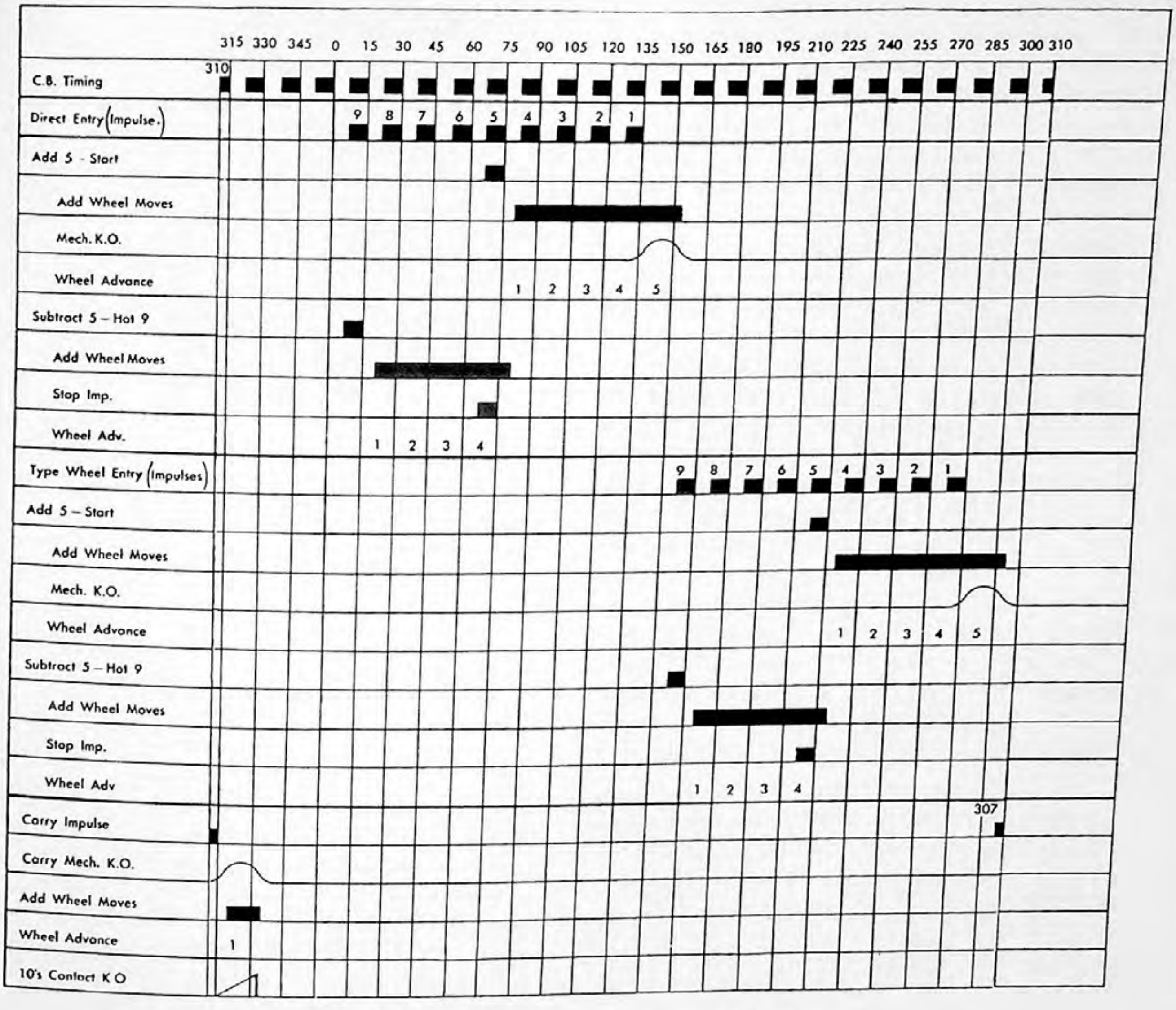


Figure 181. Timing Chart — Direct Entry and Type Wheel Entry Impulses

will be added to the counter as the result of this release. A simultaneous impulse to both magnets will not cause any armature movement because of the magnetic cancellation of the coils and detenting of the clutch lever. The armature will remain against the magnet as positioned before the simultaneous impulses are received. This condition occurs when a 9 is being subtracted on a complement basis. To prevent tripping the counter clutch, therefore, it is of extreme importance that the automatic hot 9 impulse to the start magnet and the 9 impulse from the card occur simultaneously.

COUNTER RESET

The counters are reset by adding values in each counter position that will cause the counters to have a 9 standing in each position at the end of the reset cycle. When the counter has a zero value, all the counter wheels are standing at 9. This provides a means of checking for a zero balance since the 9-10 brush is made on the 9 side when the counter wheel has a 9 standing in it. Checking for a zero balance is done after each reset cycle to ascertain that each counter position is correctly reset. The figure to be added to the counter positions in each case is the complement of the figure originally in the counter just before resetting takes place. This resetting is accomplished by a direct reading circuit established through the counter. If the figure in the counter is a true figure, the figure to be added to reset the counter must be the complement of the figure printed. In this case the counter will perform a normal subtraction operation. A hot 9 impulse energizes the start magnet on the second adding cycle of the machine cycle. A typewheel contact impulse coming from the type wheel contacts energizes the stop magnet which in turn causes the counter wheel to stop turning. The typewheel contact impulse has the same value as the impulse read from the counter. Since the start magnet had previously been energized by a hot 9, the cycle points taken by the counter wheel before being stopped by the type wheel contact impulse are equal to the complement of the figure in the counter and the figure printed. Thus, the complement is added to each counter position during the reset operation.

If a negative figure is in the counter before resetting, the same value that is printed is also added into the counter. Since a negative figure is in the counter, it is necessary to print the complement of the figure in the counter to get a true figure. The same value that is printed is added into the counter to give 9's in all positions since the complement of the figure in the counter is added to the original figure.

UNIT TYPE COUNTER

THE UNIT type counter used in the Type 101 Electronic Statistical Machine is a mechanical counter, controlled electrically. There is no need for any external mechanical drive for operating the counter. Each counter is a self-contained unit that only requires electrical connections. The counters are inserted into terminal mouldings. Electrical connections are made by means of contact springs anchored in the terminal mouldings. No timing of the counters is necessary and no external wiring is required.

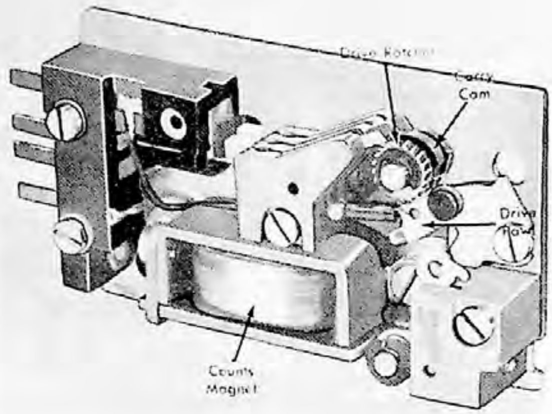


Figure 182. Units Counter

The units type counter has only one magnet, the counts magnet. When the counts magnet is impulsed, the drive pawl is moved over one tooth in the drive ratchet. The drive ratchet and two cams are advanced one tooth, or one position by spring action, when the counter magnet is de-energized. The counter advances one position, or unit, for every impulse it receives. The units counter is shown in Figure 182.

The ratchet and two cams rotate as an assembly on a stud riveted to the counter plate. The two cams operate contact levers which in turn operate wire contacts. The cam nearest the mounting plate operates the reset contact. The reset contact is closed except when the counter is at zero. This contact is used when resetting the counter; a series of impulses is sent to the counter through the reset contact. The reset contact is opened when the counter is advanced to zero; as a result no more impulses can reach the counts magnet.

The second cam from the mounting plate is the carry cam. This contact is opened except when the counter is at nine. This contact is used for carry into the next higher order counter and for printing.

The carry contact recognizes when the counter contains a nine, and as a result of the next impulse received, a carry is accomplished. The carry contact directs the impulse on to the next higher order position and if this position also contains a nine, the impulse will be extended to the third position, etc.

The read out of this counter occurs during a reset cycle. The carry cam permits the carry contact to make when the counter reaches the nine position. The next impulse causes the counter to advance to zero, but, at the same time, the impulse is allowed to pass through the carry contact to print.

IBM uses several counters which operate on the principle of adding a single unit for every impulse received; the other types use an emitter to read out, and can read out without resetting.

VACUUM TUBE COUNTER

A VACUUM tube counter is used in the Type 604 Electronic Calculating Punch. The electronic counter works on the principle that a vacuum tube circuit can be arranged to have two definite states. If the control grid of a vacuum triode is at cathode potential, the tube conducts. If the grid is made very negative, the tube is cut off. Two triodes are combined in an electronic circuit called a *trigger;* these tubes control each other so one conducts when the other is cut off, and vice versa. This electronic circuit is analogous to a toggle switch in that it can stay in either of two conditions. Each electrical impulse causes the triggers to change states. Triggers are the building blocks of which the electronic counter is composed.

Number Systems

Some background of numbering systems is desirable for a better understanding of an electronic counter. The decimal system in common use is based on the number ten. It is very likely that this system originated because there are ten fingers on the two hands. However, there are systems based upon other numbers in limited use today; for example, counting by dozens, etc.

A system can be developed using any number as a base, and a knowledge of only a few fundamentals is necessary to do this. The decimal system begins with zero, as all systems must, and as we count, it progresses to nine and returns to zero while a one is carried into the second position. If a system of numbers is to be developed on a base 5, it would begin with zero and progress to 4, then return to zero and carry a 1 into the second position. The following table shows a comparison of a base 10 system, a base 5 system and a base 2 system.

Base 10	Base 5	Base 2
0	0	0
1	1	1
2	2	10
3	3	11
4	4	100
5	10	101
6	11	110
7	12	111
8	13	1000
9	14	1001
10	20	1010
11	21	1011
12	22	1100
13	23	1101
14	24	1110
15	30	1111
16	31	10000

This table could be carried as far as desired; however it has been extended far enough to show the principles.

Observe that the system of numbers on the base 2 begins with a zero and advances to one when one unit is added. When a second unit is added, the first position returns to zero and carries into the second position. This process is continued until any desired number is reached.

The important fact to note about a number system based on 2 is that there are actually only two numbers involved, zero and one; the name *binary* system is given to the base 2 system for this reason. All positions in the number must contain either a zero or a one. Because relays and electron tubes also have two states, they are ideal for storing binary numbers. One of the two states will represent the presence of a zero; the other will show the presence of a one. By definition, a trigger which is ON will indicate a one in that position.

The binary system can be converted to the decimal system rather readily. There is a formula which can be used to convert a number on any base to a decimal base. The binary system has a definite and recognizable pattern as the number of positions increases. The value of each position added has a value in the decimal system exactly double the decimal value of the preceding position.

A table of decimal equivalents can be made from this knowledge.

Binary Value		Decimal Equivalent
1st position	1 =	1
2nd position	10 =	2
3rd position	100 =	4
4th position	1,000 =	8
5th position	10,000 =	16
6th position	100,000 =	32
7th position	1,000,000 =	64
8th position	10,000,000 =	128
9th position	100,000,000 =	256
10th position	1,000,000,000 =	512
11th position	10,000,000,000 =	1024

The decimal value of a binary figure, such as 1001, can be found by the following procedure:

The one in the 4th position =	+8
The zero in the 3rd position =	+0
The zero in the 2nd position =	+0
The one in the 1st position =	+1
The total decimal value	9

The first table will verify these results and this method. The same method can be used regardless of the size of the number. For example, the decimal value of 110001011 is:

The one in the 9th position =	256
The one in the 8th position =	128
The one in the 4th position =	8
The one in the 2nd position =	2
The one in the 1st position =	1
The total decimal value	395

It is possible to make up entire counters using only the binary system. However, there are many advantages in being able to read directly into and out of a counter. Consequently, it is desirable to keep each position on a decimal base. Each counter position would require triggers for each of the ten possible digits if the decimal system were used. However, by modifying the binary system, only four triggers will be necessary for each counter position. Figure 183 shows how electronic triggers are used to accumulate using the binary system. If a trigger is ON (containing a one) it is represented by a white circle; a black circle represents a trigger which is OFF, representing zero.

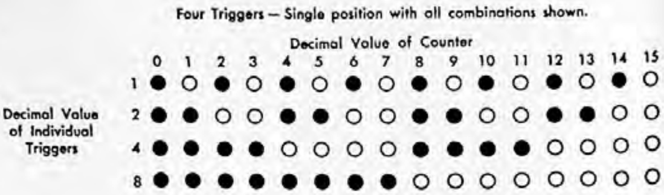


Figure 183. Schematic of Electronic Counter

Notice that the triggers follow exactly the pattern developed in the chart shown earlier. Because each counter position accumulates 9 and then goes to zero, controlling circuits beyond the scope of this book are used to stop the counter action at 9. Each impulse sent to the triggers causes the counter to increase, up to 9. The tenth impulse turns OFF all the triggers in that counter position and causes an impulse to be sent to the next higher position. The next position will accumulate one as a result.

It is evident that the counting capacity of a position is not fully utilized, but this is offset by the advantage of having the counters operate directly in decimal numbers.

To add into these counters, the information, read from a card, is sent to the individual counter position in the form of a series of impulses. For example, if a nine is sensed and is to be accumulated in position one, nine impulses will be sent to trigger one in position one. The first impulse to trigger one will turn it on, indicating one has been accumulated. The second impulse turns trigger one off and turns trigger two on, indicating two has been accumulated. The third impulse turns trigger one on again and trigger two is still on, indicating a three. The fourth impulse turns triggers one and two off and turns trigger three on, indicating a four. The counter continues to accumulate using the binary system until a nine is indicated as a result of the nine impulses directed to trigger one. The next impulse received by trigger one will turn off all of the triggers in that position and carry a one into the next higher position.

PRINTING MECHANISMS

PRINTING is one of the most important functions of IBM Data Processing Machines. It is through the medium of printing that the finished products of the Data Processing Method of Accounting are produced. These products are printed reports and document forms which are required by the customer for the efficient operation of his business. He is vitally interested in the quality and legibility of the printing on these forms because many of them, such as statements, invoices and shipping notices are placed in the hands of his own customers.

The Data Processing Machines provide the quality and legibility desired. There are many factors which contribute to satisfactory printing results. A number of these are listed below:

1. Paper — its texture and ability to receive the inked type impression clearly and sharply.
2. Ribbon — affects the clearness of printing.
3. Carbon paper — determines legibility of carbon copies and is particularly important when numerous copies are required.
4. Impression — affects the quality and legibility of the printed character. Impression is affected by the impact or pressure of the type against the paper, and also by the hardness of the platen.

In addition to the above, an important factor is the design and type of the printing mechanism. It is with this principle that this chapter will deal primarily.

Printing Systems

Books, magazines and newspapers are commonly produced by letterpress printing, in which the ink is carried by the raised portions of type. Similarly, typewriters and accounting machines produce their results by pressure from the raised surfaces of type. In the printing of books, the individual type pieces required to make up each page are usually set up in a form. These forms are placed in a printing press which produces the desired quantity of printed pages. In the adaptation of printing to typewriters, adding machines, desk calculators, electric accounting machines, etc., the methods differ because the setup changes with each printing operation. A selecting mechanism is provided to select the individual type characters which are to be printed. To accomplish this, two distinct systems are employed; serial and parallel printing.

Serial Printing

The typewriter is an example of the serial printing system. The characters are individually selected and printed one character at a time, on the printing line. Immediately following the printing of each character, the paper is moved to the left by a carriage, positioning the paper to receive the printing of the next character.

Parallel Printing

This method of printing is used generally on desk calculators, adding machines and IBM Data Processing Machines. The mechanism used consists of groups or banks of type bars, wheels or sectors, in parallel arrangement. Each of these carries a full complement of numerical characters, or numerical and alphabetical characters. During the selection or setup portion of the operation, the desired character in each type bar or wheel is selected and positioned at the printing line. At a definite time later in the cycle of operation all of the type characters are pressed against the paper simultaneously. Thus an entire line is printed at the

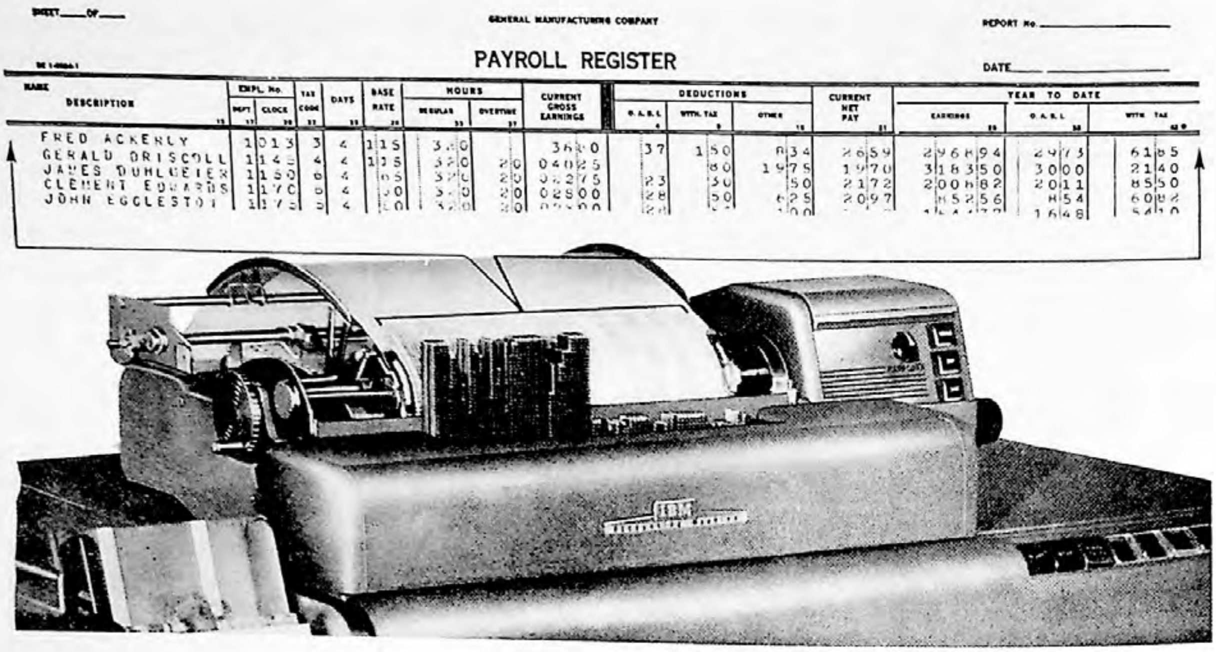


Figure 184. Parallel Printing

same time, as seen in Figure 184. The chief advantage of the Parallel System is the printing speed factor. Because it prints a complete line at once, it is capable of a greater output than the series system.

Components of an IBM Printing Mechanism

Figure 185 shows the basic components of an IBM printing mechanism combined to perform a printing operation. The type, hammer and control mechanism may vary and differ in size, shape, and design as they are adapted to a machine to form a specific printing mechanism, but they will perform the same function in all units.

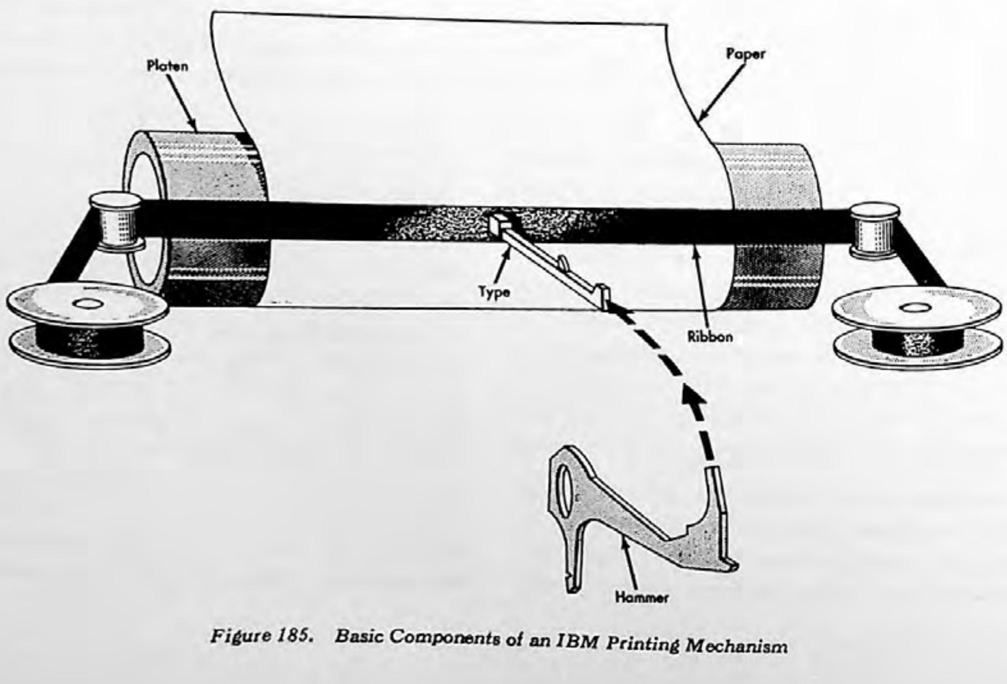


Figure 185. Basic Components of an IBM Printing Mechanism

TYPE 402 PRINTING MECHANISM

Numerical Type Bar

Some knowledge of the construction of a type bar is necessary before the operation of the type bar can be fully understood. The Type 402 Machine has two different kinds of type bars; numerical and alphamerical.

Figure 186 shows the numerical type bar found in the type 402 machine. The type bar holds 11 pieces of type. The piece of type in the top position can be one of two characters, either a credit symbol (CR) or an asterisk (*): These two pieces of type are used to identify totals, and are located in alternate type bars (for example, all even numbered type bars will have a CR symbol while all odd numbered type bars will have an *). The other ten pieces of type are the ten numerical digits (9 through 0). Each piece of type is free to move independently and each has its own spring to return it after the hammer strikes it.

There are ten teeth on the numerical type bar, one for each piece of type except zero. The type bar will be stopped by the tooth corresponding to the digit to be printed. If it is not stopped by a tooth, it will be stopped in the zero position. The distance between the lands of the teeth is equal to the distance between centers of adjacent pieces of type.

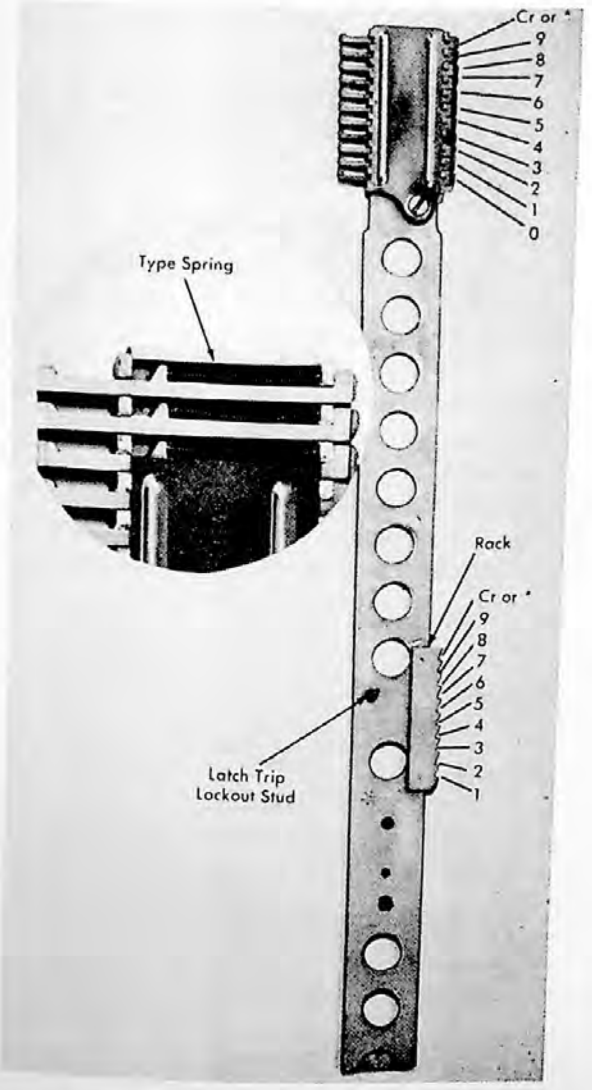
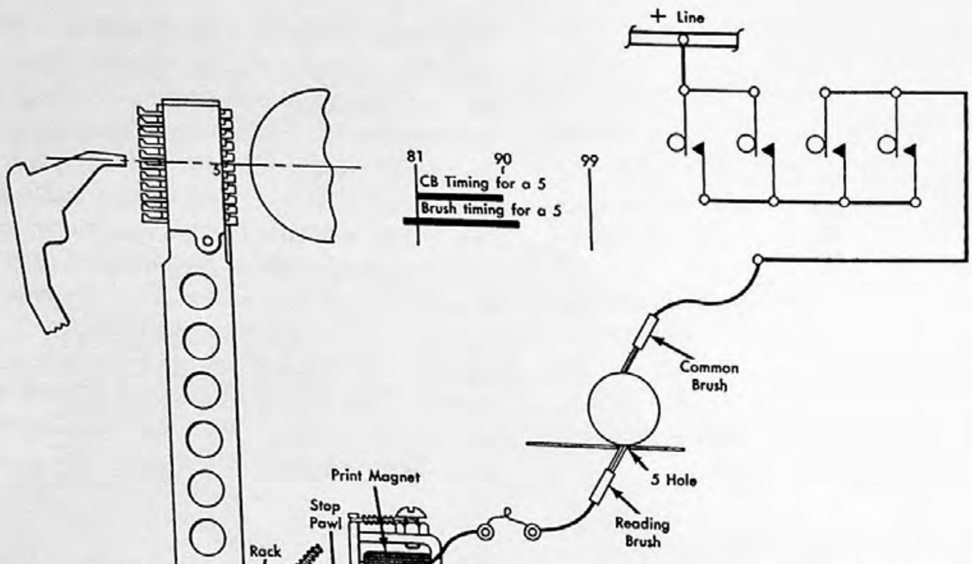


Figure 186. Type 402 Numerical Type Bar

Type Bar Synchronism

As the type bar moves up to print, it is stopped by a stop pawl which is under the control of a magnet (print magnet). The print magnet is generally impulsed as a result of a brush sensing a hole in a card. The type bar must move in synchronism with the card so that the type bar will be accurately stopped in a predetermined position. Figure 187 shows a numerical type bar being set up to print a 5.

The 402 and 405 machines, which use this type bar, are both 20 cycle point machines. This results in 18° per cycle point which signifies that the card requires 18° to move from one position on the card to the next. It also indicates that the type bar must move a distance equal to the distance between lands in 18°. Both machines feed a card 9-edge first, so the 9-type is located above the other numbers on the bar. In Figure 187, the type bar and card are shown at 81° on the index when the brush is reading a 5-hole. The hole is sensed and the print magnet is energized to release the stop pawl. The stop pawl is not directly opposite the land of the 5 tooth. Actually the type bar has moved so that the land of the 6 tooth is 3° past the stop pawl; thus the type bar must move 15 more degrees before being stopped by the 5 tooth. This arrangement is necessary to allow the pawl time to swing in to engage the tooth. It can be seen that the next tooth that can engage the stop pawl is the 5 tooth and a 5 will be positioned to print. However, to be sure the pawl does not engage the 6 tooth, the print magnet is not energized until after the stop pawl is beyond the 6 tooth. The distance (3°) that the stop pawl overlaps the 6 tooth is called list lap.



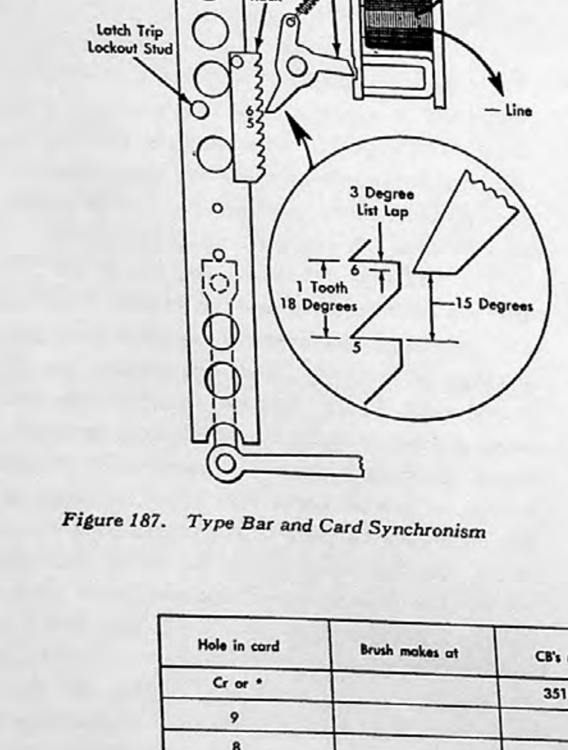


Figure 187. Type Bar and Card Synchronism

The timing for a CR or * and a 5-hole are indicated in Figure 188. Fill in the other spaces to complete the table.

Numerical Type Bar Bail Assembly

The numerical type bar bail is operated by two complementary cams through a forked cam follower and connecting link (Figure 189). As the cams rotate and the connecting link is raised, it raises the spring bail and the restoring bail. The type bar operating arm is held against the restoring bail by the springs which are connected to the type bar operating arm and to the spring bail. As the restoring bail moves up, the type bars are raised by the spring tension, lifting the operating arm. Note that as the type

Hole in card	Brush makes at	CB's makes at	CB's breaks at	TB stop at
Cr or *		351 degrees	360 degrees	6 degrees
9				
8				
7				
6				
5	77-78½ degrees	81 degrees	90 degrees	96 degrees
4				
3				
2				
1				
0				

Figure 188. Type Bar Table

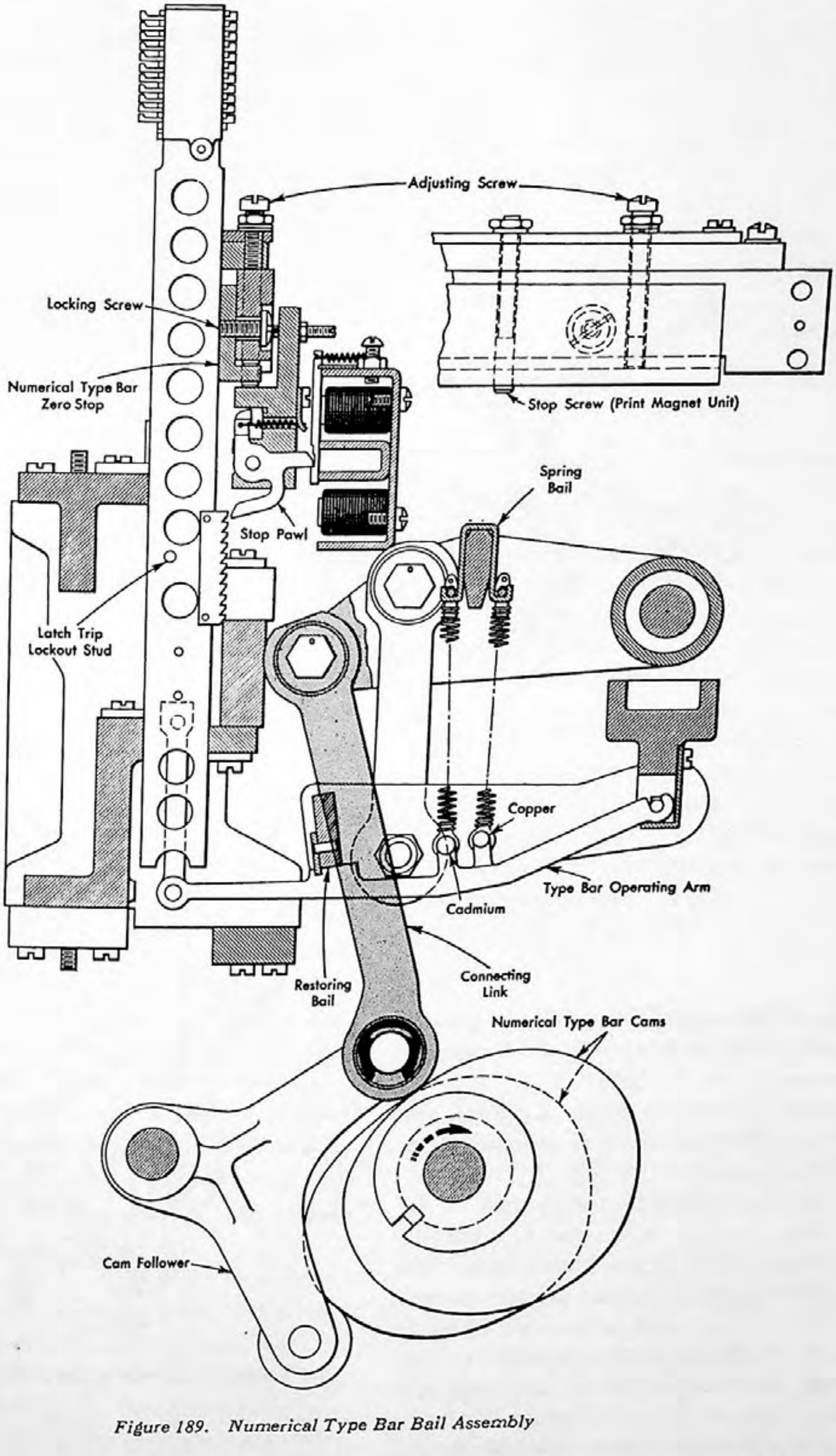


Figure 189. Numerical Type Bar Bail Assembly

bars move up, the spring bail also moves up so that the spring tension is not lost. If the type bar is stopped by a stop pawl, it will be held against the stop pawl by the spring tension which will increase as the restoring bail and spring bail continue to move upward. If, however, the type bar is not stopped by

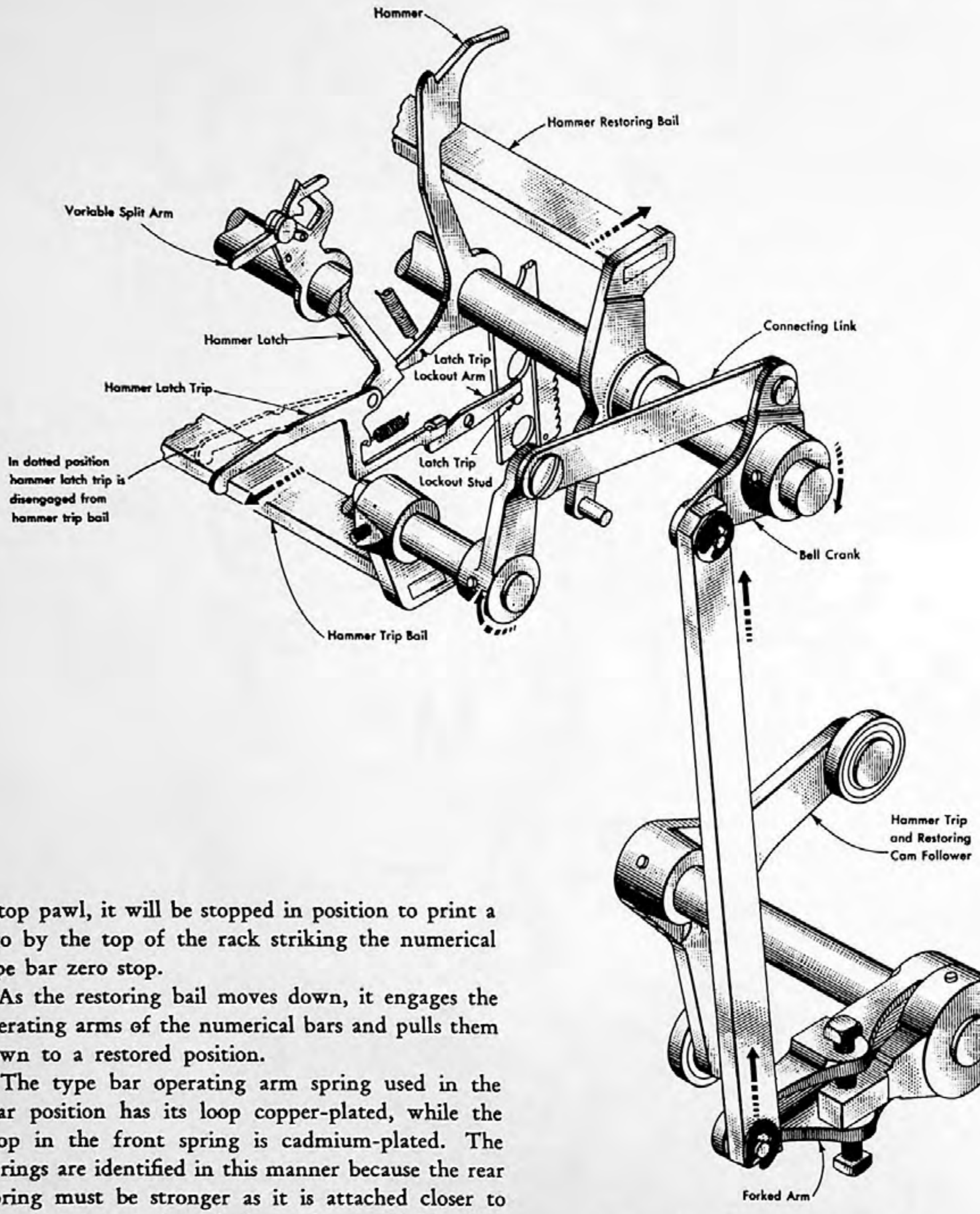


Figure 190. Hammer Unit Mechanism

a stop pawl, it will be stopped in position to print a zero by the top of the rack striking the numerical type bar zero stop.

As the restoring bail moves down, it engages the operating arms of the numerical bars and pulls them down to a restored position.

The type bar operating arm spring used in the rear position has its loop copper-plated, while the loop in the front spring is cadmium-plated. The springs are identified in this manner because the rear spring must be stronger as it is attached closer to the pivot point. A method must be provided to align the type in the bars stopped by the zero stop with that in the bars stopped by the stop pawls. The print magnet and stop pawl position is fixed so the numerical type bar zero stop is made adjustable up and down to align the top and bottom of the zeros with the other characters (Figure 189). A good test for this alignment is to have zeros and eights in alternate type bars (8080808), although any character, such as CR or 1, that can be aligned both top and bottom with the zero will be satisfactory.

Hammer Unit Assembly

The hammer unit assembly is designed to print the information which is set up in the type bars. The hammers are released at approximately 196°, after all type bars have been correctly positioned for printing. The hammer unit assembly also restores the hammers so that they are clear of the type before the bars begin to move down.

Figure 190 shows the hammer unit mechanism. The hammer is being held by a latch while the hammer spring is attempting to rotate the hammer in a clockwise direction. The hammer will be held by the latch until 196° when the latch is pulled away. Then the hammer is free to rotate and strike the tail of a piece of type.

The hammer unit mechanism is operated by two complementary cams and cam followers which cause the forked arm and the bell crank to operate. The arrows in the figure show the direction of movement as it approaches 196° (hammer firing time). The hammer restoring bail is moving away from the hammers so the hammers will be free to fire. The hammer trip bail is moving to the left pulling the hammer latch trip with it. The hammer latch trip is connected to the hammer latch which is pulled clear of the hammer permitting the hammer to fire.

The mechanism is then restored and the direction of movement is opposite the direction indicated by the arrows. The restoring bail pulls the hammer back and the hammer trip bail permits the latch to snap over the hammer, relatching it.

The procedure described above is the same for all positions set up to print anything other than a zero. If a type bar rises until stopped by the zero stop, the latch trip lockout stud strikes the latch trip lockout arm. The turned over ear on the latch trip lockout arm will pull down on the hammer latch trip. This will lift the end which is hooked over the hammer trip bail clear of the bail (Figure 191). The hammer trip bail will not pull the hammer latch trip to free the hammer as it moves to the left. As a result, the hammer in that position will not be tripped in the normal manner.

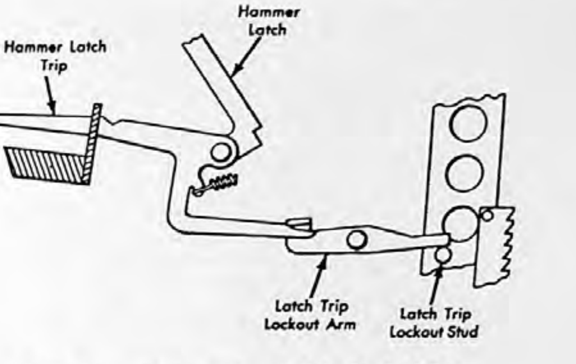


Figure 191. Hammer Latch Trip Locked Out

It is desirable not to automatically fire hammers in positions which have zeros set up, because it would result in all numerical type bars printing zeros. As a result, the report printed would be hard to read. Figure 192 shows what a numerical report would look like if zeros printed automatically. It is important, however, to print zeros which are to the right of a significant digit; for example, in the number 1001 the zeros should print. Variable split arms are provided to control the printing of zeros to the right of significant digits.

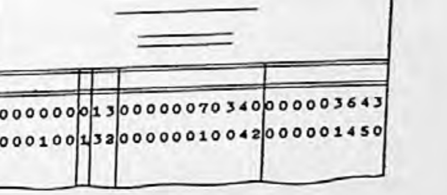


Figure 192. Report Showing All Zeros Printing

Variable Split Arm

In Figure 190, note that anything which causes the hammer latch to pivot in a clockwise direction will cause the hammer in that position to fire. From Figure 193 it can be seen that at the top of the hammer

Figure 193. Hammer Latch and Variable Split Arm

latch a variable split arm is attached and the hammer latch forms another arm with a turned-over ear. It should also be noted that there is a projection on the variable split arm. When the hammer latches are placed side by side, the turned-over ear on the latch is directly in front of the projection on the variable split arm in the adjacent position (Figure 194). If the hammer latch in the back is rotated to release its hammer, the variable split arm moves forward. The projection on the variable split arm strikes the turned-over ear on the hammer latch in the front causing it to move forward. The latching portion will be moved away from the hammer causing it to fire. The variable split arm in that position will cause the next position to fire, etc. Figure 195 shows a report with all of the variable split arms causing positions to the right of a significant digit to fire. The zeros on the extreme

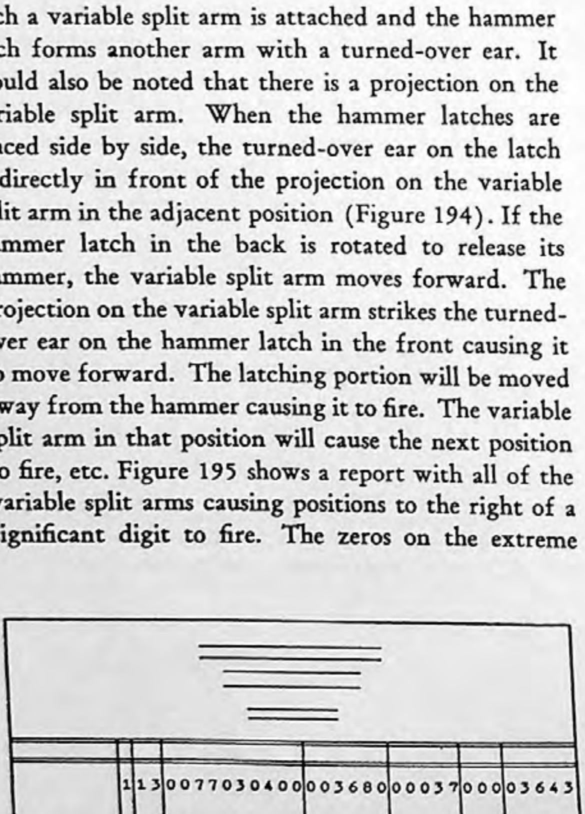


Figure 195. Report Showing All Zeros Printing After the First Significant Digit

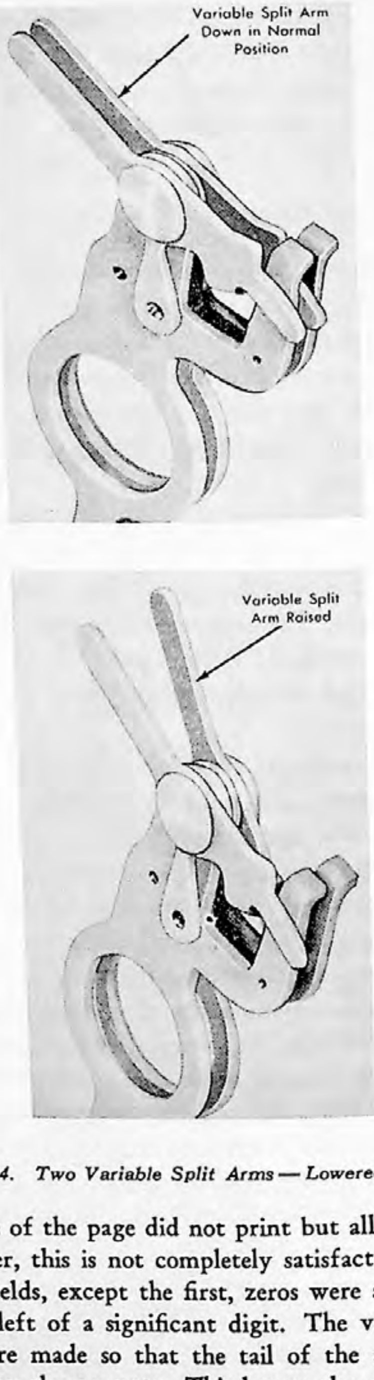


Figure 194. Two Variable Split Arms — Lowered and Raised

left side of the page did not print but all others did. However, this is not completely satisfactory because in all fields, except the first, zeros were still printed to the left of a significant digit. The variable split arms are made so that the tail of the arm can be raised by the operator. This lowers the projection so that it will pass under the turned over ear and not fire the adjacent hammer (Figure 194). If the variable split arm is raised in the units position of each field, it will not fire hammers in the field to the right. The same report shown previously is repeated in Figure 196 with the variable split arms raised in the units position of each field.

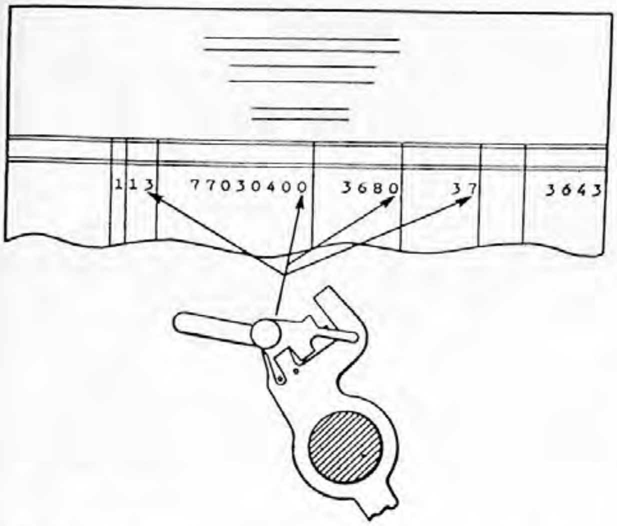


Figure 196. Report Showing Zeros Printing Only After the First, Significant Digit in Each Field

Hammerlock Assembly

The hammers can be prevented from firing in another manner, even though a significant digit might be set up to print. Hammers may be controlled by a hammerlock assembly, which is located on top of the hammer unit. For each hammer there is a hammerlock spring, short hammerlock lever, and a long hammerlock lever. All of these parts are mounted on a hammerlock bar. Figure 197 shows the position of the hammerlock spring in relation to the hammer when either of the hammerlock levers is raised.

The hammerlock spring is a leaf spring which prevents the hammer from firing when it is down far enough to engage the notch in the top of the hammer. The hammer will be prevented from firing anytime the short hammerlock lever is raised. If the long

Figure 197. Hammerlock Assembly

hammerlock lever is raised, it can be seen from Figure 197 that the hammerlock spring does not move down far enough to prevent the hammer from firing. However, the hammerlock bar to which all the hammerlock springs are attached, is supported by a hammerlock magnet armature through a link and armature arm. When the hammerlock magnet is energized, the hammerlock bar will be lowered. The positions where the long hammerlocks are raised will have the hammers blocked. The magnet is controlled by control panel wiring to suppress printing certain information or all except certain information.

The hammer will be released by the latch to fire regardless of the hammerlock springs. The springs only prevent the hammer from continuing forward to strike the type.

Alphamerical Type Bar

The alphamerical type bar is designed to print both alphabetical and numerical characters. Figure 198 shows the construction and nomenclature of an alphamerical type bar. There are 38 pieces of type, 26 alphabetical characters, 10 numerical characters, one special character (&), and one extra zero. There are ten lands on the lower section (one for each numerical character). The type bar is stopped in the same manner as the numerical bar. When a hole is read, the print magnet is energized and the stop pawl swings in to engage one of the ten teeth and stop the type bar. In this manner the type bar will print numerical information just as the numerical type bar did. However, it is also desired to print alphabetical information from the same type bar.

An alphabetical character is a combination of two punches, a zone punch and a numerical punch, in the same column. All characters which can be printed by the type bar are divided into four zones: numerical zone, 12 zone, 11 zone, and 0 zone, as follows:

Numerical Zone	12 Zone	11 Zone	0 Zone
1	A	J	
2	B	K	S
3	C	L	T
4	D	M	U
5	E	N	V
6	F	O	W
7	G	P	X
8	H	Q	Y
9	I	R	Z

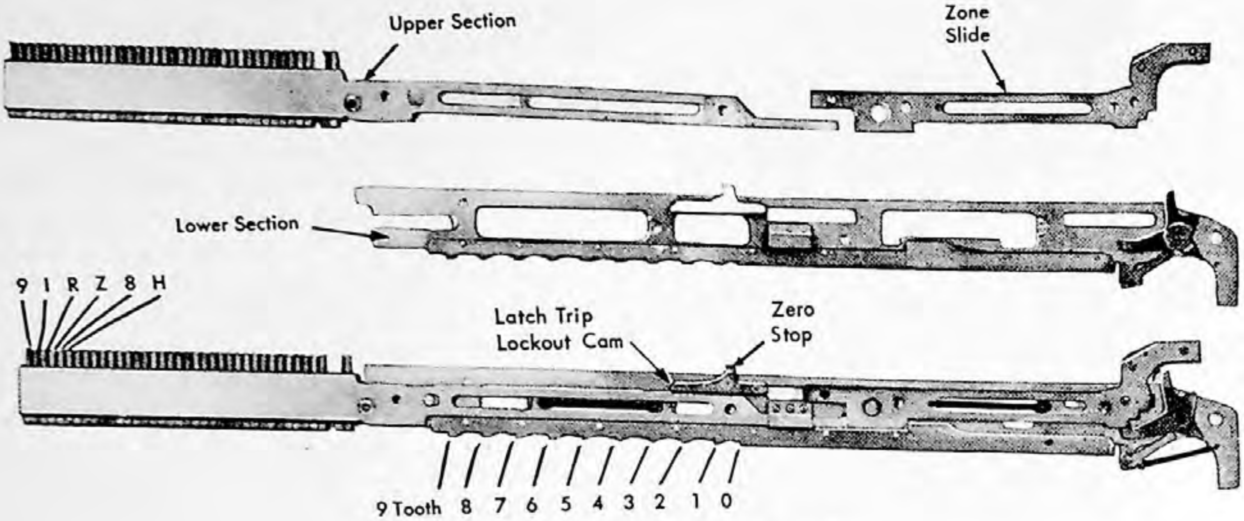


Figure 198. Type 402 Alphamerical Type Bar

Note that there is no 0-1 combination; with 26 letters in the alphabet, this combination was not required and for circuit reasons it is desirable to eliminate this combination.

The zone information must be mechanically combined with the numerical to set up the type bar properly. The spaces between the lands of the teeth are more widely spaced than those on the numerical type bar. This is because, for the numercial portion of an alphabetical character, one of these teeth will stop the type bar, but when zones are combined there are generally three more characters possible and space must be allowed for them between the numerical type. The type is grouped according to the numerical portion of the character. Starting at the top of the type bar, the first type is a nine, because the card is fed 9-edge first, and the type bar moves in synchronism with the card. The character directly beneath a numerical character is that number combined with the 12 zone, in this case an I. The next character will be that number combined with an 11 zone, or in this case an R. Then the Z type which is a 9 combined with a 0 zone. Sequence of remaining type can be determined using the same sequence and the combinations shown above.

The type bar is composed of three major parts: the upper section, the lower section and the zone slide. The upper section is held down against the zone slide by spring tension. When the type bar is not zoned, the zone slide rests against a shoulder on the lower section. With the zone slide and upper section in this position, if the type bar is stopped by the five tooth, a numerical 5 will be positioned to print. However, if a type bar is stopped by the five tooth, there are four possible characters which may be printed: 5, E, N, or V (Figure 199).

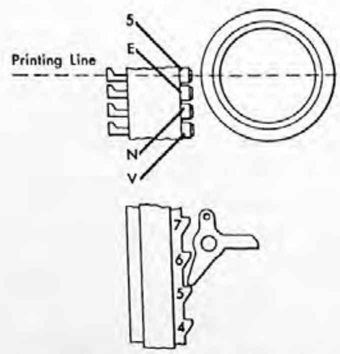


Figure 199. Four Characters Possible with Type Bar Stopped by the 5 Tooth

The character which prints is determined by the position of the zone slide. The lower portion of the zone slide has three surfaces against which the setup pawl may rest. These correspond to the three zones which can be read from the card. If the type bar zone slide and upper section is raised so that the setup pawl rests in the first notch, or 12 zone, it will print

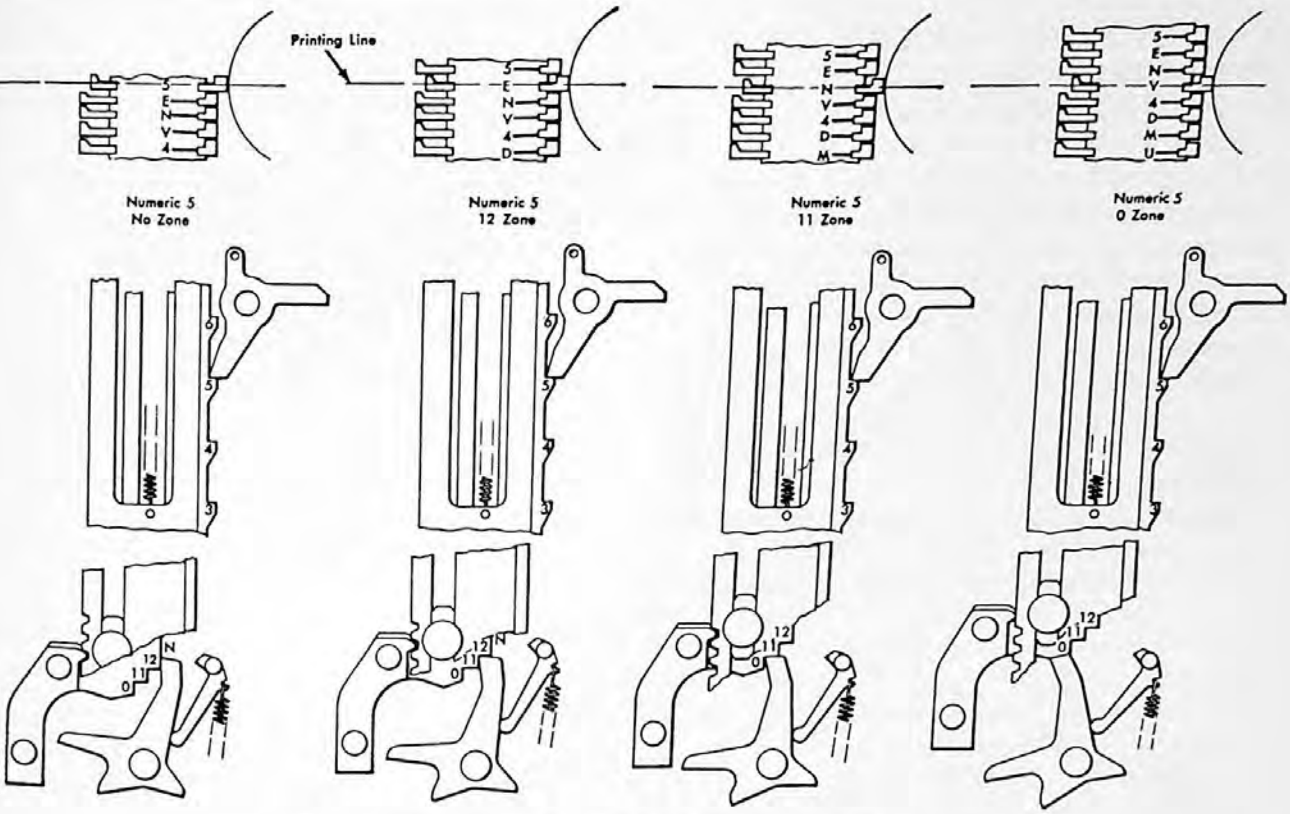


Figure 200. How the 5, E, N, and V Are Each Positioned to Print

an E rather than a 5. The movement of the zone slide from one step to the next moves the upper section a distance equal to the distance between centers of adjacent pieces of type. Figure 200 shows the position of the setup pawl, zone slide, lower section, and upper section for a 5, E, N and V.

The distance between the one tooth and the zero tooth is less than the distance between the other teeth. This is because there is no 0-1 combination and a space is not required there. Since the zero was placed directly beneath the J, the land was moved up the distance equal to one type position, to properly position the zero to print.

If an alphamerical type bar is permitted to rise to the limit of its travel (not stopped by a stop pawl), it will be stopped by the latch trip lockout cam—zero stop. The blank position will be on the printing line in this case. The alphamerical type bar does not stop at zero as the numerical bar does because in printing names, addresses, and other alphabetic data, spaces occur between words, and the columns in which this occurs vary from line to line. The hammers will be fired in columns where the spaces occur because of the variable split arms causing hammers to the right of significant information to fire. If a zero, rather than a blank is set up, a zero will print instead of leaving a space. It is not practical to raise the variable split arm to prevent this, because on subsequent lines a zero may be in that column, and the hammer must be fired by the position to the left.

A zero punched in a card is unique in that it can represent either a number (zero) or a zone (zero zone). If the control panel is wired for numerical information only, and a zero is read from a card, the type bar will be positioned as shown in Figure 201. The type bar is stopped by a stop pawl engaging the zero tooth; the type bar will not be zoned because the control panel is not wired to recognize zones. A zero will be positioned to print; this is called a numerical zero (the zero directly beneath the J).

There are many occasions when an alphamerical type bar will print both numerical and alphabetical information, as in printing a name and address:

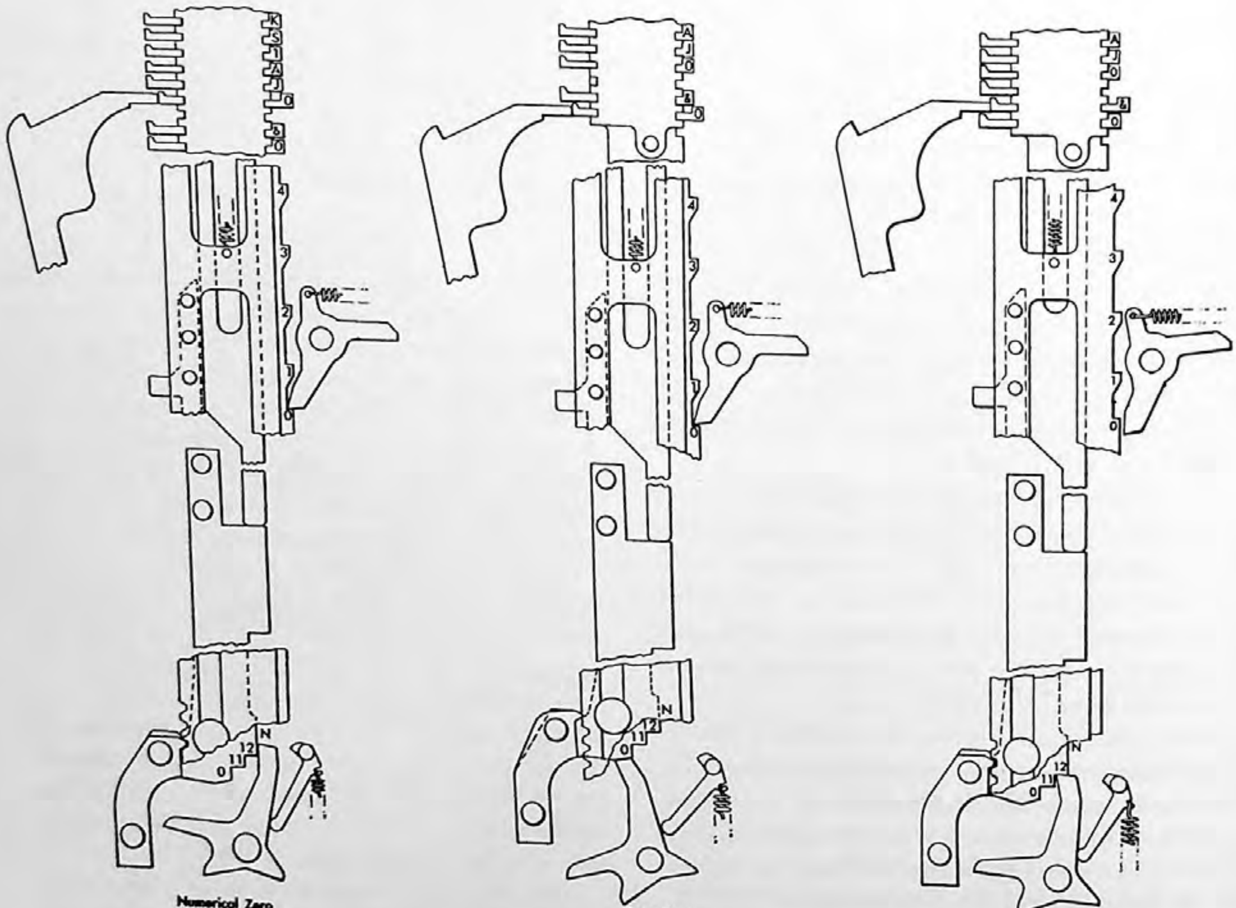
```
SLUG TYPE COMPANY
1200 SANDY BOULEVARD
PORTLAND, OREGON
```

In this case, the control panel is wired to recognize zone punches as well as numerical punches. The type bar is stopped by a stop pawl engaging the zero tooth as it was for a numerical zero, but the type bar is also zoned. A check of the zone slide in Figure 201 will show that the zone slide and upper section are raised by a distance equal to three pieces of type. This positions the zero below the & to print, and it is called a zone zero. In the example above both zeros in 1200 will be zone zeros.

A special character is installed in alphabetical type bars in the position just below the blank space. An ampersand (&) is standard, but other symbols such as $, @, –, or % may be installed as requested. It should be noted that to print the special character, only a 12 punch is needed. The type bar will move up until stopped by the hammer trip lockout cam—zero stop. If the type bar has not been zoned, the hammer will fire in the blank space. However, if it is zoned for a 12, it will move the type bar up one position so that the special character will print.

Zone Bar and Setup Mechanism

Zone information is read on the cycle preceding the reading of numerical information and the printing cycle. This requires two sets of brushes one cycle apart. The zone information is read and placed in a zone unit. At the beginning of the next card feed or print cycle, the information is placed in the type bar.



Numerical Zero — Zone Zero — Special Character

Figure 201. Zero and Special Character Printing

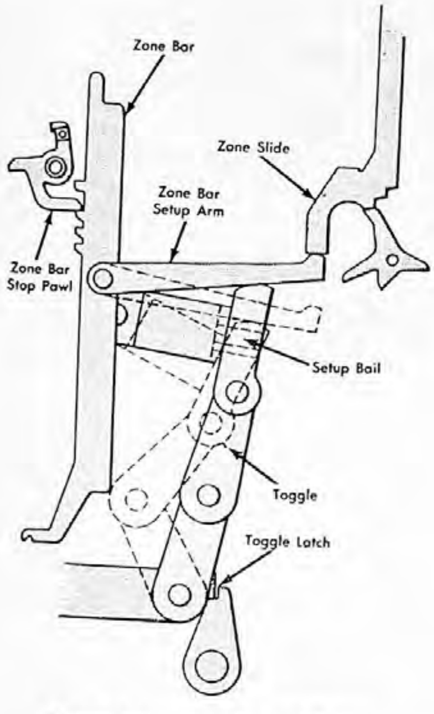


Figure 202. Zone Bar and Setup

The zone bars in the zone unit move in synchronism with the card, as do type bars. The zone bar only moves during the time that zones are sensed, and is capable of setting up a numerical, 12, 11, or 0 zone.

The elements of the setup mechanism are shown in Figure 202. The zone bar setup arm is the medium through which the zone is actually transferred into the type bar. The zone bar setup arm pivots on a stud on the zone bar and rests on the setup bail by its own weight. This figure shows both positions of the toggle, i. e. collapsed and straightened. When the toggle is straightened, the toggle latch will support the lower end of the toggle if the type bars are to be zoned.

The setup bail always rises to the same point when the toggle is straightened. If the setup bail was stationary while the zone bar moved up and down, the position of the zone bar setup arm against the zone slide would depend on the position of the zone bar. In that case, the setup bail would merely act as a fulcrum. The same effect is achieved by positioning the zone bar and then straightening the toggle. When the toggle is straightened, the position of the zone slide will be determined by the position of the zone bar.

The lower the position of the zone bar, the higher the zone slide on the type bar will be lifted. Because the zero zone is the first zone to be read, the first tooth that can engage the zone bar stop pawl represents a zero. This is the *lowest* position the zone bar can stop in. This also results in lifting the zone slide on the type bar to its *highest* position. Figure 203 shows the four possible positions of the zone bar and zone slide. It is obvious from this figure why the type was arranged as it was with the 12 zone type immediately under the numerical, etc.

Zone Control Drive Unit

The zone control drive unit is the mechanism which operates and controls the zone unit assembly. It consists of an assembly of 4 cams (Figure 204), which is driven by the card feed mechanism and operates only when the card feed clutch is engaged. The cams operate bails in the zone unit assembly so that it may accept the 0-11-12 information punched in the card and place this information in the corresponding type bar zone slide position.

Zone Unit Assembly

The zone unit assembly has 43 zone bars and zone bar setup arms, one for each alphamerical type bar (Figure 205). The zone bar is raised by spring tension and its position and operation are controlled by the cams of the zone control drive unit.

Zone Cam 1 — Figures 206 and 207

Cam 1 in the zone control drive unit, through arms and cam followers, operates the zone bar restoring bail. The main purpose of the bail is to control the rate at which the zone bar will rise in relation to the stop pawl. This relation of the 0, 11, and 12 teeth to the stop pawl is called zone lap and corresponds to list lap when speaking of the type bars. Zone lap is the overlap of the zone unit stop pawl on a tooth of the zone bar at the time the circuit breaker impulse is made for a 0, 11, or 12-hole, no time being allowed for slowness or delay in the action of the stop pawl or zone bar.

The time required to raise the zone bar from the 0 to the 11 tooth, or one unit, is 18° which corresponds to the distance between the 0 and 11 punches in the card. Therefore, if an impulse for an 11-hole is completed by the circuit breakers at 189° and the stop pawl brings the zone bar to rest at 204°, the

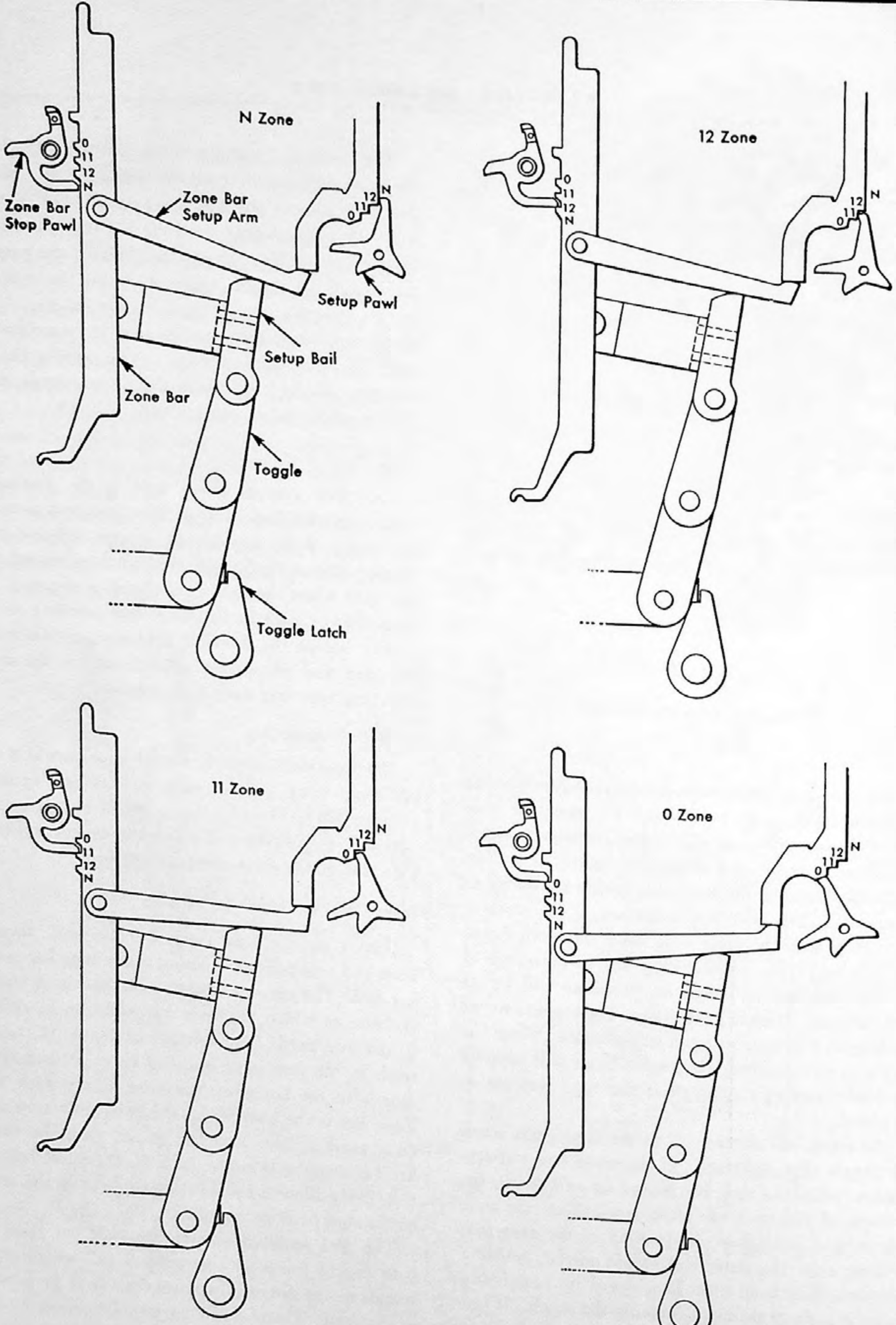


Figure 203. Zone Bar and Setup Mechanism Position for Each Zone

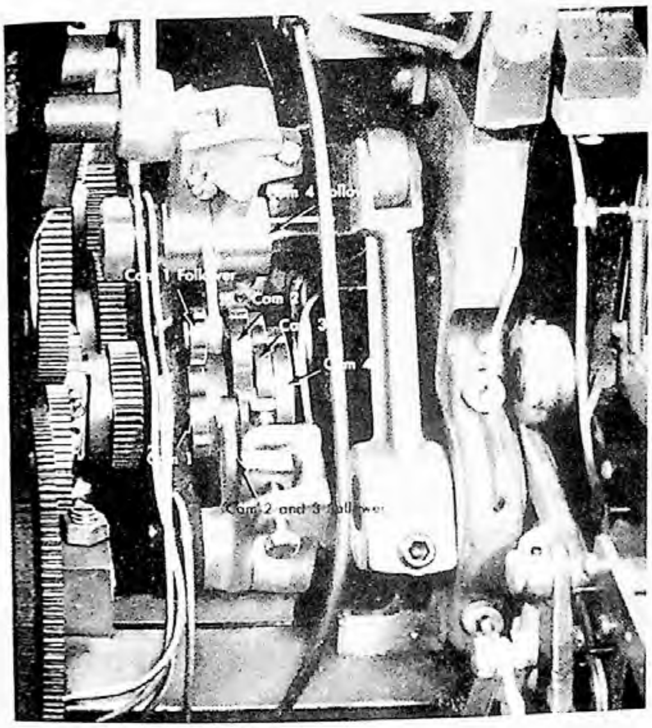


Figure 204. Zone Control Drive Unit

zone bar will rise that distance in 15°. This will allow 3° zone lap or overlap of the stop pawl on the 0 tooth at the time the stop pawl zone magnet is energized. The 15° safety factor will give the stop pawl time to swing into position to stop the zone bar before it comes to rest on the 11 tooth.

The restoring bail on the down movement causes the stop pawls to be restored back upon the latches. Additional linkage performs other functions; it operates the latch restoring bail and the toggle latch restoring link, and causes the toggle armature latch to be restored back upon its armature.

The forked arm on the cam 1 follower is adjusted so that the zero tooth of the zone bar will come to rest against the stop pawl when the machine index is at 186°. A similar condition is also true for the 11 tooth and the 12 tooth of the zone bar at the correct time shown on the mechanical timing chart.

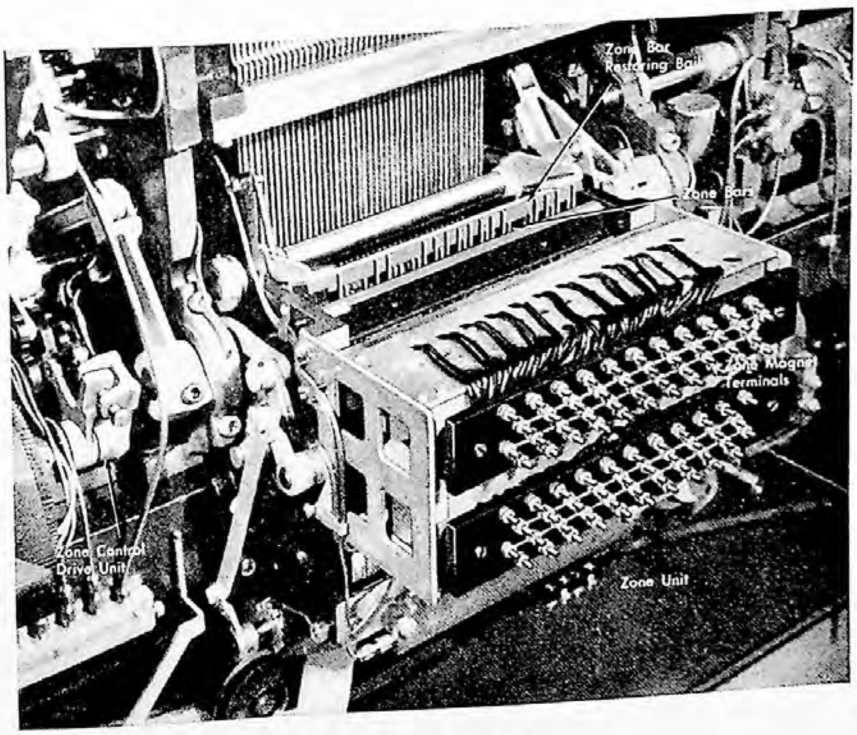


Figure 205. Zone Unit

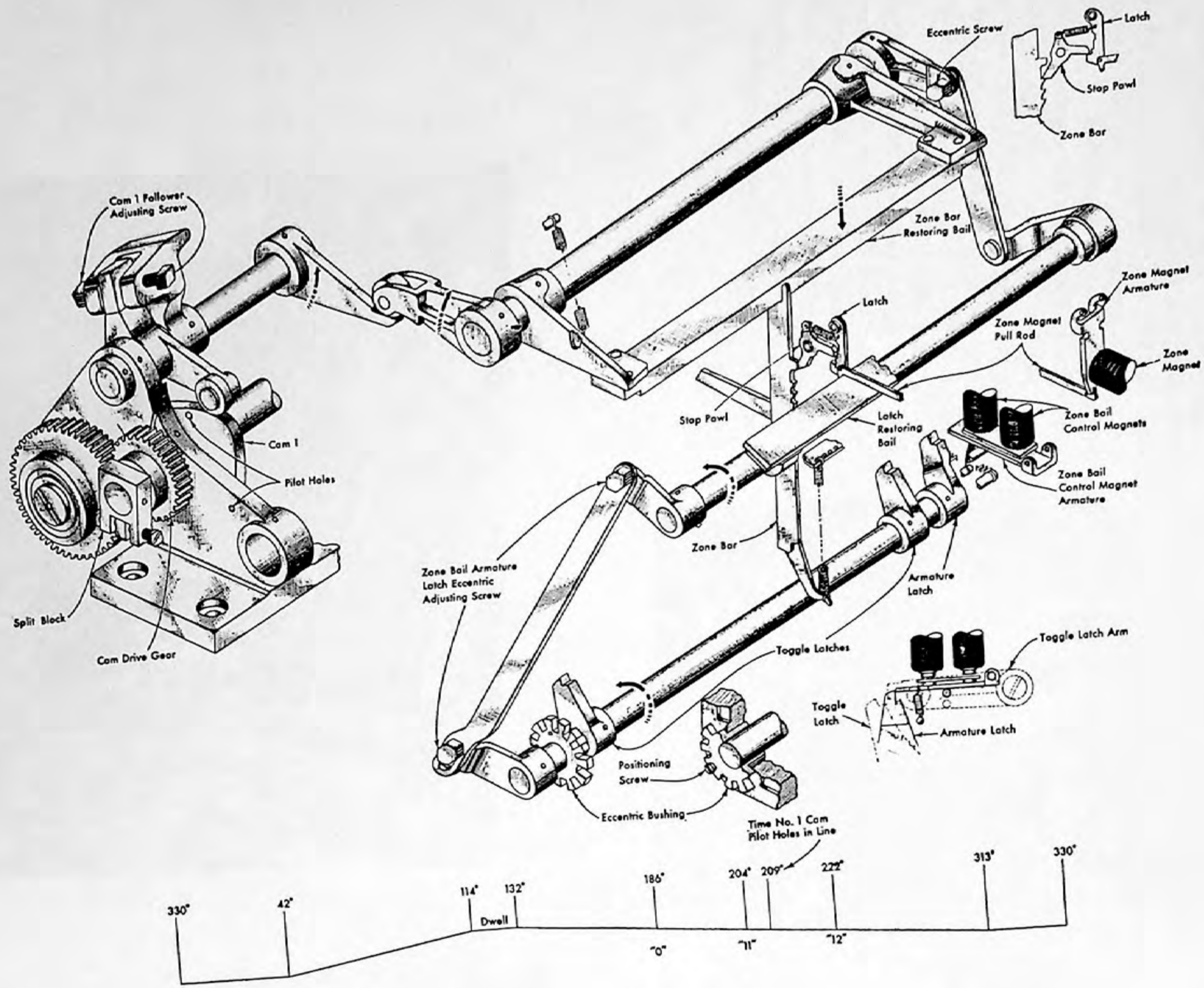


Figure 206. Cam 1 Operation

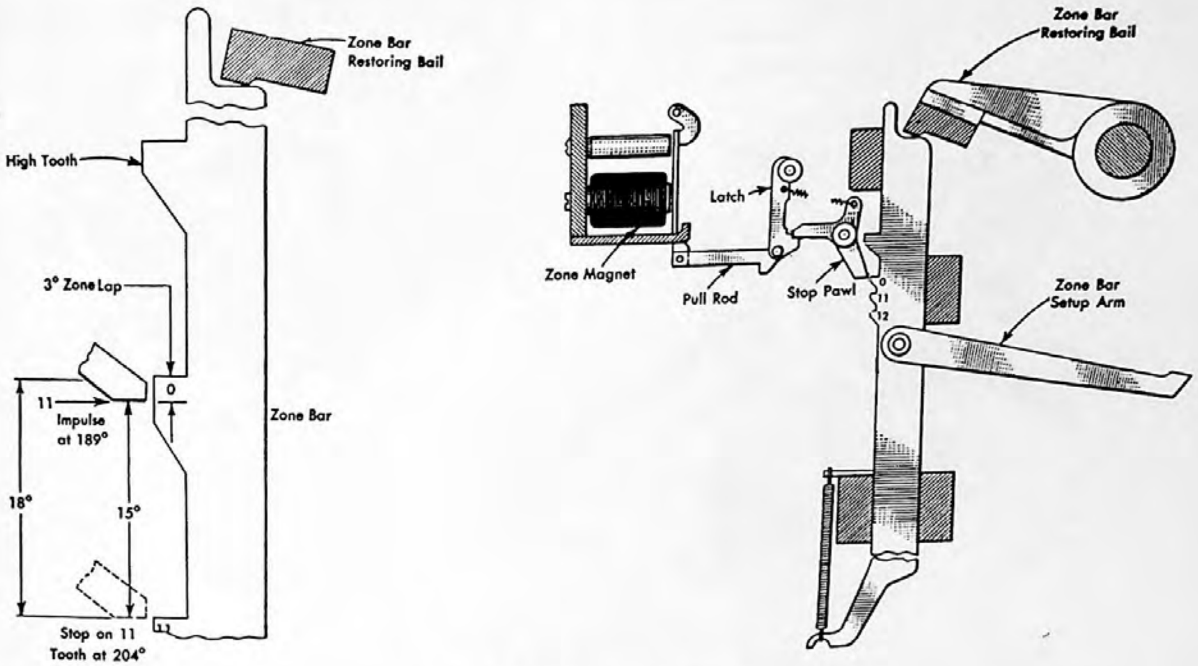


Figure 207. Zone Bar Zone Lap

Zone Cam 2 — Figure 208

Cam 2 through connecting linkage causes the toggles, when resting on their latches, to straighten out. This in turn raises the setup bail and causes the zone bar setup arm to raise the type bar zone slide so that the setup pawl may fall into the correct zone position. This places the zoning originally read from the card by the reading brushes in the type bar.

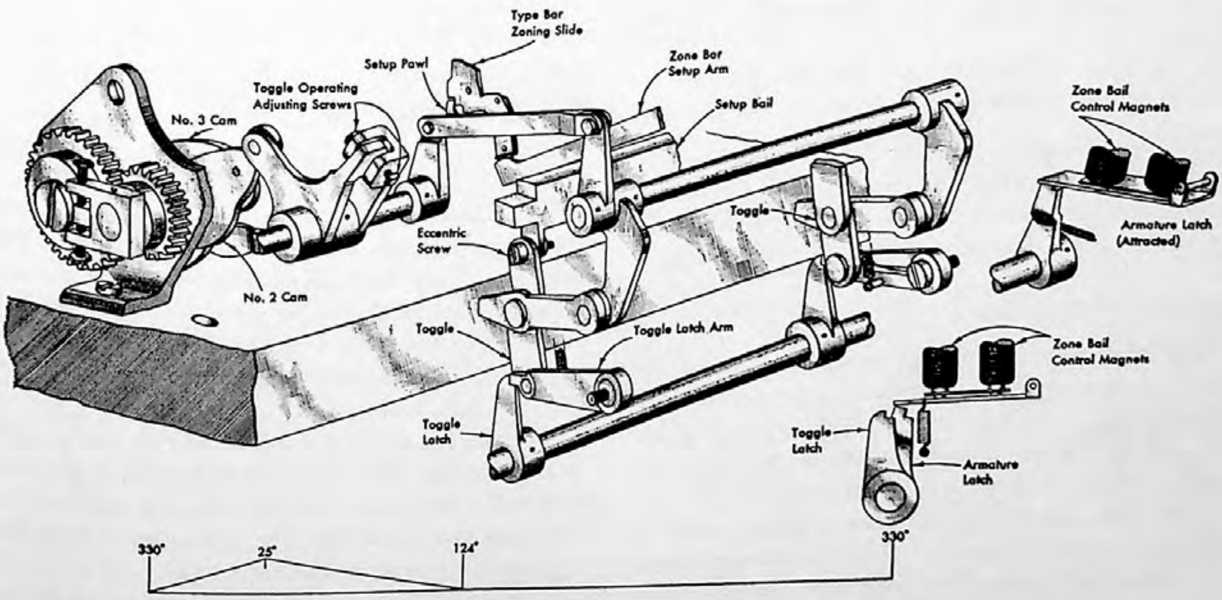


Figure 208. Cam 2 and 3 Operation

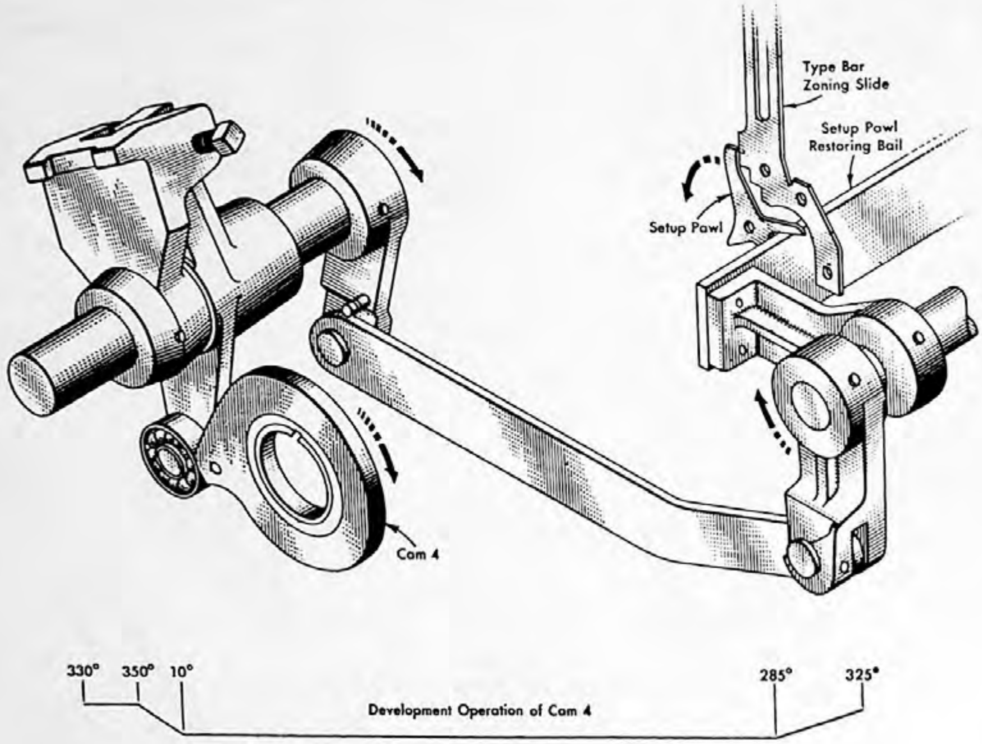


Figure 209. Cam 4 Operation

Zone Cam 3 — Figure 208

Cam 3, through connecting linkage, causes the toggle to be restored or returned to its normal collapsed position.

Zone Cam 4 — Figure 209

Cam 4, through connecting linkage, operates the setup pawl restoring bail. This causes the setup pawls, which have been previously zoned, to be restored to the numerical zone before accepting a new reading.

Sequence of Operation

The relation of the various parts, at the time the zone unit is completing a setup of the type bar zone slide, is shown in Figure 210. The sequence chart (Figure 211) shows the relationship of the operations performed by the cams in the zone control drive unit.

The zone unit is able to retain a reading because the zone control drive unit does not operate except on a card feed cycle. Therefore, any reading placed in the zone bars will not be transferred to the alphamerical type bar zone slide until the card from which the zone section was read is ready to be moved past the brushes reading the numerical punching in that same card. When the electrical circuits are studied, it will be seen that the zone bail control magnet may be impulsed every card feed cycle.

Alphamerical Type Bar Bail Assembly

The alphamerical type bar bail assembly is very similar in principle to the numerical type bar bail assembly. They are both cam operated and are designed to raise and lower the type bars. The restoring bail moving up permits spring tension to raise the type bars, and the restoring bail moves down to restore the type bar.

The major difference between the two mechanisms is that the alphamerical spring bail has a fixed location and, consequently, maximum spring tension when the type bars are down. The alphamerical type bar bail assembly is shown in Figure 212.

The list lap is the same for the alphamerical bar as it is for the numerical bar. The type bar will move

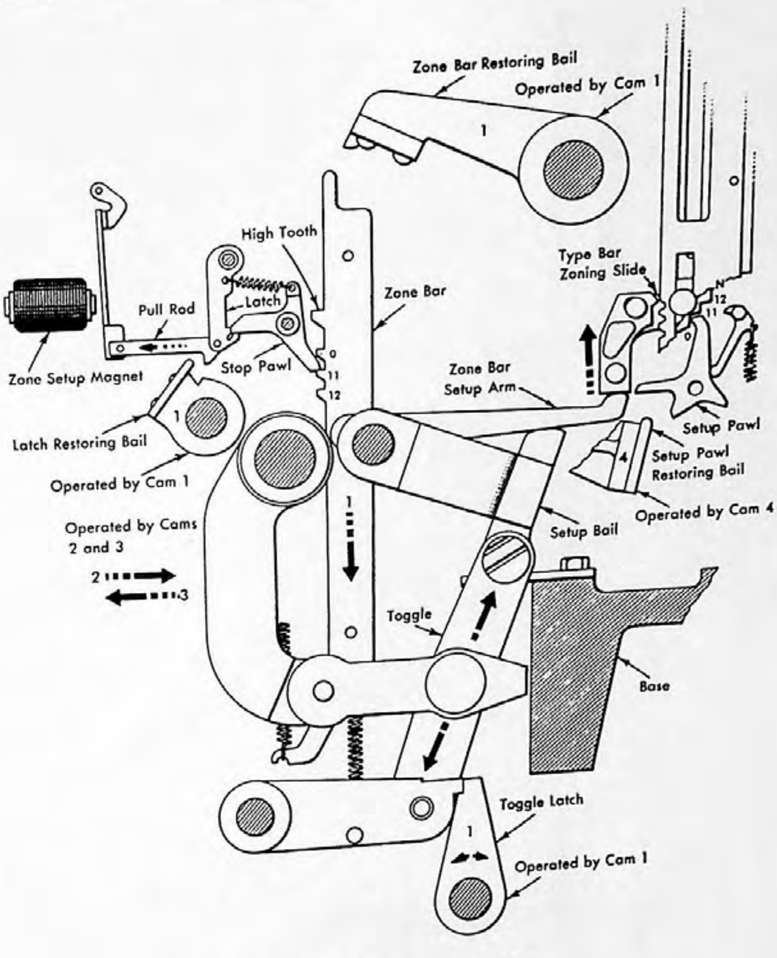


Figure 210. Zone Unit Operation

in synchronism with the card so that it requires 18° on the index to move from one tooth to the next. The list lap is 3° leaving 15° of type bar movement after the stop pawl magnet is energized, before being stopped by the stop pawl.

Hammer Unit

The hammer unit and hammerlock assembly is the same mechanism previously described. The alphamerical type bar has a hammer latch trip lockout cam instead of the stud on the numerical bar, but it serves the same function.

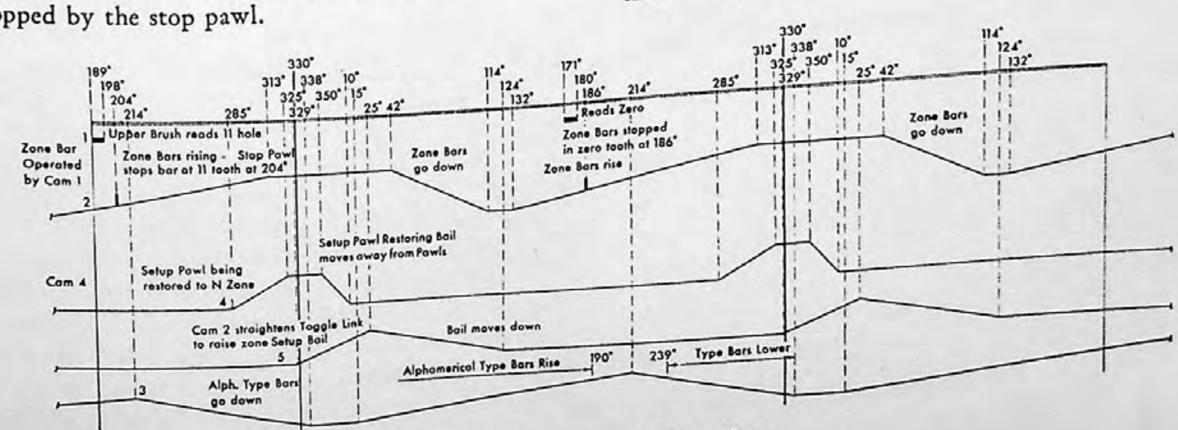


Figure 211. Sequence of Operation

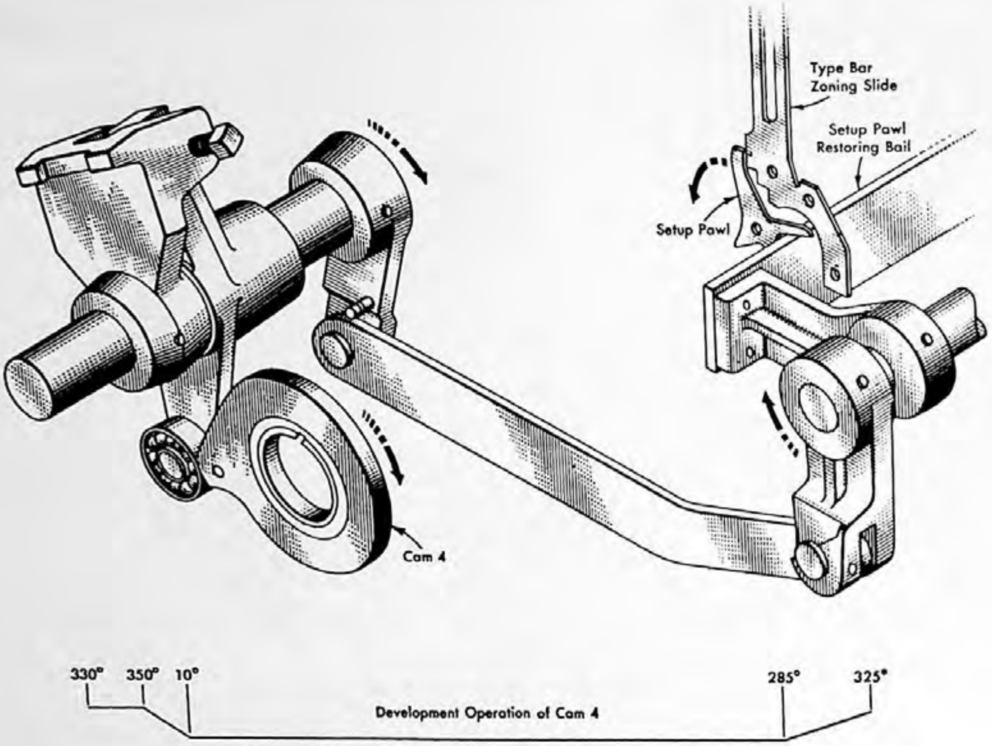


Figure 209. Cam 4 Operation

Zone Cam 3 – Figure 208

Cam 3, through connecting linkage, causes the toggle to be restored or returned to its normal collapsed position.

Zone Cam 4 – Figure 209

Cam 4, through connecting linkage, operates the setup pawl restoring bail. This causes the setup pawls, which have been previously zoned, to be restored to the numerical zone before accepting a new reading.

Sequence of Operation

The relation of the various parts, at the time the zone unit is completing a setup of the type bar zone slide, is shown in Figure 210. The sequence chart (Figure 211) shows the relationship of the operations performed by the cams in the zone control drive unit.

The zone unit is able to retain a reading because the zone control drive unit does not operate except on a card feed cycle. Therefore, any reading placed in the zone bars will not be transferred to the alphamerical type bar zone slide until the card from which the zone section was read is ready to be moved past the brushes reading the numerical punching in that same card. When the electrical circuits are studied, it will be seen that the zone bail control magnet may be impulsed every card feed cycle.

Alphamerical Type Bar Bail Assembly

The alphamerical type bar bail assembly is very similar in principle to the numerical type bar bail assembly. They are both cam operated and are designed to raise and lower the type bars. The restoring bail moving up permits spring tension to raise the type bars, and the restoring bail moves down to restore the type bar.

The major difference between the two mechanisms is that the alphamerical spring bail has a fixed location and, consequently, maximum spring tension when the type bars are down. The alphamerical type bar bail assembly is shown in Figure 212.

The list lap is the same for the alphamerical bar as it is for the numerical bar. The type bar will move

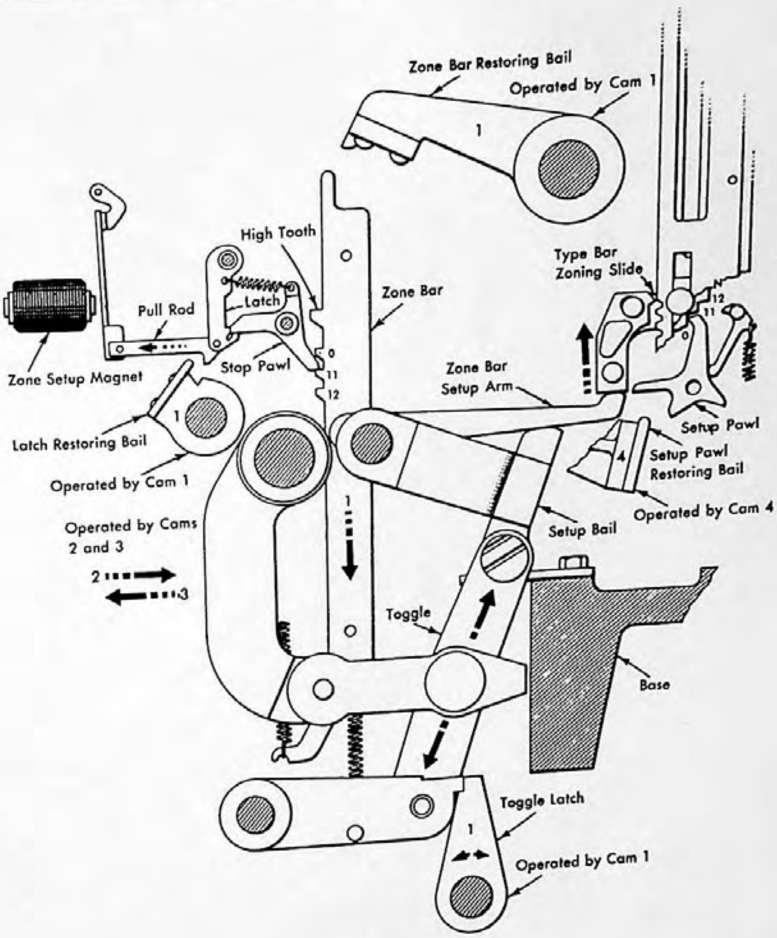


Figure 210. Zone Unit Operation

in synchronism with the card so that it requires 18° on the index to move from one tooth to the next. The list lap is 3° leaving 15° of type bar movement after the stop pawl magnet is energized, before being stopped by the stop pawl.

Hammer Unit

The hammer unit and hammerlock assembly is the same mechanism previously described. The alphamerical type bar has a hammer latch trip lockout cam instead of the stud on the numerical bar, but it serves the same function.

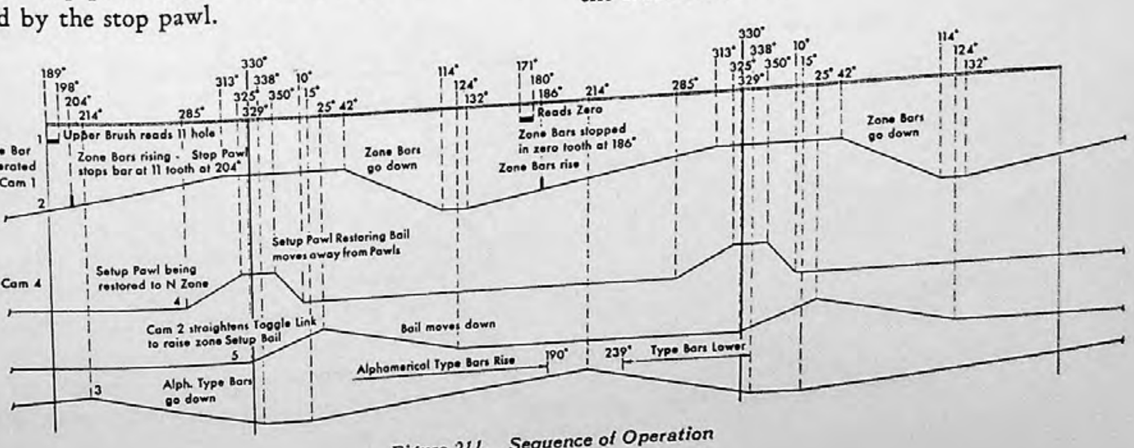


Figure 211. Sequence of Operation

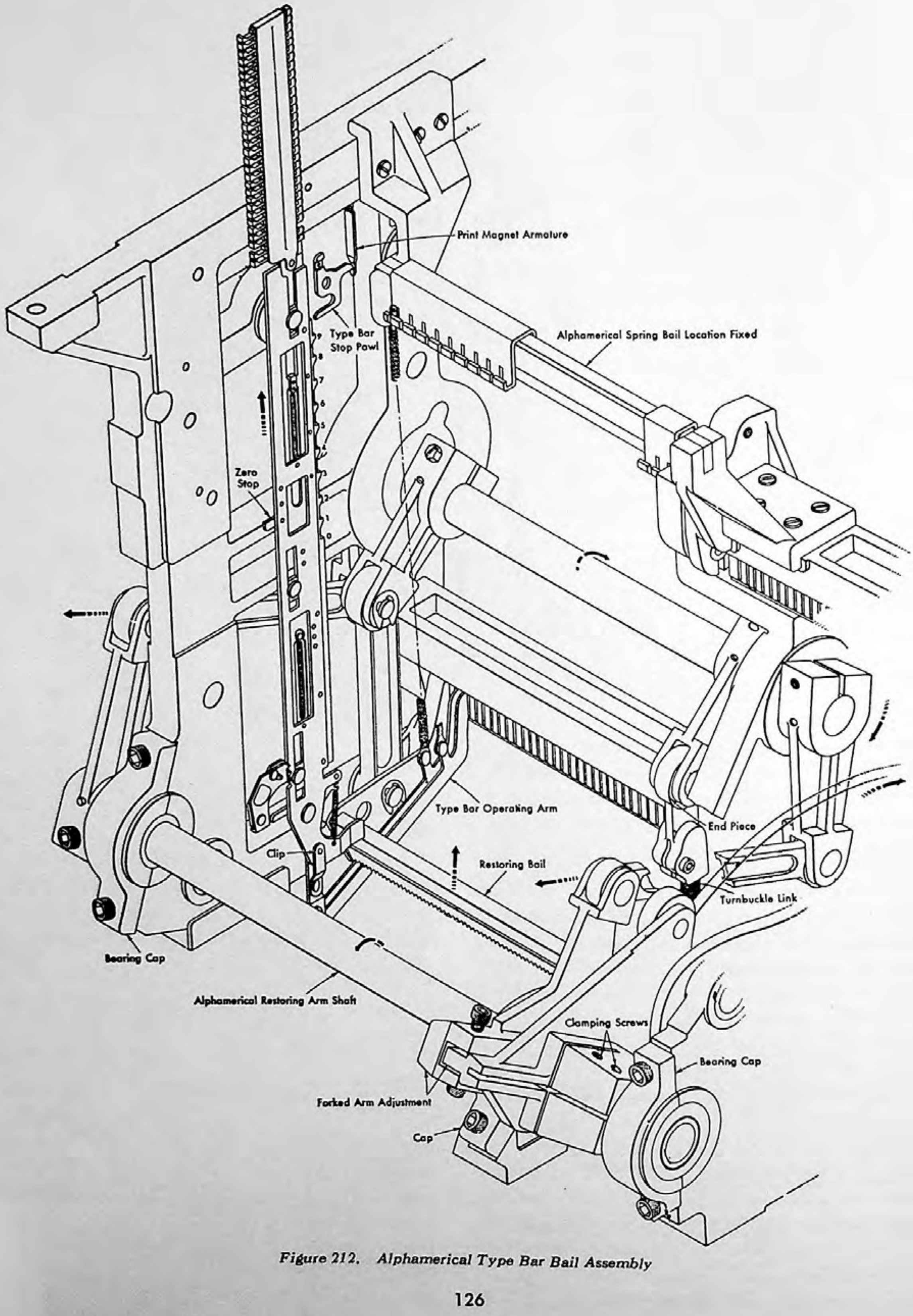


Figure 212. Alphamerical Type Bar Bail Assembly

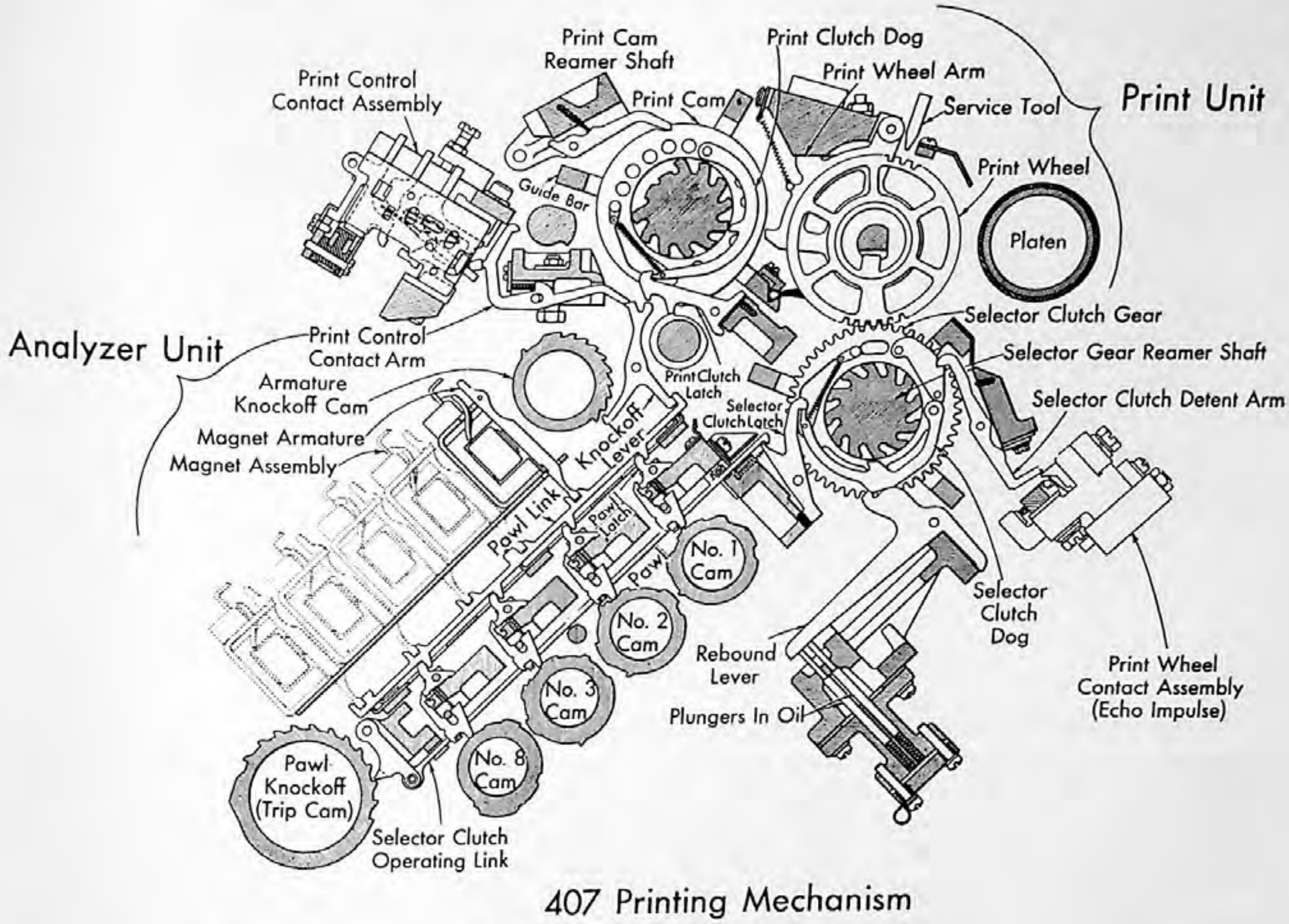


Figure 213. Printing Mechanism

TYPE 407 PRINTING MECHANISM

THE OVER-ALL operation of the print unit will be discussed first and will be followed by a description of the units in detail.

The printing of this machine is performed by the type wheel print mechanism. The print mechanism (Figure 213) will print 120 alphabetic or numerical characters at the rate of 150 operations per minute. The type wheels are positioned to print ten characters per lateral inch. Each of the 120 printing positions is capable of printing forty-eight characters; ten numerical characters, twenty-six alphabetic characters and twelve special symbols. The numerical and alphabetic characters are selected by the holes in the card in the usual manner, a lower punch alone for the digit and the lower and upper combined for alphabetic. Both the upper and lower impulses are received during the same cycle from the same card to print the alphabetic characters. It is not necessary to read the zone impulse a cycle early as in previous accounting machines. The twelve special symbols are selected by various combinations of holes in the card or by impulses from the character emitter. An 8 and a 4 impulse or an 8 and a 4 in combination with each of the zone impulses 0, 11, and 12 will provide four different symbols. An 8 and a 3 alone or in combination with each of the zone impulses 0, 11, and 12 will provide four more symbols. A zero and 1 will provide one more symbol. By using the 11 and 12 impulses alone, two more symbols can be obtained; by using the N impulse (no zone impulse, available on each machine cycle) one more symbol can be obtained, making twelve in all. See Figure 214 for the individual codes. The character emitter may be used to print any of the 48 characters without any punching in the card. Several other entry and exit hubs may be used to print certain symbols as covered in the *Circuits* section.

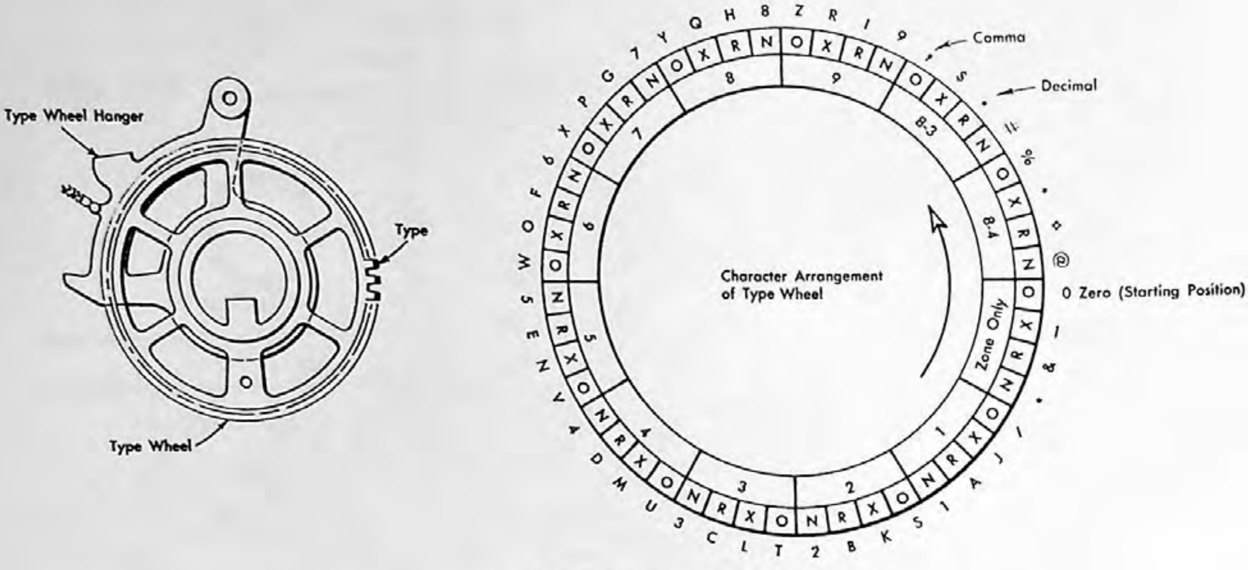


Figure 214. Type Wheel

Type Wheel

The type wheel (Figure 214) upon which the 48 characters of type are located is positioned for printing by means of the selector clutch gear assembly (Figure 215) and the print cam assembly (Figure 216) working in conjunction with each other. The selector clutch gear is controlled by the lower readings (1-9) of the card, counter, emitter, storage or N impulse, whereas the print cam is controlled by the 0, 11, 12, or N impulse.

Print Magnet

Both the selector clutch gear and the print cam are under control of the same print magnet (Figure 213). The time at which the print magnet becomes energized determines whether the selector clutch gear or the print cam will operate. During the time the 9 through 1 impulses are received from the card, counter, emitter, or storage units, the print magnet is energized; this later causes the selector clutch dog to be released and in turn causes the selector clutch

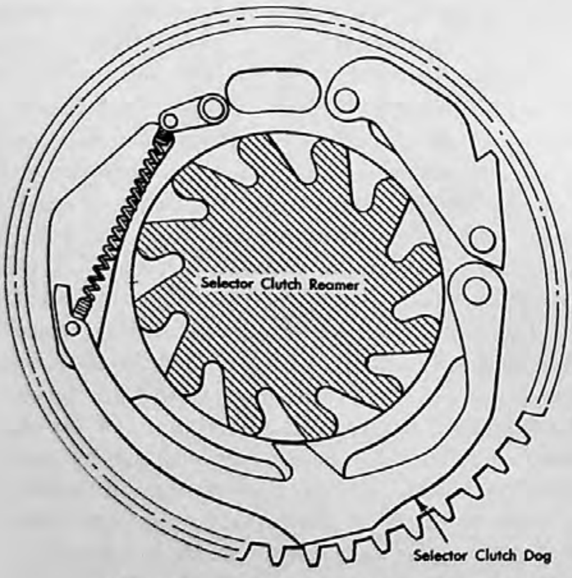


Figure 215. Selector Clutch Gear Assembly

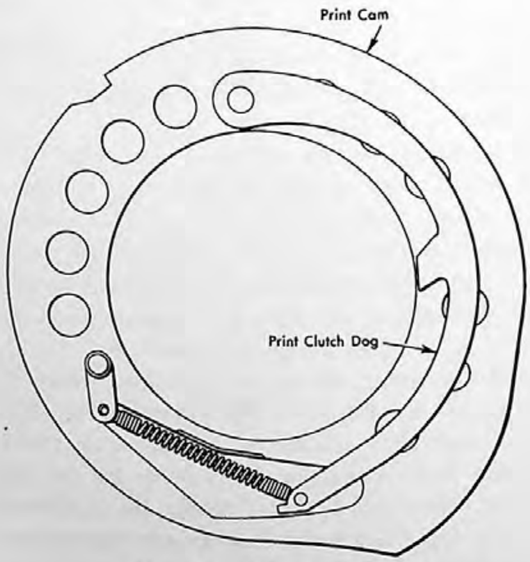


Figure 216. Print Cam Assembly

gear to operate. The N impulse, an automatic machine impulse coming through at 187°, may also cause the selector clutch gear to operate if the print magnet has not previously been energized. This depends upon the control panel wiring and the condition of adjacent positions. When the selector clutch gear operates, the type wheel also operates since they are geared together.

It should be noted here that the surfaces of contact of the clutch dogs and the clutch reamer flutes are 90° to a line drawn through the surface and

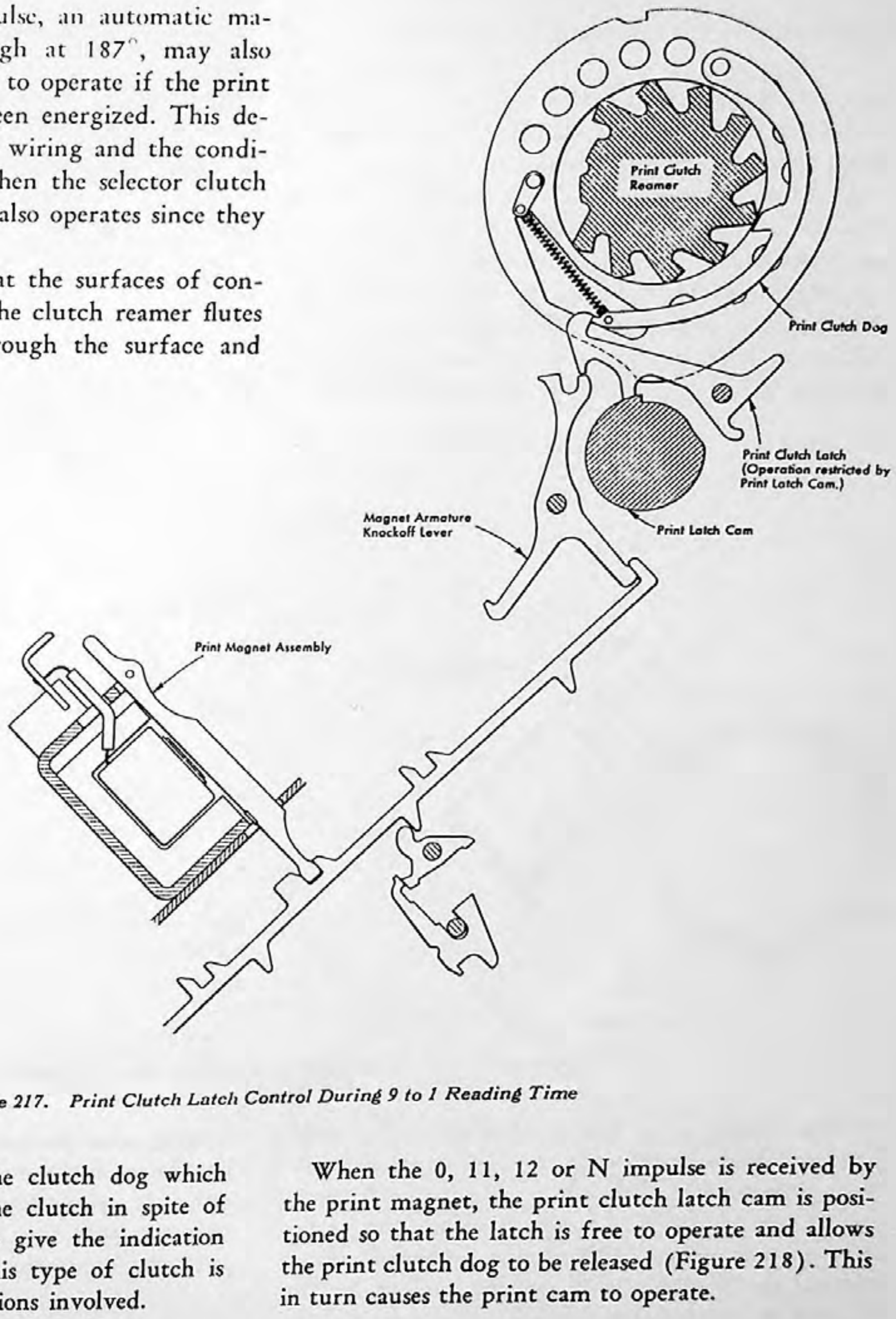


Figure 217. Print Clutch Latch Control During 9 to 1 Reading Time

through the pivot point of the clutch dog which assures positive operation of the clutch in spite of the appearance which tends to give the indication that the clutch might slip. This type of clutch is most satisfactory for the operations involved.

Print Clutch Latch

During the 9 through 1 impulses the print clutch latch is not affected because the print latch cam prevents the print clutch latch from being released (Figure 217). Consequently, the print cam does not operate as a result of a 9 through 1 impulse from any source.

When the 0, 11, 12 or N impulse is received by the print magnet, the print clutch latch cam is positioned so that the latch is free to operate and allows the print clutch dog to be released (Figure 218). This in turn causes the print cam to operate.

Variable Speed

At the time the selector clutch dog is engaged in the selector clutch reamer, the reamer is turning at the rate of 300 RPM. The movement between each flute on the selector clutch reamer is equal to a movement of four teeth on the selector clutch gear. Since the selector clutch gear is geared to the type wheel,

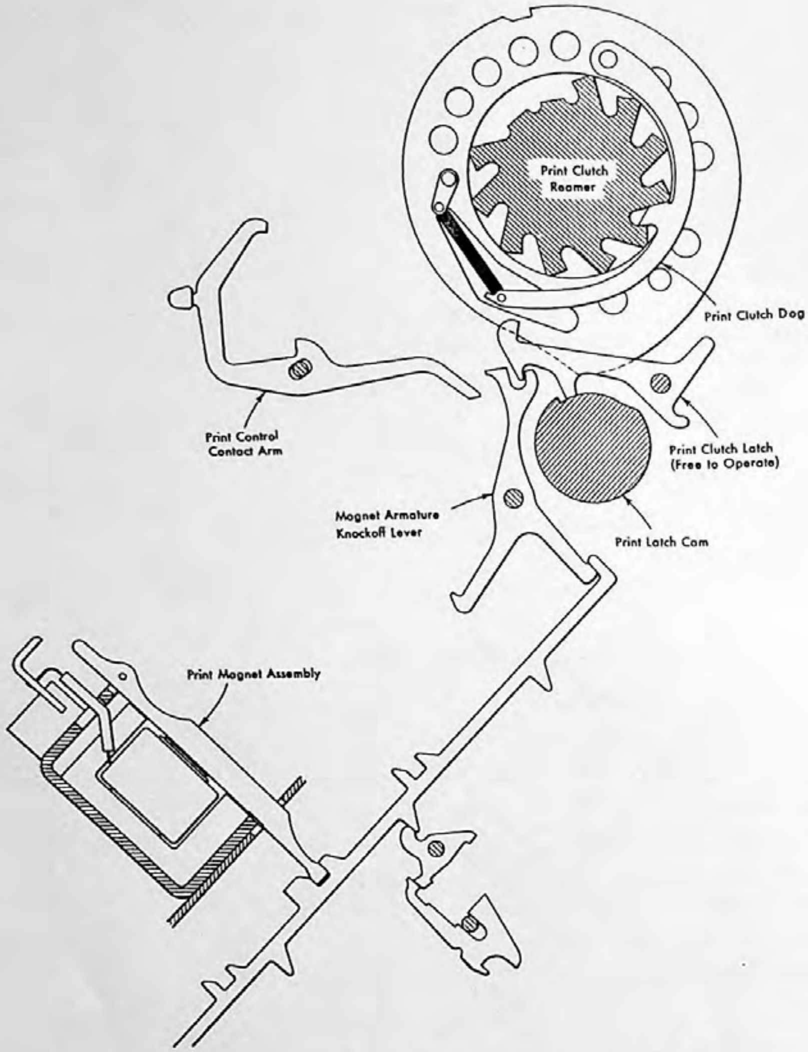


Figure 218. Print Clutch Latch Control During 0, 11, 12, and N Time

the type wheel moves four type positions for each flute movement of the reamer. This represents one cycle point or 15°. This means that for each selection of the selector clutch gear, printing may take place in any one of four places depending upon whether the character to be printed has a 0, 11, or 12 zone or whether it is a numerical character with an N impulse. This also makes it necessary to print at four different times in one machine cycle. Unlike former machines, all printing is not done at the same instant. The time of printing depends upon the time that the print cam starts to operate and that may be at any one of four different times (0, 11, 12, or N). Printing takes place at 300°, 315°, 330°, and 345°. The flutes of the print reamer shaft are machined with a 7° spiral. Since the shaft turns two revolutions per cycle, this causes the print clutch dog for position 1 to engage 3½° earlier than position 120.

Type Wheel Selection

The selection between the four type positions is accomplished by controlling the printing time which depends upon the zone of the character to be printed. The type wheel turns up to the time that the printing is performed. The printing actually takes place when the type wheel is cammed toward the platen. The print cam does not cam the type wheel fully against the platen by positive action. The type wheel is cammed to within approximately 1/16″ of the platen and is forced against the platen by its own momentum.

The print clutch dog (Figure 218) is released when the print magnet is energized by a 0, 11, 12 or N impulse, allowing the dog to become engaged in the continuously running print clutch reamer. This revolves the print cam, the high lobe of the print cam comes in contact with the type wheel hanger, the type wheel is rocked toward the platen, and printing takes place.

Since the type wheel is turning at the time the print cam forces the wheel against the platen, the character to be printed can be controlled by timing the camming action. The selector clutch gear has been set up to position the type wheel so that any one of four positions may print. If the lower impulse which controls the operation of the selector is a 5, the selector clutch dog will become engaged with the proper reamer flute to print a V, N, E or 5. The one flute will position the selector gear for printing all

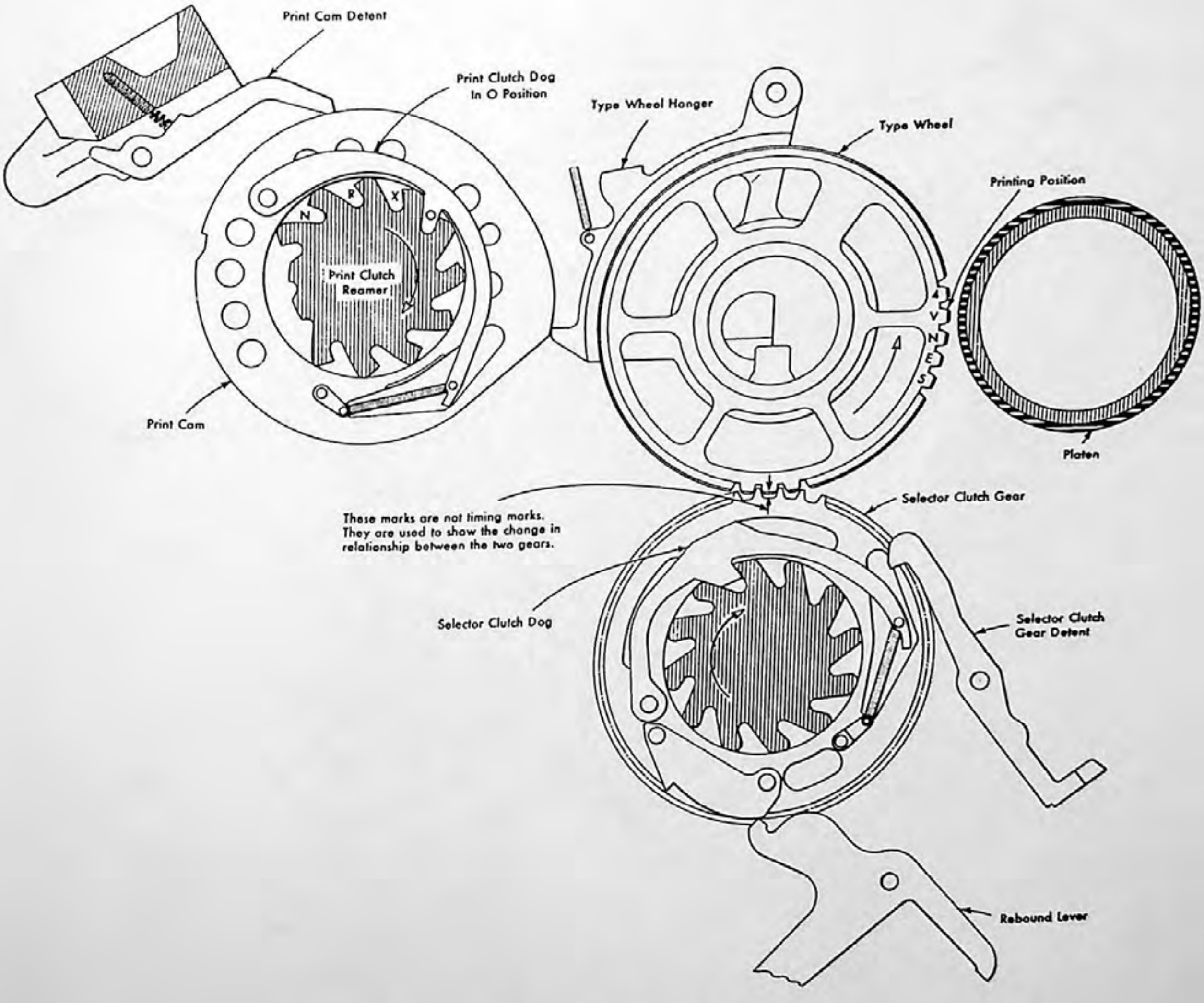


Figure 219. Printing Mechanism Positioned for Printing V

four of these characters. The character that is printed is dependent upon the zone impulse that is received by the print magnet the second time. As mentioned previously, printing takes place when the print cam operates against the type wheel hanger and forces the type wheel against the platen. If a zero (0) impulse is received by the print magnet, causing the print cam to start operating at 155°, the V which is the first character of the group will be printed at 300°, since this is the time when the highest point of the print cam comes in contact with the type wheel hanger assembly. (Refer to Figure 219 for the operation of the print cam and selector clutch gear.) If an 11 impulse is received by the print magnet causing the print cam to start operating at 170°, the N, which is the second character of the group, will be printed at 315°. (Figure 220 shows the relative position of the print cam and selector clutch gear when printing an N.) If a 12 impulse is received by the print magnet causing the print cam to start operating at 185°, the E, which is the third character of the group, will be printed at 330° (Figure 221). If no zone impulse is received, the character printed will be a number, in this case a 5. As previously mentioned the print cam must operate for printing to take place. Therefore an impulse is needed to engage the print clutch. The N impulse, which is an automatic machine impulse coming through at 187°, energizes the print

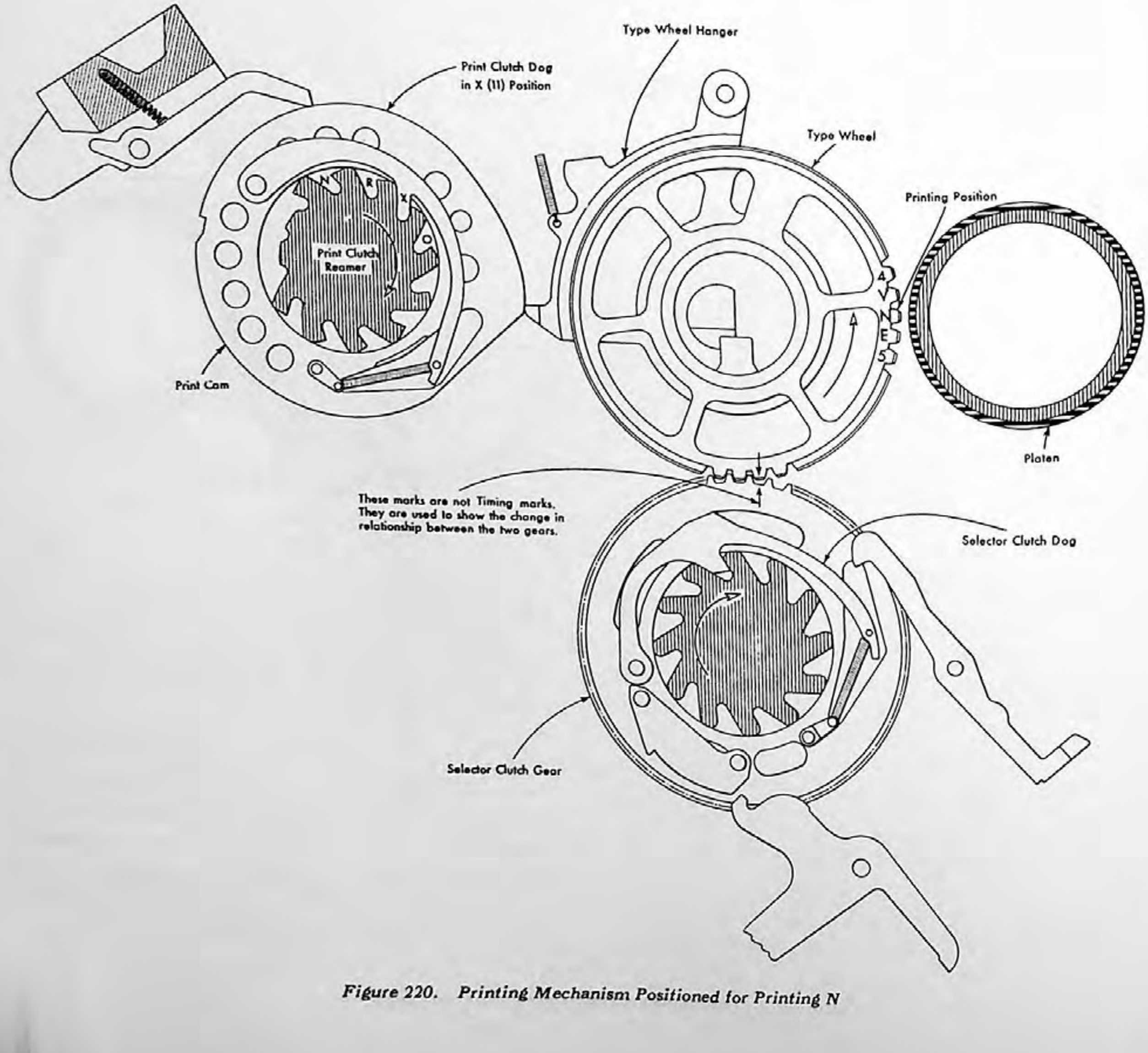


Figure 220. Printing Mechanism Positioned for Printing N

magnet and causes the print cam to start operating at 200° and the 5 to be printed at 345° (Figure 222).

The N impulse is also received on the three preceding conditions but, since the print magnet had previously been energized by zone impulses, no other effect is caused by the N impulse because the zone impulses take preference.

When the selector clutch gear is set up, the selector clutch reamer from one flute to the next moves the selector clutch gear the distance of four teeth in 15°. Since the selector clutch gear has 48 teeth and is meshed with the type wheel which also has 48 character positions, the type wheel must move four character positions for each flute of the selector clutch reamer.

At the time of printing one of the four characters must be selected. As mentioned above, the particular character to be printed is determined by the time at which the print cam operates against the type wheel hanger. Since the flutes on the print clutch reamer operate at the rate of one for each 15°, the selector clutch reamer must be slowed down to one-quarter the normal speed at printing time so that one flute of the print clutch reamer will correspond to one type position on the type wheel instead of the usual four positions. Therefore, the speed of the selector clutch

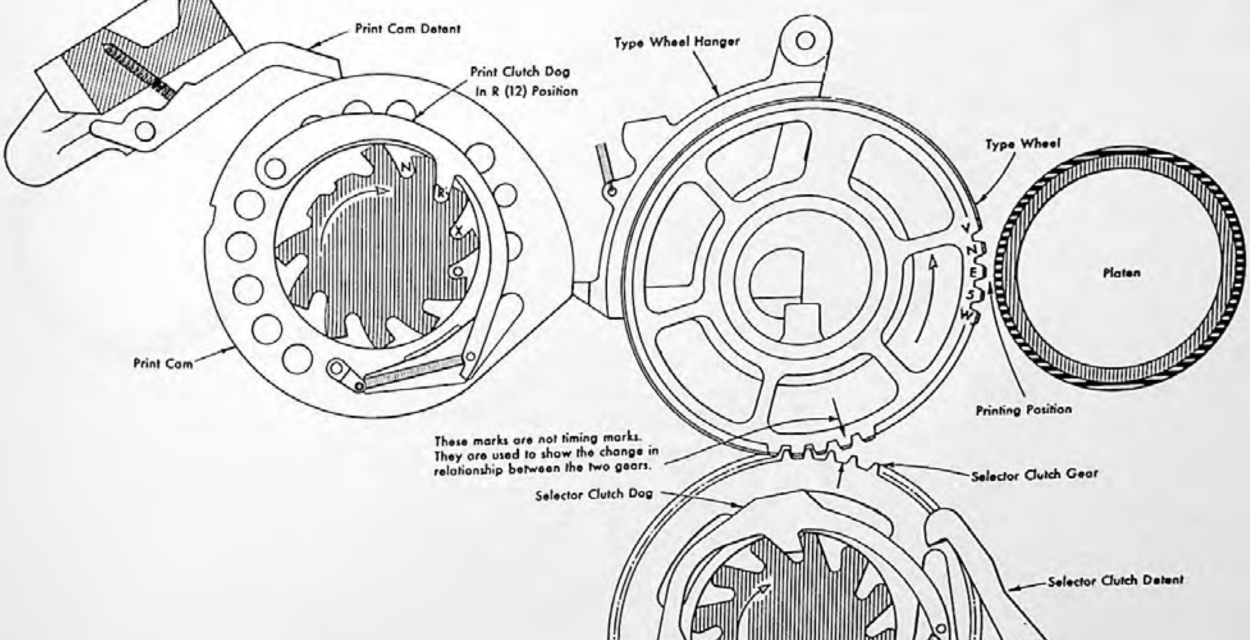


Figure 221. Printing Mechanism Positioned for Printing E

reamer at printing time (300°-345°) is 75 RPM. The speed of the print clutch reamer remains constant (300 RPM). Consequently, the movement of the four flutes of the print clutch reamer at printing time corresponds with the movement of one flute of the selector clutch reamer which is four character positions. Thus each flute of the print clutch reamer moves the distance of one character position during printing time.

The change in speed is accomplished by a variable speed drive.

The selector clutch gear drives the type wheel in a counterclockwise direction. When the print cam operates against the type wheel hanger, the type wheel tends to turn in a clockwise direction because of the pivoting action. The result of these two actions at printing time keeps the type wheel stationary for the printing operation.

The following sections cover the individual units in more detail.

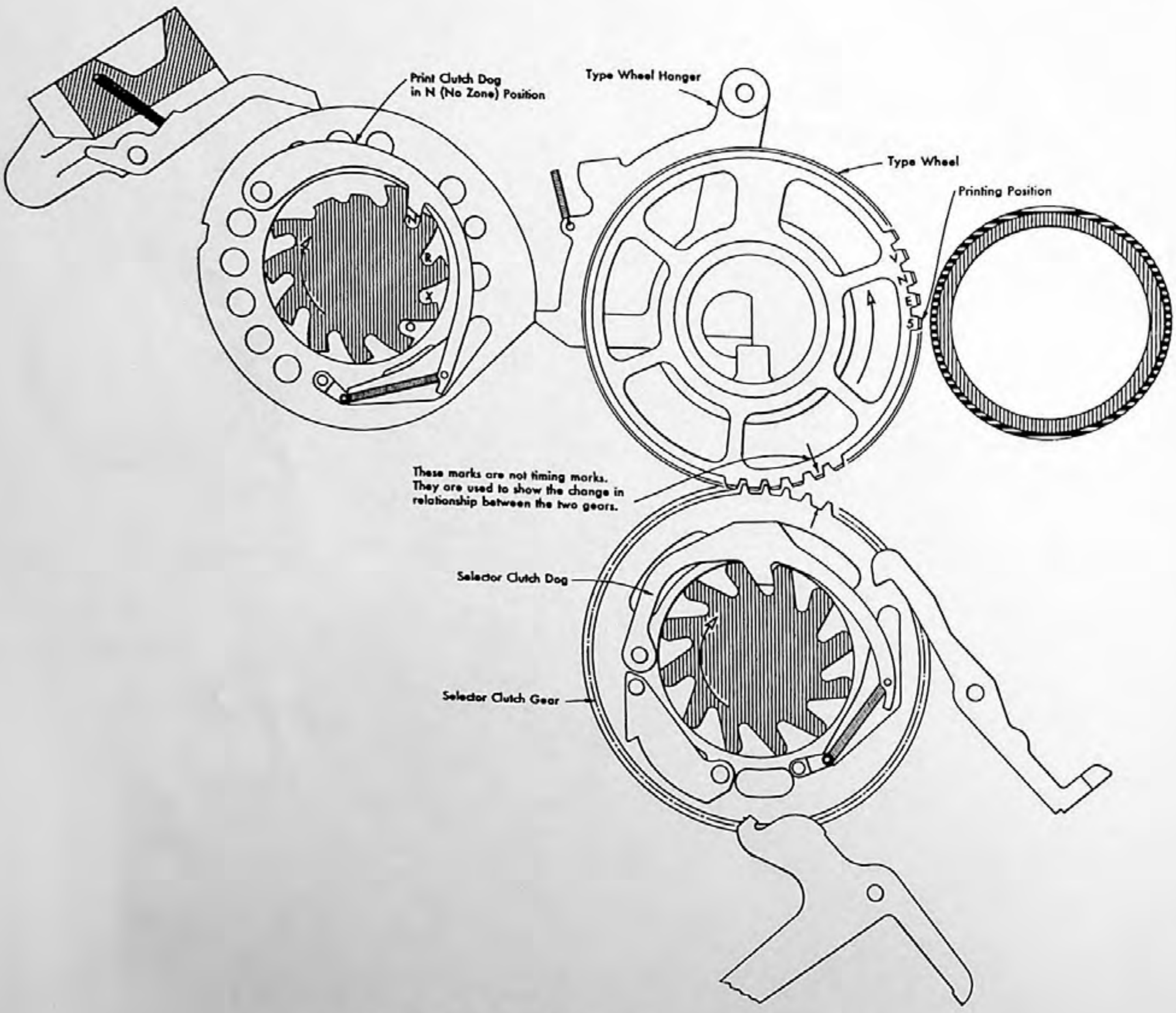


Figure 222. Printing Mechanism Positioned for Printing 5

Analyzer (Mechanical Delay) Unit

The selector clutch reamer, which operates the selector clutch gear through the selector clutch dog, has twelve flutes into which the clutch dog may fall. Selection of the proper flute must be made according to the impulse received. However, the engaging of the selector clutch dog with the reamer must be delayed beyond the time of receiving the impulse from the card or counter. This is accomplished through the mechanical delay operations of the analyzer unit. The delayed action is necessary to delay releasing the selector clutch dog until sufficient time has elapsed for sensing both impulses in one position if a special character is to print. Special characters use an 8-3 and an 8-4 combination in conjunction with zone punches. Consequently, time must be allowed to read a 3 hole before the type wheel is set up.

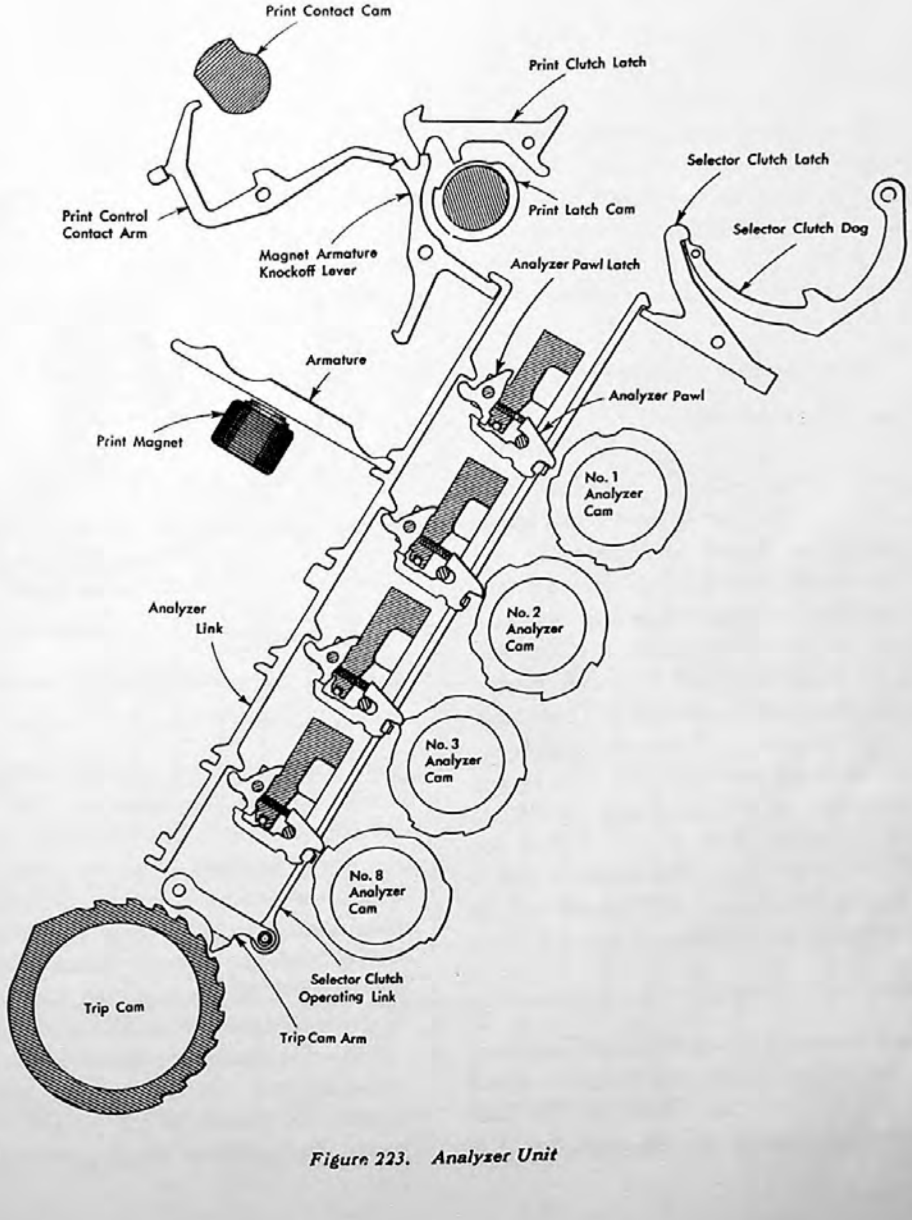


Figure 223. Analyzer Unit

Analyzer Cams and Pawls

Among the various parts of this unit are the four analyzer cams which operate the four analyzer pawls for each type wheel position. These analyzer cams extend over the length of the analyzer unit, therefore, each printing position is under control of all four analyzer cams. Each of the four analyzer cams has a different peripheral surface. The surfaces of these cams provide for three distinct heights — low, intermediate and high. The chart shown in Figure 227 gives the relative peripheries of these cams.

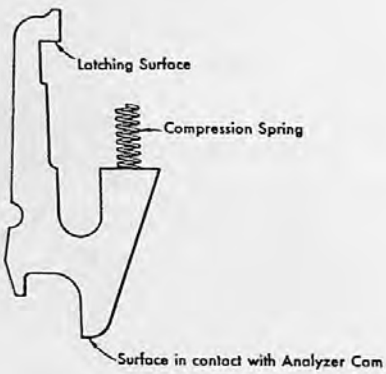


Figure 224. Analyzer Pawl

Operating against these analyzer cams are the analyzer pawls. The analyzer pawls shown in Figure 223, and as a close-up in Figure 224, normally remain in contact with the periphery of the analyzer cams by means of the compression spring between them and the latches of the analyzer pawls. (Constant reference should be made to Figure 213 while studying the operation of the analyzer unit.) These analyzer pawls are free to move and constantly slide up and down as the analyzer cams revolve. The exception to this occurs when the analyzer pawls are latched; during this time they do not follow the periphery of the analyzer cams. (See analyzer cam 1 in Figure 223.) The latching of these pawls will be covered in subsequent paragraphs.

Selector Clutch

As mentioned in preceding sections, it is necessary to have both the selector clutch and the print clutch engaged in order to print any character. The analyzer pawls have no bearing on the engagement of the print clutch but definitely control the operation of the selector clutch. Therefore, for the time being, the operation of the selector clutch gear will be considered.

By referring to Figure 213, it can be seen that to operate the selector clutch gear the selector clutch dog must be released to become engaged with the selector clutch reamer. The selector clutch dog is held in the latched or disengaged position by the selector clutch latch which in turn is operated by the selector clutch operating link. The selector clutch operating link is under control of the analyzer pawls and the trip cam which controls the actual time of tripping of the clutch dog.

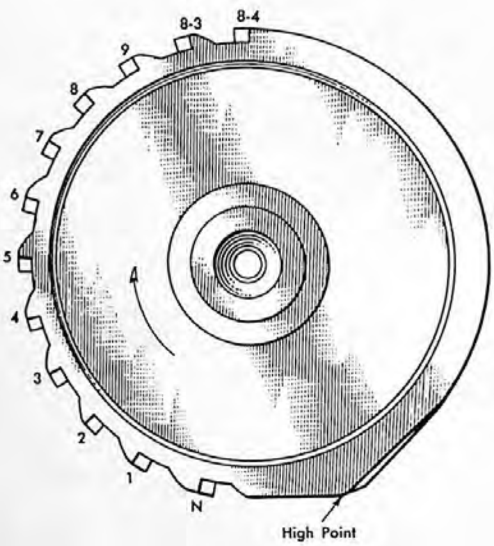


Figure 225. Trip Cam (High Point Unlatches Analyzer Pawls)

The trip cam, shown in detail in Figure 225, is used to test for the movement of the selector clutch operating link at a definite time. Because the trip cam works in conjunction with the analyzer pawls, the selector clutch dog will be released only at definite times during the cycle when the dog has the proper overlap with the selector clutch reamer flutes. The highest dwell of the trip cam also serves to unlatch all pawls that may be latched at the end of the cycle.

The other controlling factor for the selector clutch operating link, operating to the left to release the selector clutch dog, is the position of the analyzer pawls. Each selector clutch operating link (Figure

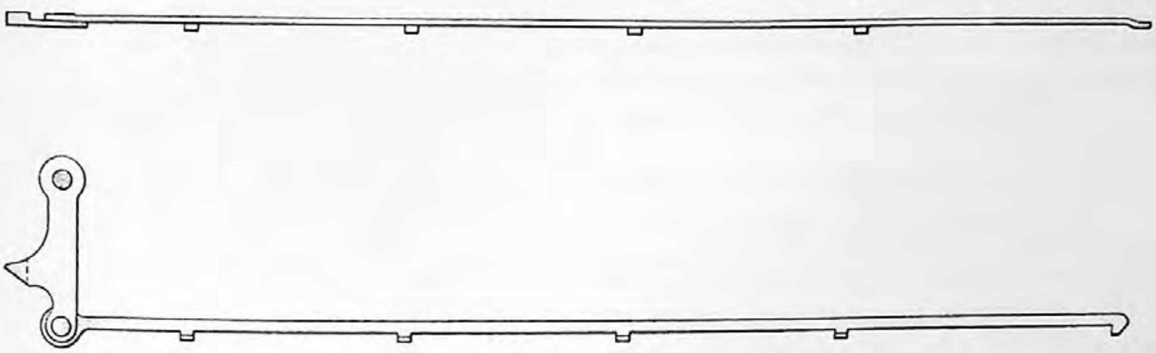


Figure 226. Selector Clutch Operating Link

226) has four turned-over ears which may or may not be in contact with the corresponding analyzer pawl. Whether or not the turned-over ears are in contact with the analyzer pawls depends upon the position of the analyzer pawls which are under control of the analyzer cams and the analyzer pawl latches. As can be seen from Figures 213 and 223, when an analyzer pawl is operating against the low dwell of the analyzer cam, the analyzer pawl comes in contact with the turned-over ear of the selector clutch operating link and prevents any movement to the left. Because of spring action, the selector clutch operating link tends to move to the left and release the selector clutch dog. Any one of the analyzer pawls in the lowest position is sufficient to keep the selector clutch operating link from moving to the left. In order to have the selector clutch operating link operate to the left, all four analyzer pawls must

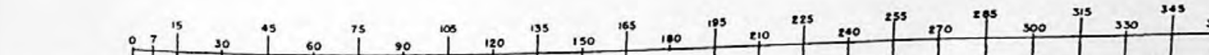


Figure 227. Mechanical Timing Chart — Analyzer Unit and Print Cam Control

be on the intermediate or high dwell of the analyzer cams. If an analyzer pawl is latched, however, it no longer has control over the operation of the selector clutch operating link.

The main purpose of the analyzer unit is to allow the selector clutch operating link to move to the left at the proper time by controlling the operation of the analyzer pawls. Figure 227 shows the relationship between the periphery of the analyzer cams indicating the high, intermediate and low sections. The movement of the selector clutch operating link is controlled by both the analyzer pawls and the trip cam; the chart in Figure 227 shows that at all testing positions of the trip cam, at least one of the analyzer pawls is located at the lowest level of one of the analyzer cams. With all pawls operating normally (none latched) the selector clutch operating link will not move to the left and, consequently, the selector clutch dog will not be released and no printing will take place.

If one or more of the analyzer pawls are latched in a position where they will not interfere with the movement of the selector clutch operating link, however, the selector clutch dog will be released and operate the selector clutch gear. Thus the main purpose of the analyzer unit is seen. By latching the proper analyzer pawl, or the proper combination of pawls, the selector clutch operating link will cause the selector clutch gear to rotate at the proper time to print the desired character.

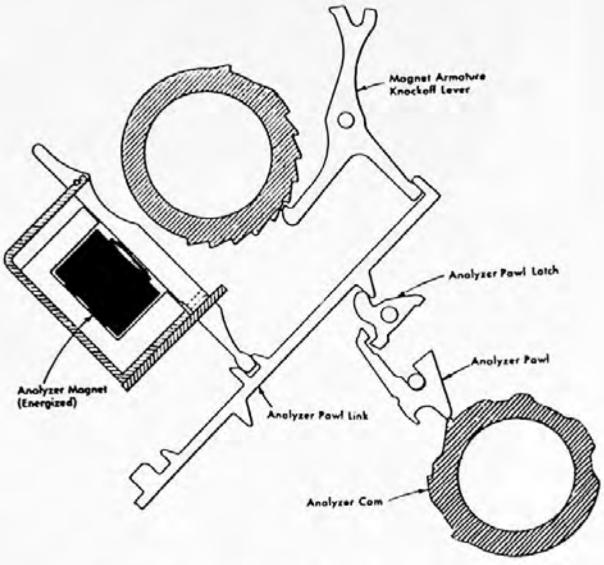


Figure 229. Analyzer Pawl Latching Position

Analyzer Operation for Printing a 1

Assume that a 1 is to be printed. Figure 227 shows that at read impulse 1 time (127°-135°) analyzer cam 1 has its highest surface against the analyzer pawl. This means that the analyzer pawl under control of analyzer cam 1 (right cam) is at its highest position. (This is true for all 120 positions — analyzer pawl 1 is at its highest position.) If the print magnet is energized at this time, the analyzer pawl latches

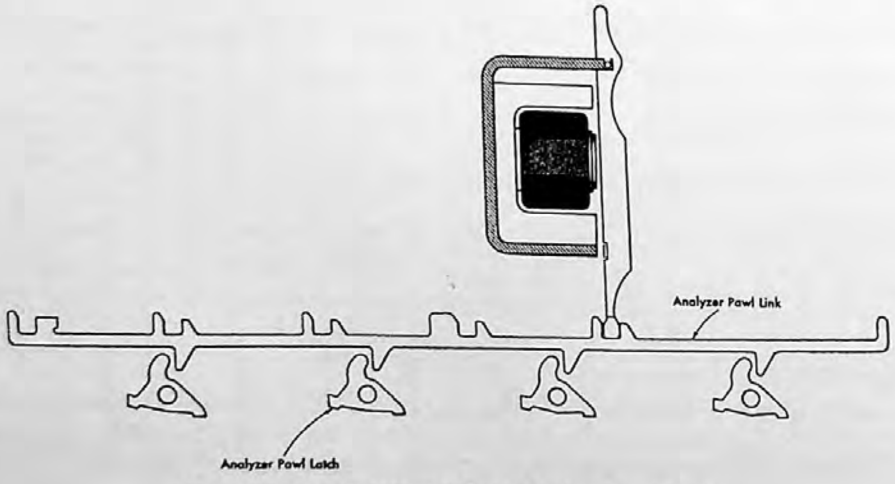


Figure 228. Analyzer Pawl Link and Analyzer Pawl Latches

of all four pawls of each position in which the print magnet is energized will be pivoted in a counterclockwise direction by the analyzer pawl link being operated. Each analyzer pawl link has four projections which operate against the analyzer pawl latches whenever the analyzer pawl link is moved (Figure 228). Since the analyzer pawl for the analyzer cam 1 is at its highest position at this time, the analyzer pawl latch will pivot below the latching surface of the analyzer pawl 1 (Figure 229). The remaining three analyzer pawls for this particular printing position will not become latched on the pawl latch since these analyzer pawls are not at their highest position at 1 time (chart, Figure 227).

As the machine continues to operate, analyzer cam 1 will move its high point of the cam away from the analyzer pawl but, since the pawl latch is positioned under the latching surface, the analyzer pawl will remain latched. When the analyzer pawl is latched, it has no control over the selector clutch operating link. Consequently, the selector cutch operating link is under control of only three analyzer pawls (2, 3, and 8) and the trip cam. The analyzer cams are numbered 1, 2, 3, and 8, from right to left (Figure 223). They are numbered this way since a 1 impulse will latch the analyzer pawl 1 only, a 2 impulse will latch analyzer pawl 2 only, a 3 impulse will latch the analyzer pawl 3 only, and an 8 impulse will latch the analyzer pawl 8 (extreme left) only. All other impulses 4, 5, 6, 7, and 9 will latch a combination of pawls while 0, 11, and 12 will not latch any pawls.

Refer at this time to Figure 227 and disregard the position of analyzer cam 1 since the cam has no effect as long as its corresponding pawl is latched. Under these conditions it will be found that the first time that the selector clutch operating link is not held by at least one analyzer pawl the trip cam is at 254° which is test time for 1. This means that the selector clutch dog is released at 254°. The clutch dog becomes fully engaged and the selector clutch gear starts to operate at 271°.

The type characters are positioned on the type wheel in such a manner that, when the selector clutch gear starts operating at 271°, the type wheel will be in position to print /, J, A, or 1 depending upon whether the print magnet receives a 0, 11, 12, or N impulse at the second energization (Figure 214).

According to machine operation the print clutch becomes engaged and causes the printing to take place as a continuation of the above operations. For the time being, however, discussion will include only the operation of the selector clutch gear.

Operation for Printing a 7

Referring again to the chart (Figure 227) it can be seen that when a 7 impulse is received by the print magnet, the number 1, 2, and 3 analyzer pawls are at their highest position because of the position and contour of their corresponding analyzer cams. When the analyzer pawl link operates and pivots the analyzer pawl latches, the latches for analyzer pawls 1, 2, and 3 will latch the corresponding pawls. Thus, as a result of a seven impulse to the print magnet, analyzer pawls 1, 2, and 3 are latched. The selector clutch operating link is under control of the trip cam and analyzer pawl 8 only. According to the chart (Figure 227) analyzer pawl 8 does not reach an intermediate or high position after the trip cam is in position for testing until 164°. This is the time for testing for a 7. In other words if a 7 is to be printed, the selector clutch dog must be released at this time. Since analyzer pawl 8 is the lone controlling pawl, as soon as the intermediate position of this pawl is reached, the selector clutch operating link will operate in conjunction with the trip cam and cause the selector clutch dog to become engaged. The usual overlap of the clutch dog to the reamer flutes is necessary as in any clutch mechanism at engagement time. Consequently, it is not until 179½° that the selector clutch dog has come face to face with the reamer flutes to actually operate the selector clutch gear.

With the selector clutch gear starting to operate at 179½°, the type wheel, which is geared to the selector clutch gear, will be in position to print an X, P, G or 7 at printing time depending upon the second impulse to the print magnet (Figure 230). This second impulse (0, 11, 12 or N) to the print magnet causes the print clutch to become engaged and complete the printing operation.

From the above it is apparent that 1-9 impulses to the print magnets, whether from the card, counter, storage unit or emitter, will cause one or more analyzer pawls to be latched. The remaining analyzer pawls, working in conjunction with each other and the trip cam, will cause the selector clutch operating link to release the selector clutch dog at the proper time for the selector clutch gear to position the type wheel for the desired character.

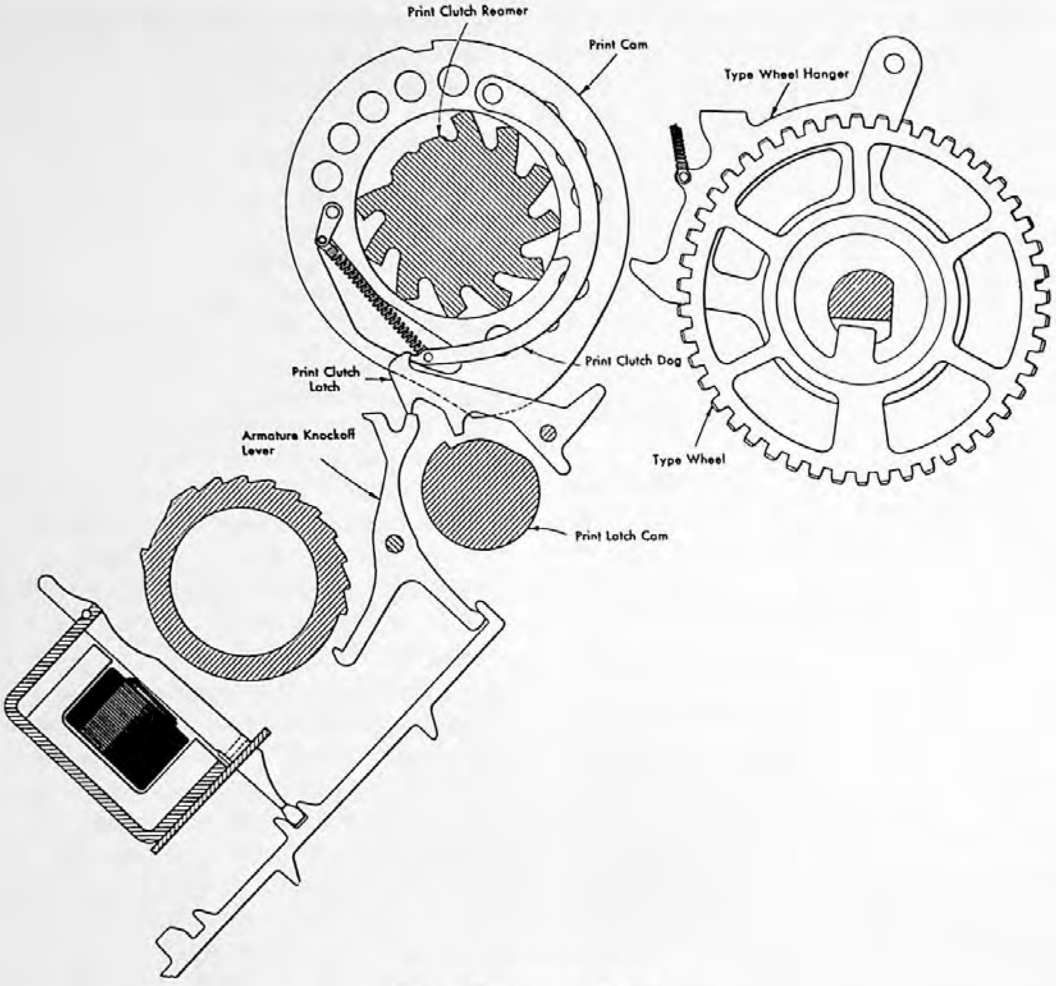


Figure 230. Print Cam Operation

It should be noted from the chart (Figure 227) that the trip cam does not start to test until after the 4 impulse has had time to be effective, because of the special character combinations using 8 and 4, with or without zone impulses. Consequently, both the 8 and 4 impulses must have ample time to set up the analyzer unit before any testing is done. In the meantime the 3 impulse is in the process of setting up the analyzer unit. As mentioned before, testing is the process of determining when the selector clutch operating link should operate and in turn cause the selector clutch dog to be engaged. For example, when testing for a 9, the trip cam, in conjunction with the four analyzer pawls, checks whether the pawls are in position to allow the selector clutch operating link to operate at 134°. If the type wheel is to print a 9, or a letter using 9 as the lower punch, the selector clutch dog must be released at 134° which is 9 testing time. Releasing the selector clutch dog at 134° causes the selector clutch gear to operate at 149½°. Remember that the selector clutch gear must position the type wheel to print in one of four places. It is the function of the print cams to pick up the individual position. This operation is described in the next section.

Print Cam Operation (Figure 230)

While the analyzer unit delays the release of the selector clutch dog until the proper test has been made, the 0, 11, 12 or N impulse is received by the print magnet.

The energization of the print magnet causes the print magnet armature to operate the analyzer pawl link. The analyzer pawl link pivots the armature knockoff lever which also operates as a stop for the print clutch latch. This causes the print clutch latch to release the print clutch dog and allow it to become engaged with the print clutch reamer. There is no delay here except for the time needed to have the clutch dog come face to face with the reamer flutes as a result of the overlap at the time the impulse is received.

The print cam may begin to rotate at 155°, 170°, 185°, or 200°, depending upon when the impulse is received (Figure 227). The N (machine) impulse comes through to the print magnet on every cycle that a previous impulse has been received by the print magnet. However, if the 0, 11, or 12 impulse is received, the N impulse will have no effect on machine operation as the zone impulses come through first.

Since the print cam may start turning at four different times, the high point of the cam can come in contact with the type wheel hanger at four different times, namely, 300°, 315°, 330°, and 345°.

At the time the selector clutch dog is engaged with the selector clutch reamer, the movement of one flute of the reamer moves the type wheel through four character positions. The movement of one flute at this time equals 15°. The movement of one flute of the print clutch reamer also equals 15°. If these speeds remained the same through printing time, only one of the four characters could ever be printed, and even that would be a poor specimen. Therefore, the type wheel must be slowed down at printing time to allow the print cam to operate against the type wheel hanger at any one of four times while the type wheel is moving four character positions; this is equivalent to the movement of one flute. This is accomplished by a variable speed drive which reduces the speed of the selector clutch gear and the type wheel to one-quarter the speed when selecting; this is also one-quarter of the speed of the print cam reamer. Consequently, the print cam reamer will travel four flutes in the same length of time that it takes one flute of the selector clutch reamer to move during printing time. Thus, one flute of the print clutch reamer will move for each individual character position of the typewheel.

When the print cam starts operating at the earliest time, the type wheel is cammed against the platen when the first character of the group is in line with the platen. If the print cam starts turning at the next starting time (when the dog is engaged with the second flute of the print clutch reamer), the print cam will operate against the type wheel hanger when the second character of the group is opposite the platen. Because of the reduction in the speed of the selector clutch gear, the type wheel moves only one character position for each flute movement of the print clutch reamer and print cam.

Operation for Printing a G

By referring to Figure 213 and the chart in Figure 227, the sequence of operation for printing the letter G (as an example) can be followed.

At 37° the print magnet receives the 7 impulse which is the lower value of the letter G. The chart (Figure 227) indicates that the analyzer cams are holding the analyzer pawls 1, 2 and 3 in their highest position at the time the print magnet receives the impulse at 37°. The operation of the analyzer pawl link will cause the analyzer pawl latches to pivot. Since analyzer pawls 1, 2 and 3 are at their highest position, the analyzer pawl latches for those positions will pivot below the latching surface of the analyzer pawls. As the machine continues in operation and the analyzer cams change their position, analyzer pawls 1, 2, and 3 will remain in the upper or latched position because of the analyzer pawl latches. This means that analyzer pawls 1, 2, and 3 will not follow the contour of their respective analyzer cams. However, analyzer pawl 8 will be free to follow the contour of analyzer 8 cam. Thus with analyzer pawls 1, 2 and 3 latched, it only remains for the analyzer pawl 8 to be moved to its intermediate position by the analyzer cam to allow the selector clutch operating link to move to the left in conjunction with the trip cam. Moving the selector clutch operating link to the left releases selector clutch dog. As shown by Figure 227, analyzer pawl 8 does not reach the intermediate level until 164° which means that the selector clutch operating link will not release the selector clutch dog until that time. This will allow the clutch dog to be engaged with the selector clutch reamer and start the selector clutch gear and type wheel turning at 179°. When the clutch dog drops in the reamer at that time, it causes the type wheel to be in position to print an X, P, G or 7 depending upon whether a 0, 11, 12 or N impulse is received.

In the meantime, since it is assumed that a G is to be printed, the second impulse to the print magnet is a 12 impulse. This impulse energizes the print magnet at 172°. This will have no effect on the selector clutch since none of the analyzer pawls are at their highest position. In this specific case, the clutch is engaged at this time and would have no effect, regardless of the position of the analyzer pawls. However, the print clutch dog for the print cam will be tripped at this time and engaged with the print clutch reamer, causing the print cam to start operating at 185°. As the high point of the print cam strikes the type wheel hanger, the type wheel is forced against the platen by the momentum of the assembly.

As the high point of the cam approaches the type wheel hanger, the speed of the selector clutch gear and the type wheel is reduced to one-quarter speed. This allows the print cam to operate against the type wheel hanger at a time when the proper character is lined up with the platen. In this assumption, a G is lined up with the platen at the time the type wheel hanger is cammed by the print cam. The reduction in speed of the selector clutch gear allows the movement of one character for each 15° of the index which also corresponds to one flute movement of the print cam reamer.

As the type wheel hanger is rocked toward the platen, the type wheel tends to rotate in a clockwise direction since the type wheel is meshed with the selector clutch gear. At the same time the selector clutch gear tends to turn the type wheel in a counterclockwise direction. At printing time the movement of each is equal and, since one is acting against the other, the type wheel movement is lateral. Thus, at printing time the type wheel is stationary.

Print Clutch Latch Cam

By referring to Figure 230 and to the chart (Figure 227) it can be seen why the print clutch dog is not released while the 9 through 1 impulses energize the print magnets. The analyzer pawl link operates the armature knockoff lever which also acts as a stop for the print clutch latch, but the print clutch latch cam is positioned at this time to prevent the print clutch latch from releasing the print clutch dog. It is not until 149° (after the 1 impulse has been received) that the print clutch latch cam is positioned to allow the print clutch dog latch to operate.

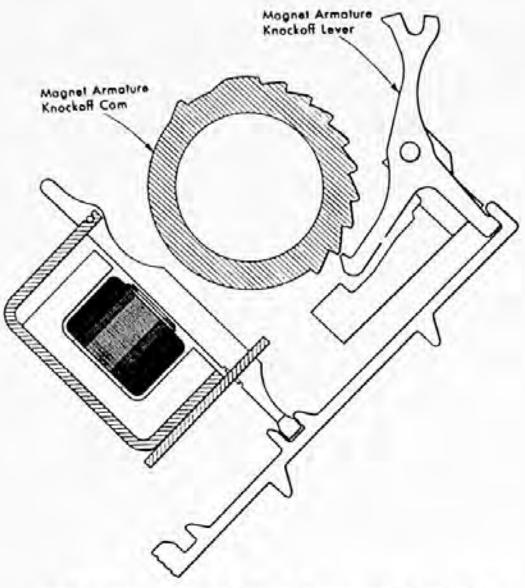


Figure 231. Print Magnet Armature Knockoff

Magnet Armature Knockoff Cam (Figure 231)

It is very necessary that the print magnet armature be attracted only for the duration of one impulse. Otherwise improper analyzer slides will be latched and the wrong character will be printed. The magnet armature knockoff cam is provided to prevent this. Figure 227 shows the time of the operation of the cam. The cam operates to force the armature away from the print magnet core after each lower reading (9 through 1) and before the 9 impulse. The knockoff is not necessary after zone impulses since they do not affect the analyzer slides. There is one more knockoff operation which takes place after a carry impulse. As will be noted in the circuit section, during a carry operation it is possible to energize the print magnet, depending upon the control panel wiring. This impulse at carry time (307°) does not affect the print unit. If the print magnet armature were not restored, the 3 and 8 analyzer slides might become latched at 337° which is the special symbol impulse time. The knockoff operation before 9 time is necessary because of the special symbol impulse coming through at 337° when printing the special dollar, decimal and comma symbols.

Trip Cam

The trip cam is used to test for the operating time of the selector clutch operating link. The trip cam arm follows the contour of the trip cam. At twelve definite positions the trip cam arm tests to see if the analyzer pawls are in position to allow the selector clutch operating link to move to the left. The trip cam controls the time that the selector clutch operating link is allowed to move. The selector clutch operating link must move to unlatch the selector clutch dog at the proper time to allow the selector clutch dog to engage with the proper flute to print the character for which the print magnet is impulsed.

The trip cam and the analyzer pawls operate in conjunction with each other. All pawls must be clear

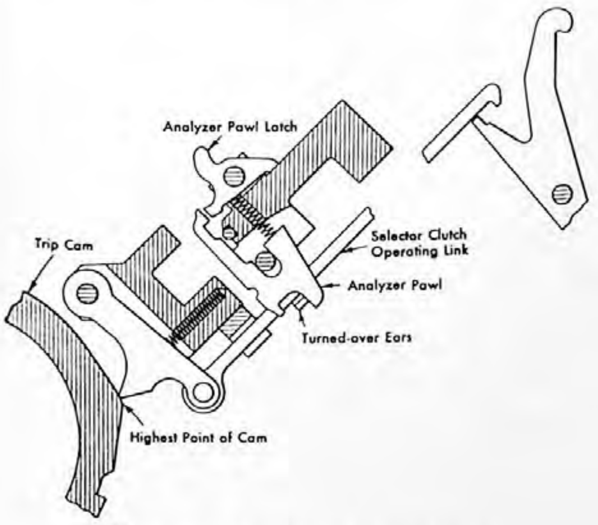


Figure 232. Unlatching Analyzer Pawl

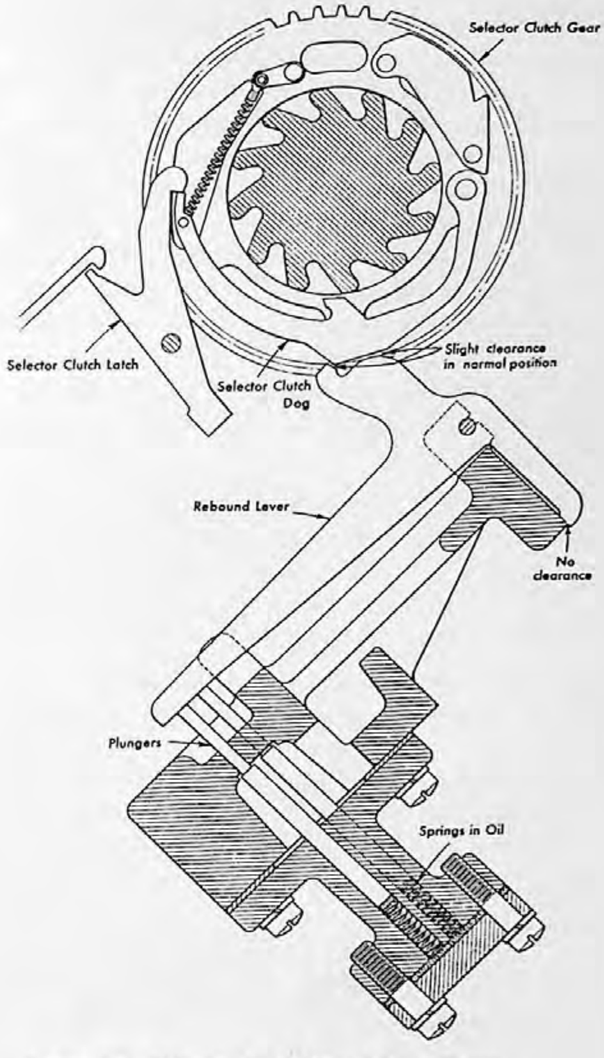


Figure 233. Selector Clutch Gear Rebound Lever

of the selector clutch operating link when the trip cam arm reaches a test position if the selector clutch dog is to be unlatched at that time. In this way the trip cam arm holds the selector clutch operating link in such a position that the turned-over ears are not in contact with the analyzer pawls while the pawls are operating. This leaves the pawls free to slide up or down. If the pressure of the selector clutch operating link were operating against the analyzer pawls, the pawls would not be free to operate.

The trip cam also has the function of unlatching all pawls that have been latched during the cycle. This unlatching time takes place at the highest point of the trip cam at 304°. As the trip cam arm operates against the high point of the trip cam, the selector clutch operating link is forced to the right. The turned-over ears of the selector clutch operating link operate against the analyzer pawls in the reverse direction and cause them to pivot so that the analyzer pawl latches return to normal (Figure 232).

Rebound Lever (Figure 233)

One complete cycle from the point where the clutch became engaged it becomes disengaged. This is not a complete machine cycle but is one revolution of the selector clutch reamer and selector clutch gear. As the selector clutch gear completes its cycle, the selector clutch dog comes in contact with the clutch latch and disengages the clutch dog from the selector clutch reamer. As this happens, there is a tendency of the clutch dog to rock counterclockwise about its pivot point and unduly stretch the spring. A cushioning or rebound mechanism has been provided to prevent this. As the selector clutch dog is disengaged from the selector clutch reamer, the outer surface of the dog strikes against the rebound lever. This lever is pivoted at the right and operates against spring pressed plungers set in oil on the left. The plungers are held out by springs and, as the plungers are forced into the oil, the oil is forced out around the plunger, thus providing a cushioning action on the rebound lever and dog.

The left part of the rebound lever should not rest against the selector clutch dog as shown in Figure 233. There should be a slight clearance between the flat surface of the selector clutch dog and the rebound lever and between the two operating points.

If the clutch dog were to unlatch and rest on the end of one of the flutes, the friction between the clutch dog and the flute will not cause the selector gear to turn since the clutch dog will still be held by the rebound lever. It is not until the clutch dog drops into one of the flutes that it is free of the rebound lever, at which time the selector gear will start to turn.

If the rebound lever did not tend to hold the clutch dog until the clutch dog moved between two flutes, trouble might result, particularly when printing zeros.

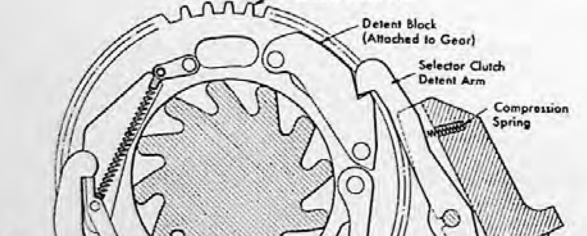


Figure 234. Selector Clutch Gear Detent

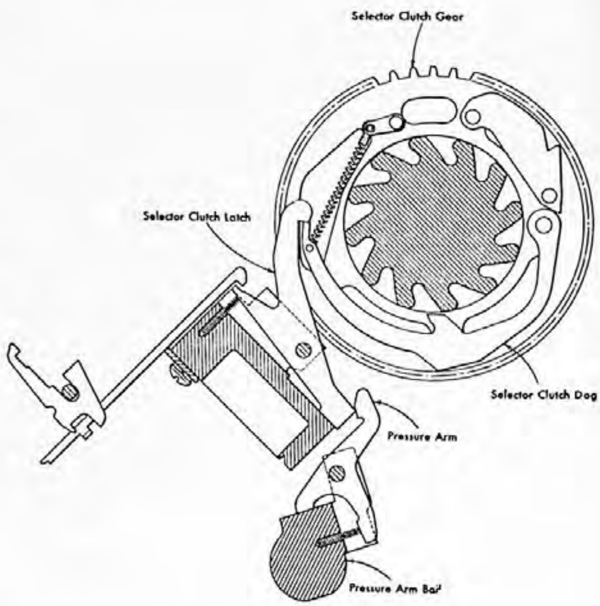


Figure 235. Selector Clutch Latch Pressure Bail

Were it not for the rebound lever, the selector clutch gear would move immediately upon unlatching the dog even though the dog does not drop between the flutes, since the friction between the clutch dog and the end of a flute would be sufficient to move the selector clutch gear, assuming that the clutch dog is not hampered by the rebound lever. This premature movement of the selector clutch dog would cause the type wheel to move too much and the printing would be out of alignment, particularly in instances where the type wheel moves very little before the printing takes place, as when printing zeros.

Selector Clutch Gear Detent (Figure 234)

As the selector clutch gear is stopped, there is a tendency for the gear to rebound counterclockwise. This action is prevented by the operation of a spring pressed detent into the detent block which is secured to each gear. This detented position also holds the selector clutch gear in such a position that the clutch dog is held clear of the selector clutch reamer which prevents the dog from riding on the reamer flutes and causing a nipping action.

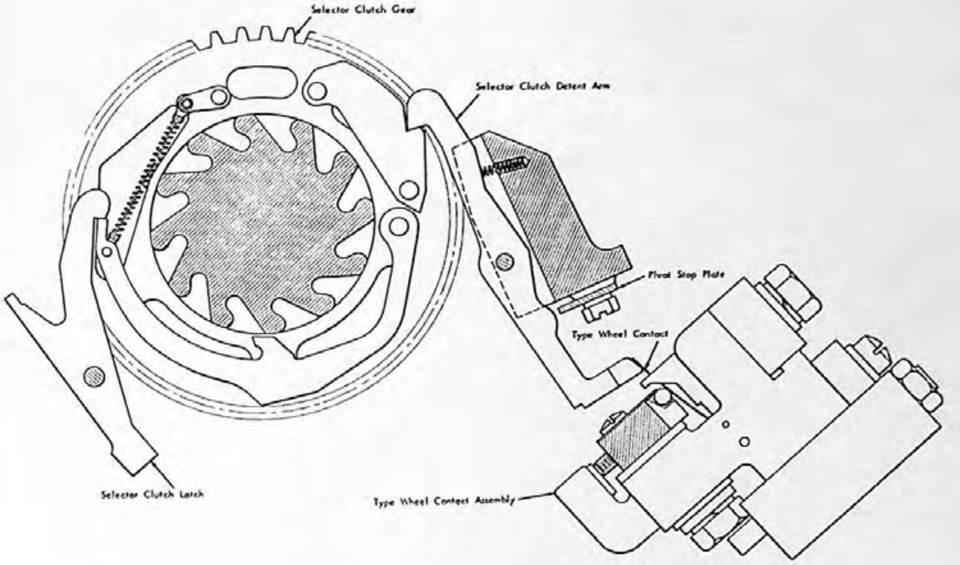


Figure 236. Type Wheel Contact Assembly

Selector Clutch Latch Pressure Bail (Figure 235)

In order to insure that the selector clutch latches are in the path of the free end of the clutch dog as the selector clutch gear completes its cycle, the selector clutch latch pressure bail has been installed. The purpose of this bail, which has pressure arms under spring tension operating against the clutch latches, is to keep constant pressure on the clutch latches after the trip cam has unlatched the analyzer pawls. This takes place from 315° to 107°. During the tripping time of the selector clutch dog, the bail is not effective since it would tend to prevent the selector clutch dog latch from operating. This bail is cammed to give pressure at the proper time and to be ineffective at other times.

The pressure arms are spring loaded to allow the high center portion of the selector clutch dogs to pass. Since the selector gears can be started at so many different times in the cycle, it follows that they will be latched at various times in the cycle. The pressure arms must be in position for latching some selector clutch dogs while the high section of other selector clutch dogs will be passing the pressure arms.

Type Wheel Contact (Figure 236)

The type wheel contacts, one for each type wheel are normally open points which are closed as the selector clutch gear starts to revolve. These contacts are operated by the selector clutch detent arm of each printing position. As the selector clutch gear revolves, the detent arm moves out of position and allows the contact to close.

These contacts complete a circuit for each lower punch impulse (9-1) at 150° *after* the original impulse is received from the card, counter, storage unit or emitter. For example, a 6 impulse at 52° to the print magnet will cause the type wheel contact to emit a 6 impulse at 202° (52° + 150°). This delayed impulse may be used to add into the counter since the counter has two distinct adding periods within one machine cycle.

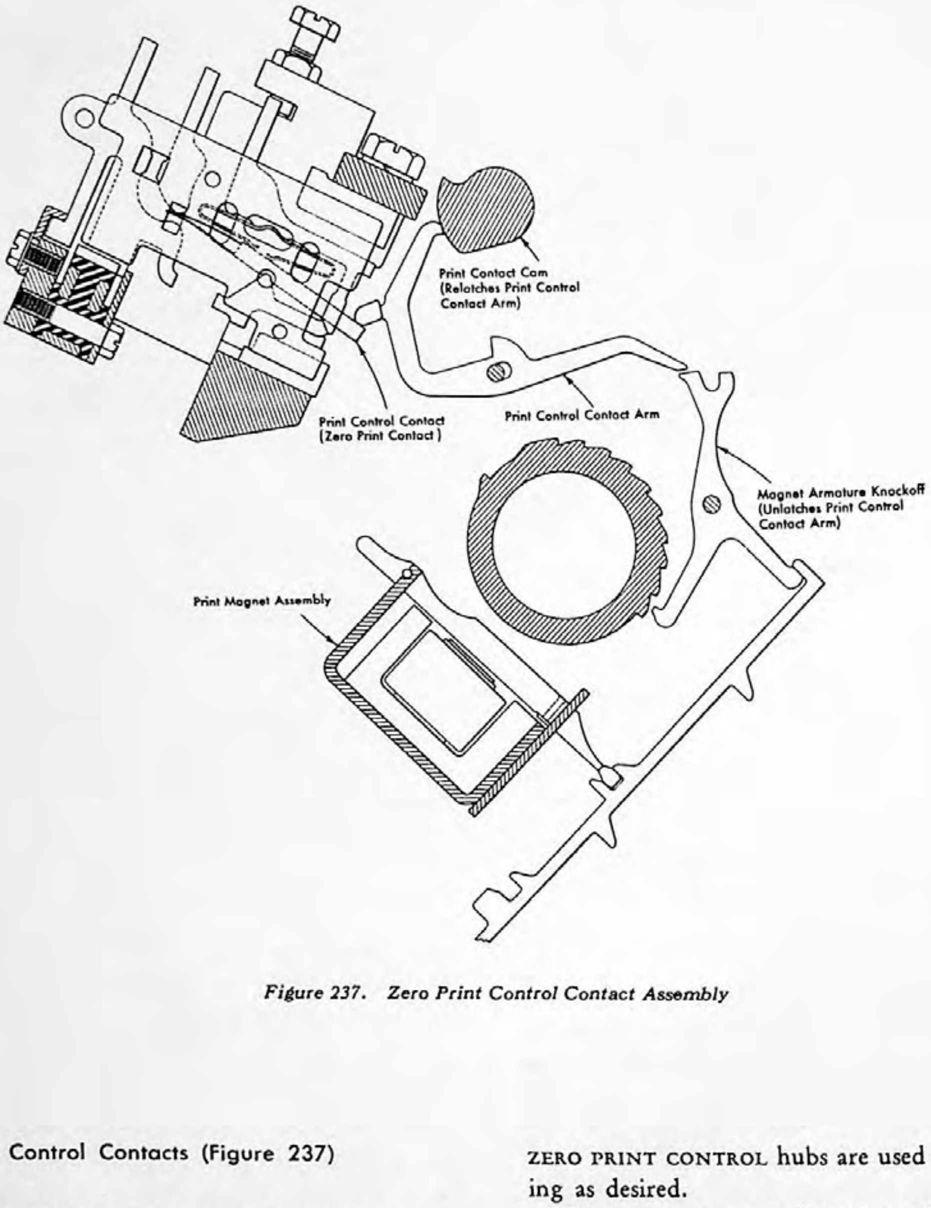


Figure 237. Zero Print Control Contact Assembly

Zero Print Control Contacts (Figure 237)

There are 120 zero print control contacts, one for each type wheel position. The zero print control contacts are transfer contacts which operate as a result of the energization of the print magnet. The purpose of these contacts is to control zero printing to the right and left of significant figures as well as special characters, such as asterisks (*), decimals, and commas. When the print magnet is energized in the usual manner, the contacts are transferred. This signals the adjacent positions that something is about to be printed in the position where the zero print contact transferred. These contacts in conjunction with the ZERO PRINT CONTROL hubs are used to control printing as desired.

These contacts are adjusted so that the normally open side closes before the normally closed side opens. This is done to prevent breaking the circuit to the print magnet during its normal energization.

One exception to the above statement, that the zero print contacts transfer whenever the print magnet is energized, occurs when the print magnet is energized at 337° for special symbol printing. The zero print contacts do not transfer at this time because the print contact cam prevents the print control contact arm from operating and transferring the contacts. This is done to prevent printing certain symbols when no other figures are being printed.

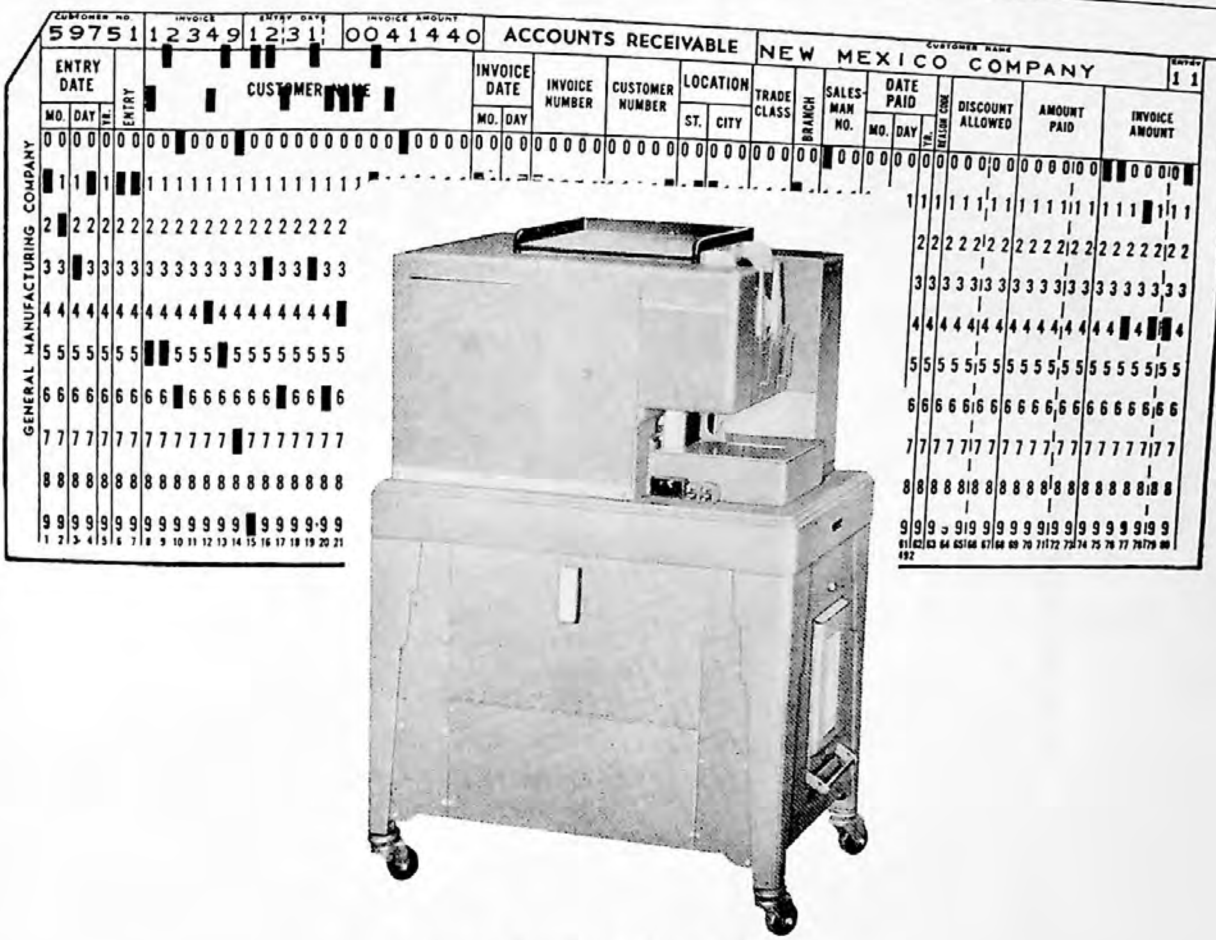


Figure 238. Type 552 and Interpreted Card

TYPE 552 INTERPRETER PRINTING MECHANISM

THE PURPOSE of the 552 Alphabetic Interpreter is to print on a card the same information which is punched in it. This makes possible the visual reading of information punched in a card. Visual reading of a card is desirable when cards are handled manually in some way, such as, selected from a file, or merged manually. Figure 238 shows an Alphabetic Interpreter and a card which has been interpreted.

The 552 Interpreter reads a card and prints the information on the card in the same cycle. The card is fed 12-edge first so that the zone information can be read, and the type bar zoned before the numerical information is read and the type bar stopped. The card is also fed face up because the contact roll also serves as a platen, and the face of the card must be out to receive the printing. Figure 239 shows a sche-

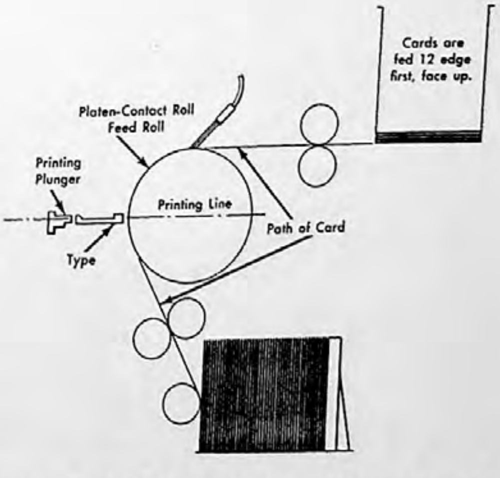


Figure 239. Type 552 Feed Schematic and Printing Essentials

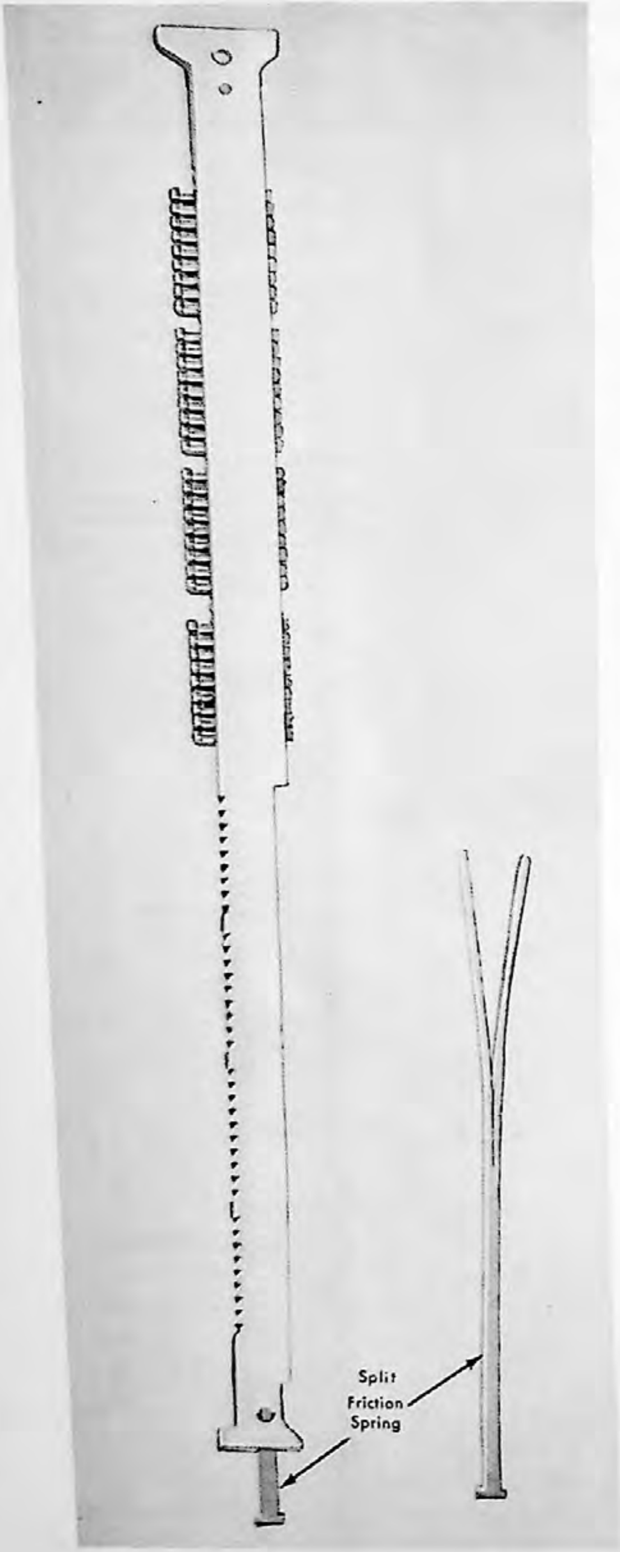


Figure 240. Type 552 Type Bar and Friction Spring

matic of the feed mechanism and the essentials to printing. It also shows that at the time printing takes place the card is upside down, which requires that the type face on the type also be upside down.

552 Type Bar

The 552 type bar is shown in Figure 240. This type bar contains 36 pieces of type (26 alphabetical characters and 10 numerical characters). There is a tooth on the rack for each piece of type instead of one for each numerical character as in the 402 type bar. Also the type in this bar is grouped according to zone punches rather than numerical punches.

The type bar is zoned before the numerical position is selected. To do this, it is necessary to determine from which group of characters printing is to take place. To explain how this is done, it is necessary first to know the construction of the print unit which houses the type bars.

Print Unit

Basically, the print unit consists of 60 type bars and their individual zoning and selecting pawls. It also has a zoning pawl restoring lever bar and a type bar restoring bail. Figure 241 shows a print unit out of the machine. Figure 242 shows the parts of the print unit removed from the unit, but in their correct relative position.

The type bars in this machine are normally held up by a zone pawl resting against a shoulder of the type bar. When the zone pawl is released, the type bars move down to reach the printing position.

Assume the zone pawls are not preventing the downward movement of the type bars. The type bars will then follow the movement of the restoring bail as it moves up and down. The type bars are connected to the restoring bail by means of the split friction spring. The friction between the split spring and the type bar is more than enough to support the weight of the type bar. This prevents the type bars from dropping onto the restoring bail when released, and causes them to move down at the same speed as the restoring bail.

As the type bars move down, a selecting pawl is moved in to engage a tooth in the rack of the type bars to position a specific piece of type to be printed. The restoring bail continues to move down pulling the friction springs out of the type bars which holds the type bar against the selecting pawl.

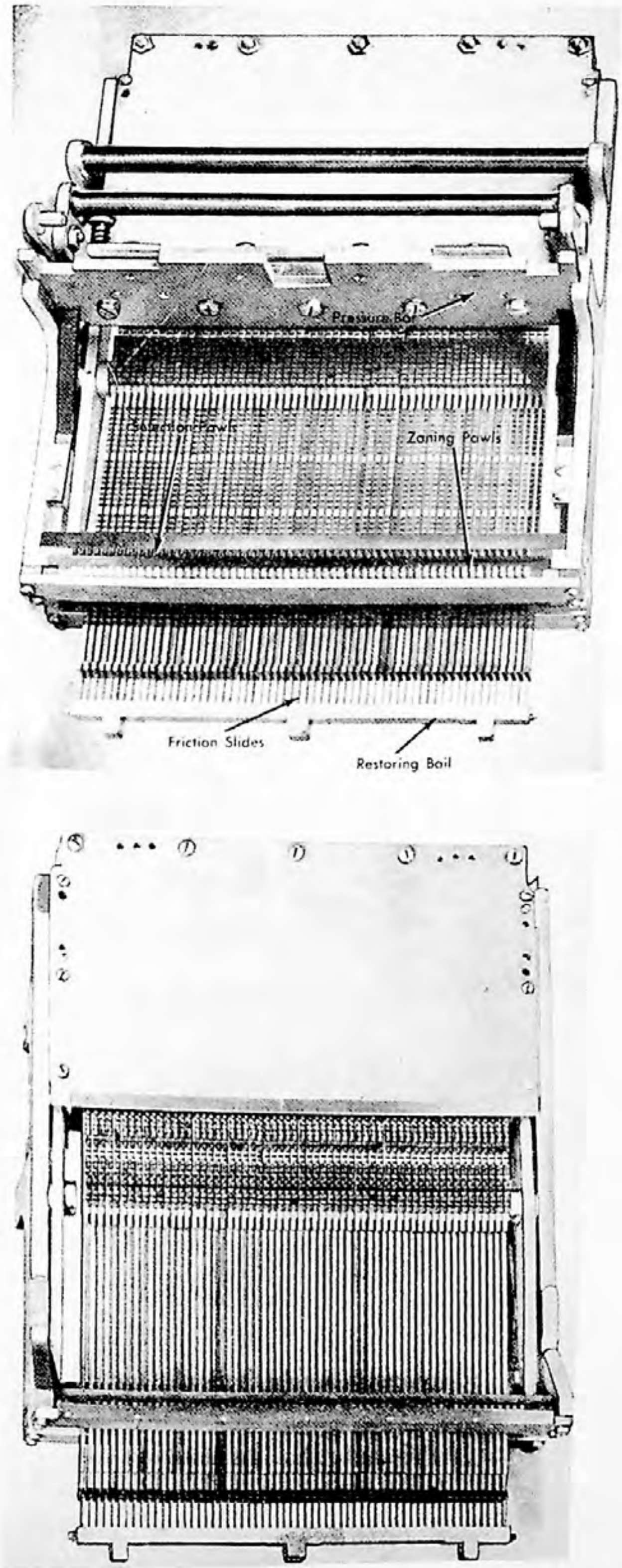


Figure 241. Type 552 Print Unit

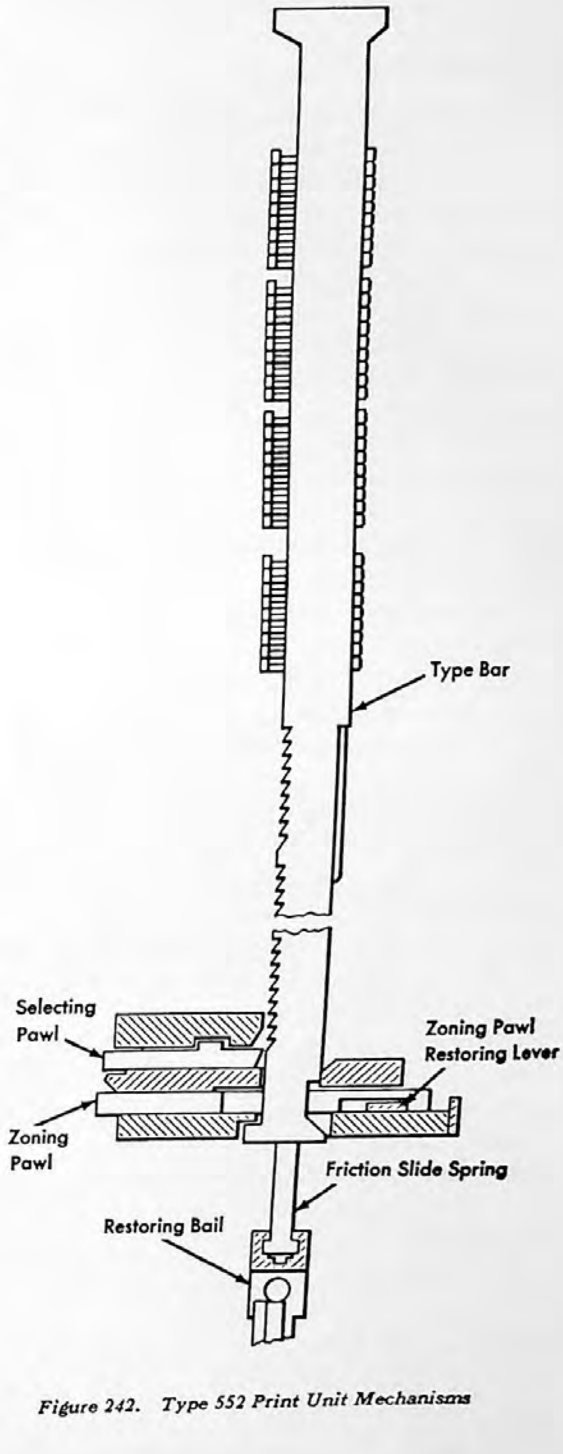


Figure 242. Type 552 Print Unit Mechanisms

Zoning and Selecting Principles

Before the type bar can move down with the restoring bail, the zone pawl for the type bar must be moved out from under the shoulder on the type bar. This is done as a result of reading a 12, 11, or 0-hole. The impulse resulting from the hole being read is directed to a print magnet. The print magnet causes its drive rod to move to the right (Figure 242), and this strikes the tail of the zoning pawl in that position. The zoning pawl moves to the right thereby unlatching the type bar so that it can follow the movement of the restoring bail. Until this occurs, the friction spring is being pulled downward and out of the type bar.

If the character to be printed is numerical rather than alphabetical, it should be noted that the type bar will not be released in the normal manner. However, the type bar must be unlatched and zoned for numerical if it is not otherwise zoned. The zoning pawl restoring lever is used to unlatch all type bars that have not been unlatched previously, just before the machine reads a one-hole. Figure 243 shows the zoning pawl restoring lever in its three positions. It is in the center of the notch (neutral) during the time for zone punches to be sensed. After zero time, and before one time, it is cammed to the right pulling the zoning pawls away from the shoulder on the type bars, thereby, unlatching them. After printing has taken place and the type bars are restored (raised to their upper limit of travel), the zoning pawl lever moves to the left pulling the zoning pawls in under the type bars, relatching them.

During zoning, the type bar must move a distance equal to the distance between zone groups on the type bar while the card is moving only the distance between adjacent punching positions. However, when selecting the numerical information, the type bar has only to move the distance between adjacent teeth on

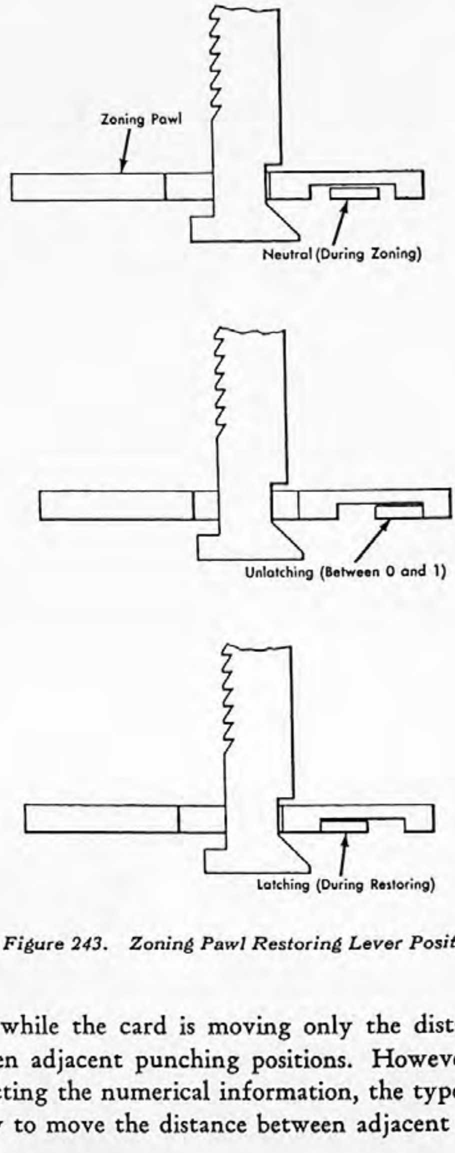


Figure 243. Zoning Pawl Restoring Lever Positions

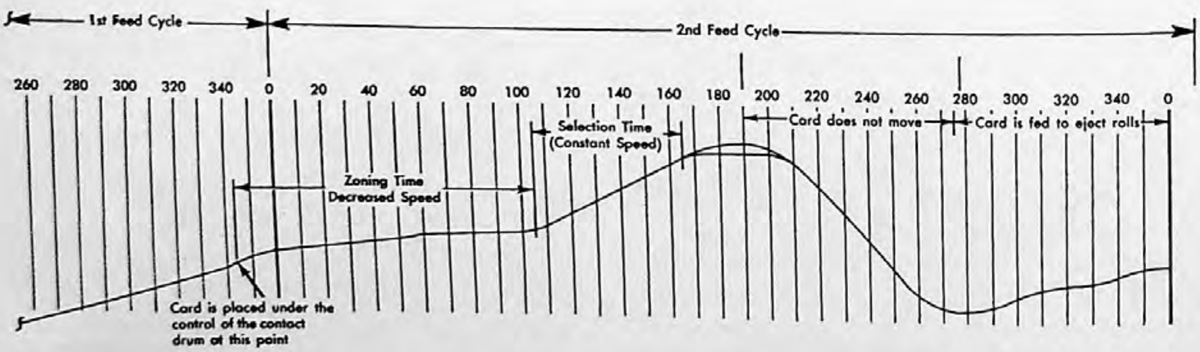


Figure 244. Timing Chart of Card Movement

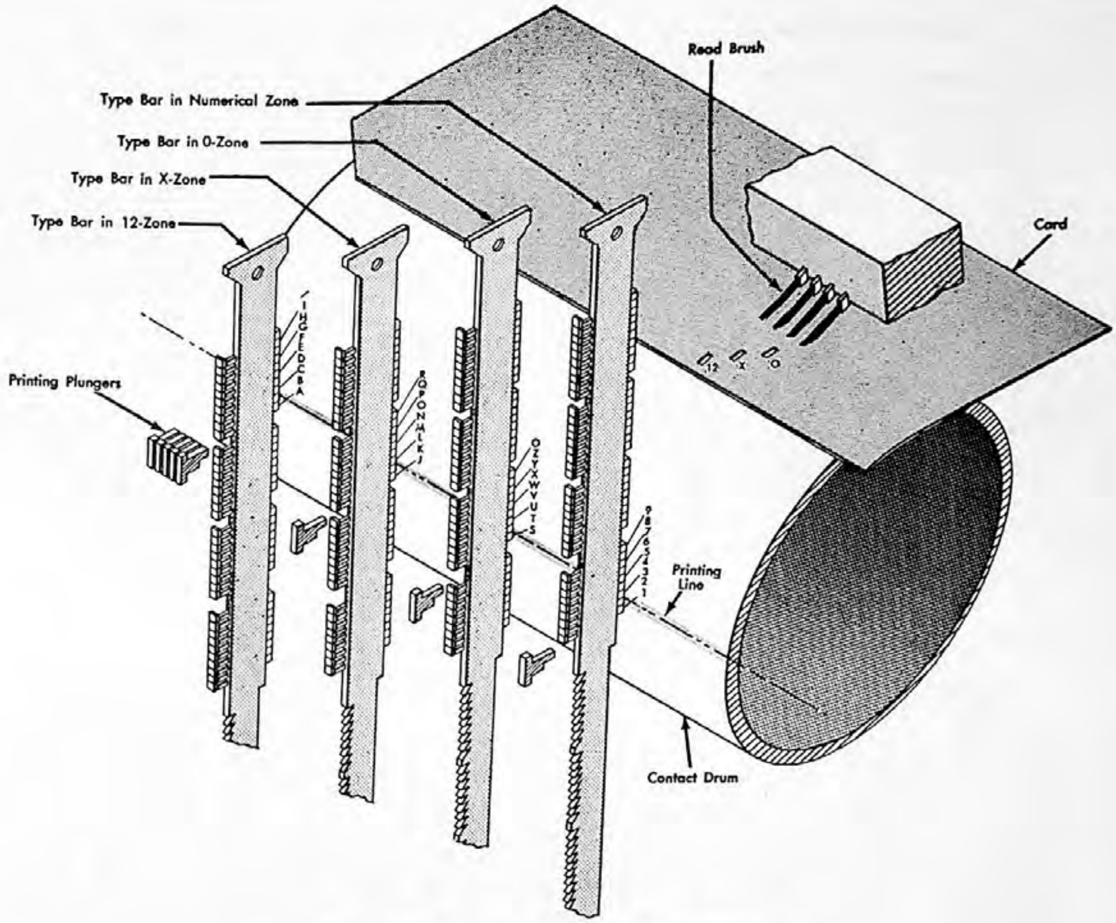


Figure 245. Type Bars with Each Zone Setup

the rack while the card moves the distance between adjacent punching positions. Consequently, the card is driven at variable speeds, slowly during zoning and faster during selection. To enable the type bars to move the distance necessary, the restoring bail and type bars move faster during zoning than during selection.

Figure 244 is a chart showing the card movement during an entire machine cycle. The line indicates relative speeds of card movement. The card actually moves only when the slope is upward, or positive, and the greater the slope the greater the speed. It should be pointed out that the cycle shown is for the time when the card is under the control of the contact drum only. The card moves at a constant speed otherwise.

Type bars zoned from 12-holes start their downward movement before any others. The next group to start down are those for an 11 zone, then a zero zone, and finally those which were not zoned from the card will be zoned for numerical. Figure 245 shows four type bars each of which is zoned for a different zone. As the card moves from 1 to 9, the type bars move down one tooth or piece of type each time the card moves from one punching position to the next.

As the type bars move down together for selection, it is just as important that they move in exact synchronism with the card, as in the Type 402 machine. The type bars, moving down with the restoring bail, are held up by the friction of the split spring alone and this is not positive enough. Also there is no assurance that the type bars are perfectly in line, which they must be in order to print properly. To be certain that these requirements are met, zone bails are provided which align all type bars and determine their movement during selection.

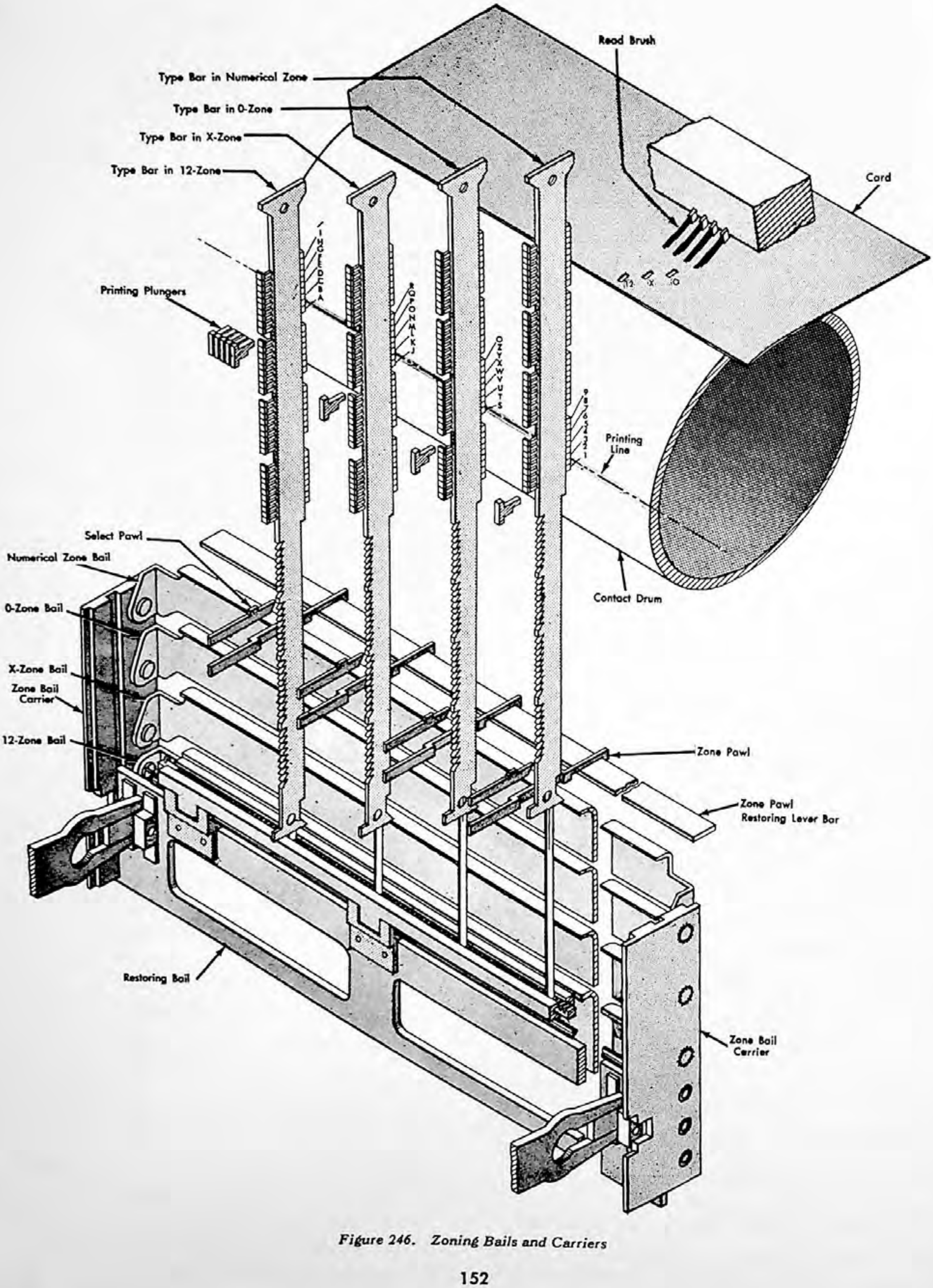


Figure 246. Zoning Bails and Carriers

The zone bails and the zone bail carriers are shown in Figure 246. In this figure, the toes of the type bars are resting on the zone bails. All of the type bars are lined up by the zone bails because the restoring bail is moving faster than the zone bails. The downward movement of the type bars continues at the speed of the zone bails while the restoring bail moves down slightly faster. This holds the type bars against the bails.

The type bars, which are zoned for a 12, must pass the numerical, 11, and 0 zone bails; those which are zoned for an 11 must pass the numerical and 0 zone bails, etc. The zone bails must permit some type bars to pass and yet stop others, with the exception of the 12 zone bail. To enable the zone bails to accomplish this, all but the 12 zone bail are pivoted so that they can be held out of the path of the type bars. Then as the type bars approach the zone bails they are to rest on, the zone bails are pivoted to engage the toe of the approaching type bars. The mechanism used to control the movement of the zone bails under the type bars is shown in Figure 247. As the cam follower moves to the low dwell, the bails will be moved in to engage the toes of the type bars. This will occur between the time that a zero and a one is read.

Very soon after the bails have moved under the toes of the type bars, all type bars which have not previously been unlatched for a 12, 11, or 0 zone will be unlatched so that they can rest on the numercial zone bail during selection time. The type bars are then moved down under the control of the zone bail carrier. The zone bail carrier, controlled by cams, is synchronized with the card movement to insure proper selection.

A select pawl is provided to engage a tooth in the type bar rack and position the type bar to print the desired character. The selecting pawl is moved in to engage a tooth as a result of an impulse from a hole in the card energizing the print magnet. The energization of the print magnet releases the drive rod which strikes the tail of the selecting pawl moving it into the teeth of the type bar rack. The drive rod is the same one used to strike the zoning pawl, and its operation will be covered in detail a little later.

Assume a type bar is zoned 12, when selection begins. The digit punching in the card column wired to this position is a 5. As the 5-hole is read, the impulse ultimately causes the drive rod to strike the tail of the selecting pawl in that position. The selecting pawl will move into engagement with the 5th tooth in the 12 zone section of the type bar. Several degrees later, as the bar continues to move downward, the 5 tooth comes to rest on the selecting pawl, thereby positioning the letter E on the printing line.

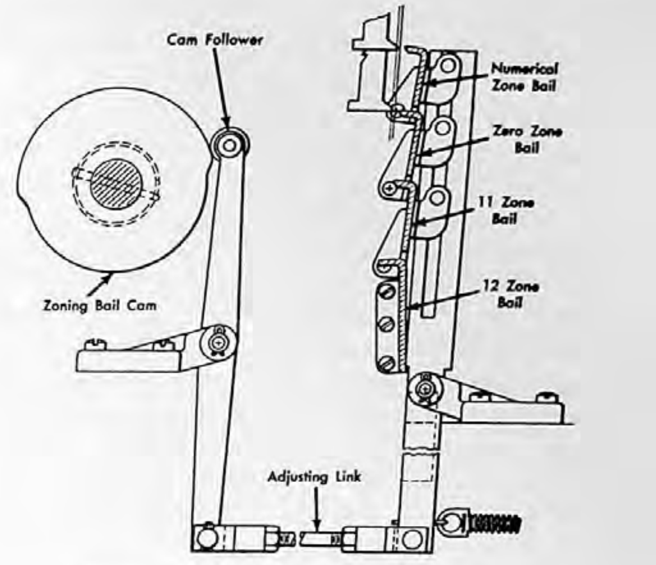


Figure 247. Zoning Bail Cam and Operation

A 5 will be positioned to print if the type bar is in numerical zone. If selection is made in the 11 zone an N will print, and if in the zero zone, a V will print. However, if there are no holes punched from 1 to 9, the type bar will move to the lower limit of its travel which is determined by the lower limit of travel of the zone bail carrier.

Observation of the type bar shows that the position immediately above the 9, R, and I is blank so that nothing will print if there is no numerical information sensed. However, a zero is in the position above the Z because if a zero is sensed and the type bar is zoned zero, but there is no other numerical information punched in the column, it is a numerical zero and should print as a zero. Special characters can be placed above the I or R to be printed from a 12 zone punch alone or an 11 zone punch alone if it is desired. A special character could also be added in the position below the S for a 0-1 combination. The space above the nine cannot be used for a special character because all type bars are zoned for numerical which are not zoned for either a 12, 11, or 0.

All positions which do not receive an impulse of any kind should be positioned in a blank space so that nothing will be printed in that position.

The blank space above the zero cannot be used for a special character because the zero is in the space which is normally blank, and the type bars can never be positioned so that the blank space above the zero is in the printing position. The distance from the blank space above the nine to the blank space above the zero is greater by one position than any other corresponding distance on the type bar. This also results in an extra tooth in the rack for the zero zone. This extra tooth and space have no use on this type bar. The space was needed on a previous model of this type bar and to eliminate a re-design of many parts of the machine and for manufacturing purposes, the extra space and tooth have been left on the new type bar.

Print Magnet Unit

The print magnet unit provides the electrical control needed so that the machine can be directed to print information which is punched in the card. The print magnet unit is designed to operate the zone pawls and select pawls by means of drive rods. Figure 248 shows a single position of the print magnet unit and its component parts. When the print magnet is energized, the armature unlatches the drive rod lever. The drive rod lever spring causes the drive rod lever to rotate in a counterclockwise direction as soon as it is unlatched. The drive rod lever then moves the drive rod to the right causing it to strike the tail of either the zone pawl or selecting pawl. The drive rod spring, being much weaker than the drive rod lever spring, will be compressed. The purpose of the drive rod spring is to return the drive rod when the drive rod lever is relatched on the armature.

During the time that zones are being sensed, the drive rods are positioned in line with the zone pawls as shown in Figure 248. However, between 0 and 1 time, the pin bail is raised by the drive rod operating arms so that, during selection time, the drive rods will be in line with the selecting pawls.

The drive rods must be restored to their normal position between 0 and 1 time, so that an impulse resulting from a digit-hole can cause the drive rod to strike the selecting pawl. Both the restoring of the print unit mechanism and the raising of the drive rods are controlled by cams, Figure 249 shows the time during the cycle when they occur, and their relationship.

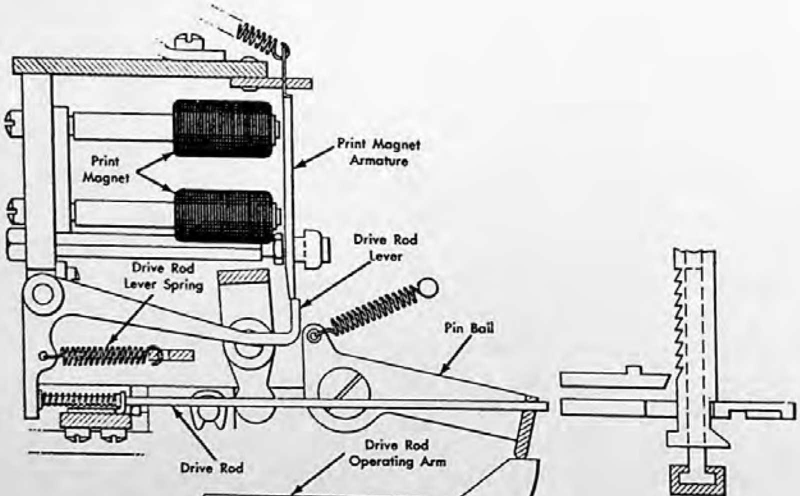


Figure 248. Print Magnet Unit

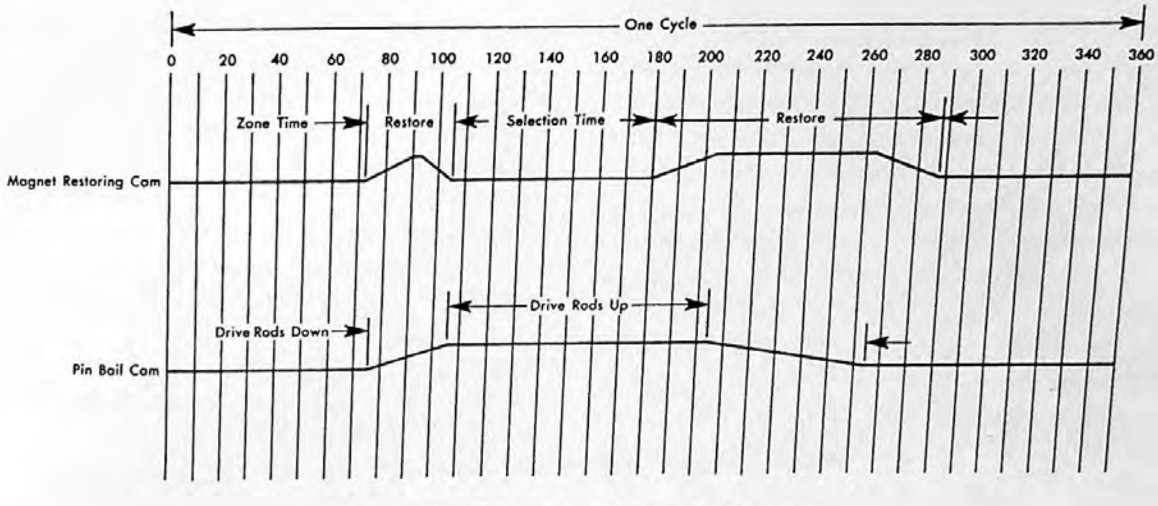


Figure 249. Print Magnet Unit Timing Chart

Printing Plungers and Pressure Bar

It should be remembered that in the Type 402 printing mechanism a hammer was used to strike the type tails to cause printing. That type of printing is referred to as impact printing.

The Type 552 printing is known as pressure printing. The printing plungers do not strike the type tails but instead are pressed against them. Figure 250 shows the pressure bar which holds the printing plungers. There is a printing plunger for each type bar but they all move together with the pressure bar. The pressure bar is operated each cycle by two cams which are geared to make one revolution per machine cycle.

Figure 251 shows the pressure bar and print cams.

Two cams mounted on a single shaft operate on the two ends of the pressure bar. The pressure bar is driven toward the type tails as it rides up the high lobes of the print cams. This action presses the printing plungers against the type tails causing printing. To prevent damage to the type and platen, the pressure is transmitted to the printing plungers through a rubber pad.

The leaf spring holds the pressure bar against the print cam. As soon as the pressure bar begins to move from the high dwell to the low dwell on the print cams the spring begins to restore the pressure bar. However, to be certain that the printing plungers are clear of the type tails before the type bars begin to move again, it is cammed back by the return cam and return cam follower.

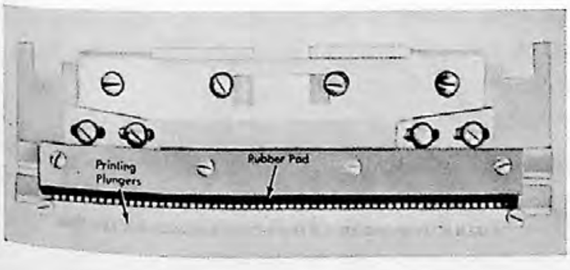


Figure 250. Printing Pressure Bar

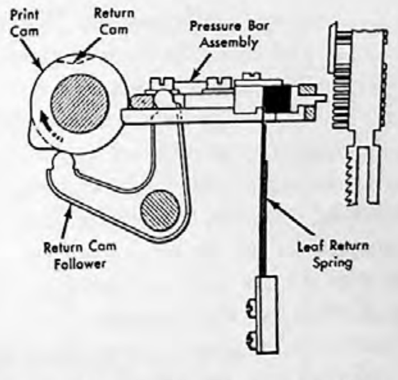


Figure 251. Print Cams and Pressure Bar

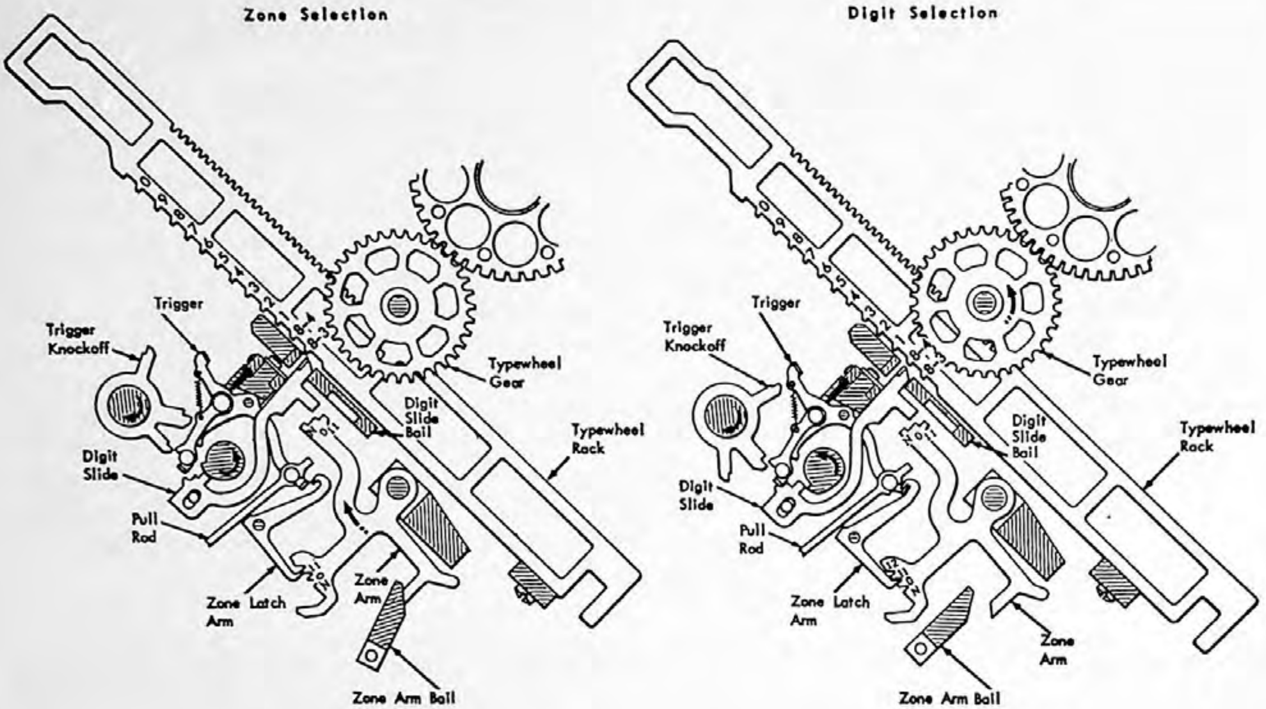


Figure 252. Zone Setup

TYPE 557 PRINTING MECHANISM

Zone Unit (Figure 252)

The three phases of the operation within the zone unit are:

1. Read in the zone information. The zone-arm bail starts at 1° and results in movement of the zone arms upward or in a clockwise direction past the zone latch arm. The zone impulse to the magnet releases the zone latch arm to stop the zone arm. This positions the upper end of the arm for zoning the slide after numerical selection. Notice the three levels on the upper position of the zone arm; also the three selection steps on the zone arm and how their relationship accomplishes the zoning.

2. Transfer the zone to the typewheel. After numerical selection and just before printing, the digit slide bail lowers the slides onto the zone arms. This turns the typewheel to select the zone position within the numerical classification. All zone arms set up for a 12 zone do not stop their respective digit slides. For 12 zones only the digit slides follow the digit slide bail past the zone arms and come to rest when the bail is stopped by the 12 zone stops.

3. Restore the zone latch arm. The zone latch arms are restored by the high point above the 12 tooth of the zone arm. This occurs when the zone-arm is at full downward position, just before reversing its direction of movement.

Numerical Selection

The rack drive cams start moving the racks downward at the beginning of the cycle.

The numerical punches in the card are read after the zones and energize the same print magnet. Attracting the armature moves the pull-rod downward to operate the trigger; and because the digit slide is now off the high dwell of the digit slide cam, the digit slide is released and projects into the teeth of the rack to stop the rack and thus control the typewheel for the numerical selection (Figure 253). Note in this illustration the numerical 3 selection on the typewheel and its relationship to the printing hammers. The *N* or numerical character is in position to print.

After the racks have been stopped by the numerical impulses and before print time, the digit slide bail operates to lower the digit slide onto the zone arm. The rack moves down with the digit slide turning the typewheel to select the zone within the numerical classification. Figure 253 illustrates how the digit slide is lowered onto the zone arm that is set up for the 11 zone and how the typewheel is rotated from the N zone character to the 11 zone character to bring the L into the printing position.

Figure 254 is a cross-sectional schematic view of the 557 showing all major operating units. The machine is positioned at print time, with neither zone nor digit select pawls engaged. Notice the hammer cam just ready to release the hammers, the typewheel aligner bail engaged in the typewheel gear, and the rack positioned at its extreme lower limit of travel by the lower typewheel rack stop bar.

Because of no zone or digit selection, the typewheel face aligned with the hammer is blank and nothing will print. For illustrative purposes the special character pawl, latch, and arm are not shown in their actual print-time position. The special character mechanism would be positioned about thirty degrees counterclockwise from its position as shown. However, to show the function of the trigger in unlatching the special character latch and pawl, the illustration is drawn with the special character mechanism in its nonoperated position.

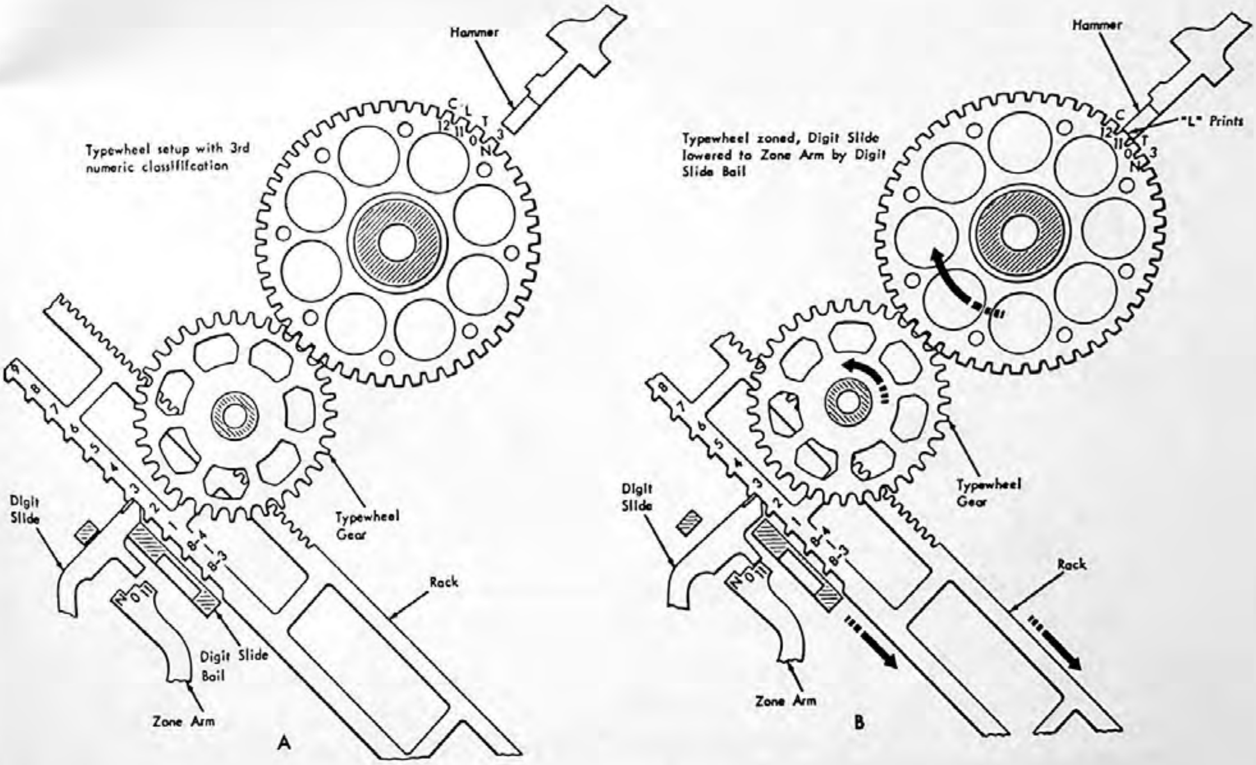


Figure 253. Zone Transfer

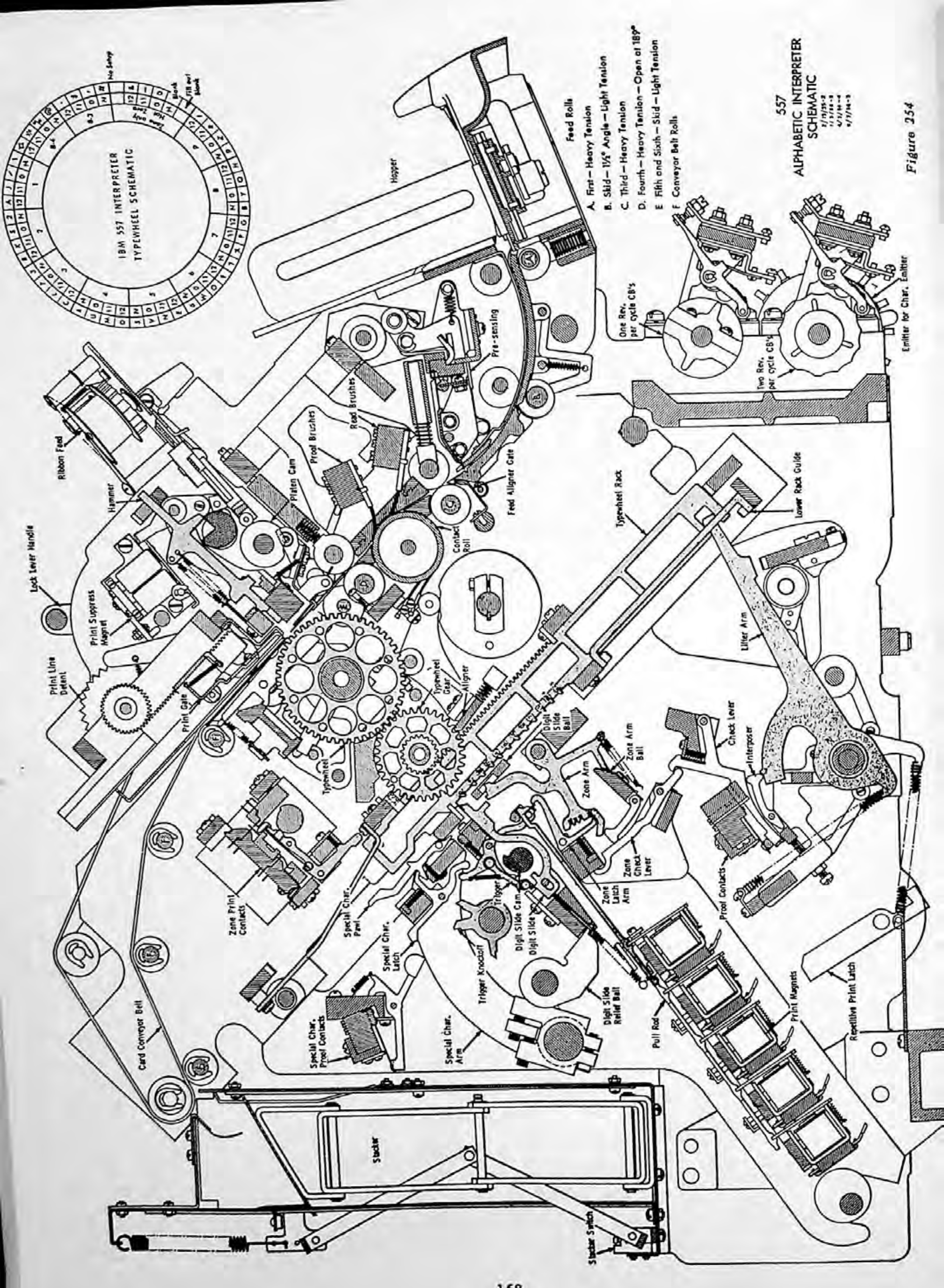

557
ALPHABETIC INTERPRETER
SCHEMATIC
Feed Rolls
A. First—Heavy Tension
B. Skid—1½° Angle—Light Tension
C. Third—Heavy Tension
D. Fourth—Heavy Tension—Open at 185°
E Fifth and Sixth—Skid—Light Tension
F Conveyor Belt Rolls
IBM 557 INTERPRETER
TYPEWHEEL SCHEMATIC
Hopper
Pre-sensing
Read Brushes
Proof Brushes
Platen Cam
Ribbon Feed
Hammer
Lock Lever Handle
Print Suppress Magnet
Print Line Detent
Print Gate
Typewheel
Typewheel Gear
Aligner
Contact Roll
Feed Aligner Gate
Typewheel Rack
Lower Rack Guide
Lifter Arm
Check Lever
Interposer
Digit Slide Bail
Zone Arm Bail
Zone Arm
Zone Check Lever
Zone Latch Arm
Proof Contacts
Trigger
Digit Slide Cam
Digit Slide
Trigger Knockoff
Special Char. Pawl
Special Char. Latch
Zone Print Contacts
Special Char. Proof Contacts
Special Char. Arm
Digit Slide Relief Bail
Pull Rod
Print Magnets
Repetitive Print Latch
Card Conveyor Belt
Stacker
Stacker Switch
One Rev. per cycle CB's
Two Rev. per cycle CB's
Emitter for Char. Emitter

Figure 254

Triggers and Trigger Knockoff Cam (Figure 254)

The operation of the triggers by the pull-rods has three functions depending upon when the magnets are impulsed.

1. Unlatches the zone latch arms to stop the zone arms.

2. Unlatches the digit slide to stop the racks.

3. Operates the special character latch to unlatch the special character pawl.

The triggers are also operated by the digit slide cam. This occurs during the time when the zone latch arms are being restored to prevent a mechanical interference between the triggers and the zone latch arms as the triggers operate within the gooseneck of the unlatched zone latch arms.

The function of the trigger knockoff cam is to knock off, or restore the print magnet armatures and triggers. Notice on the timing chart of the wiring diagram, the timing relationship at each of the three high dwells:

1. The first high dwell ends just before reading the zones and in addition to restoring the print magnet armature, it also operates the triggers to latch the zone latch arms;

2. The second high dwell ends just before reading of the numerical impulses to operate the triggers to latch the digit slides; this high dwell is longer in duration to fully restore the print magnet armature following a zero impulse;

3. The third dwell ends just before reading the eight impulse for use on machines equipped with special character device.

Digit Slide Cam

The digit slide cam performs three functions:

1. Restrains the digit slides during zone read time to prevent releasing the slides for zones.

2. Restores the digit slide to relatch onto the triggers after the racks are restored.

3. Cams the triggers to move them away from the zone latch arms so that the latch arms can be restored.

Reference to the mechanical timing chart will disclose that the high dwell ends just before reading the 1. The restoring of the slides starts when the racks are almost fully restored.

Digit Slide Bail

The digit slide bail lowers the slides to the zone arms; the racks move with the slides because of the lifter arm spring tension. The position of the zone arms determines the amount of rack movement that will result in turning the typewheels the required distance to select the zone character within the numerical classification. This turning for selecting the zone will be 3 type positions for the 12 zone, 2 for the 11 zone, 1 for the 0 zone and only a slight movement for the N or no zone. The timing chart shows that the bail starts to operate before printing and restores shortly afterwards but before the racks start to restore.

Digit Slide Spring Relief Bail

This bail relieves the spring tension on the slides shortly after the racks and slides are being restored. This reduces the wear on the parts when the racks move up during restoring.

Rack Lifter Arms (Figure 254)

The lifter arm bail operates the 60 lifter arms to move the racks downward during setup time. Springs hold the arms against the bail; and when the digit slide stops the rack, the bail continues on down carrying the other racks.

After printing, the bail moves up, restoring the racks to the top for use on the next cycle.

The mechanical timing chart for the rack drive cams shows two levels of movement: one at the lower and the other on the upward travel. The lower level is an undercut on the front and rear complementary cams to provide latching clearance between the repeat print latch and the complementary cam follower arm on machines equipped with the repetitive print device. On all machines the additional level on the upward travel provides for a ripple restore with the rear end of the bail operating 6° later than the front. This reduces the noise and distributes the load.

Print Aligner (Figure 254)

The print aligner consists of a bail that is inserted into the typewheel gears before printing time to align the typewheels. Clearance is provided between the typewheel gear and the rack to permit the aligner bail to align the typewheel gear without moving the rack.

Zero Contacts (Figure 254)

These contacts provide for the electrical control of zero printing. The low dwell of the cam lowers the levers onto the racks. The cut on the rack is so located that the contacts make only in the position where the rack has been stopped by the hot "0" or not stopped by any digit. The function of the cam is to hold the zero print contact levers clear of the racks, except during setup time, to minimize wear.

Print Gate (Figure 255)

The print gate is positioned by the print-line knob for the desired printing line, and the gate movement is controlled by a rack. A contact is operated by the detent to interlock the machine if the knob is turned while the machine is running or if the knob is left in a half-way position.

The gate is raised and lowered by a cam. When lowered, the gate fingers ride within channels on the shield with the exception of line 1 where it is off the edge of shield. Two stop screws on the print gate control the downward position at line 1. A special camming arrangement consisting of two arms raises the print gate when the print knob is turned from line 1 while the gate is down. This prevents the gate from catching on the edge of the shield.

Print Unit (Figure 255)

Sixty individual hammers are released at the same time by a cam. Springs attached to each of the hammers provide the force to the hammer for printing. The same cam restores the hammers. The lower end of each hammer has a nylon tip that strikes the card.

The hammer camshaft is driven through a one-tooth ratchet on the drive gear. This keeps the cam from turning backwards when closing the upper section.

All sixty hammers may be prevented from striking the card by means of a suppress bail. The bail is mounted on the front and rear arms that pivot about a small shaft above the hammer camshaft.

Located on the hammer camshaft is the print suppress cam that operates a roller on the rear bail arm and allows the print suppress bail to move under the projections of the hammers during print time to suppress printing. For a printing operation, the bail is latched in position so that it cannot follow the suppress cam to prevent printing. The print suppress magnet and armature latch are mounted on the inside of the gear print unit side frame.

Every cycle, the rear suppress bail arm is unlatched from the magnet armature to suppress printing unless it is controlled. This has to be set up by control-panel wiring, which will energize the suppress magnet and latch the bail to allow printing. The hammer stop bar limits the travel of the hammers. This prevents smudging when set up for a blank and prevents embossing when printing a character.

Step-by-Step Review of Printing Operation

1. Trigger knockoff relatches triggers and restores print magnet armatures.

2. Zone punches energize the print magnet, releasing the zone latch arms to stop the zone arms. If no zones are read, the zone arm will stop in the N position. The digit slides do not operate because the digit slide cam is on the high dwell.

3. Rack-drive cams begin to lower racks. Movement of racks is not significant until 1 time.

4. The digit slide spring relief bail applies pressure to the digit slide springs.

5. The trigger knockoff cam relatches triggers and restores print magnet armatures.

6. Numerical punches energize print magnets to release the digit slides and engage the corresponding tooth in the rack. This stops the rack to select the numerical classification on the typewheels.

7. The trigger knockoff relatches the triggers and restores the print magnet armatures. This is just before 8 time and is utilized in machines equipped with the special character device.

8. The hot 0 energizes the print magnet depending on zero contacts and control-panel wiring. This has no significance if previously energized by a numerical impulse. If the magnet is energized, it releases the slide to stop the rack at the 0 tooth to select the zone only classification on the typewheel.

9. The digit slide bail lowers the digit slides down onto the zone arms. Because the slides are engaged in the racks, the typewheels are turned to the 1, 2, or 3 type position to select the zone character in each classification.

10. The print aligner bail engages in the typewheel gears to align the typewheels.

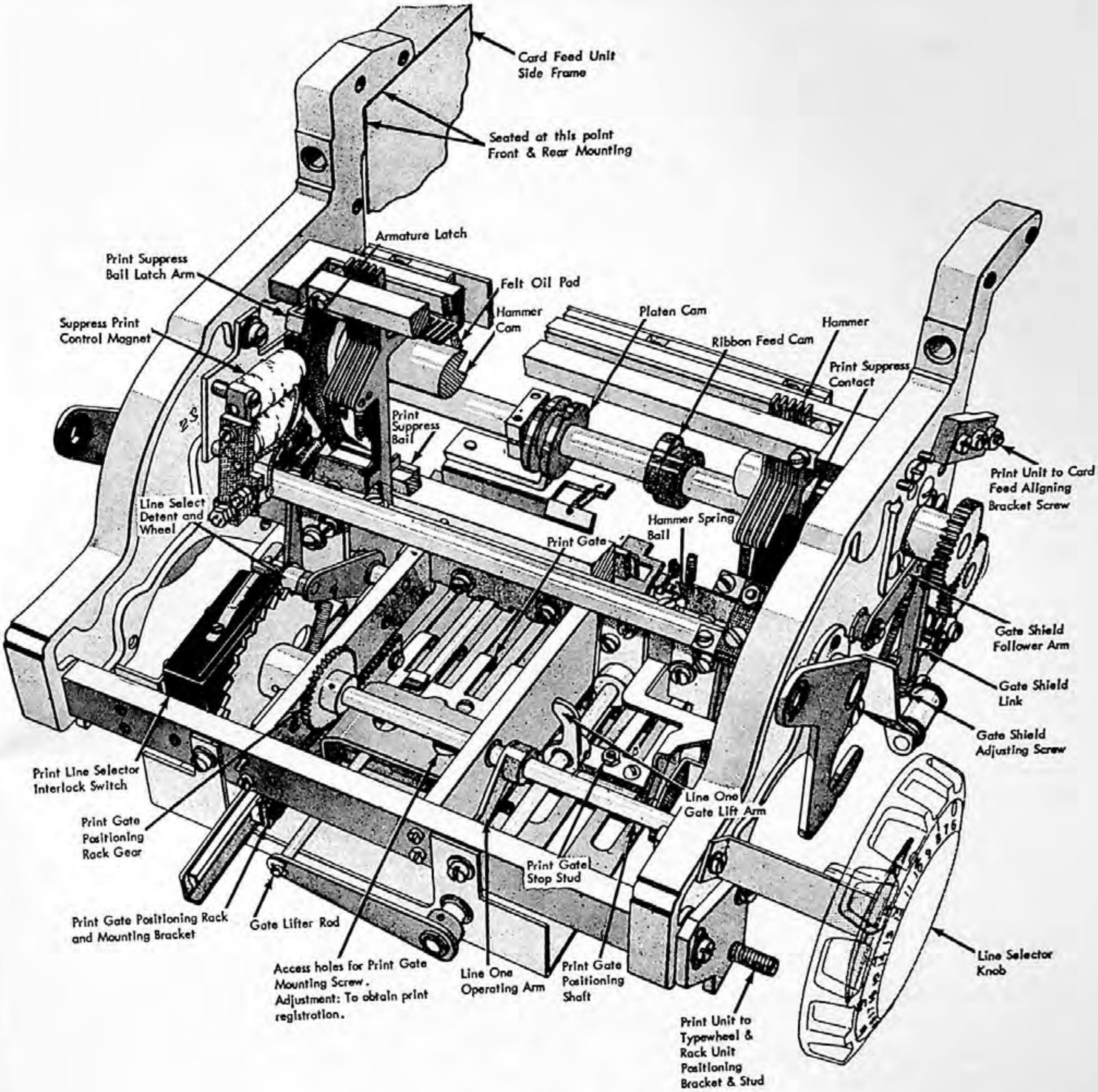


Figure 255. Print Unit

11. The platen cam lowers the card guide, and the shield cam lowers the shield to position the card close to the typewheel faces.

12. All the hammers fire to print the characters set up in the typewheels. The unused positions and zeros to the left do not print because the print magnets were not energized for numerical selection. The rack, therefore, has traveled all the way down, turning the typewheel to the no setup blank position.

13. The hammers, platen, and shield are restored.

14. The print gate is raised, and the card is advanced into the stacker.

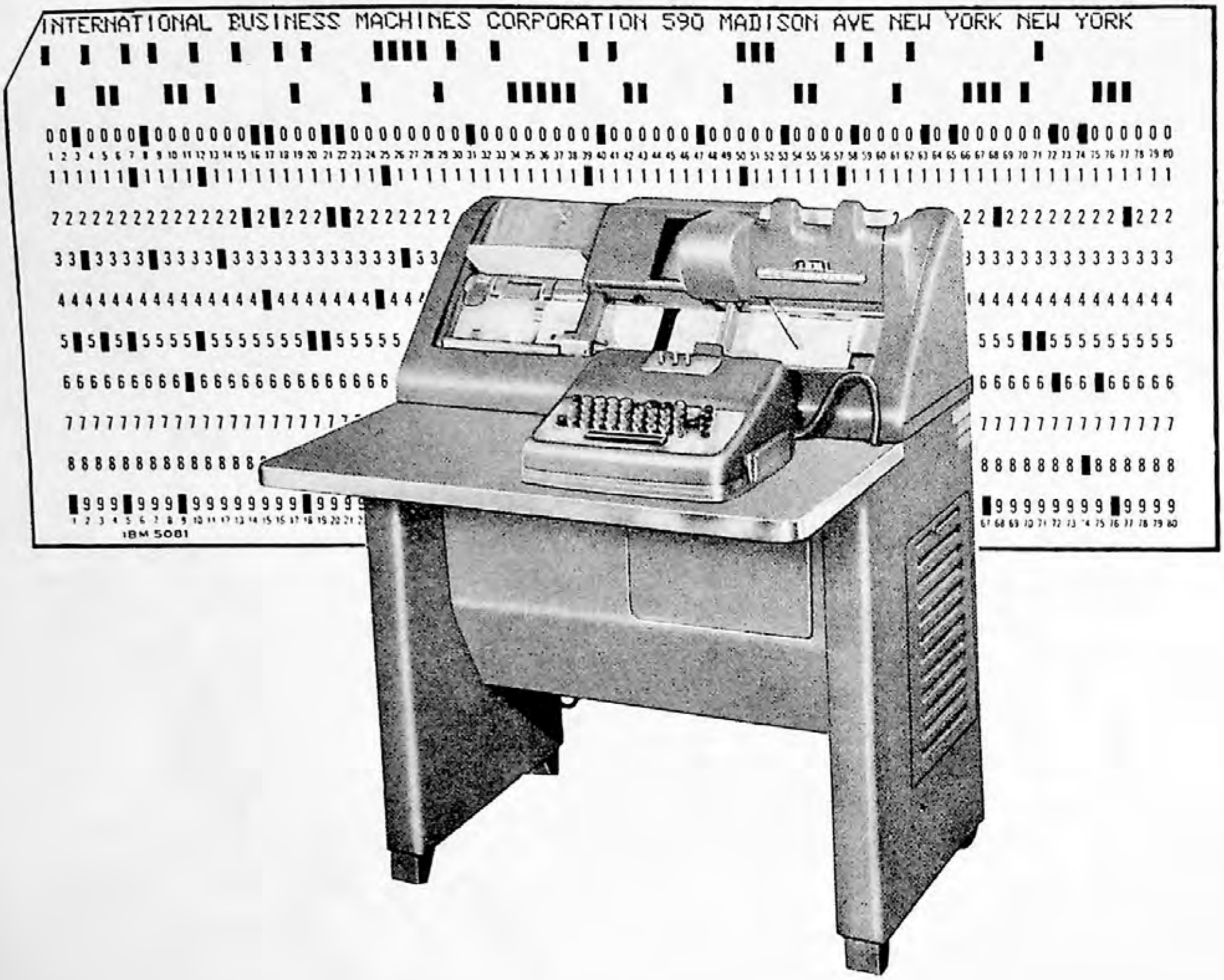


Figure 256. Type 26 Card Punch and Interpreted Card

TYPE 26 CARD PUNCH PRINTING MECHANISM

THE TYPE 26 Card Punch is used to interpret cards as the cards are punched. The Type 26 Card Punch is capable of printing information across the top of the card above each of the 80 card columns. The printing and punching takes place in the same cycle. Figure 256 shows a Type 26 Card Punch and a card which has been punched and printed by it.

This machine uses the pressure method of printing, but it is unique in that it uses stiff wires instead of type bars to form the letters. It is only necessary to have one set of wires, instead of one for each printing position, because the machine punches and prints only one column at a time.

The wire printing unit consists of 35 sturdy, flexible, stainless steel wires, .009″ in diameter, and a funnel guide which provides individual passages for the wires. At the small end of this guide, the wires converge and form a rectangle which is the overall size of a character, as seen in Figure 257.

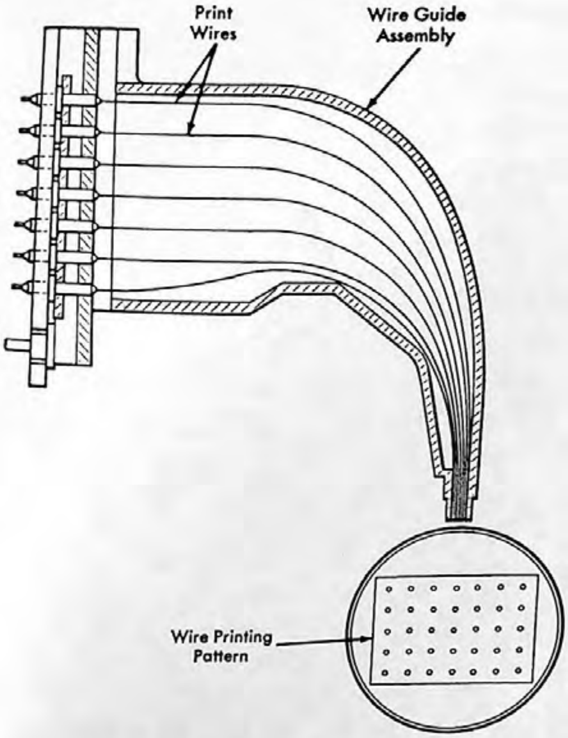


Figure 257. Print Wire Guide

A character is formed and printed by printing a series of closely spaced dots in the shape of the character desired. By pressing on a wire at the wide upper end of the funnel guide, the end of the wire at the small end will be extended to print a dot. If a number of wires are selected and pressed at the same time, a character is printed. An example of wire printing can be seen in Figure 258.

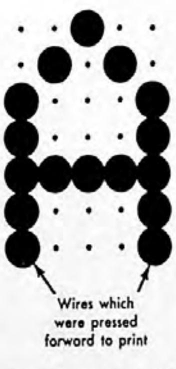


Figure 258. Example of Wire Printing

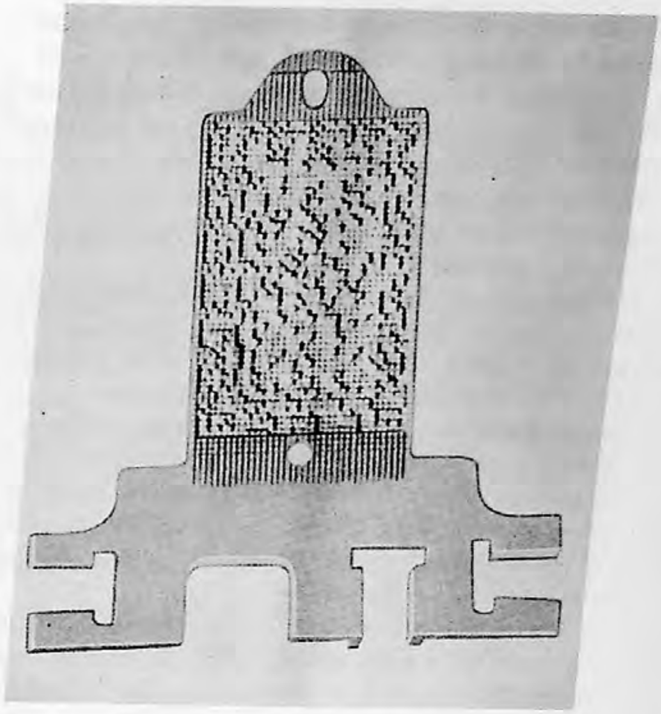


Figure 259. Type 26 Code Plate

Code Plate

To print any character desired, it is only necessary to select the wires to print and provide a means of pressing them simultaneously. A code plate has been designed which will select and transmit pressure to the wires. The code plate, as seen in Figure 259, has projections which outline all characters. The thirty-five wires are sufficient to form all the letters of the alphabet, the numbers 0 through 9, and several special symbols.

The code plate projections are placed so that by shifting the code plate either vertically, horizontally, or both vertically and horizontally, the projections are positioned to form the desired character. Figure 260 is a code plate chart which shows the position of the projections in relation to the 35 print wires. The chart shows the code plate in the normal position, and there are no projections behind any of the 35 wires. If a cycle is taken and the code plate is not shifted, nothing will be printed. This will occur during a spacing operation.

If the code plate as shown in Figure 260 is shifted to the left one square and down one square, the projections will strike wires to form an A. Recall that the wires converge at the small end of the funnel guide so that, although the wires are widespread at the top, they are held close together at the printing end, with the rectangular form maintained. The wires which are not used to form the A will be over a blank spot on the code plate so that those wires will not be extended to print.

Observe from the same chart, that by shifting the code plate in different combinations, any character can be selected. None of the projections are used for more than one character. The characters appear upside down on the code plate and chart; this is because the code plate is vertical while the card is horizontal. In Figure 261, the print unit is above the 12-edge of the card. The funnel guide has the effect of rotating the character through 90° so that it prints right side up on the card.

Figure 262 is a print code chart which shows the character to be printed, and in small letters the punch code which causes it to be printed. The shift of the code plate can also be determined from this figure. For example, from the normal position, indicated by the blank square approximately in the middle of the

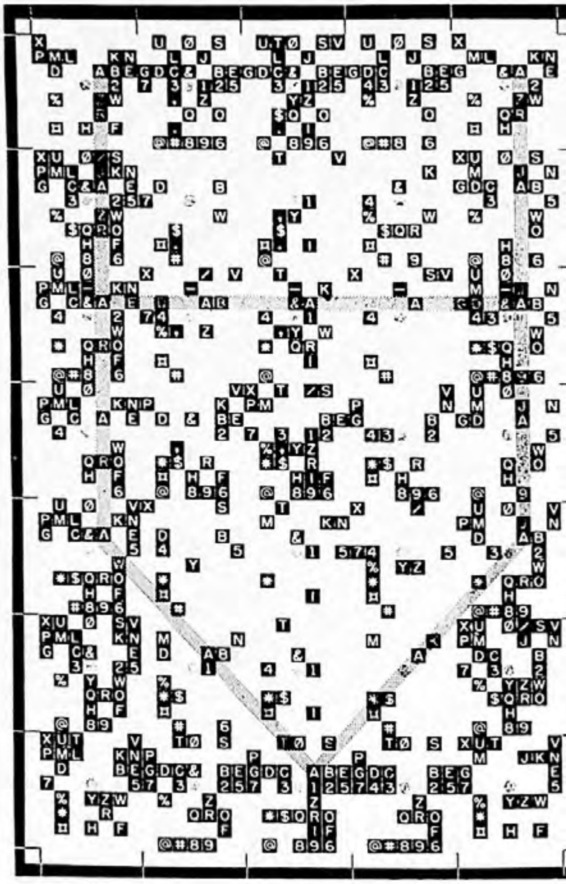


Figure 260. Code Plate Chart

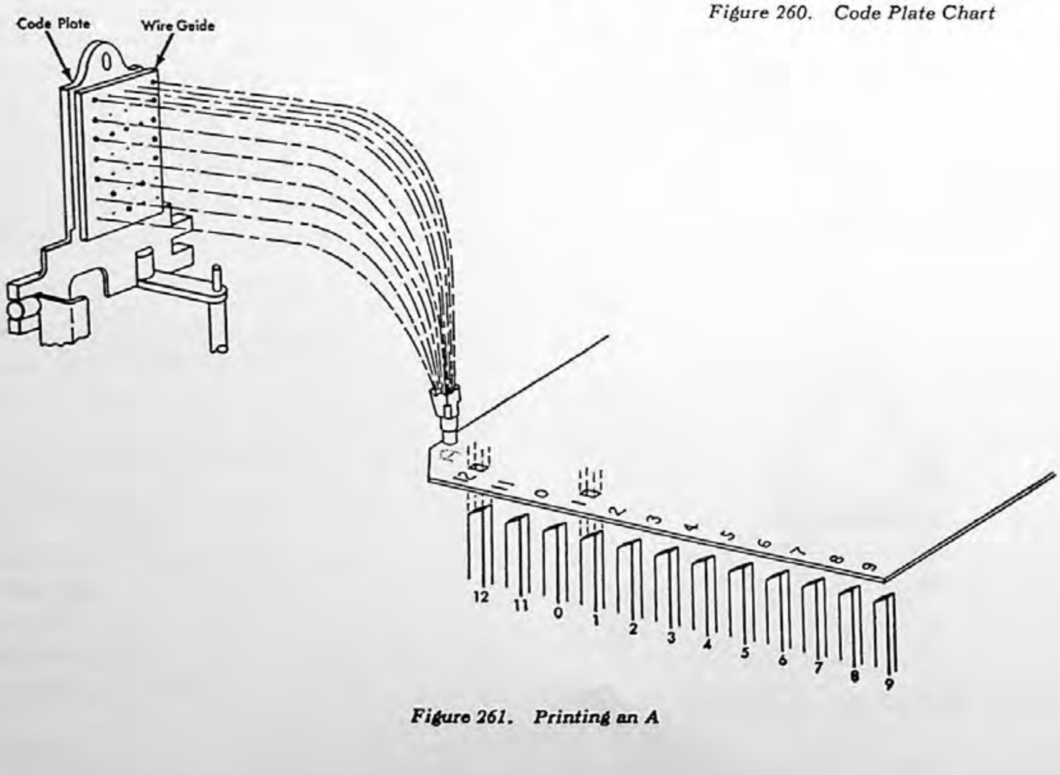


Figure 261. Printing an A

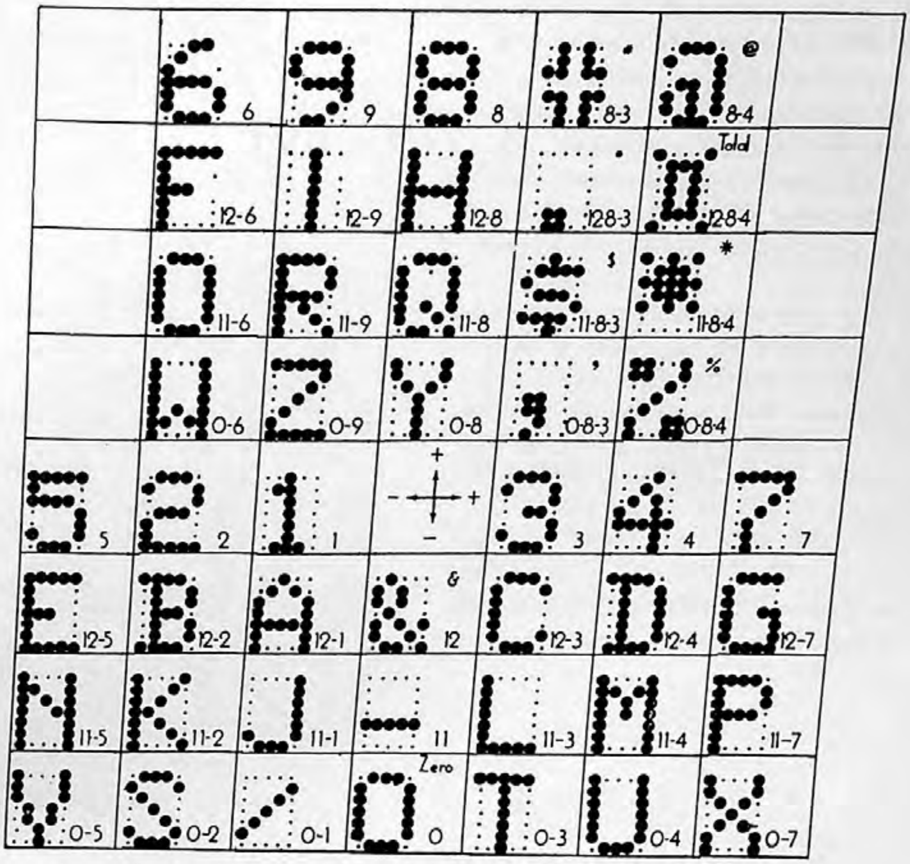


Figure 262. Print Code Chart

chart, the A is displaced one square to the left and one square down. It should be recalled that this was The shift for any character can be determined by the shift required by the code plate to print an A. its disposition from the blank square.

Print Interposers

Print interposers are used to shift the code plate both vertically and horizontally. Figure 263 shows that the code plate is shifted by means of a vertical shift plate and a horizontal shift lever. The horizontal shift lever movement is controlled by the horizontal slide and print interposers. The print interposers are shown in their normal positions, and in this position all interposers have the same width. If the 1 interposer is raised, the cylindrical discs will be able to move into the recesses cut in the interposer. As a result of this action, the spring on the horizontal shift lever will move the horizontal slide in to take up the slack. Consequently, the code plate will be shifted to the left. The recess in the interposer is described as a negative quantity because the code plate is moved to the left. The amount of movement of the code plate will depend on the depth of the cut in the interposer.

If the 3 interposer is moved up, the raised portions of the interposer will force the cylindrical discs apart. This will cause the code plate to be shifted to the right.

The vertical slide and interposers result in a vertical movement of the code plate. The interposers which have a recess cause the code plate to move down; the interposers which have raised portions raise the code plate.

The numbering of the interposers is the same as the punch which operates it. For example, if an A is punched, it should also be printed, and the 12 and 1 interposers will be raised because a 12 and 1 are punched. The two interposers are both "minus one" interposers which is the shift necessary to print an A, as pointed out earlier. In Figure 263, both the 6 and

9 punch operate two print interposers, one vertical and one horizontal. All other punches operate one print interposer, either a vertical or a horizontal.

The interposers are operated by means of a punch extension and interposer yoke (Figure 264). The punch extension is connected to the interposer yoke which will move up with the punch when it is driven up to punch a hole. As a result, whatever is punched will also be printed.

A pressure plate is provided to effect the actual printing after the code plate has been shifted. A return plate which works in conjunction with the pressure plate pulls the wires back to a normal position after printing. Figure 265 shows these parts and their operating mechanism. The code plate is located between the pressure plate and the return plate.

The print drive rod is pulled downward by spring action, under the control of a cam. The downward movement of the drive rod and connecting links pulls the print drive arms downward. As the print drive

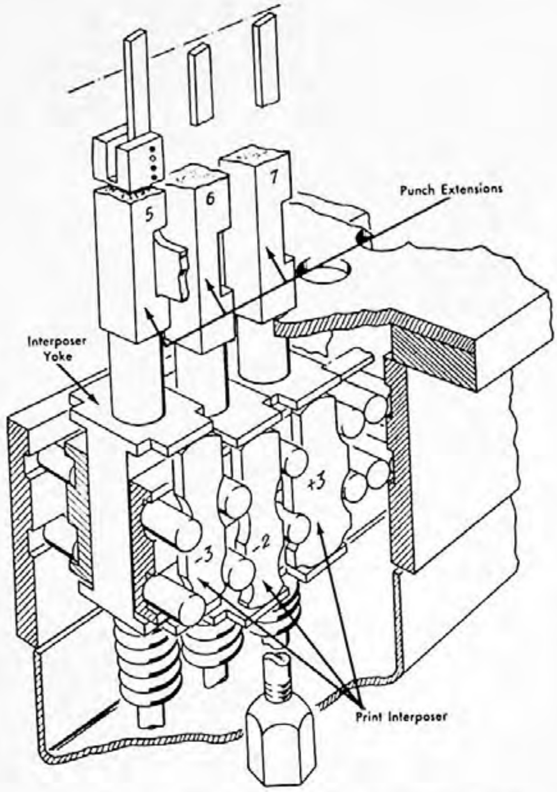


Figure 264. Punch Extensions and Interposer Yokes

arms rotate about their pivot points, the points which are connected to the pressure and return plates move to the right. This forces the pressure plate against the code plate, which is forced against the wires to cause printing.

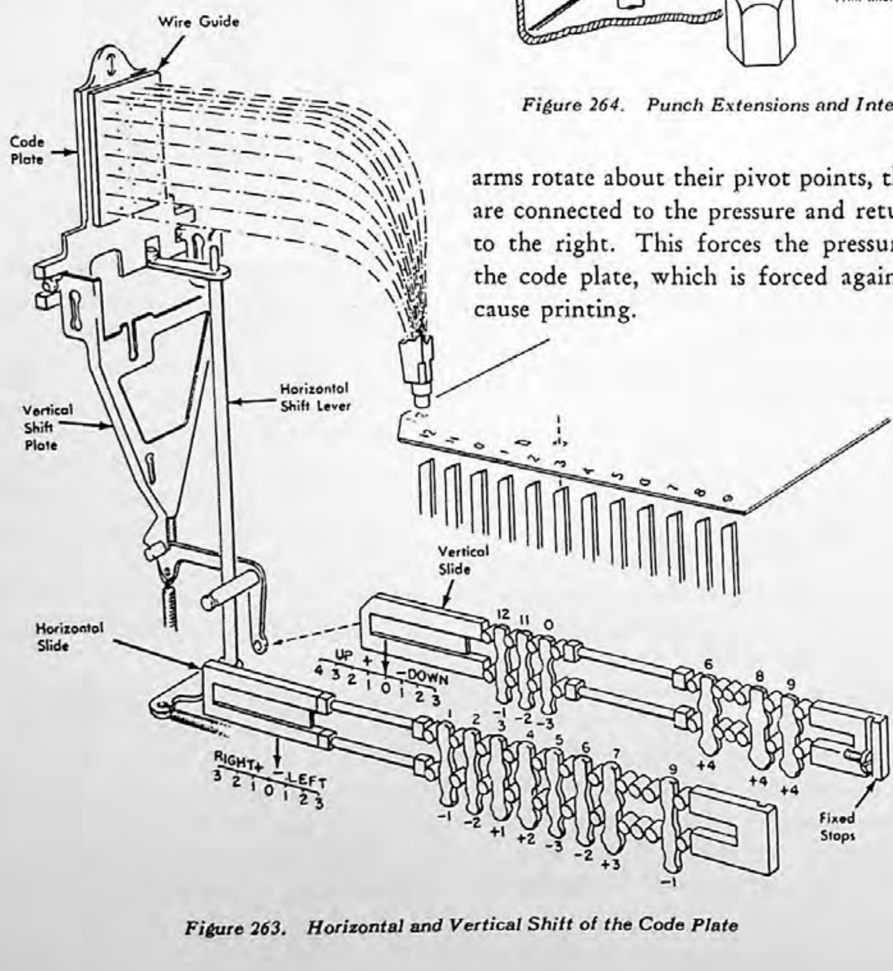


Figure 263. Horizontal and Vertical Shift of the Code Plate

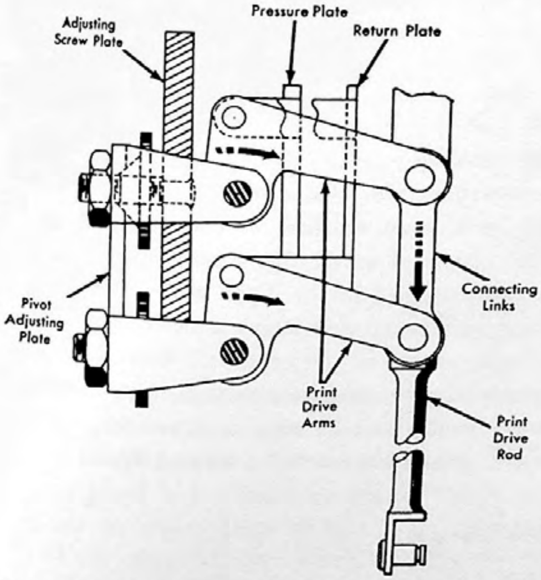


Figure 265. Pressure Plate, Return Plate, and Operating Mechanism

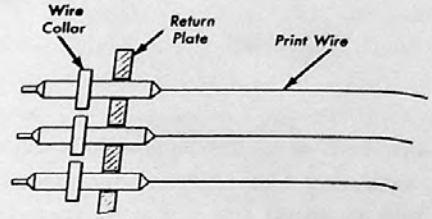


Figure 266. Return Plate and Print Wires

The movement of the print drive rod upward causes the pressure plate to move to the left away from the code plate. The code plate is then returned to normal by spring tension. The return plate also moves to the left pulling the wires back to their normal position. The return plate acts against a collar, which is attached to the print wire and is located between the return plate and code plate (Figure 266).

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.

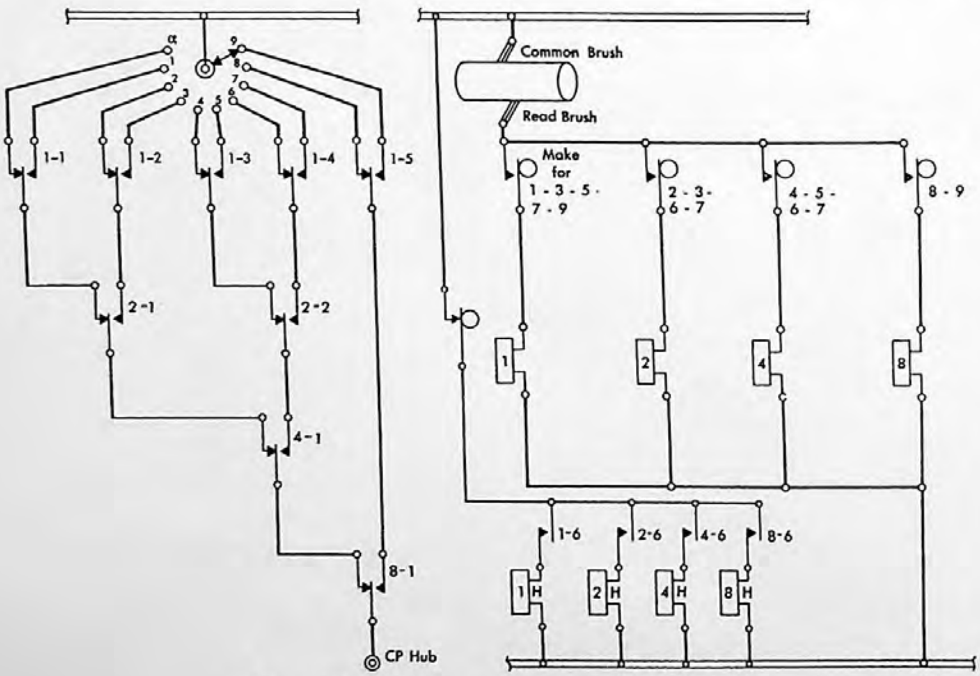


Figure 267. Relay Storage — Read In and Read Out

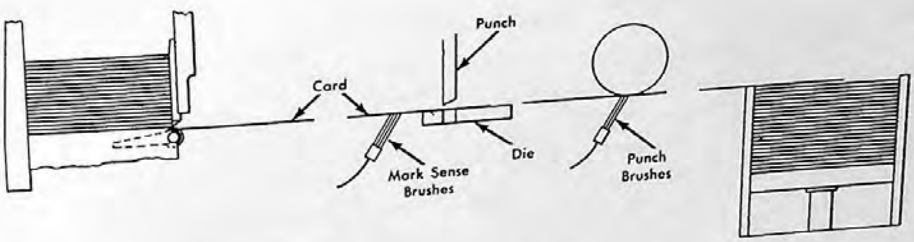


Figure 268. Mark Sense Feed Schematic

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.

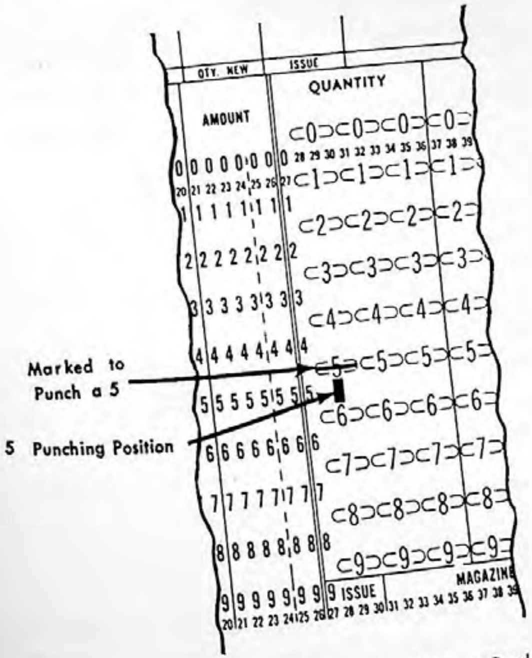


Figure 269. Marking Position on a Mark Sense Card

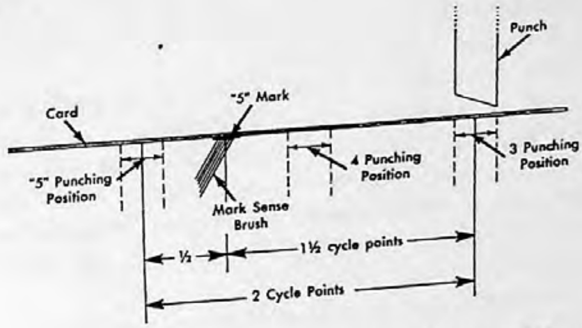


Figure 270. Cycle Point Relationship of Mark Sensing and Punching Mechanism

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

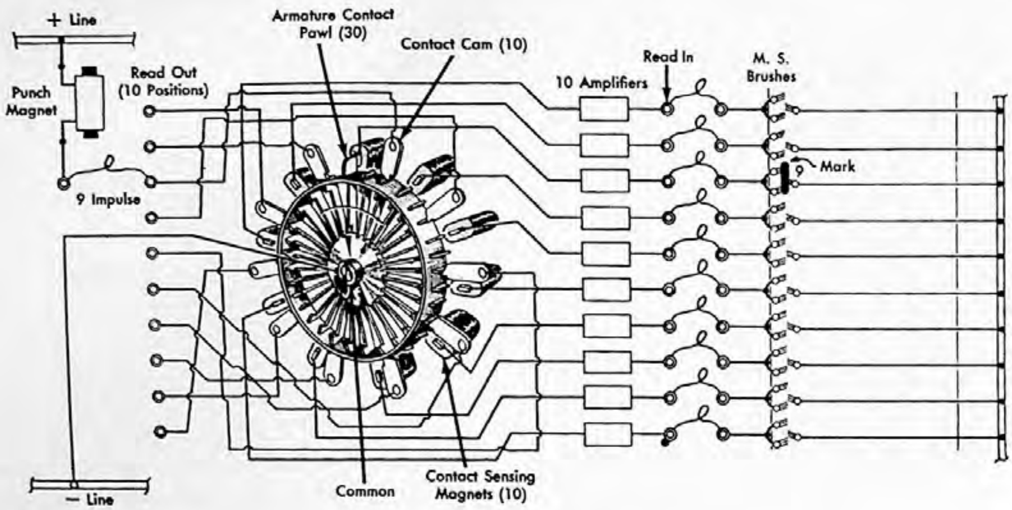


Figure 271. Mark Sense Delay Unit

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

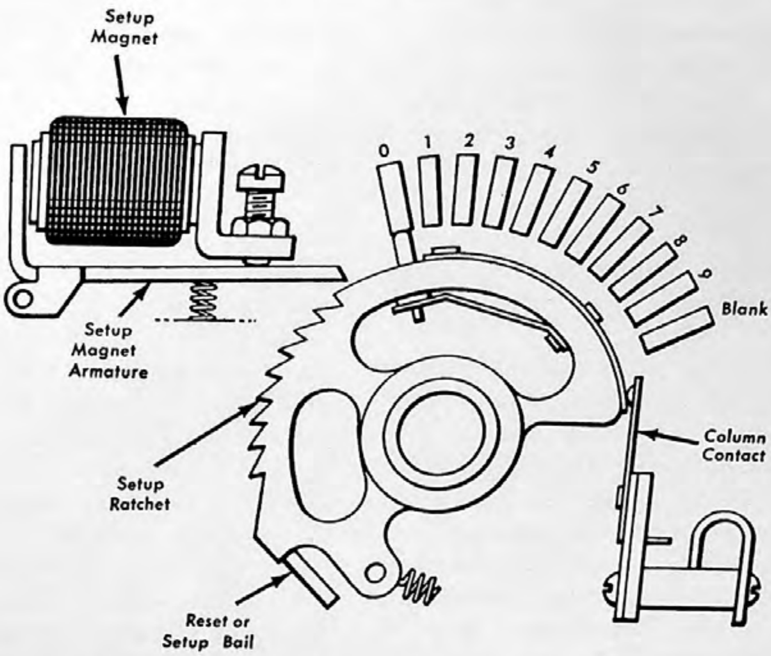


Figure 272. 602A Type Storage Unit — Single Position

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

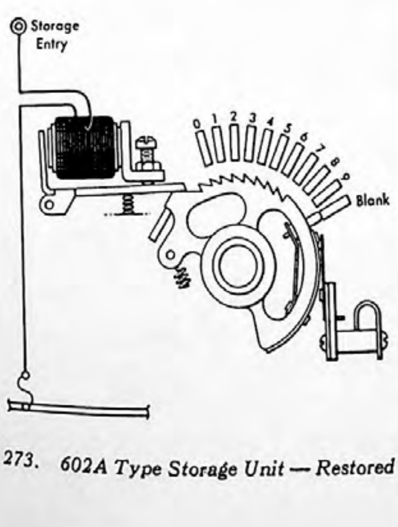


Figure 273. 602A Type Storage Unit — Restored Position

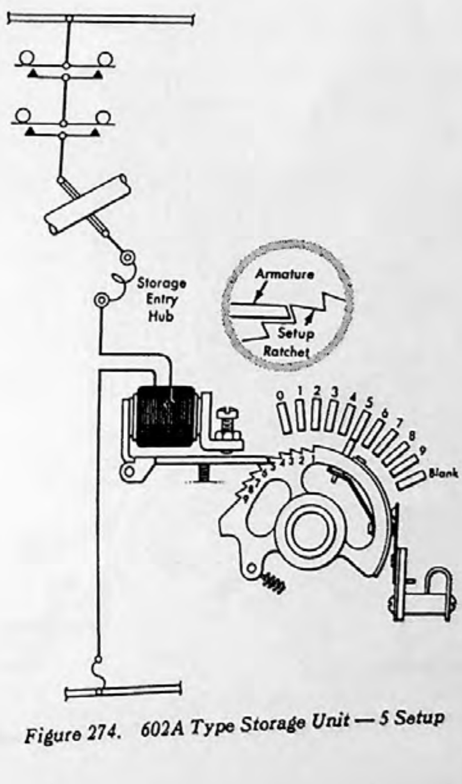


Figure 274. 602A Type Storage Unit — 5 Setup

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.

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.

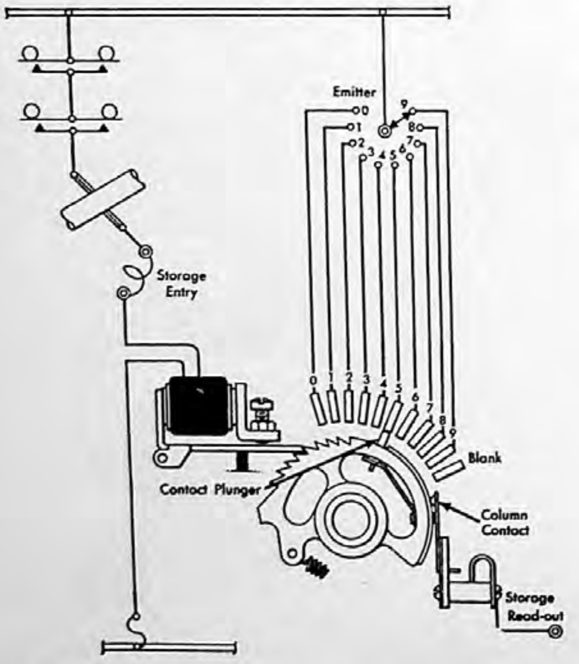


Figure 275. 602A Type Storage Unit — Read Out Circuit

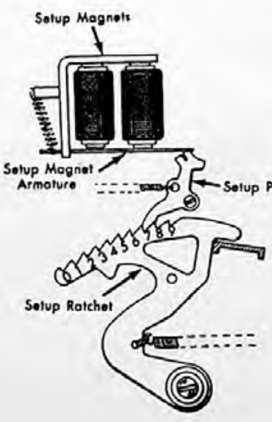


Figure 277. Type 77 Storage — Setup Magnet and Ratchet

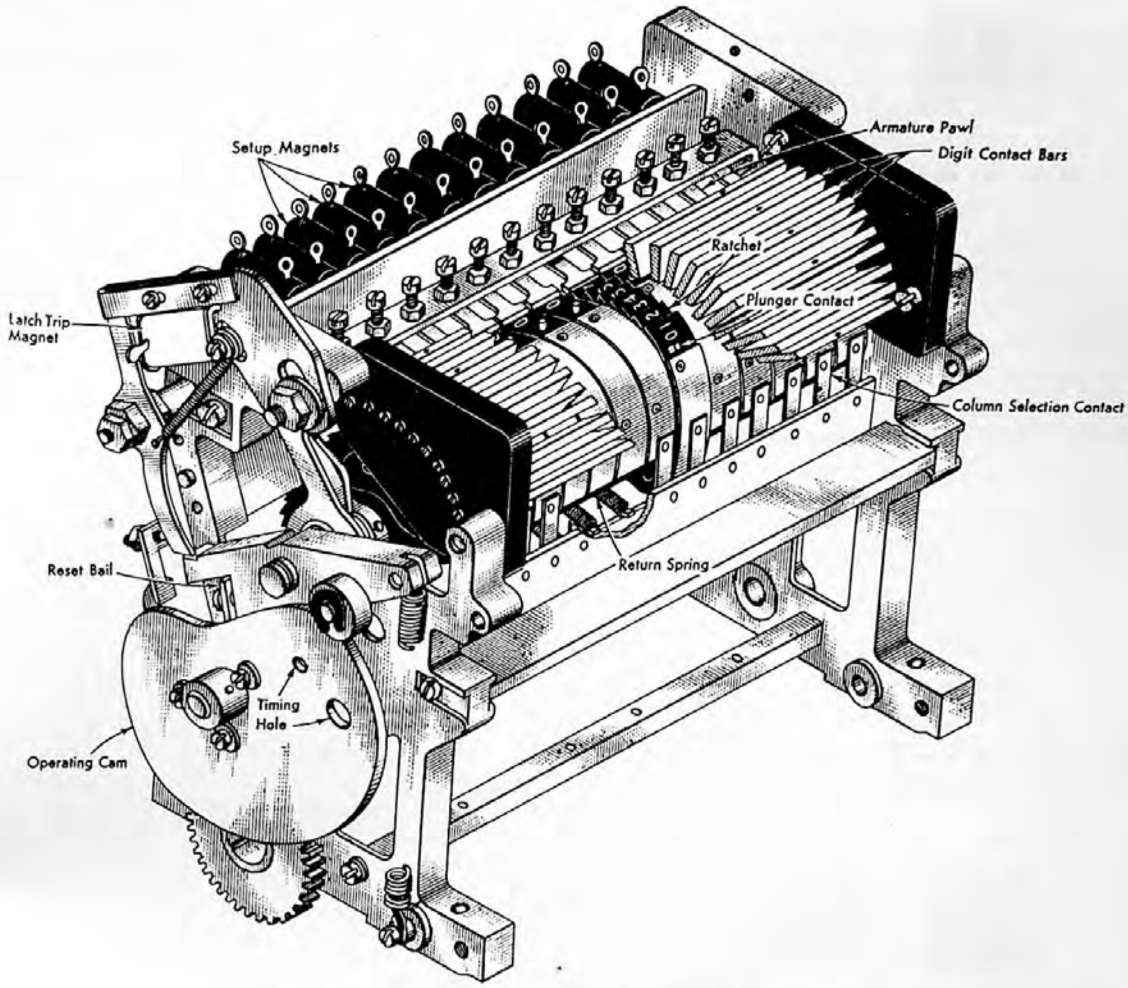


Figure 276. Entire 602A Type Storage Unit — 12 Positions

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.

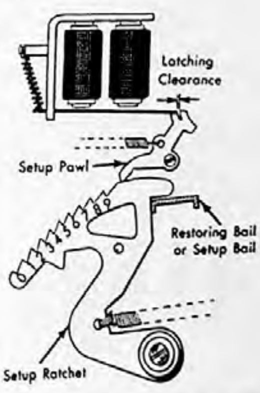


Figure 278. Type 77 Storage — Restored Position

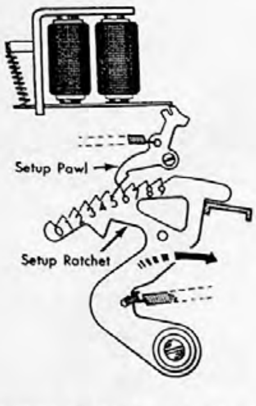


Figure 279. Type 77 Storage — Impulsed to Setup a 5

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.

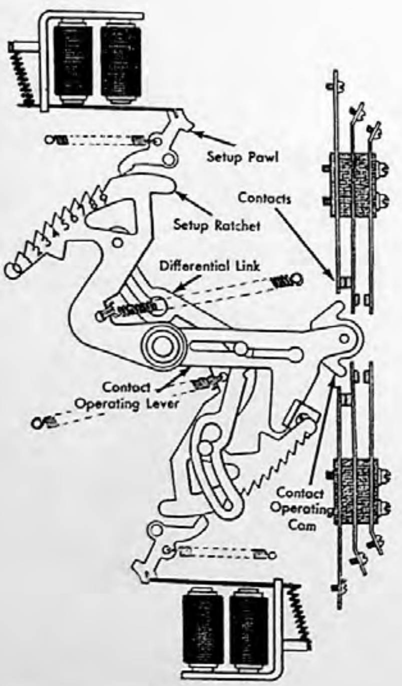


Figure 280. Type 77 Storage — Upper and Lower Section — Single Position

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

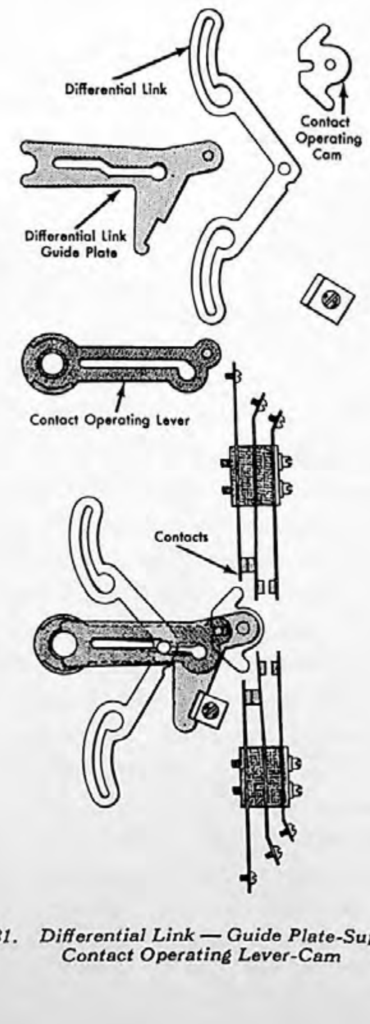


Figure 281. Differential Link — Guide Plate-Support Bail — Contact Operating Lever-Cam

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

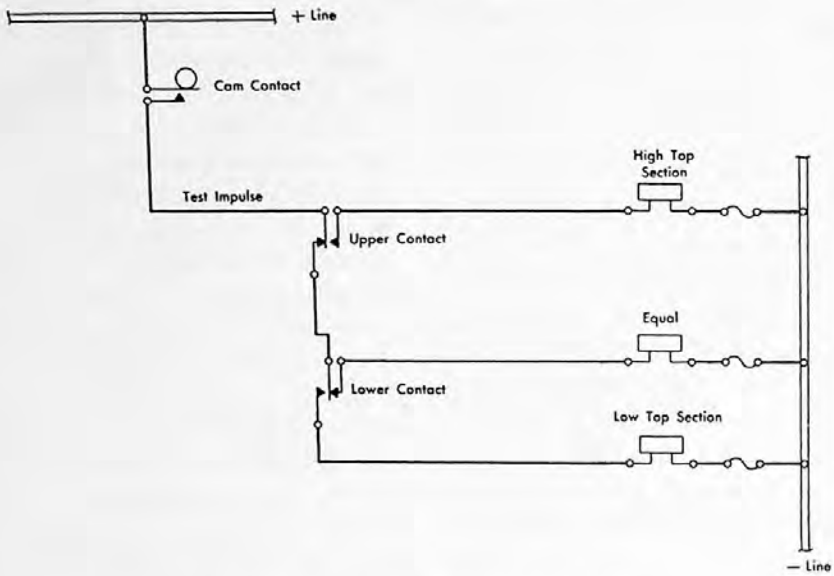


Figure 283. Test Circuits — Single Position

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

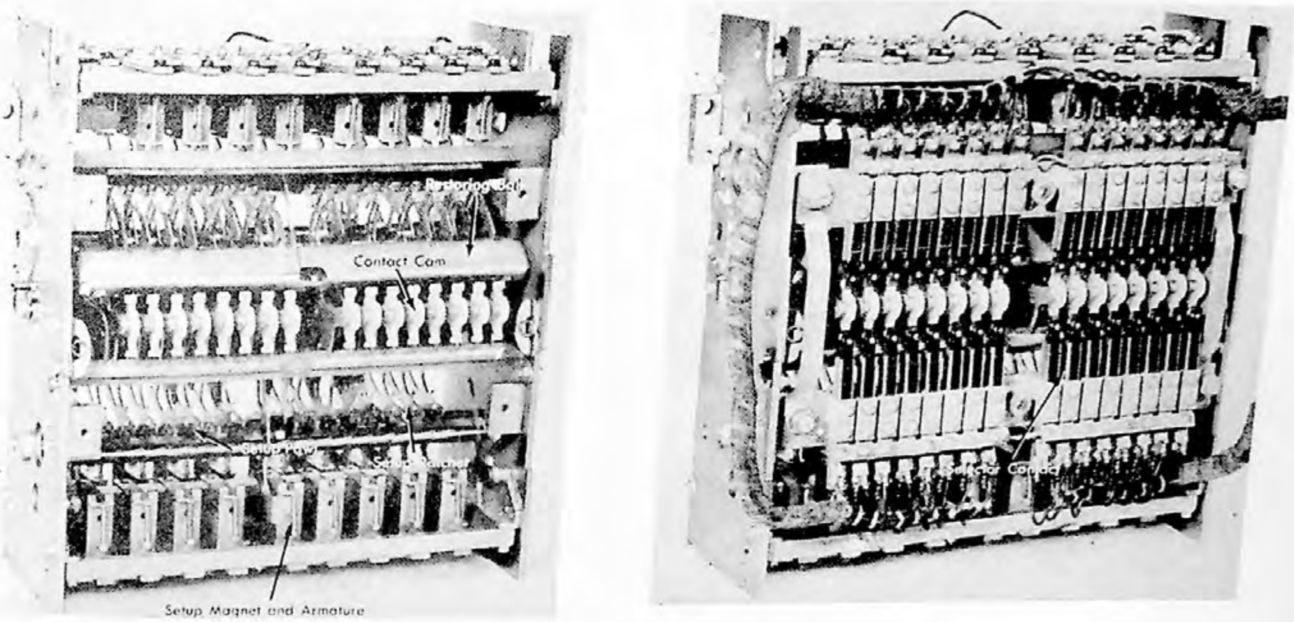


Figure 284. Entire Type 77 Storage Unit — 16 Positions

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.

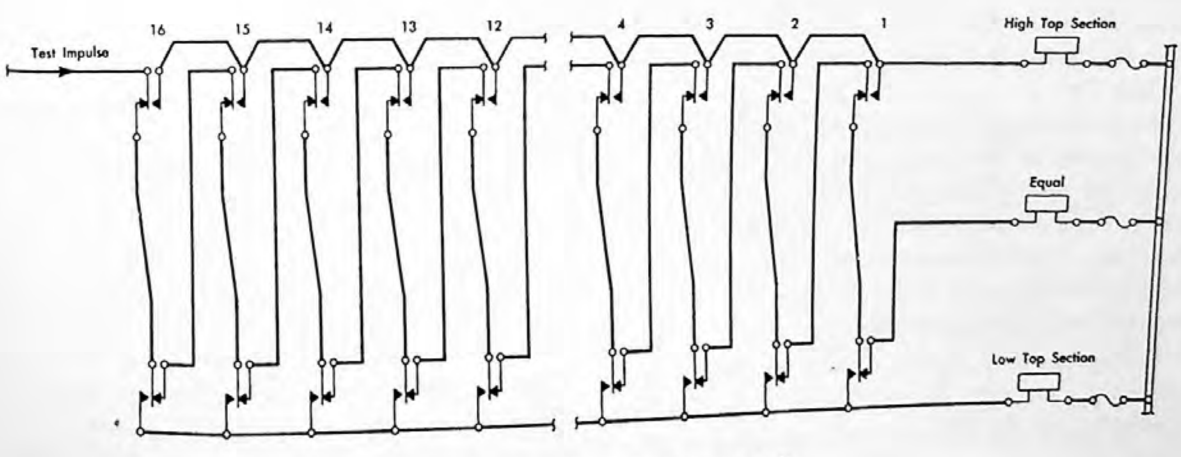


Figure 285. Test Circuits for Complete Unit

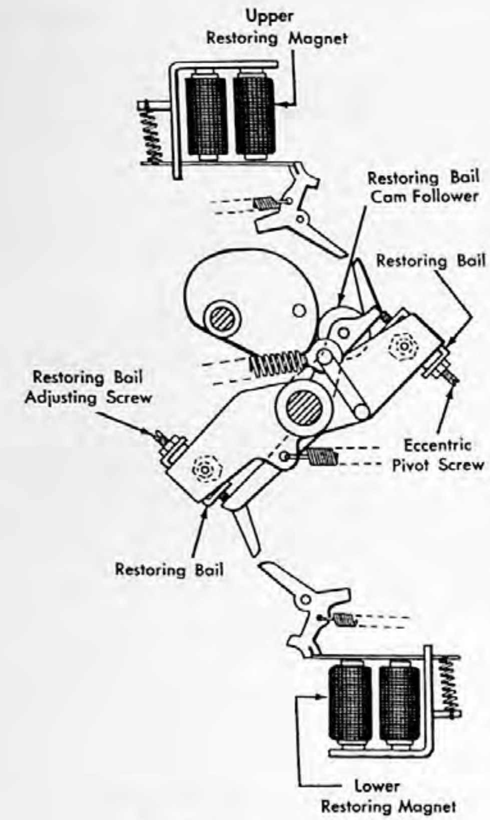


Figure 286. Restoring Mechanisms

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

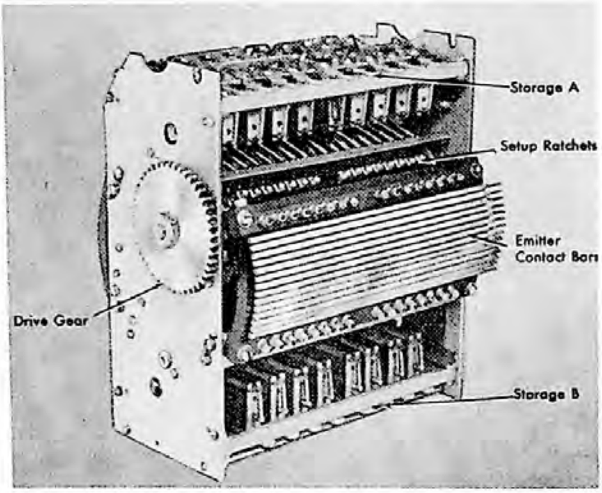


Figure 287. Storage Unit

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.

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

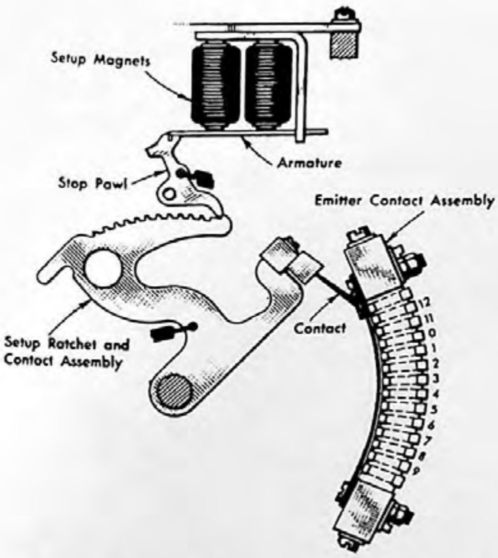


Figure 288. Storage Unit — Setup Ratchet and Emitter Contact

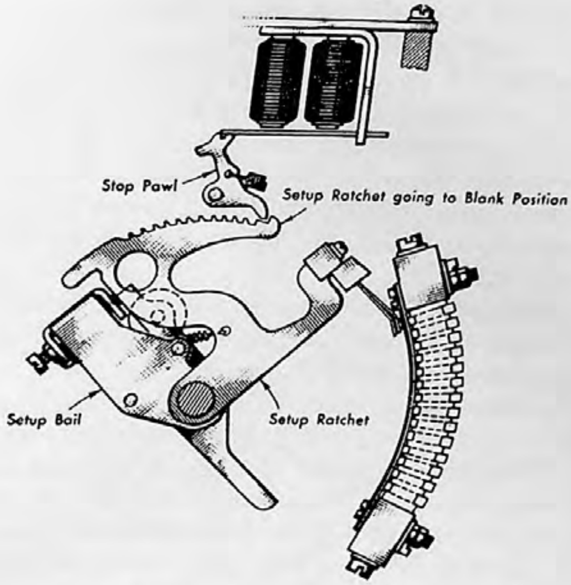


Figure 289. Setup Ratchet at Blank Position

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.

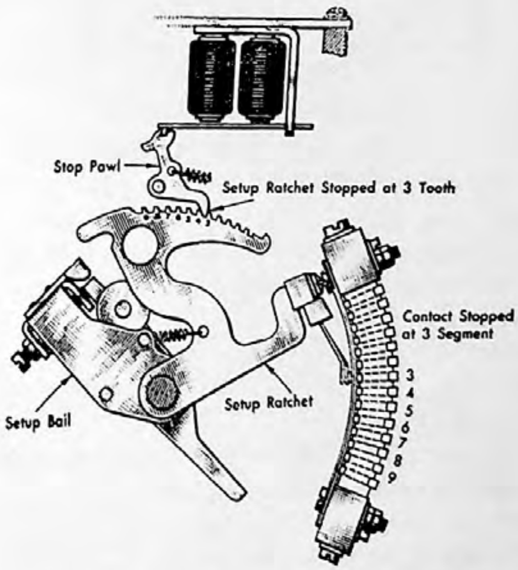


Figure 290. Setup Ratchet Stopped by the 3 Tooth

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

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

The setup bail is under control of the restoring agnet. Consequently, the length of time that a fig- re is stored is dependent upon the energization of he restoring magnet. Each storage unit has two re- storing 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 re- storing 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 en- ergized, the setup bail is held in a latched position and does not operate with the cam follower (Fig- ure 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

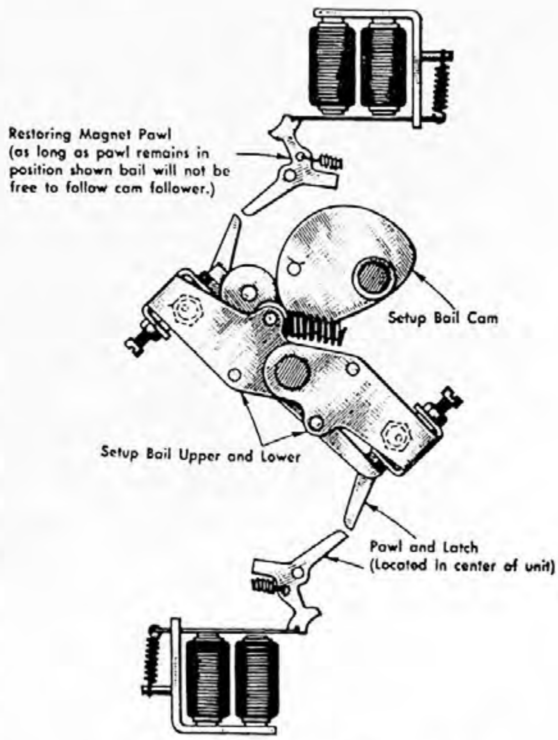


Figure 291. Setup Bail and Cam

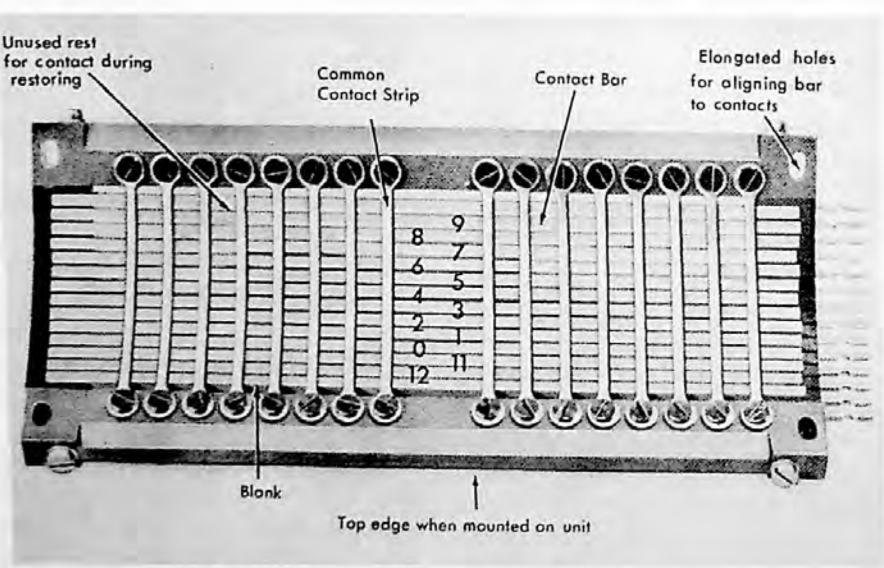


Figure 292. Storage Unit Contact Emitter Assembly

the tooth that the stop pawl engaged. The figure in-
serted 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 ec-
centric studs. This operates the magnet armature
knockoff bail and forces the magnet armatures away
from the cores (Figure 293).

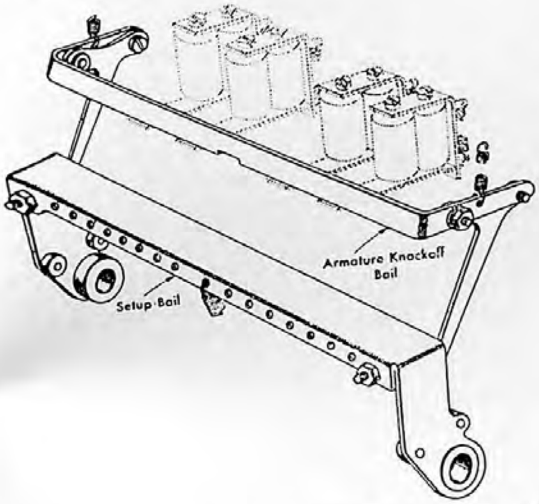


Figure 293. Storage Unit Magnet Armature Knockoff Bail

A knockoff for the restoring magnet armature and
a method of restoring the magnet pawl are also neces-
sary. 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 mag-
net pawl to fully restore it. Each cam is used for both
the upper and lower section. Refer to Figure 294 for
linkage.

Magnetic Drum Storage

Another device offering good possibilities for rapid
storage and transfer of numbers in electronic calcu-
lators is the electromagnet. Use is made of that fact
that a magnetic material can be magnetized and de-

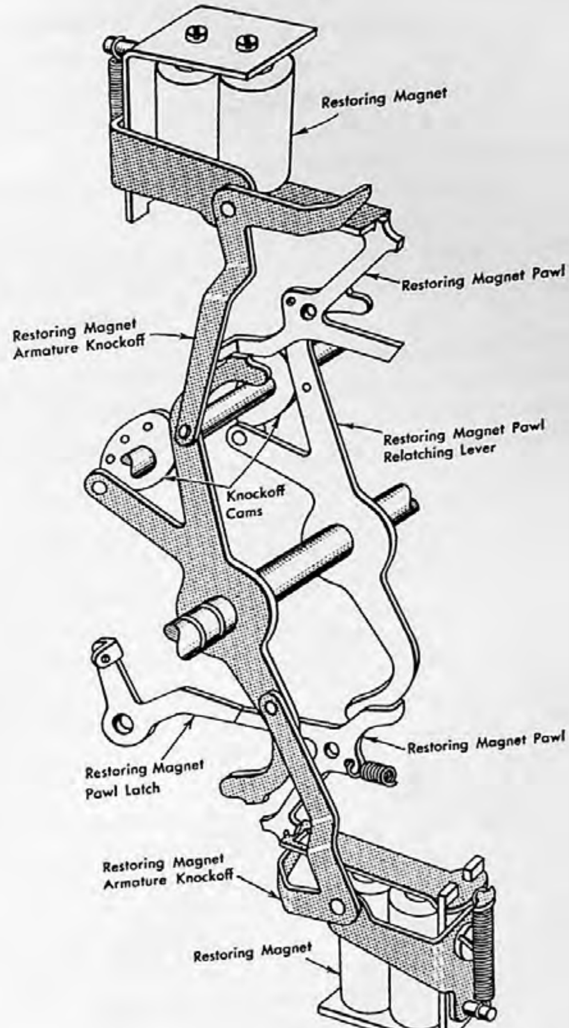


Figure 294. Storage Unit Restoring Magnet Armature

magnetized quickly. Once the material has been mag-
netized, 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 re-
tains 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,

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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.

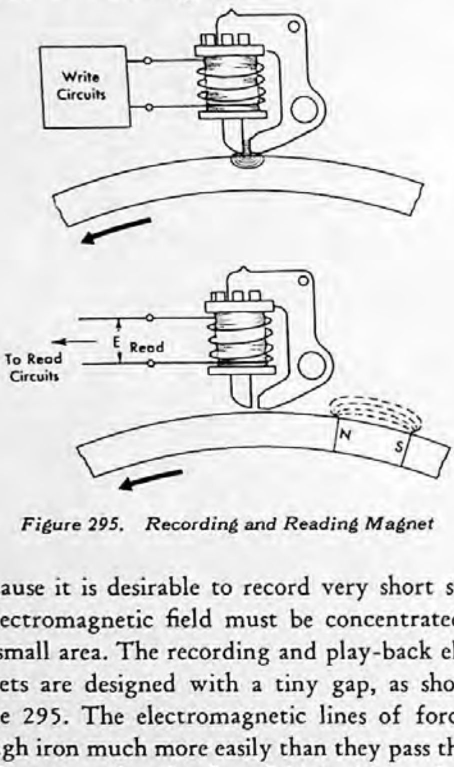

Figure 295. Recording and Reading Magnet

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

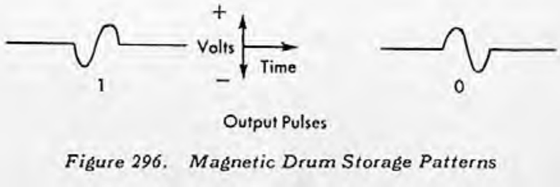

Figure 296. Magnetic Drum Storage Patterns

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.

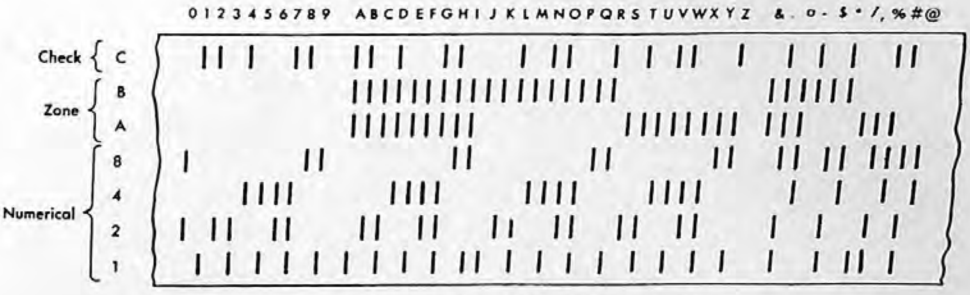

Figure 297. Character Coding on Magnetic Tape

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-

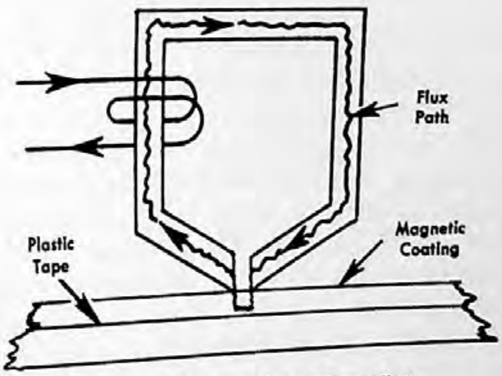

Figure 298. Principle of Recording

cle is additive. The spot on the magnetic tape will be ngthened because the tape is moving under the head t 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

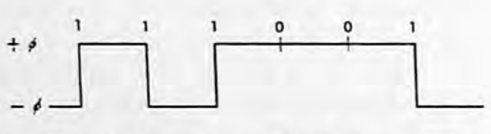

Figure 299. Relation between Flux Pattern and Binary Information

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.

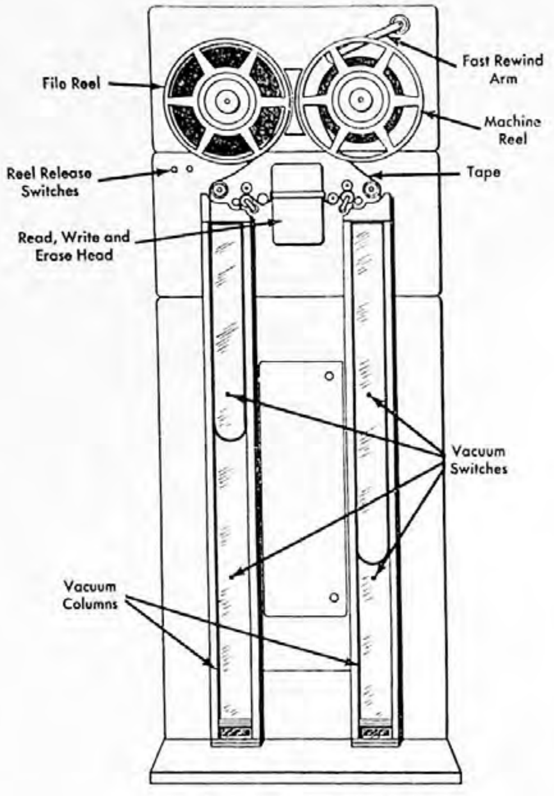

Figure 300. Tape Unit

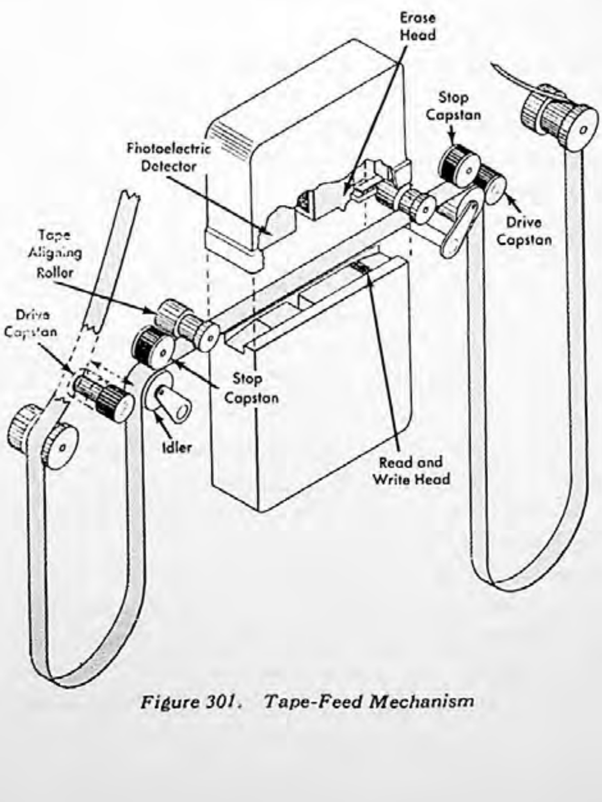

Figure 301. Tape-Feed Mechanism

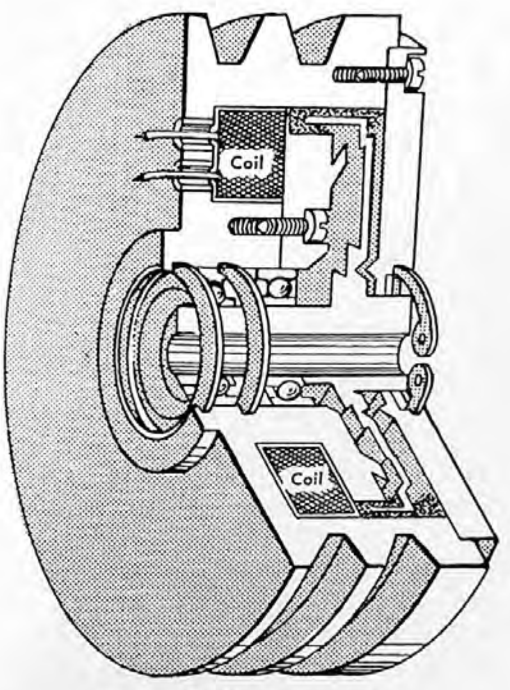

Figure 302. Magnetic Clutch

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

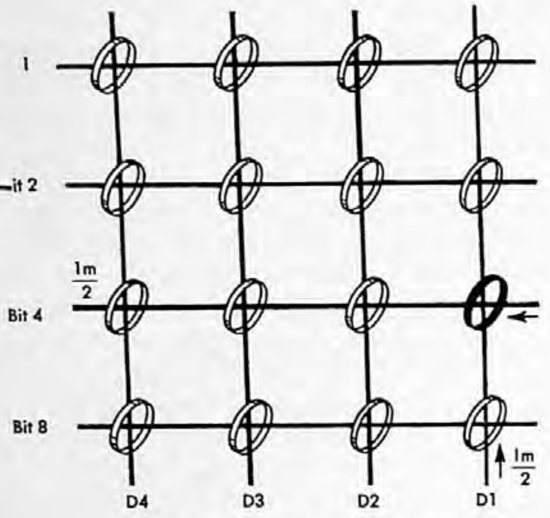

Figure 303. Typical Array of Cores

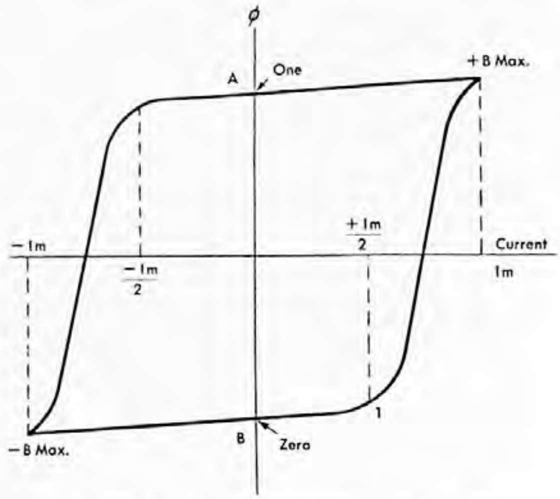

Figure 304. Hysteresis Loop of a Ferrite Core

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 wil appear on the sense wire. This output pulse is in th order of 60-80 millivolts and consequently must b amplified before it can be used in any type of ma chine circuit.

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

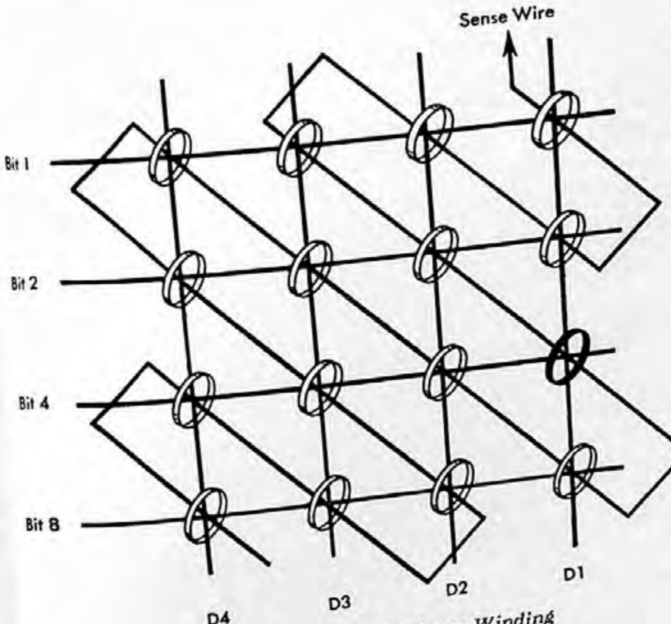

Figure 305. Core Matrix with Sense Winding

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.

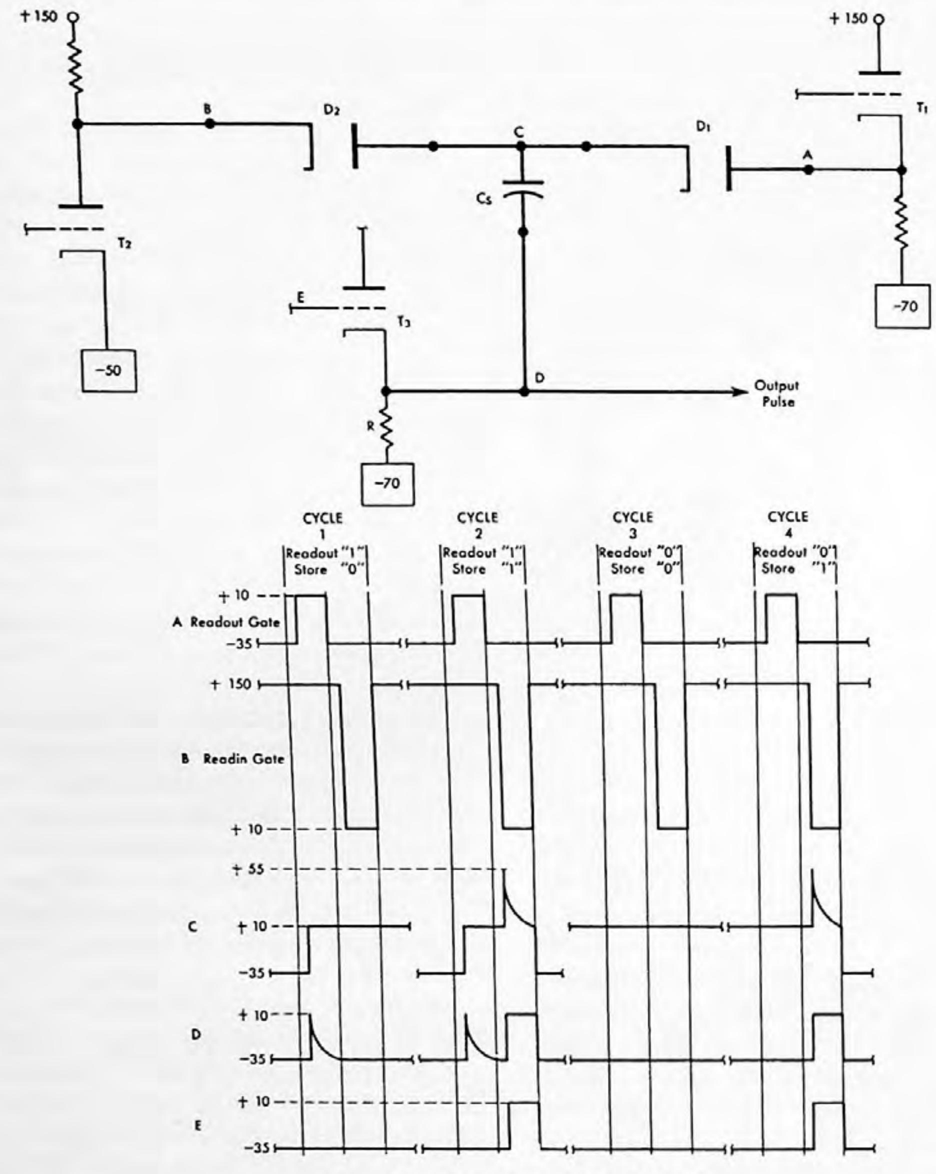

Figure 306. Basic Capacitor Storage Cell

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. Thi is done by taking the output pulse that is obtaine when a one is regenerated and allowing it to actuat the RI control circuits to provide a pedestal puls When a zero is regenerated, no output is availab and so no pedestal is available.

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

CALCULATING MECHANISMS

CALCULATING is the computing of a result by multiplication, division, addition or subtraction. IBM calcultors all use counters of some type to accumulate the results. As stated in an earlier section, a counter is actually only capable of adding; subtraction is actually accomplished by adding complements. Multiplication and division must also be accomplished by adding.

TYPE 602A CALCULATING PUNCH METHOD OF CALCULATION

Arithmetic Principles of Multiplication

A review of the principles and theory of mental multiplication at this time will establish a foundation upon which the explanation of the machine method can be based.

Multiplication is normally a process of multiplying one digit by another. For example, assume the following multiplication is to be done manually:

$$\begin{array}{r} 9\ 5\ 2 \\ \times\ 7 \\ \hline 6\ 6\ 6\ 4 \end{array}$$

The multiplication is actually accomplished by multiplying 7 times 2, 7 x 50, and 7 x 900, and adding the results. The addition of the results is accomplished after each multiplication step. This is done by a process of left and right-hand components. As a result of the multiplication of 7 x 2 the result has two components. The right-hand component is a 4 and the left-hand component is a one. The right-hand component is written down and the left-hand component is remembered or jotted down to be added to the right-hand component of the next digit. This procedure is repeated until multiplication is completed.

The addition of the left and right-hand components need not take place until after the multiplication is complete. The left-hand component of the first digit is always in the tens position, or in other words, offset one position. Similarly all left-hand components are offset one position to the left. We can, therefore, place a zero in the units position of the left-hand components. The same problem which was worked by the normal manual method above, is worked below by adding left and right-hand components after multiplication is completed.

This method is adaptable to machine operation and is used in the Type 601 and 602 Calculating Punches. The left-hand components are directed to a counter and the right-hand components are directed to another counter. On the next cycle, the right-hand components are transferred to the left-hand components counter. Thus the product is accumulated in the left-hand components counter.

The 602A uses a modification of the left and right-hand components method explained above. A saving of time, which is very desirable, would result if the left and right-hand components could both be placed in the same counter during the same cycle. A study of previous sections shows that a counter is capable of accumulating a nine during any one cycle. Therefore, if the right and left-hand components total nine, it is conceivable that they could both be entered into the same counter during one cycle.

The table shown in Figure 307 is a multiplication table showing all possible combinations. It is possible that, for any digit used as a multiplier, the largest right-hand component will be added to the largest left-hand component. From the table the highest components for any multiplier can be determined quickly. The chart shows that 1, 2, and 5 are the only multipliers whose maximum left and right-hand components do not total more than nine.

Multiplicand \ Multiplier	1	2	3	4	5	6	7	8	9
1	1	2	3	4	5	6	7	8	9
2	2	4	6	8	10	12	14	16	18
3	3	6	9	12	15	18	21	24	27
4	4	8	12	16	20	24	28	32	36
5	5	10	15	20	25	30	35	40	45
6	6	12	18	24	30	36	42	48	54
7	7	14	21	28	35	42	49	56	63
8	8	16	24	32	40	48	56	64	72
9	9	18	27	36	45	54	63	72	81

Figure 307. Multiplication Table

The following is an example of multiplication entering both left and right-hand components during a single cycle:

```
  7 4 5   multiplicand
    × 5   multiplier
  -----
  5 0 5   RH comp.
3 2 2     LH comp.
-------
3 7 2 5   product
```

All multipliers must be broken down into combinations of 1, 2, and 5 if the above method is used. For example, if the multiplier is 7, the multiplicand will be multiplied by 5 and by 2 and the products totalled. The result will be the same as if the multiplicand had been multiplied by 7 originally. Algebra takes advantage of this fact as shown by the examples below:

$$5x + 2x = 7x$$

In this case, x is the multiplicand and the multipliers are 2, 5, and 7. This can be proven by substituting a value for x. Assume that x = 6; then substituting in the equation it becomes:

$$5(6) + 2(6) = 7(6)$$
$$30 + 12 = 42$$

Formation of a Multiplier

The information given is now sufficient to determine how a multiplier will be formed. The table in Figure 308 shows the combination used by the machine to form the actual multiplier digit. Note that in addition to a X1, X2, and X5, the machine also uses a X10. The X10 is merely a X1 with a shift of one position. The formation of the machine multiplier for a 4 and a 9 follows the rules established above if it is in the units position. However, if a 4 or 9 is encountered in any other position of the multiplier, the machine multiplier deviates from the standard. This is done to save machine cycles and time.

Assume a multiplier of 54352. The first multiply cycle is a X + 5 operation with a shift of 4 (50000) and is determined by the 5 in the high order, or fifth position. The next multiplier is determined by the 4 in the fourth position. The machine will select a 5 as the multiplier digit with a shift of 3 (5000). However, since the 4 is not in the units position, the X-1 multiplier which would be expected at this time to correct the multiplier to a 4 is not selected. Instead, the machine tests the next, or third position for the next multiplier digit. However, the multiplier developed up to this point is 55000 which is greater by one, in the fourth position, than the actual multiplier. To correct the multiplier, the complement of the remaining digits is subtracted. The remaining digits are 352 and their complements are 648. If 648 is subtracted from 55000, the result is 54352 which is the correct multiplier. Therefore, when the third position is tested, it is read as a 6 and the product subtracted to correct the partial product.

A general rule governing the selection of multipliers for 4's and 9's not in the units position is as follows: When a multiplier of 4 is encountered, multiply by 5 and for all remaining positions multiply by the complement and reverse the sign (+ or −); when a multiplier of 9 is encountered, multiply by 10 and for all remaining positions multiply by the complement and reverse the sign.

The complete multiplier for the number assumed (54352) is formed in Figure 309. The first multiplier encountered is a +5 with a shift of 4 or +50000.

Actual Multiplier	Machine Multiplier
1	Times 1 (written X + 1)
2	X + 2
3	X + 5, X − 2
4	X + 5, X − 1 In the units position. X + 5 in all other positions
5	X + 5
6	X + 5, X + 1
7	X + 5, X + 2
8	X + 10, X − 2
9	X + 10, X − 1 In the units position. X + 10 in all others

Figure 308. Machine Multiplier Selection Table

```
     64
 54 ⌐ 35 ⌐2

1st Multiplier  + 50000
2nd     "       +  5000
3rd     "       −   500
4th     "       −   100
5th     "       −    50
6th     "       +     2
                -------
                  54352 Total Multiplier
```

Figure 309. Multiplier Formation

The second multiplier is a 4 which will be a machine multiplier of +5 with a shift of 3 because it is not in the units position. However, the machine recognizes the 4 and for each multiplier henceforth; until it encounters another 4 or a 9, it will operate on a complement basis and reverse the sign. The next multiplier is a 3 but will be recognized as a 6 which is the 9's complement of 3. Also instead of adding it will subtract the product because the sign was changed from plus to minus. The machine multipliers for a 6 in this case are a X-5 and X-1. The next multiplier is a 5 but it appears as a 4. As a result it is treated as a − 5 with a shift of one (− 50). However, this will again reverse the sign and return the multipliers to true figures. Therefore the next multiplier is a +2 with no shift.

$$69\overline{)32}\quad 68$$

1st	Multiplier	+ 5000
2nd	"	+ 1000
3rd	"	+ 1000
4th	"	− 50
5th	"	− 10
6th	"	− 10
7th	"	+ 2
		6932 Total

Figure 310. Multiplier Formation

Figure 310 shows the formation of another multiplier. The difference between the formation of this multiplier and the one previously explained is that the sign is not reversed a second time and complement figures are used throughout the remaining multipliers. Note that the complement of the units position multiplier is based on 10 instead of 9.

COUNTER OPERATION DURING MULTIPLICATION

X1 Operation

A X1 operation is the same as straight accumulation, and will be considered first. The ratchet type counter is a complements counter, as pointed out in the section on counters. Figure 311 is a counter chart showing the counter operation for a multiplicand of 5902 and a multiplier of 1. There are no left-hand components and the highest right-hand component possible is a 9. Therefore, since the counter is capable of accumulating a maximum of 9, it becomes the same operation as straight accumulation. On a plus operation, all positions are started at 9 time by a bot 9 impulse. To enter a component, an impulse is

MC					5	9	0	2
MP							+	1
RHC	0	0	0	0	5	9	0	2
LHC	0	0	0	0	0	0	0	0
9	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)
8	0	0	0	0	0	9	0	0
7	1	1	1	1	1	9	1	1
6	2	2	2	2	2	9	2	2
5	3	3	3	3	3	9	3	3
4	4	4	4	4	3	9	4	4
3	5	5	5	5	3	9	5	5
2	6	6	6	6	3	9	6	6
1	7	7	7	7	3	9	7	6
0	8	8	8	8	3	9	8	6
11	c 8	c 8	c 8	c 8	c 3	9	c 8	c 6
12	(8)	(8)	(8)	(8)	(3)	(9)	(8)	(6)
13	9	9	9	9	4	0	9	7
14								
15								
16								

Figure 311. Counter Operation for an X + 1 Multiplier

directed to the stop magnet at the digit time corresponding to the digit to be entered. If a digit impulse is not received, the counter will be stopped at zero time by an impulse which is directed to all positions. Carry is affected in the normal manner through the 9-10 brush at 12-time but the counter is stopped by an electrical impulse to all stop magnets at 13-time.

Figure 312 shows the same problem with a X-1 multiplier. Note that it is precisely the same as a plus operation of a Type 402 counter.

X2 Operation

A X2 operation requires that the cycle be divided into two parts: one for the entry of the right-hand components; another for the entry of the left-hand components. It must be divided so that an 8 can be entered as a right-hand component. Since a counter turns through one cycle point for each digit added, the start and stop impulses must be arranged so that the counter may rotate for 8 cycle points during one portion of the cycle. This is done by arranging the internal automatic start and stop impulses 8 cycle points apart. Figure 313 shows the automatic start and stop shots for a plus operation and the time they occur. This figure assumes no right-hand components and there are, therefore, no impulses to the stop mag-

MC					5	9	0	2
MP							—	1
RHC	0	0	0	0	5	9	0	2
LHC	0	0	0	0	0	0	0	0
9	9	9	9	9	9	9	9	9
8	9	9	9	9	9	0	9	9
7	9	9	9	9	9	1	9	9
6	9	9	9	9	9	2	9	9
5	9	9	9	9	9	3	9	9
4	9	9	9	9	0	4	9	9
3	9	9	9	9	1	5	9	9
2	9	9	9	9	2	6	9	9
1	9	9	9	9	3	7	9	0
0	9	9	9	9	4	8	9	1
11	9	9	9	9	¢4	¢8	9	¢1
12	9	9	9	9	4	8	9	1
13	0	0	0	0	5	9	0	2
14								
15								
16								

Figure 312. Counter Operation for an X −1 Multiplier

nets until 1 time. The counter wheels turned through 8 cycle points, so it is possible to add or subtract an 8. The counters contain a 7 when stopped at 1 time.

MC								
MP								
RHC								
LHC								
9	9	9	9	9	9	9	9	9
8	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1
6	2	2	2	2	2	2	2	2
5	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
3	5	5	5	5	5	5	5	5
2	6	6	6	6	6	6	6	6
1	7	7	7	7	7	7	7	7
0	7	7	7	7	7	7	7	7
11	¢8	¢8	¢8	¢8	¢8	¢8	¢8	¢8
12	8	8	8	8	8	8	8	8
13	9	9	9	9	9	9	9	9
14								
15								
16								

Figure 313. Counter Charts of Automatic Impulses for an X 2 Multiplier

MC						6	5	4
MP							+	2
RHC	0	0	0	0	0	2	0	8
LHC	0	0	0	0	1	1	0	0
9	9	9	9	9	9	9	9	9
8	0	0	0	0	0	0	0	9
7	1	1	1	1	1	1	1	9
6	2	2	2	2	2	2	2	9
5	3	3	3	3	3	3	3	9
4	4	4	4	4	4	4	4	9
3	5	5	5	5	5	5	5	9
2	6	6	6	6	6	5	6	9
1	7	7	7	7	7	5	7	9
0	7	7	7	7	7	5	7	9
11	¢8	¢8	¢8	¢8	¢7	¢5	¢8	¢0
12	8	8	8	8	7	5	8	0
13	9	9	9	9	8	6	9	1
14								
15								
16								

Figure 314. Counter Operation for an X + 2 Multiplier

The counters are started again at zero time for the purpose of entering left-hand components. The stop magnets will all receive an impulse to stop at 11 time since a one is the highest left-hand component possible on an X2 operation.

All counters will carry in the example shown because all counters went from 9 to 0, and as a result all will contain 9's to indicate nothing has been accumulated.

Figures 314 and 315 show an X +2 and an X−2 operation. A counter wheel is either caused to rotate a given number of cycle points or remain stationary a given number of cycle points to accumulate a given digit. To accumulate during a plus operation, it is necessary to *prevent* the counter from rotating.

Figure 314 shows the counter operation for a multiplier of +2 and a multiplicand of 654. The units position has a right-hand component of 8 to be placed in it. The stop magnet must be impulsed at 9 time so that the counter wheel does not turn at all. This is necessary because the counter must be *prevented* from turning during 8 cycle points and there are only 8 cycle points between 9 time and 1 time. Previously the impulses have been available at the time corresponding to the digit accumulated. However, this is not true in this type of multiplication process. The circuit network supplies the impulse to the stop magnet the desired number of cycle points before the internal stop impulses.

Figure 314 also shows the right-hand component of 2 being entered. Note that the impulse is available 2 cycle points before 1 time. If a 4 and a 6 are to be entered as right-hand components, the impulses will be directed to their stop magnets 4 and 6 cycle points before the stop impulses.

The above figure shows that in positions which have a left-hand component of 1 to be accumulated, the start and stop magnets are impulsed simultaneously to prevent the counters from turning.

The carry takes place in the usual manner and the counter value of the amount accumulated in the counter is 998691. This is the complement of 001308 which is the correct product.

Figure 315 shows the counter operation for the same problem with a minus sign. In a minus operation it is necessary to cause the counter wheel to *turn* the desired number of cycle points. The amount is accumulated as a true figure on a minus operation.

X5 Operation

The cycle is divided into two parts for an X5 operation as on an X2 operation, for the entry of left and right-hand components. However, the division is made at a different point in the cycle to accommodate different maximum components. The largest right-hand component is a 5 while the largest left-hand component is a 4.

The cycle is divided to provide 5 cycle points in the first half to accumulate a right-hand component of 5. Four cycle points are used in the second half of the cycle to provide the cycle points necessary to accumulate a 4.

Figures 316 and 317 show the counter operation of an X +5 and an X −5 with a multiplicand of 947.

The control circuits and multiplying network circuits will not be studied at this time, but will be studied with the machine in which they are used.

Arithmetic Principles of Division

The objective of a division operation is to find the quotient of a dividend and a divisor. The quotient is

MC						6	5	4
MP							—	2
RHC	0	0	0	0	0	2	0	8
LHC	0	0	0	0	1	1	0	0
9	9	9	9	9	9	9	9	9
8	9	9	9	9	9	9	9	0
7	9	9	9	9	9	9	9	1
6	9	9	9	9	9	9	9	2
5	9	9	9	9	9	9	9	3
4	9	9	9	9	9	9	9	4
3	9	9	9	9	9	9	9	5
2	9	9	9	9	9	0	9	6
1	9	9	9	9	9	1	9	7
0	9	9	9	9	9	1	9	7
11	9	9	9	9	t0	t2	9	t7
12	9	9	9	9	0	2	9	7
13	0	0	0	0	1	3	0	8
14								
15								
16								

Figure 315. Counter Operation for an X − 2 Multiplier

MC						9	4	7
MP							+	5
RHC	0	0	0	0	0	5	0	5
LHC	0	0	0	0	4	2	3	0
9	9	9	9	9	9	9	9	9
8	0	0	0	0	0	9	0	9
7	1	1	1	1	1	9	1	9
6	2	2	2	2	2	9	2	9
5	3	3	3	3	3	9	3	9
4	4	4	4	4	4	9	4	9
3	4	4	4	4	4	9	4	9
2	5	5	5	5	4	0	5	0
1	6	6	6	6	4	1	5	1
0	7	7	7	7	4	1	5	2
11	t8	t8	t8	t8	t4	t1	t5	t3
12	8	8	8	8	4	1	5	3
13	9	9	9	9	5	2	6	4
14								
15								
16								

Figure 316. Counter Operation for an X + 5 Multiplier

MC						9	4	7
MP							—	5
RHC	0	0	0	0	0	5	0	5
LHC	0	0	0	0	4	2	3	0
9	9	9	9	9	9	9	9	9
8	9	9	9	9	9	0	9	0
7	9	9	9	9	9	1	9	1
6	9	9	9	9	9	2	9	2
5	9	9	9	9	9	3	9	3
4	9	9	9	9	9	4	9	4
3	9	9	9	9	9	4	9	4
2	9	9	9	9	0	4	9	4
1	9	9	9	9	1	4	0	4
0	9	9	9	9	2	5	1	4
11	9	9	9	9	3	6	2	4
12	9	9	9	9	3	6	2	4
13	0	0	0	0	4	7	3	5
14								
15								
16								

Figure 317. Counter Operation for an X – 5 Multiplier

the largest quantity by which the divisor can be multiplied to produce a product which is not greater than the dividend.

It is difficult to multiply mentally by factors which are larger than 10 and it is usually done by decimal steps. The process is actually one of selecting various multipliers, using them to multiply the divisor, and then reducing the dividend by the amount of the product. This process is continued until the dividend has been reduced to zero or left with a remainder less than the divisor. Figure 318 is an example of manual long division.

The machine accomplishes division in a manner very similar to manual long division. The divisor is compared to the dividend and a multiplier is selected.

```
                2342 Quotient
Divisor 295 ) 691054 Dividend
             -590
              1010
              -885
               1255
              -1180
                 754
                -590
                 164 Remainder
```

Figure 318. Example of Manual Long Division

The divisor is then multiplied by the multiplier selected and the product subtracted from the dividend counter. The divisor is then compared to the remainder in the dividend counter to select another multiplier or quotient digit. This operation is repeated until the remainder is zero or less than the divisor.

One basic difference between the machine operation and the manual operation is the selection of a multiplier. In a manual operation as many of the divisor digits as practical on the high order end are compared to the dividend to be sure that the remainder does not go negative. If the multiplier selected is too large it is erased and another one selected. However, the machine is limited to the quotient digits which can be selected because each is to be a multiplier of the divisor, and the machine is only capable of multiplying by 1, 2, or 5. Therefore, the quotient selected will often be too large, causing the remainder to go negative. However, the circuits are so arranged that computations are carried on just as well with a negative remainder as with a positive one. The sign of the quotient is changed and the product added rather than subtracted.

A quotient is selected by comparing only the high order digit of the divisor to the high order digit of the existing dividend. The circuit network for quotient selection is designed to select quotients according to the table in Figure 319. The table is arbitrarily arranged to provide the fewest number of cycles to calculate a quotient.

Divisor High Order Digit	Dividend High Order Digit 1	2	3	4	5	6	7	8	9
1	1	2	2	2	5	5	5	5	5
2	.5	1	1	2	2	2	2	2	5
3	.5	.5	1	1	2	2	2	2	2
4	.2	.5	1	1	1	1	2	2	2
5	.2	.5	.5	1	1	1	1	2	2
6	.2	.5	.5	.5	1	1	1	1	1
7	.2	.2	.5	.5	.5	1	1	1	1
8	.2	.2	.5	.5	.5	1	1	1	1
9	.2	.2	.5	.5	.5	.5	1	1	1

Figure 319. Quotient Selection Table

Figure 320 shows the machine method of division. The divisor is placed in a storage unit because it does not change; the dividend is placed in a counter because it must be reduced. As a result of the first test for a quotient, a two is selected (see chart in Figure 319). The two is then used as a multiplier to multiply the divisor and has a shift of four. The product is then subtracted from the dividend leaving, in this case, a dividend of 298490, and its sign is still plus. The high order position of the new dividend or remainder is now compared to the high order position of the divisor to select the next quotient. A quotient of one is selected. When the machine recognized that the original high order position had been reduced to zero, it stepped down to test the next position and also reduced the multiplier shift to three. The dividend is now reduced by the product of the new quotient factor and the divisor. As a result, the high order position and the next high order position are both reduced to zero. The machine recognizes this and steps down two positions to test the one and also reduces the multiplier shift to a shift of one. The quotient factor selected is five-tenths (.5), and it has a shift of one. The fact that it is a tenths factor is the same as a right shift of 1 and the resultant is a quotient factor of 5 with no shift.

```
          shift of four          Formation of
divisor     20000                    the
297 | 6238490 dividend             Quotient
     - 594                         + 20000
      298490                       +  1000
      297000                           + 5
      001490                        21005
        1485
        0005 remainder
```

Figure 320. Formation of a Quotient — Machine Method

The dividend is reduced, as a result of the 5 multiplier, to a remainder of 5. The machine recognizes that this is less than the divisor and is still positive and it ends the divide operation.

Figure 321 is another example of machine division. However, in the case shown the dividend goes negative on three occasions, which causes the product to be *added* to the dividend and the quotient factor *subtracted*. Note also that until the high order factor is reduced to zero, there is *no change* in *shift*.

```
                        Quotient
                        Formation
297 | 7958690           + 20000
     - 5940000          + 10000
     + 2018690          -  5000
     - 2970000          +  2000
     - 0951310          -   200
     + 1485000          -     5
     +  533690          +     2
     -  594000          -     1
     -  060310
     +   59400          + 20000   - 5000
     -  000910          + 10000   -  200
     +    1485          +  2000   -    5
     +     575              + 2   -    1
     -     594          + 32002   - 5206
     -     019          -  5206
     +     297           26796 Quotient
     +     278
```

Figure 321. Quotient Formation

604 ELECTRONIC CALCULATOR METHOD OF CALCULATION

THE ARITHMETIC PRINCIPLES used in the Electronic Calculator are much simpler than those of the Calculating Punch. This is possible because of its tremendous speed, which is due to a lack of mechanical devices. The Type 604 uses an electronic counter of the type studied in Accumulating Mechanisms. The electronic counter consists of a group of triggers which operate on a modified binary system. These counters accumulate as a result of a series of pulses and each pulse increases the amount in the counter by one. The normal operating frequency of the pulses in the Type 604 Electronic Calculator is 50kc. Therefore, each pulse requires .00002 seconds, or 20 micro-seconds. There are 25 pulses in an electronic cycle which compare to the 360° found in electro-mechanical machines. An add cycle then would require 25 pulses, .0005 seconds, or 500 micro-seconds.

Electronic Calculator Method of Multiplication

The components method of calculation used in other machines is used as a time saving device, but, as stated above, the speed of calculation of the electronic counter makes it unnecessary in the Electronic Calculator. The method used in the electronic system is much more straightforward and simple. If 125 is to be multiplied by 5 the machine merely adds 125 five times. Basically this calculation would require 5 cycles or .0025 seconds.

A sample multiplication is shown graphically in Figure 322. The multiplicand is placed in a storage unit because it does not change. The multiplier is placed in a special storage unit so that it can send information from any position to a special single position counter. The multiplier storage unit has a capacity of 5 digits. Therefore, it will accommodate a 5 digit multiplier.

In essence the multiplicand storage unit instructs the product counter of the number to be added. The multiplier storage unit, in conjunction with the single position counter, instructs the product counter how many times the multiplicand should be added and the column shift necessary.

All multiplication and division operations automatically begin in a column shift of 5. The high order position of the multiplier is tested to determine how many times the multiplicand is to be added in the counter in CS-5 (column shift of 5). Any digit found in the high order position of the multiplier is placed in the single position counter in 10's complement form. The entry of a digit in the single position counter signals the machine to begin multiplying. In the case shown in Figure 322 when the 5th position is tested, a zero is found and no multiplication takes place. The machine did require a cycle, however, to make the test. The product counter remains at zero. The test cycle finding a zero in the multiplier causes a shift from column shift 5 to column shift 4.

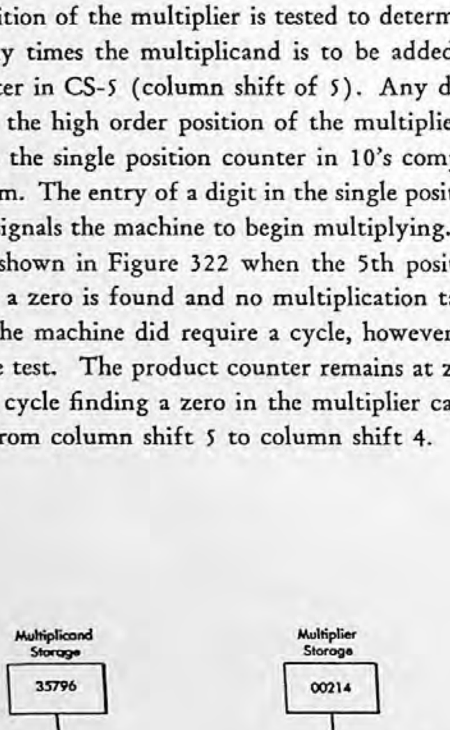

Figure 322. Electronic Method of Multiplication

On the second cycle, the 4th position is tested because a CS-4 is indicated. Again, finding a zero, a step down to CS-3 is provided.

A third cycle results in testing the 3rd position since a CS-3 is now indicated, but this time a 2 is encountered. As a result an 8, which is the 10's complement of 2, is entered into the single position counter. The product counter has not accumulated as yet because all cycles have been test cycles and the partial product is still zero. However, the entry now of a significant digit into the single position counter allows the multiplicand to be accumulated in the product counter in CS-3 during the next cycle. During the next cycle, the multiplicand is added once into the product counter, and a 1 is added in the single position counter. The single position counter now contains a 9 which permits multiplication to continue and a CS-3 is still indicated. On the next cycle, the multiplicand is again added into the product counter in CS-3 and another 1 added to the single position counter. The single position counter now contains a zero. Ordinarily a counter which passes from 9 to 0 causes a carry. However, the impulse resulting in this case instructs the machine to end multiply. It also results in a step down from CS-3 to CS-2. On the next cycle the second position of the multiplier is tested, and a 9 is placed in the single position counter. One cycle of accumulation is made as a result.

This procedure is carried on until the single position counter goes to zero while a CS-1 is indicated. The machine recognizes this as the end of the multiplication and ends the multiply operation.

The entire multiplication operation required 12 cycles. The time required is .0005 x 12 or .006 seconds.

Electronic Calculator Method of Division

A division operation requires that the dividend be reduced to a zero value or have a positive remainder which is less than the divisor. In the electronic calculator, the dividend is placed in the counter and the divisor subtracted from it until it is reduced to meet the requirement of division as stated above. The dividend is placed in the counter in 9's complement form and will remain a complement as long as it remains positive.

The divisor is placed in a storage unit, so that it may instruct the dividend counter of the amount to be subtracted.

The quotient factors are placed in the same special storage unit used to store the multiplier in a multiplication operation. The electronic storage unit used is a series of triggers arranged in a manner similar to the electronic counter, but with no provision for carrying.

The first cycle of division always has a column shift of 5 just as it did in multiplication. The divisor, therefore, is subtracted from the dividend with a shift of 5. If the remainder is still positive, the shift will remain the same and the divisor will again be subtracted from the dividend remainder. However, if the remainder went negative, it indicates that the quotient is too large. The shift will remain the same and the divisor added to the remainder to return it to a positive value. The shift will then step down one position and the divisor subtracted again.

Figure 323 is a chart illustrating the machine operation for a specific division problem. The objective is to divide 1728 by 144. The dividend is placed in the 13 position counter provided and the divisor in a storage unit.

Problem $\frac{1728}{144} = 12$

Cycle		Dividend	Ctr Balance	Quotient
	____	9999999998271	+	00000
		1440000		
1		9999990338271		
	Carry	11111111 1		
	____	0000001438272	−	00000
		9999998559999		
2		9999999987161		
	Carry	1111		
	____	9999999998271	+	00000
		144000		
3		9999999032271		
	Carry	111111111 1		
	____	0000000142272	−	00000
		9999999855999		
4		9999999997161		
	Carry	111		
	____	9999999998271	+	00000
		14400		
5		9999999902671		
		111111111 1		
	____	0000000012672	−	00000
		9999999985599		
6		9999999997161		
		111		
	____	9999999998271	+	00000
		1440		
7		9999999999611		
		1		
	____	9999999999711	+	00000
		1440		
8		9999999990151		
		1111111111 1		
	____	0000000001152	−	00010
		9999999998559		
9		9999999999601		
		11		
	____	9999999999711	+	00010
		144		
10	____	9999999999855	+	00010
		144		
11	____	9999999999999	+	00011
		144		
12		9999999999033		
		1111111111111		
	____	0000000000144	−	00012

Figure 323. Electronic Method of Division

First Cycle. On the first cycle the divisor is subtracted from the dividend in a CS-5. As a result the dividend becomes negative. The machine recognizes that it has subtracted too much and it goes through a correction cycle.

Second Cycle. On the second, or correction cycle, the complement of the divisor is added to the dividend which returns it to its original value.

Third Cycle. The column shift is reduced to a shift of 4 and the divisor is subtracted again. Again the remainder becomes negative and another correction cycle is necessary.

Fourth Cycle. Correction cycle.

Fifth Cycle. The column shift is reduced to a shift of 3 and the divisor subtracted again. Again the remainder goes negative and another correction cycle is necessary.

Sixth Cycle. Correction cycle.

Seventh Cycle. The CS is reduced to a shift of two and the divisor subtracted from the dividend again. On this cycle the dividend remainder stayed a plus value which indicates a valid quotient factor. This permits an entry of 1 in the CS-2 position of the quotient storage unit. However, the entry will take place on the following cycle.

Eighth Cycle. The CS remains the same and the divisor is again subtracted from the dividend remainder. This time the remainder goes negative again indicating the divisor is too large to go into the remainder again. Another correction cycle is required.

Ninth Cycle. Correction cycle.

Tenth Cycle. The shift is reduced to a CS-1 and the divisor subtracted from the remainder. The remainder is still positive after the reduction which indicates a valid quotient factor, which is entered on the next cycle.

Eleventh Cycle. The shift remains the same and the divisor is subtracted from the remainder again. After the reduction, the remainder is still positive which again indicates a valid quotient factor. The one factor from the previous cycle is entered in the units position. Observation of the remainder shows that the dividend counter contains all 9's which is a zero remainder. However, the machine does not recognize this and it makes another attempt to reduce the dividend remainder.

Twelfth Cycle. The subtraction of the divisor again causes the remainder to go negative. Another 1 is entered into the units position of the quotient storage unit. The machine recognizes that the remainder has gone negative with a CS-1, and as a result it takes a correction cycle and ends division.

Thirteenth Cycle. Correction cycle.

Fourteenth Cycle. Shift out of CS-1 and end division.

This division problem required 14 cycles at .0005 seconds per cycle or .007 seconds for the entire calculation.

ELECTRONIC COMPUTERS

IBM's NEWEST CONTRIBUTIONS to the field of business management are the Electronic Computing Machines. This equipment has developed from IBM's wide experience and practical research in the use of electronics for effective management tools.

The electronic computing machines are powerful tools for management. They are a system of accounting using the latest electronic devices—magnetic tapes, magnetic drums, and electrostatic storage. These machines are designed to meet the needs of management and science for handling large amounts of data or solving complex calculating problems at electronic speed.

Data are introduced into this system from either IBM punched cards or from previously recorded magnetic tapes. Calculations can be performed on this information, and—in one operation—the results can be printed, punched in cards, or recorded on magnetic tapes. Engineers have designed a flexible system to accept a number of input and output devices as necessary for customer applications.

Typical of the electronic computing systems is the Type 702, in which the principal record and file storage medium is the magnetic tape. This tape is a plastic oxide-coated tape similar to that used in tape sound recorders. Information can be stored on this tape in the form of magnetized spots with a density of 200 characters per inch. This information can be recorded or read at a speed of 75 inches per second.

The principal working storage in the machine is electrostatic storage or memory unit. This memory unit uses cathode ray tubes to store up to 10,000 characters in the form of charged spots on the face of the tubes. This memory unit is capable of storing or reading information at the rate of 23/1,000,000 of a second per character. Combined with this rapid reading or storing ability, this type of storage unit also has a highly flexible system for locating any particular characters in storage. This makes possible the rapid selection of any unit record, field, or character from storage to be used by the arithmetic and logical unit of the machine.

It is also possible to include in the system of machines additional storage in the form of magnetic drums. Each drum has a capacity of 60,000 characters, and it is possible to have from one to thirty drum storage units included in the system.

In order to understand the operation of electronic computing machines, it is necessary to first visualize the work they do.

First consider the procedure used in a standard IBM punched-card accounting system. To follow through the complete procedure of running a given report, we must start with the source documents. The first step is transferring the information to punched cards. These cards may be verified, sorted, and possibly merged with other cards. Some type of calculation may be performed, master cards selected, and other cards such as year-to-date cards merged in. At this point the cards are placed in the accounting machine and a complete report is printed along with the preparation of new year-to-date summary cards. Following this, the operator must separate from the deck certain master name cards, etc., to be returned to a file for use next month.

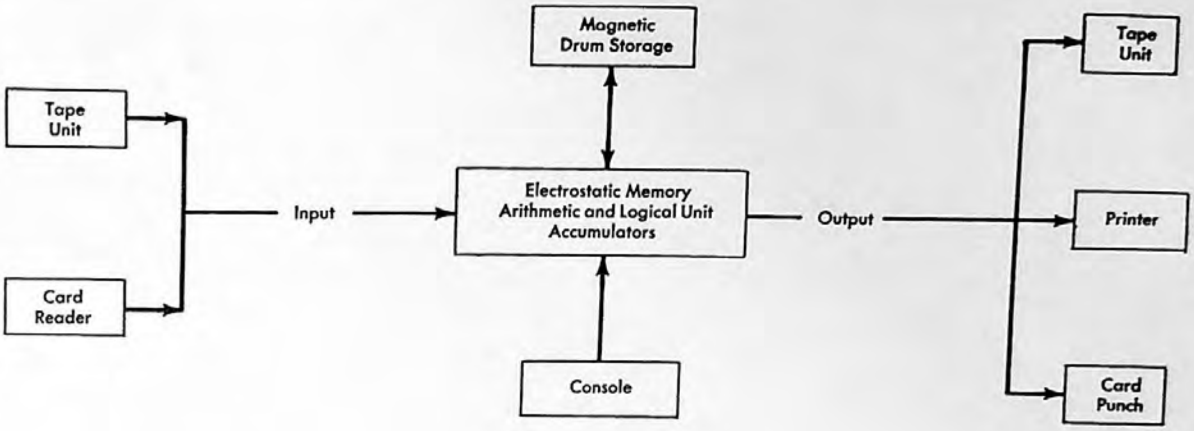

Figure 324. Type 702 Data Flow System

This is a common system that is merely a semi-mechanized system of data processing. In this system the machines did the actual work with the data punched in the card, but it was the duty of the operator to set up each machine properly, and to move the cards from one machine to the other in the proper sequence. If any situation arises requiring special handling, it is the operator who must know what to do in each particular case.

Now look at a similar application that might be applied to an electronic computing machine. It must be remembered that an electronic computing machine is more than just a machine, it is a complete high-speed automatic system for handling vast quantities of data.

The first step in the process is a detailed study of the job to be done. This includes not only the main job but also a study of each and every special case that might arise. From this, a planner will write a program for the machine, telling it, in detail, each little step to be performed. The program tells the machine where to store each piece of data, when to use it, and what operations are to be performed. It must include logical tests to be made and tell the machine what to do as a result of these tests. Once the program is established, the raw data are fed into the machine by an operator, and all other operations are performed by the machine in the proper sequence at electronic speed.

The machine takes in all the data and then can perform all the sorting, merging, calculating, etc., on just the numbers, without having to move cards as was done in the punched card system. The transfer of data from storage to the arithmetic and logical unit and back, and then to the output units is all done by high-speed electronic pulses.

By using this electronic computing system it is possible to process large amounts of data rapidly and without the possibility of human error. The machine cannot forget a portion of the processing or overlook a case that needs special handling.

Figure 324 shows a schematic layout of the Type 702 Data Processing system showing the major units and the paths for data flow between them.

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