SECTION 2

MECHANICAL UNITS

The mechanisms in this book divide roughly into two groups:

a. those which are *purely mechanical,* and

b. those which are partly mechanical and partly electrical—*"electromechanical."*

Section 2 describes the mechanisms which are purely mechanical.

Within this strictly mechanical section the mechanisms divide into two groups:

a. those which do some type of mathematical computation, such as addition, multiplication, or trigonometric—the *computing mechanisms,* and

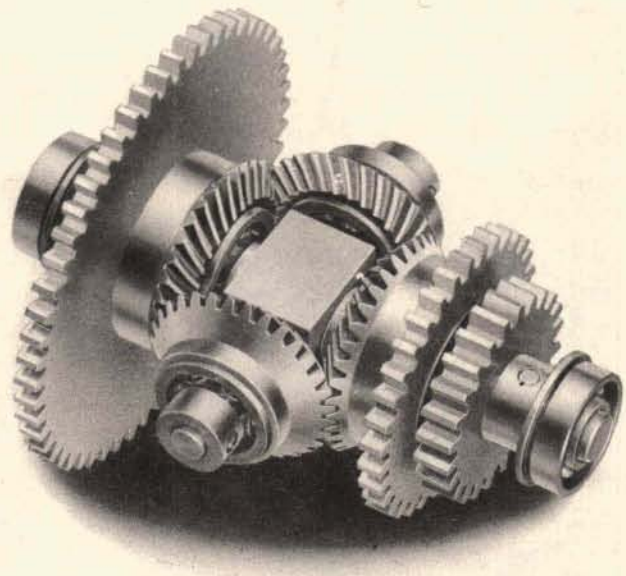
b. those that do not compute, but do other useful things—the *non-computing mechanisms.*

The computing mechanisms are covered first. They are arranged roughly in the order of increasing complexity, beginning with the relatively simple bevel gear differential and concluding with the component integrator. The non-computing mechanisms are grouped together in the concluding chapter of this section.

DIFFERENTIALS

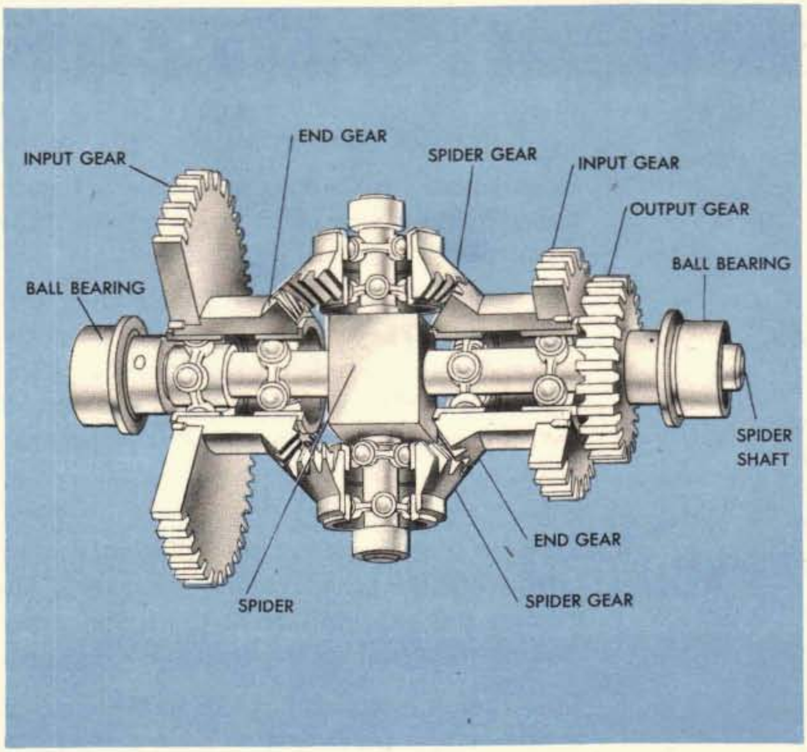
A differential is a mechanism that does addition and subtraction. To put it more precisely, it *adds* the total revolutions of two shafts—or *subtracts* the total revolutions of one shaft from the total revolutions of another shaft—and delivers the answer by positioning a third shaft.

A differential will add or subtract any number of revolutions, or very small fractions of single revolutions, continuously and accurately. It produces a continuous series of answers as the inputs change.



This is the symbol used to indicate the differential in schematic drawings. The cross in the center represents the spider. The arrows pointing inward represents inputs. The arrow pointing outward is the output. There are always two inputs and one output.

NOTE: In the illustrations which follow, the spider of the differential is assumed always to be the output. Actually the spider can be one of the two inputs.



The bevel gear differential

Above is a "cut away" drawing of a bevel gear differential showing all its parts and how they are related to each other. Grouped around the center of the mechanism are four bevel gears, meshed together. These four gears and the spider shaft are the heart of the differential.

The two bevel gears on either side are "end gears." The two bevel gears above and below are called "spider gears." The spider gears are meshed with the end gears.

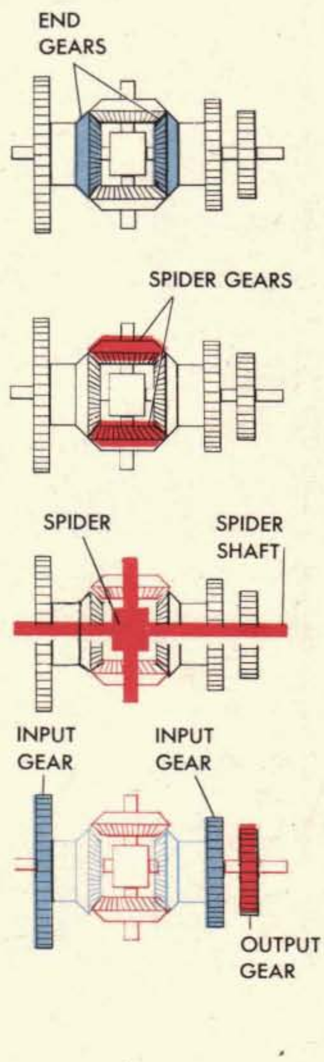
The cross shaft and spider gears taken together are called the "spider" and the long shaft is called the "spider shaft." All four of the bevel gears are free to rotate on precision bearings.

The three spur gears in the illustration are used to connect the two end gears and the spider shaft to other mechanisms. They may be any convenient size.

Each of the two input gears is attached to an end gear. An input gear and an end gear together are called a "side" of the differential.

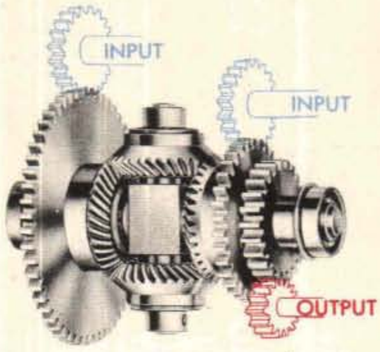
The output gear is pinned to the spider shaft. It is the only gear in the mechanism that is pinned directly to a shaft.

For the present it is assumed that the two sides are the inputs and the gear on the spider shaft is the output. Later it will be shown that any of these three gears can be either an input or an output.



How the SPIDER GEARS

1



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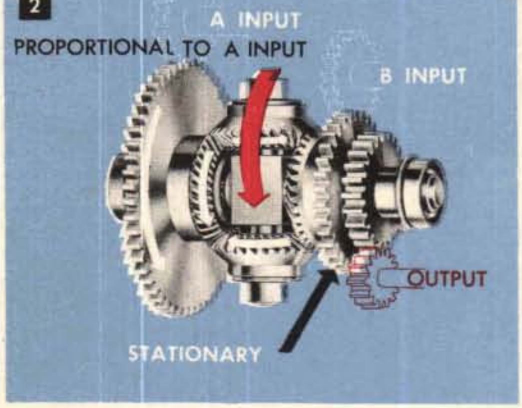

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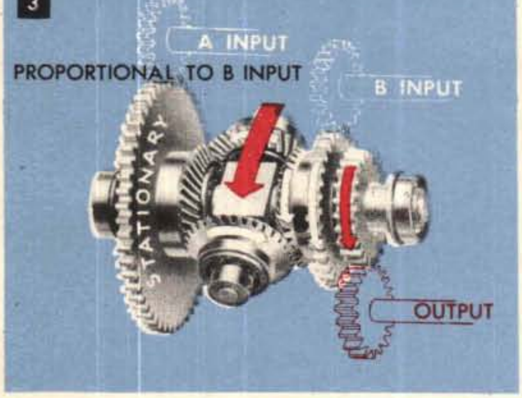

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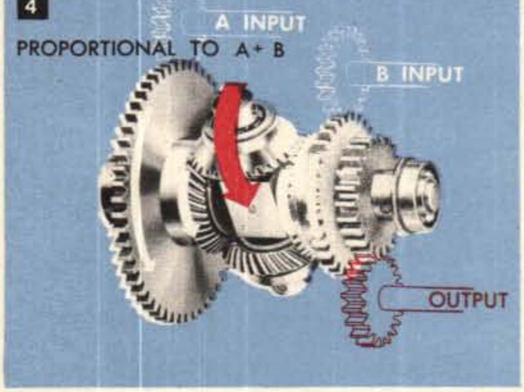


1 In this hook-up the two end gears are positioned by the input shafts, which represent the quantities to be added or subtracted.

The spider gears do the actual adding and subtracting. They follow the rotation of the two end gears, turning the spider shaft a number of revolutions proportional to the sum, or the difference, of the revolutions of the end gears.

2 Suppose the left side of the differential is rotated while the other remains stationary. The moving end gear will drive the spider gears, making them roll on the stationary end gear.

This motion rotates the spider in the same direction as the input and, of course, turns the output shaft with it. The output shaft will turn a number of revolutions proportional to the input.

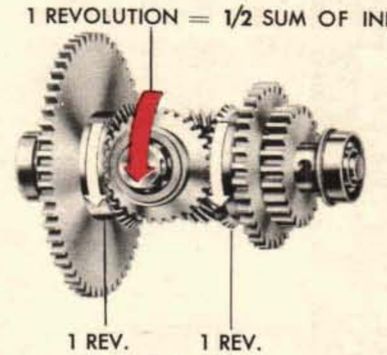
3 If the right side is now rotated and the left side held stationary, exactly the same thing will happen. The spider gears will again turn and roll on the stationary end gear, turning the spider in the direction of the moving side. The output shaft will turn a number of revolutions proportional to the input.

4 From these two examples it is easy to see that if *both* sides of the differential are turned in the same direction AT THE SAME TIME, the spider will be turned by *both at once*.

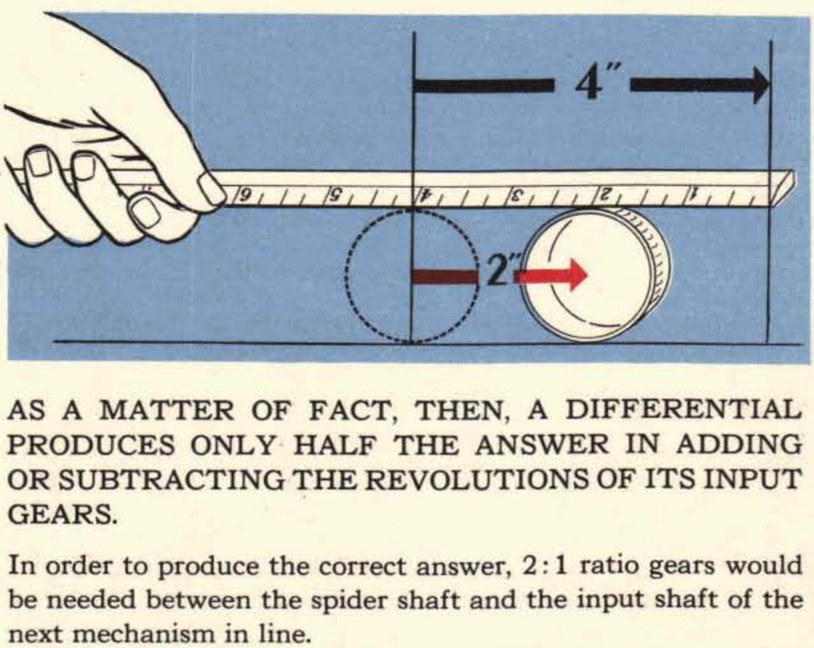
The output will be proportional to the *sum* of the two inputs.

work . . .

But the spider output will not be the whole sum of the two inputs. Actually, the spider makes ONLY HALF as many revolutions as the sum (or the difference) of the revolutions of the end gears. This is because the spider gears are free to *roll* between the end gears.



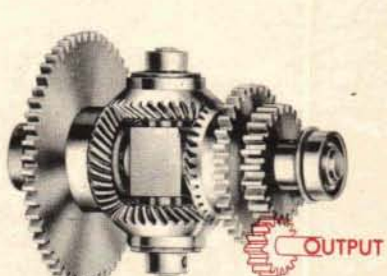
To understand this easily, imagine that a cylindrical drinking glass is being rolled along a table top by pushing a ruler across its upper side. The glass will roll only HALF as far as the ruler travels. The spider gears in the differential roll against the end gears in exactly the same way.



AS A MATTER OF FACT, THEN, A DIFFERENTIAL PRODUCES ONLY HALF THE ANSWER IN ADDING OR SUBTRACTING THE REVOLUTIONS OF ITS INPUT GEARS.

In order to produce the correct answer, 2:1 ratio gears would be needed between the spider shaft and the input shaft of the next mechanism in line.

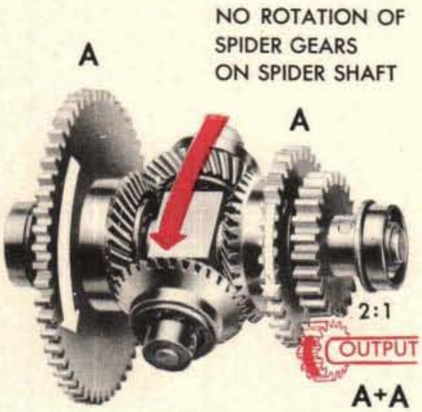
Actually, the 2:1 ratio is seldom found in differential gearing in any computer for reasons of design.



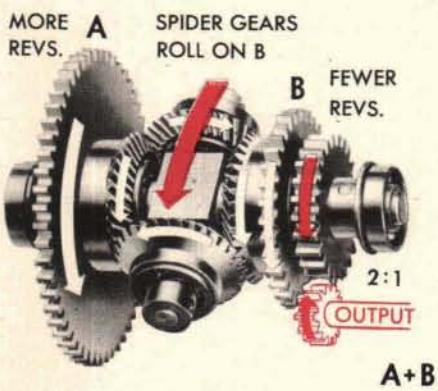
For the sake of clarity, it is assumed here that all differentials have 2:1 gearing and that the final output is complete and correct.

How the differential ADDS

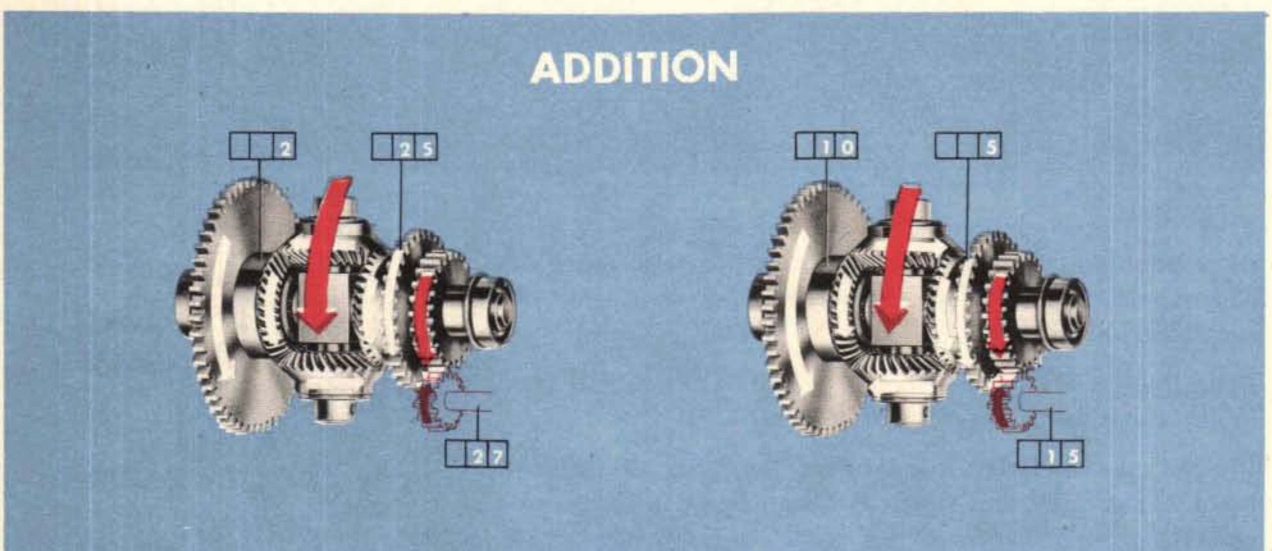
When both inputs of a differential rotate in the same direction, the differential *adds*.



If both sides of the differential turn in the same direction for the same number of revolutions, the spider gears do not rotate on the cross shaft. Instead they maintain a fixed position between the end gears and rotate with them, carrying the spider around to a new position. The rotations of the spider shaft are equal to half the sum of the revolutions of the two inputs.



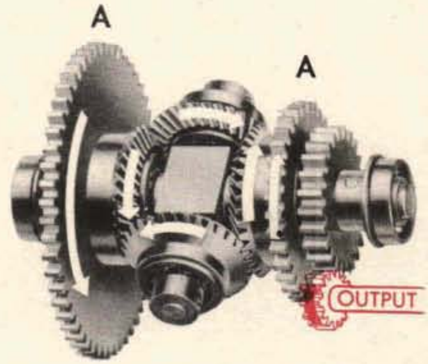
If one side of the differential makes more revolutions than the other, the spider gears will be carried around by both end gears. At the same time, the spider gears will roll on the end gear that is making the lesser number of revolutions. The spider shaft will be so positioned that it makes half the sum of the revolutions of the two inputs.



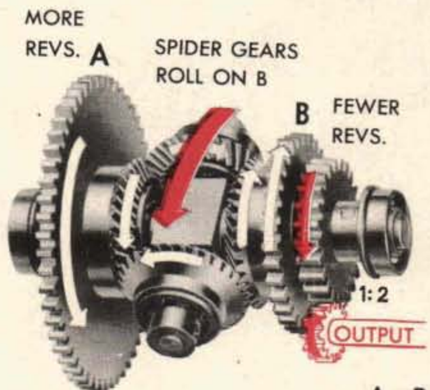
and SUBTRACTS

When the two inputs of a differential rotate in *opposite* directions, the differential *subtracts.*

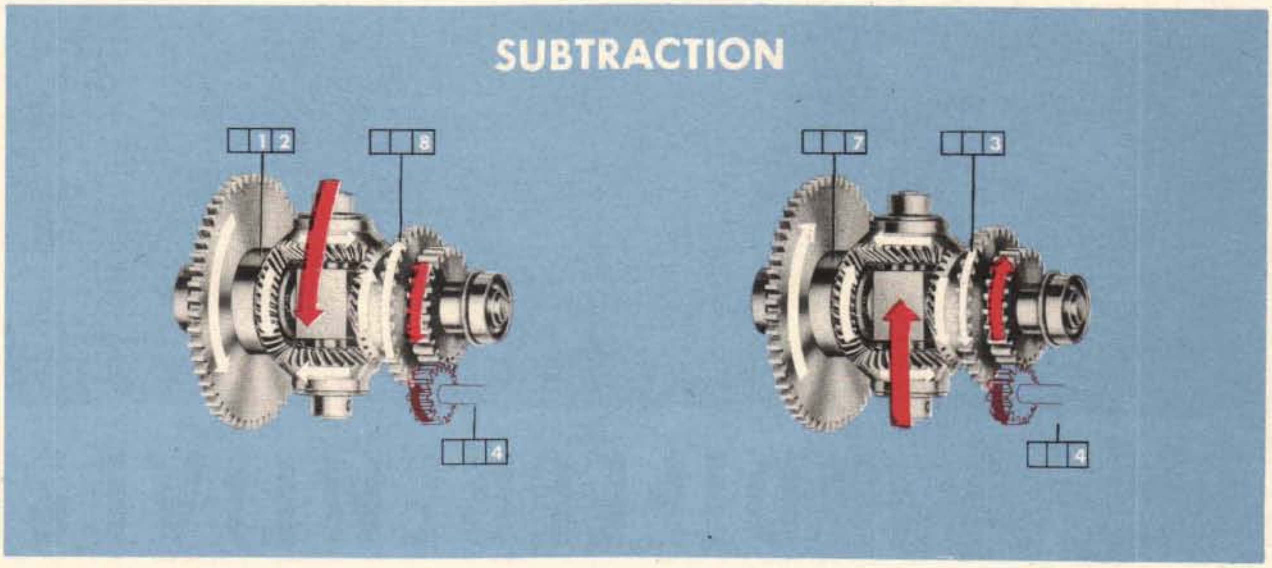
If the two inputs turn in opposite directions for the same number of revolutions, the spider gears roll between the end gears without moving the spider at all. The output is zero. If the two inputs turn in opposite directions for an unequal number of revolutions, the spider gears roll on the end gear that makes the lesser number of revolutions, rotating the spider in the direction of the input making the greater number of revolutions. The motion of the spider shaft is equal to half the *difference* between the revolutions of the two inputs.



A–A = O



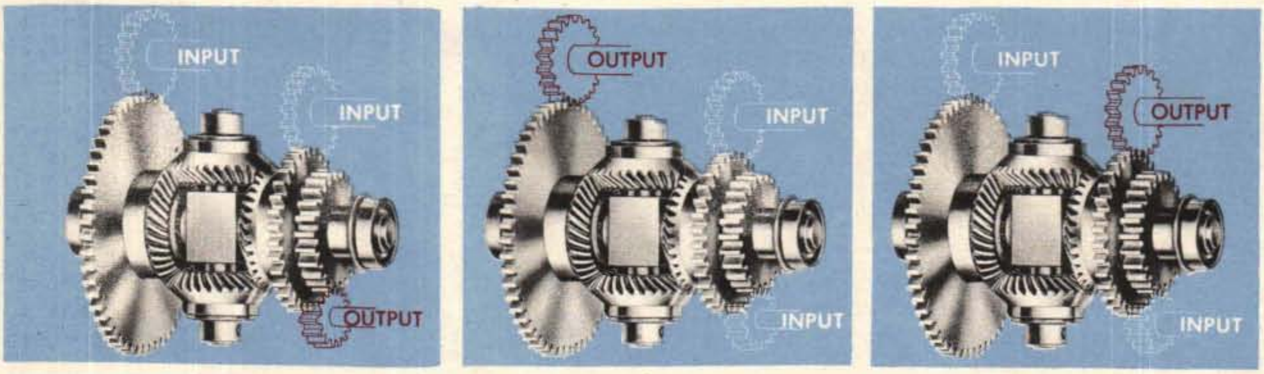
A - B

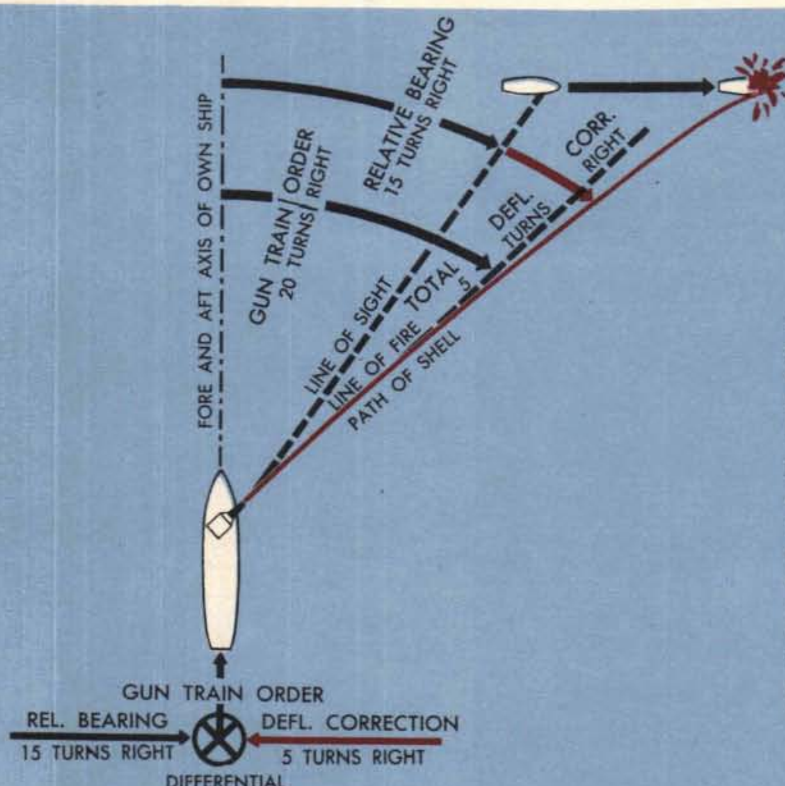


Various differential hook ups

As long as it is recognized that the spider follows the end gears for half the sum or difference of their revolutions, it is not necessary to use the side gears as inputs and the gear on the spider shaft as an output. The spider shaft may be used as one of the inputs and either of the sides used as the other input. In this case the second side becomes the output.

This fact permits three different hook-ups for any given differential. In computers any of the three hook-ups may be used, depending upon which proves most convenient mechanically.





Here is the kind of arithmetic problem that the differential solves. The total deflection correction is being added to relative bearing to produce gun order.

Few gunnery problems are, of course, as simple as this one. In a modern fire control system, differentials are invariably used in combination with other mechanisms to aid in the solution of a highly complex problem. A single computer may contain as many as 200 differentials.

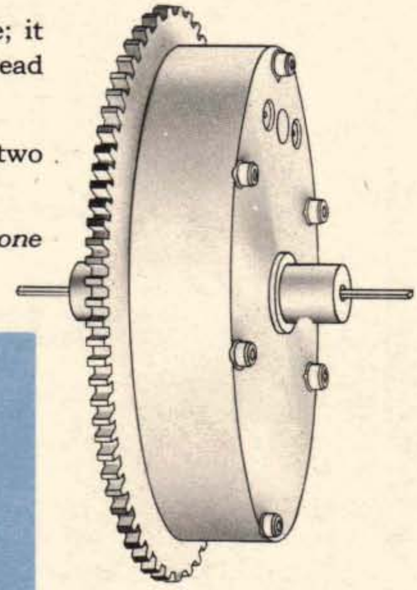
The JEWEL differential

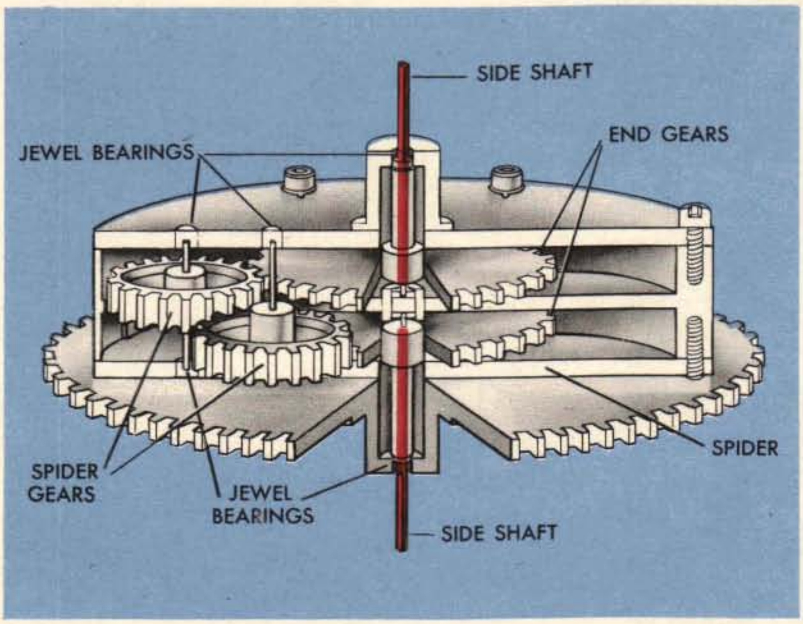
A differential can be made of spur gears instead of bevel gears. The jewel differential is an example.

The jewel differential works just like the bevel gear type; it differs only in construction and in the use of spur gears, instead of bevel gears.

The spider of the differential is a case which encloses the two end gears and the two spider gears.

The two spider gears mesh together, and each meshes with *one* of the end gears.





The shafts of the spider gears turn on jewel bearings set into the spider, so that the spider gears travel around with the spider just as in the bevel gear differential.

Each side of the jewel differential consists of a spur end gear and a side shaft.

In the jewel differential most of the shafts run on jewel bearings so that the mechanism is sensitive to very small and very light inputs, and runs very smoothly. It is used in follow-up controls where the signals come from receiver rotors and where the exact amount of turning is very important.

The jewel differential is designed to operate only small mechanisms with light loads, such as electrical contacts.

CAMS

CONSTANT LEAD CAM

RECIPROCAL CAM

SECANT CAM

SQUARE CAM

FLAT BALLISTIC CAM

BARREL BALLISTIC CAM

Cams have such different shapes and sizes and do so many different jobs that it is difficult to see what they have in common.

All of them have in common some kind of curved surface—such as a groove or a ridge, or a contour. The curved surface is positioned by the *input*. Each point on the curved surface represents a different *output* value.

Every cam also has some device like a roller or a ball called a "follower," which bears against the curved surface. At any given position of the cam, the follower is pushed by the curved surface into a position which registers the *output* value for that point of contact.

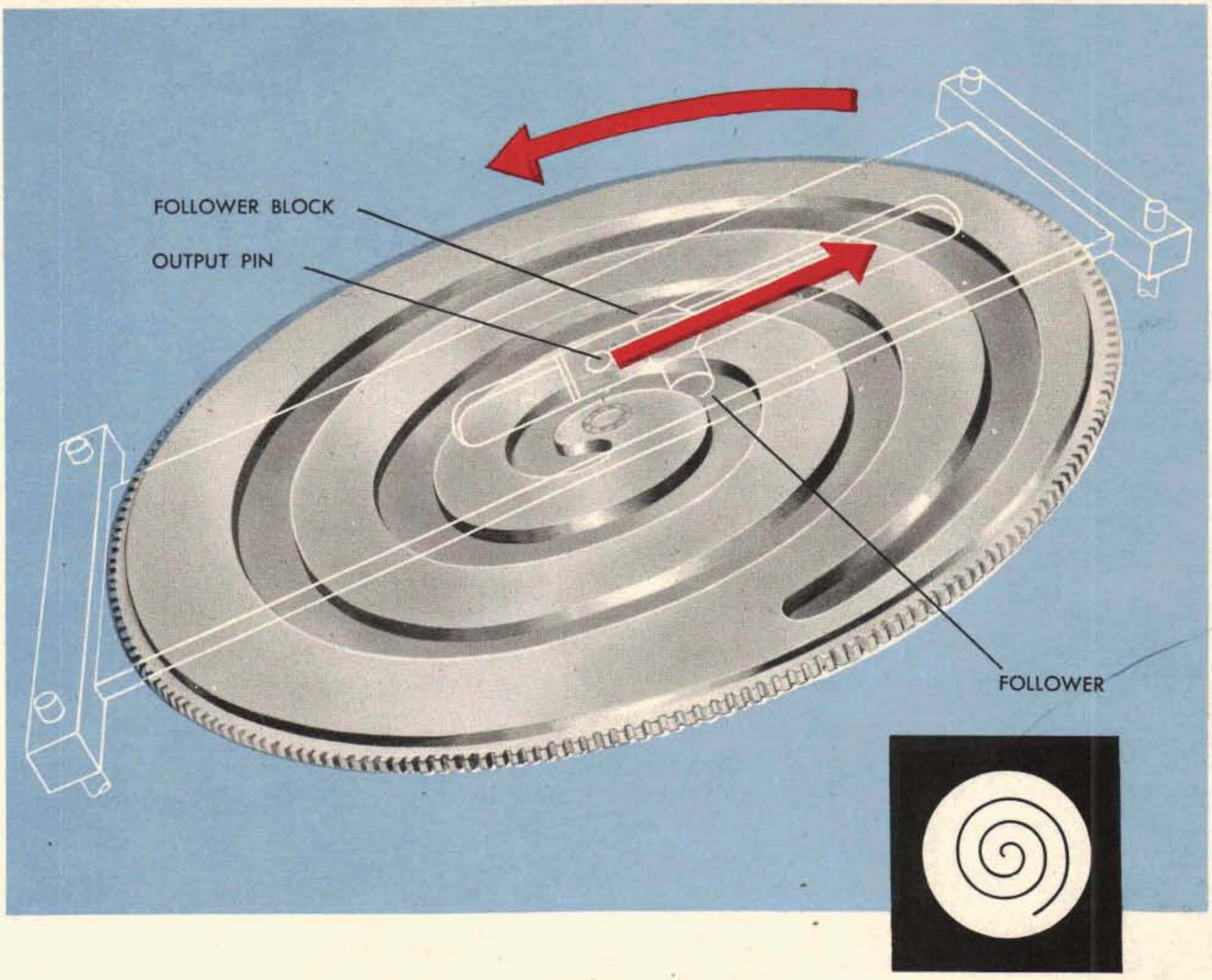
THE CONSTANT LEAD CAM

The simplest cam has a uniform or "constant lead" spiral groove. Each point on the spiral corresponds to an output that is directly proportional to the input. If the input is own ship speed in knots, each point on the groove will simply represent a different speed from 0 to, say, 45 knots.

COMPUTING CAMS

In all other cams, each point on the output surface represents a "function" of the input—such as a reciprocal, or a tangent, or a square of the input. These cams can be called *computing* cams to set them apart from the "constant lead" cam.

In computing cams, the follower position represents a quantity which is proportional to a function of the input. If, for example, the input of a tangent cam is *elevation angle,* the output is the *tangent* of elevation angle.



The spiral groove in a phonograph record carries the needle inward toward the center. If the record were run backward, the groove would move the needle from the center outward.

The groove in the spiral cam works in much the same way.

The CONSTANT LEAD CAM

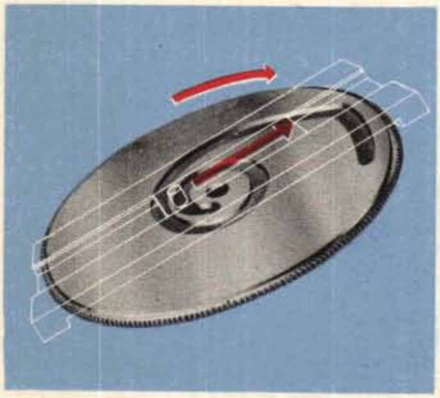
The constant lead cam consists of a spiral groove cut in a circular plate. If the cam is rotated in one direction, the spiral will force the follower block outward from the center along a straight slot. If the plate is turned in the opposite direction the spiral will force the follower block inward, toward the center.

The follower itself never travels to the center of the cam, but the *output pin* is offset on the follower block so that it can be positioned directly over the center of the cam. This is the *zero position* of the output pin.

The cam *output* is the distance from the center of the cam to the *output pin.*

The constant lead cam is a SPECIAL CASE. ITS OUTPUT IS SIMPLY A STRAIGHT MOTION OF THE FOLLOWER DIRECTLY PROPORTIONAL TO THE ROTARY MOTION OF THE INPUT. All other cams compute a FUNCTION of the input.

This is a RECIPROCAL CAM



One of the easiest ways to divide one number by another *mechanically* is to *multiply* the first number by the reciprocal of the second number.

THE RECIPROCAL OF A NUMBER IS 1 DIVIDED BY THAT NUMBER.

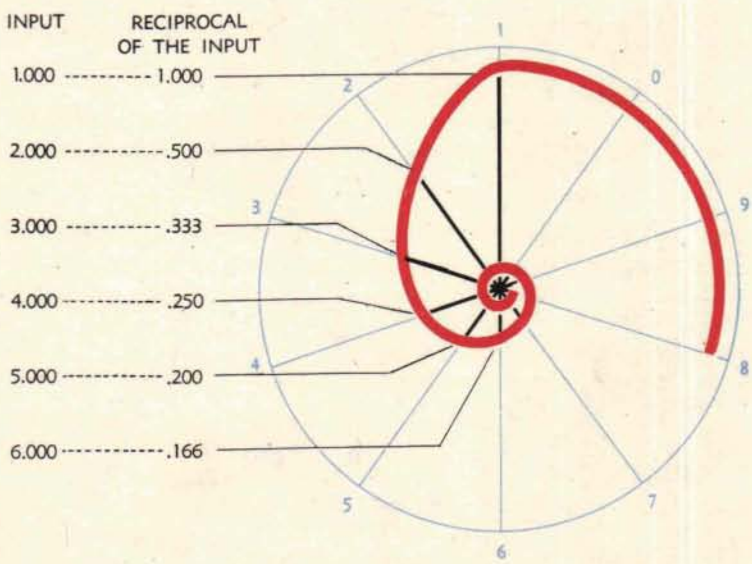
The reciprocal of 1 is 1; the reciprocal of 2 is ½, and so on.

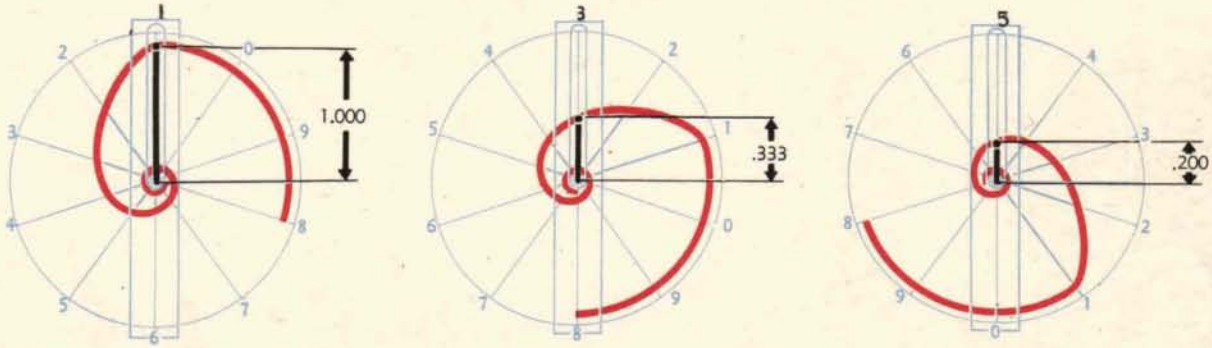
These reciprocals can also be expressed in decimals; the reciprocal of 1 is 1.00; the reciprocal of 2 is .500; the reciprocal of 3 is .333.

Obviously, dividing one number by another is the same as multiplying the first number by the reciprocal of the second:

$$\frac{a}{b} = a \times \frac{1}{b}$$

A reciprocal cam can be made by laying out reciprocal values along radii and connecting them by a curved groove.





To get the reciprocal of a number the cam is turned to the position corresponding to that number. The output pin on the follower will then be a distance from the center corresponding to the reciprocal of the number.

In goes the number—out comes the reciprocal.

Notice that the follower travels along a straight line from the center to the edge of the cam. This type of follower is called a "radial" follower.

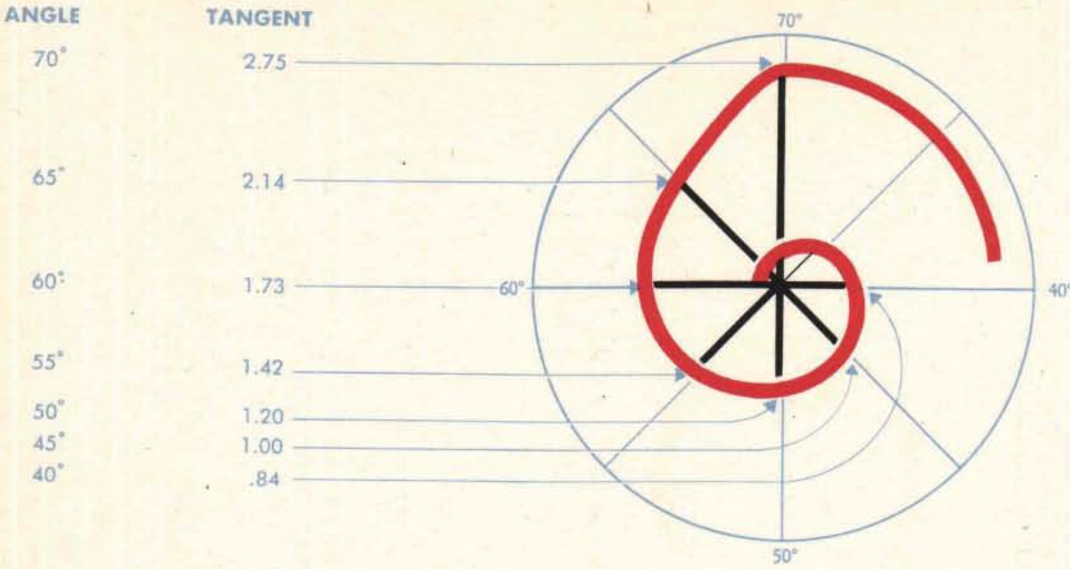
THE "RUNOUT"

Often cams cannot be cut to compute an output for *all* values of the input. So they are cut for values between certain limits.

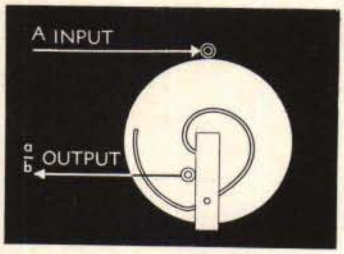
When these limits are reached, the follower passes onto the "runout." The runout consists of a transition section and usually a constant radius section.

While the follower is on a constant radius it remains the same distance from the center and there is no change in the output as the cam is turned.

Computing cams generally have a runout section at both ends of the computing section. So there may be an *inner* constant radius as well as an outer one.

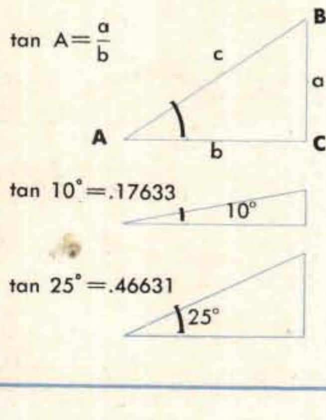


The TANGENT CAM is one of the TRIG CAMS



Almost any table or values can be cut into a cam. Grooves can be cut to give most of the Trigonometric Functions. The tangent cam is an example.

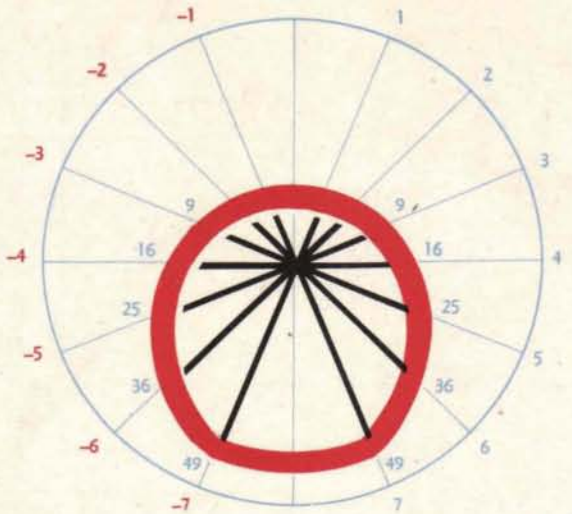
Except for the special tangent grooving, the tangent cam is like any other grooved cam. It can be mounted and used in exactly the same way. Its job is to give the tangent of an angle. The input is an angle —the output is the tangent of that angle.



Remember?

In a right triangle, the tangent of either of the two acute angles is the side opposite the angle divided by the side next to the angle.

This value changes, of course, as the angle changes. It increases rapidly as the angle becomes greater.



Here is a SQUARE CAM

The square cam works like the trig cams, but instead of a trig function it gives the square of any number.

If the input is 1 the output will be $1^2 = 1$

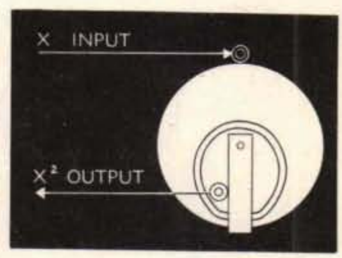
If the input is 2 the output will be $2^2 = 4$

If the input is 3 the output is $3^2 = 9$

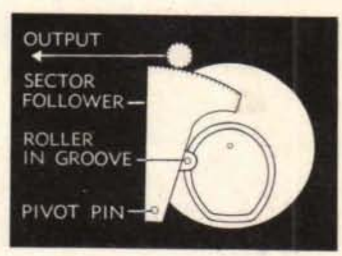
It also works for negative values:

If the input is -3 the output is $(-3)^2 = 9$, and so on.

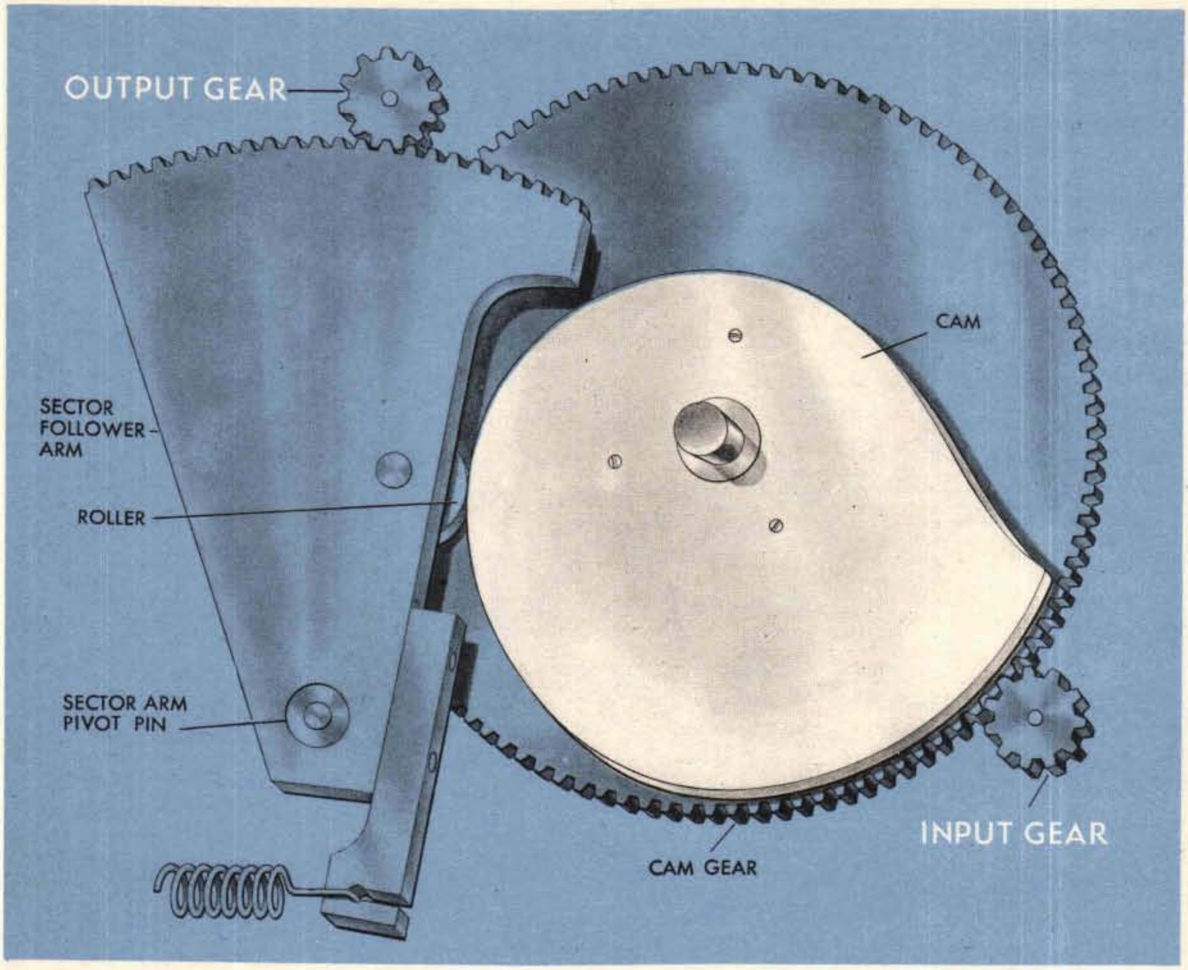
The output of a square cam is always positive.



A RADIAL follower similar to those already shown may be used with the square cam.



A SECTOR type follower may also be used. In this case the output is not a straight distance. With a sector type follower the output is the *angle* through which the sector arm has moved from its zero position. The cam groove, in this case, is slightly different from that used with radial followers.



A FLAT BALLISTIC CAM

The EDGE of this cam does the computing. It has no grooving.

The input gear turns the cam gear. The cam is mounted on the cam gear and turns with it.

A roller on the output sector arm is held against the edge of the cam by a spring at the bottom of the sector arm.

The distance from the center of the cam gear to the edge of the cam surface is different at each point around the cam, so the roller is pushed back and forth as the cam turns.

This movement of the roller pivots the sector arm, which turns the output gear.

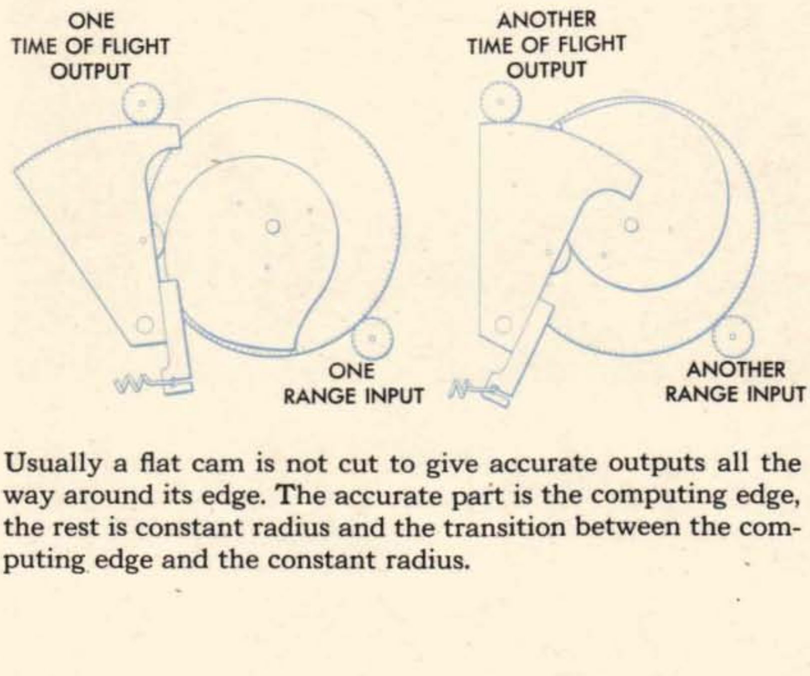
The Time of Flight Cam for surface fire is a good example of a flat ballistic cam.

In surface fire the time of flight of a shell is a function of range (advance range, to be more exact).

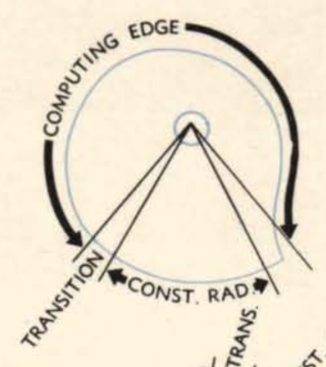
The greater the range, the longer the time the shell takes to reach the target, but the time does not increase in direct proportion to the advance range.

The input to the time of flight cam is advance range, which turns the cam gear. The cam moves the sector arm. The sector arm turns the output gear.

The output from the cam is time of flight, because the cam is shaped so that the POSITION OF THE OUTPUT GEAR ALWAYS CORRESPONDS TO THE TIME OF FLIGHT OF THE SHELL FOR THE VALUE OF THE ADVANCE RANGE INPUT.

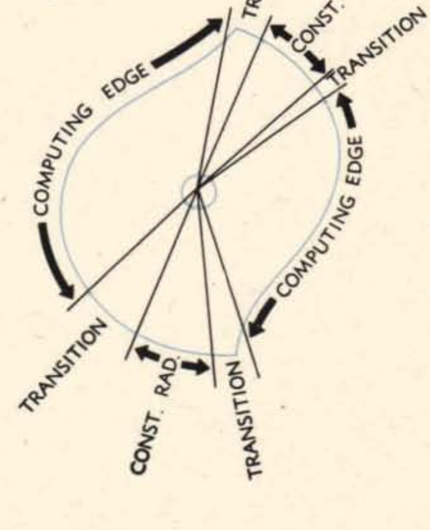


Usually a flat cam is not cut to give accurate outputs all the way around its edge. The accurate part is the computing edge, the rest is constant radius and the transition between the computing edge and the constant radius.

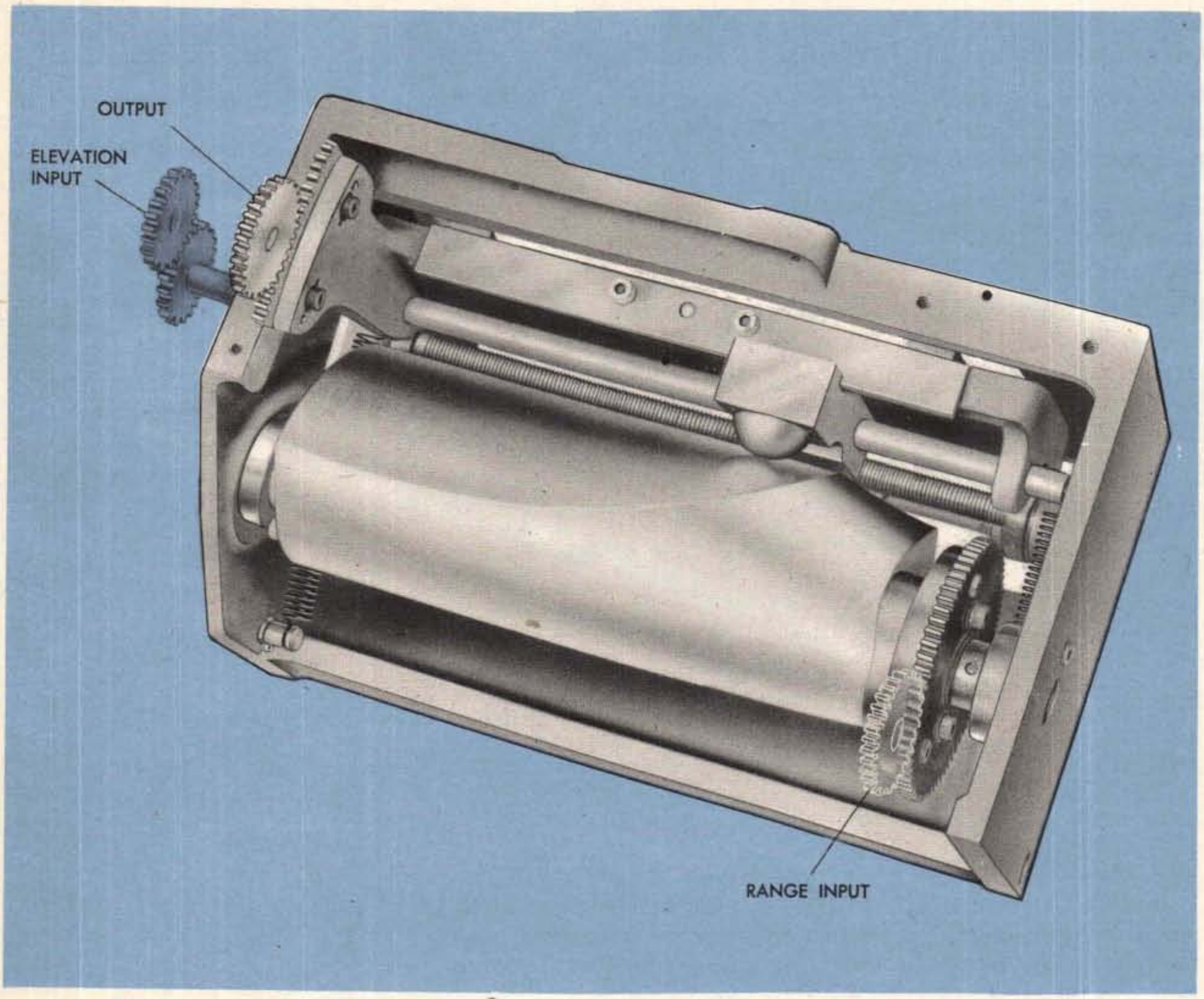


Sometimes two completely independent functions are cut on one cam, one function on each half. The outputs represent different functions of the input, for example, time of flight for two different kinds of projectiles, or two different powder charges.

To change from one set of values to the other, the cam is simply turned around 180°. The 180° change in position is put in by hand through a differential in the cam input line.



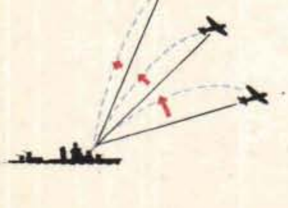
A BARREL BALLISTIC CAM



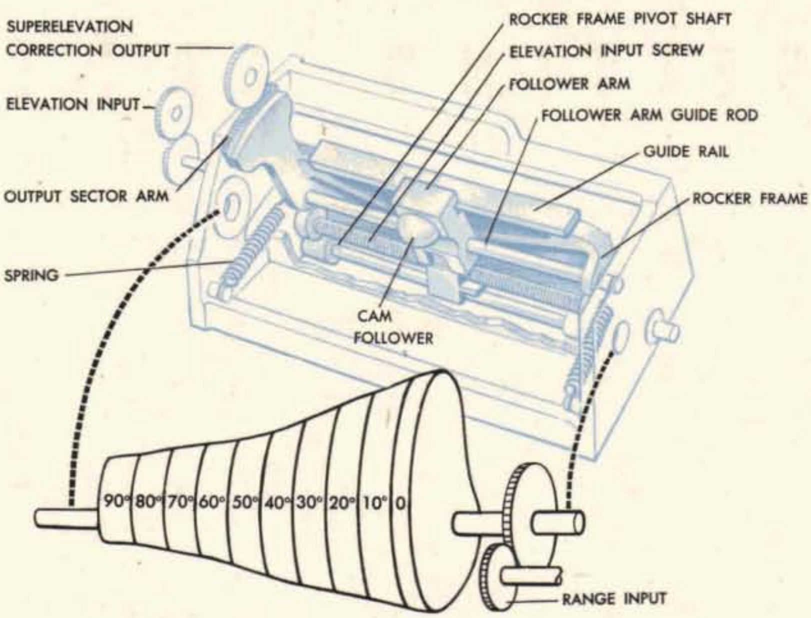
The BARREL CAM computes a *single* output which is a function of TWO different and independent inputs.

An example is the ballistic cam which computes the correction to gun elevation for fall of the projectile due to gravity. This correction is called "superelevation." Superelevation is a function of both advance range and elevation.

Superelevation *increases as advance range increases,* though not in direct proportion.



Superelevation *decreases as advance elevation increases,* again not in direct proportion.



The barrel cam is like a series of different shaped thin flat cams stacked side by side.

Each flat cam would give values of superelevation correction for all values of range at ONE ELEVATION ONLY. There would have to be a separate cam for each elevation angle.

The shape of the barrel cam varies gradually from one end to the other in such a way that EACH CROSS SECTION APPROXIMATELY REPRESENTS A DIFFERENT ELEVATION.

The elevation input gear turns the long screw which moves the cam follower along its guide selecting the cross section of the cam to be used. As the surface of the cam is curved, movement of the follower ALONG the cam PIVOTS the follower arm and guide. The follower arm is held against the cam by a spring.

The range input turns the cam, which also changes the position of the follower arm and guide.

The position of the output gear depends on two things:

a. The position of the follower arm along the cam

b. and the turning of the cam itself.

Each point on this particular cam surface, then, represents the superelevation correction for a *particular range and a particular elevation.*

Time of flight and fuze time for air targets are computed by similar cams.

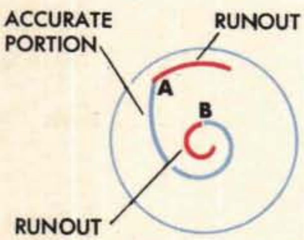
NOTE: The barrel cams in the Computer Mark 1 and Range Keeper Mark 10 do not compute their outputs directly. Instead they compute the difference between a given function and a straight line. How this is done is explained in Ordnance Pamphlets 1064 and 1065.

SETTING CAMS

On all trig cams and the reciprocal cam, the cam path is steeper in one place than another. The two important points for setting are:

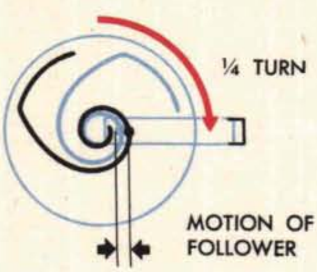
1. The point of greatest steepness
2. The point of least steepness

Here is a typical cam

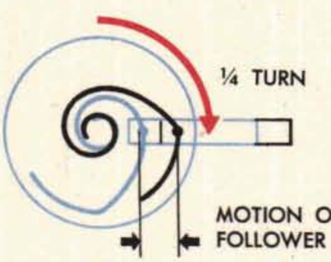


The accurate portion of this cam's path lies between points *A* and *B*.

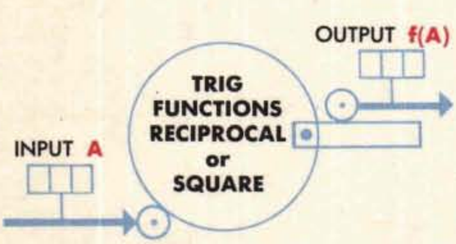
The rest of the cam path is known as "runout" and is present so that the cam follower will not hit the end of the cam.



When the follower is at the point of least steepness (on this cam this point is near the INNER CONSTANT RADIUS), a large movement of the cam produces little motion of the follower.



When the follower is at the point of greatest steepness (on this cam this point is near the OUTER CONSTANT RADIUS), the same movement of the cam produces greater movement of the follower.



The problem of setting a cam becomes one of setting the cam follower.

The cam input is *A*.

The cam output is a function of *A*, usually written: $f(A)$.

The function depends upon the shape of the cam. If it were a tangent cam, the output would be tangent *A*; if it were a reciprocal cam, the output would be $1/A$, etc.

To set a computing cam

Assume that the steepest part of the cam is at an input of 60, and that at this point $f(60) = 2.00$.

1 Put the input counter on 60 and wedge the input.

2 Run the cam follower to the point of greatest steepness.

NOTE: The computer's setting notes will give the input counter reading and approximate cam position for that reading.

3 Slip-tighten the input setting clamp.

4 Put the output counter on 2.00 which equals $f(60)$.

5 Slip-tighten the output setting clamp. The input is now approximately set.

6 Now run input *A* until the input counter has the reading for a very flat part of the cam. In this case the reading used is 0.

7 Set the reading of the output counter. It should be $f(0)$ which in this example equals zero.

NOTE: The output is now approximately set.

8 Now return the input counter to 60 and observe the *output counter reading.*

9 Here the setting is correct. The input counter shows 60, the output counter reads 2.00 and the cam follower is properly placed at a steep point on the cam.

10 Here the setting is incorrect. The input counter reads 60. The output counter reads 1.92. This means that the follower is incorrectly positioned.

11 To correct this input error, hold input *A* at 60 and slip the cam through the setting clamp until the output counter reads 2.00.

12 Tighten the input setting clamp.

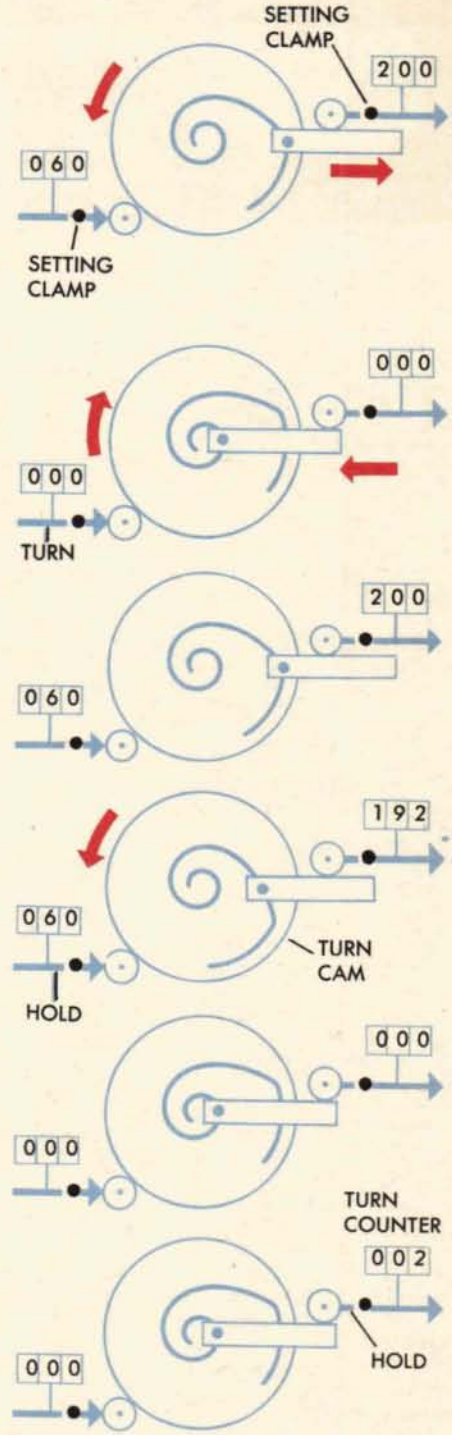
13 Now run input *A* counter to 0. Observe the output counter reading.

14 Here the output counter has the proper reading, zero.

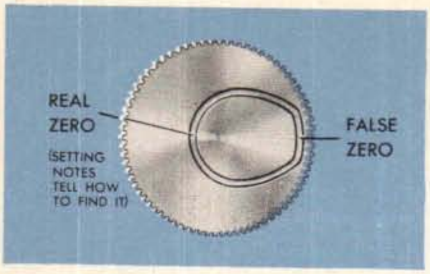
15 Here the output counter reads incorrectly, 2.

16 To correct, hold the cam output and slip counter through to read zero.

NOTE: This, of course, will cause the cam output to be in error at the 60 reading by the amount the output counter has just been moved. Refine the two settings further by repeating steps 8, 11, 13 and 16 until minimum error is observed in steps 8 and 13.



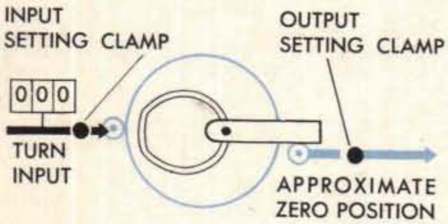
Setting the SQUARE CAM



Because of the shape of this cam two. points on it appear to be zero positions. Only one of these, however, is the real zero position.

NOTE: The computer's setting notes give the zero position for each square cam.

Once the *real* zero position has been identified the cam may be set.



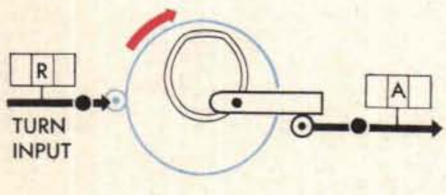
1 Turn the input to the square cam until the counter reads zero.

2 Turn the cam until it is approximately at its real zero position.

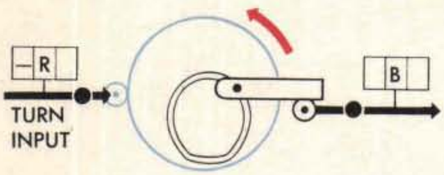
3 Put the output counter at zero.

Slip-tighten the input setting clamp and the output setting clamp.

The following steps are usually necessary to refine the above approximate setting.



4 Turn the input shaft to move the follower from 0 to *R*. Record both the input and the output readings.



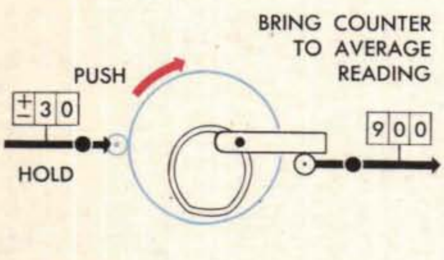
5 Now move the follower in the opposite direction to $-R$. Record both the input and the output readings.

6 Fill in the following table: for example:

INPUT READING	OUTPUT READING	INPUT READING	OUTPUT READING
R	*A*	+30	*A*
0	0	0	0
$-R$	*B*	–30	*B*

7 Here the cam was set incorrectly and readings *A* and *B* do not agree:

INPUT READING	OUTPUT READING
+30	+880
0	0
–30	+920



8 To correct first get the average reading by adding the output readings and dividing by 2.
$880 + 920 = 1800 \div 2 = 900$

9 With the cam input counter held at +30, slip the cam through the input setting clamp until the output counter is on the average reading. Check that with the input counter at –30 the output has this same average reading. Tighten both clamps.

10 Here the cam was set correctly. *A* and *B* are equal both in quantity and in sign:

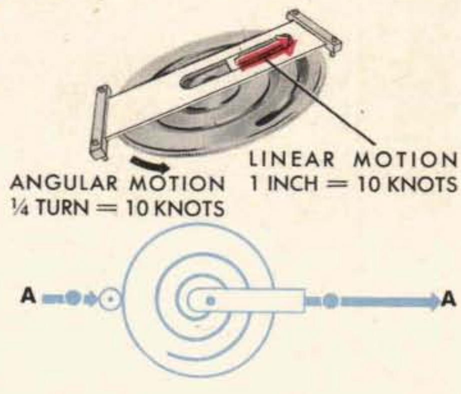
INPUT READING	OUTPUT READING
+30	+900
0	0
-30	+900

Setting the CONSTANT LEAD CAM

On a constant lead cam the input is *A*, and the output is *A*. The only difference is that an angular motion is converted to a linear motion.

To set a constant lead cam requires only finding the "zero position" of the follower. With the follower in this position the input and output counters are set at zero.

Constant lead cams are used in component solvers. To set a constant lead cam, see the component solver setting notes.



Setting the FLAT BALLISTIC CAM

Ballistic cams must be set very accurately. These cams are set with a setting rod.

1 Insert the setting rod.

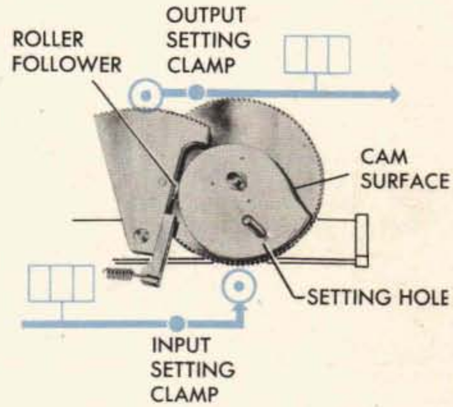
NOTE: The computer's setting notes tell how to use the setting rod on the cam to be set; it also gives the counter settings which should be made when the rod is inserted.

2 Turn the input until the counter reading agrees with the specified reading for the setting rod position.

3 Put the output counter at the value give in the computer setting notes.

4 Tighten the input setting clamp and the output setting clamp.

5 Remove the setting rod.



Setting the BARREL CAM

1 Insert the setting rod. It must go through the follower block and into the cam.

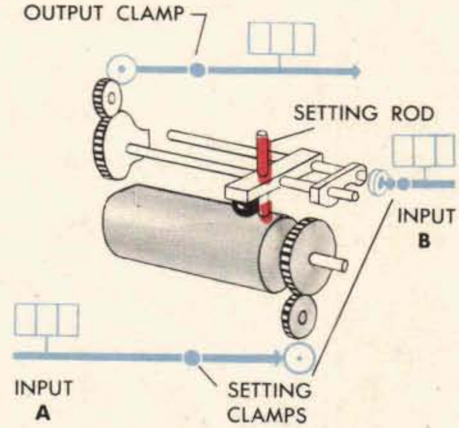
2 Put *A* and *B* input counters on readings given on the ballistic unit for the setting rod position.

3 Tighten the input clamps.

4 Put the output counter on the reading given in Computer's setting notes.

5 Tighten output clamp.

6 Remove the setting rod.

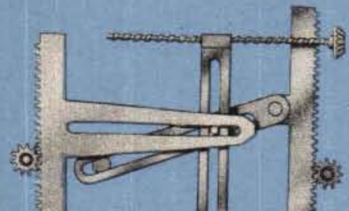


MULTIPLIERS

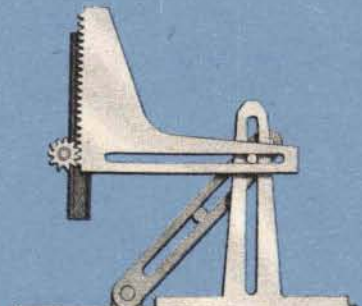
In solving a fire control problem it is often necessary to multiply two continually changing values to produce a continuous series of products. The device that accomplishes this is called a *multiplier.* There are several types of multipliers but they usually produce a solution through the use of similar triangles.

For mechanical reasons it is more convenient to build a multiplier that delivers a fixed fraction of the answer, such as a tenth or a twelfth, rather than the complete numerical value required. This fraction can be "stepped up" to produce a complete answer by the proper choice of input and output gearing, but this is seldom necessary.

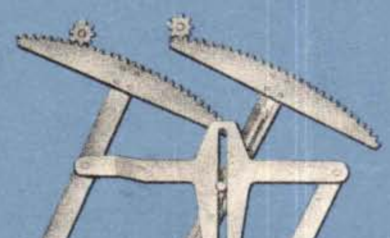
MULTIPLIERS CAN TAKE TWO CONTINUALLY CHANGING INPUT VALUES AND DELIVER AN OUTPUT THAT IS *PROPORTIONAL* AT EVERY INSTANT TO THE PRODUCT OF THE TWO CHANGING INPUTS.



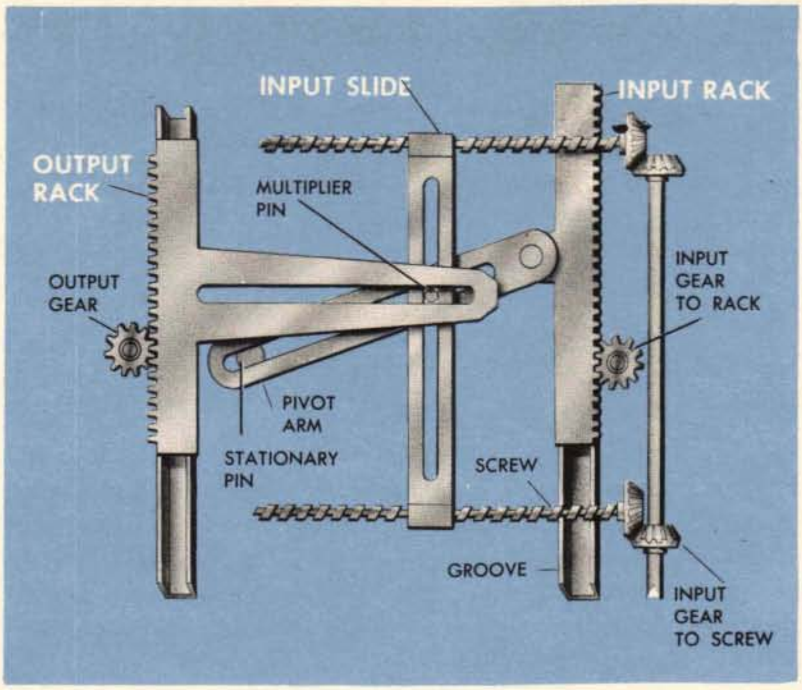
SCREW TYPE MULTIPLIER



RACK TYPE MULTIPLIER



SECTOR TYPE MULTIPLIER



NOTE:
The input slide of most screw-type multipliers is grooved rather than slotted. The slide is pictured as slotted in order to show more clearly the relationship and movement of the multiplier's parts.

The SCREW TYPE MULTIPLIER

The screw-type multiplier has two inputs: a **SLIDE** and a **RACK.**

The *input slide* is moved back and forth by two long lead screws.

The *input rack* is moved up and down by a spur gear.

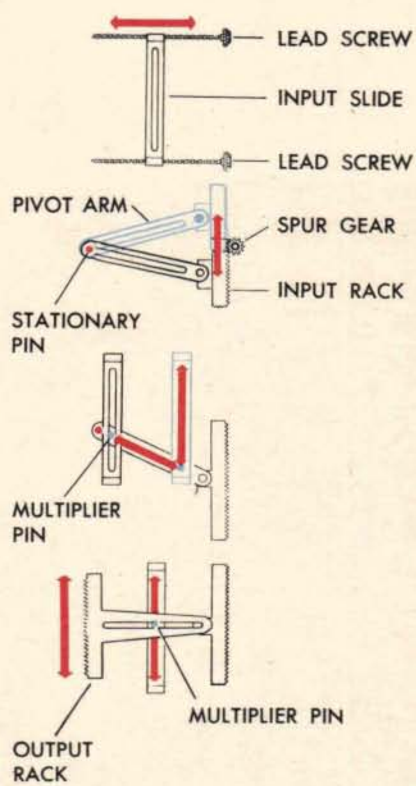
The input rack moves a slotted pivot arm that pivots around a stationary pin as the input rack is moved.

A pin called the "multiplier pin" is mounted in the slots of the input slide and the pivot arm where these slots cross. The position of this pin is changed by movement of the input slide or the input rack.

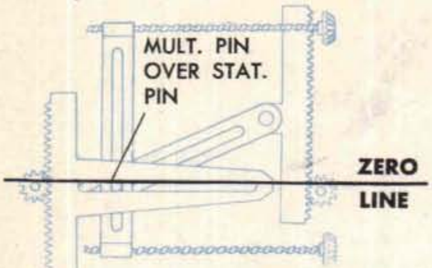
The multiplier pin also fits into a slot in the **OUTPUT RACK.** As it changes position this pin moves the output rack up or down.

THE POSITIONS OF THE *INPUT SLIDE* AND THE *INPUT RACK* REPRESENT THE TWO VALUES TO BE MULTIPLIED TOGETHER.

THE POSITION OF THE *OUTPUT RACK* REPRESENTS THE OUTPUT VALUE, WHICH IS ALWAYS PROPORTIONAL TO THE *PRODUCT* OF THE TWO INPUTS.

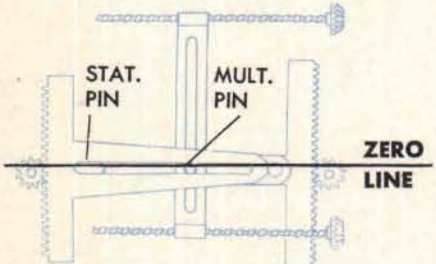


How it multiplies



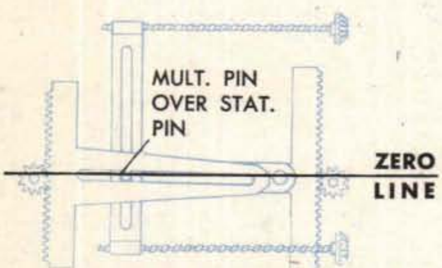
ZERO POSITION OF INPUT SLIDE

Suppose the lead screws are turned until the multiplier pin lies directly over the stationary pin. This is known as the *zero position* of the ***input slide,*** since, with the slide in this position, movement of the input rack will not produce any movement of the output rack.



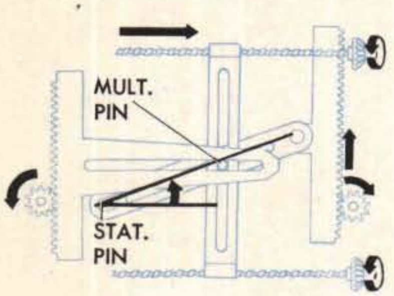
ZERO POSITION OF INPUT RACK

Similarly, if the slot in the pivot arm is positioned parallel to the slot in the output rack, no amount of motion of the input slide can cause any vertical motion of the multiplier pin or of the output rack. This position is known as the *zero position of the input rack.*



ZERO POSITION OF BOTH INPUTS

Here are both inputs at their zero position.



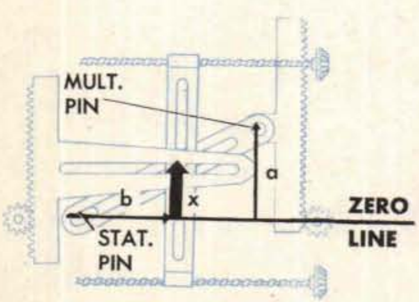
Now, suppose both input gears turn a few revolutions in the directions indicated.

The input slide will move to the right.

The input rack will move up its groove, bringing the pivot arm into an angular position.

The multiplier pin will be pushed to its new position by the combined action of the pivot arm and the slide.

This pin will move the output rack, and the output rack will turn the output gear.

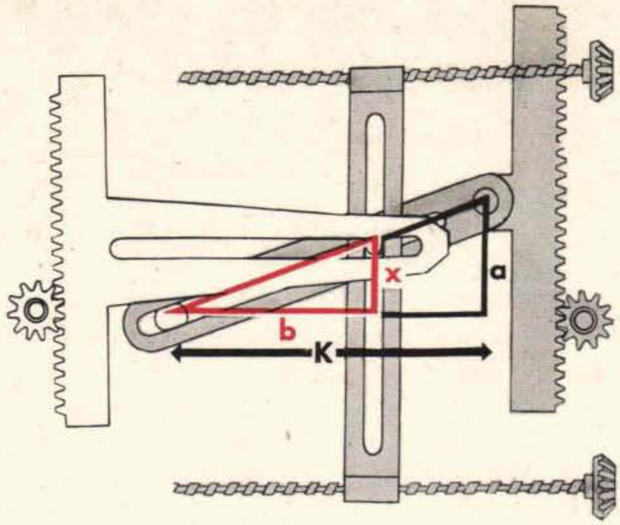


Now, label the distances each part has traveled from the zero line:

The input rack has moved up a

The input slide has moved over b

The output rack has moved up x



If these distances are drawn on the diagram of the multiplier, they form two right triangles.

IN THE SMALLER TRIANGLE—the HEIGHT, x, is the distance the output rack moved from zero. The BASE, b, is the distance the input slide moved from zero.

IN THE LARGER TRIANGLE—the HEIGHT, a, is the distance the input rack moved from zero. The BASE, K, is the fixed distance along the zero line from the stationary pin to the pivot on the input rack.

Notice that the larger triangle is the same *shape* as the smaller triangle. The only difference between the triangles is that one is larger than the other. They are *similar* triangles.

Now it can be seen that the ratio between the height and the base of the smaller triangle is equal to the ratio between the height and the base of the larger triangle.

That is:

$$\frac{x}{b} = \frac{a}{K}$$

Multiplying both sides by b:

$$\frac{bx}{b} = \frac{ba}{K}$$

Then:

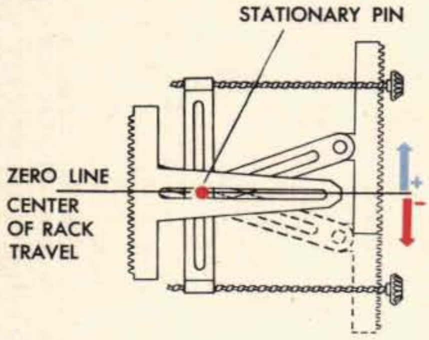
$$x = \frac{ba}{K}$$

This equation shows that the distance the output rack moved from zero is equal to the product of the distances the input slide and rack have moved from zero, DIVIDED BY A CONSTANT.

IN OTHER WORDS, THE OUTPUT IS ALWAYS PROPORTIONAL TO THE PRODUCT OF THE TWO INPUTS.

Since K is a fixed distance, it is a CONSTANT value in each multiplier. Its effect is taken care of by proper choice of input and output gearing for the multiplier.

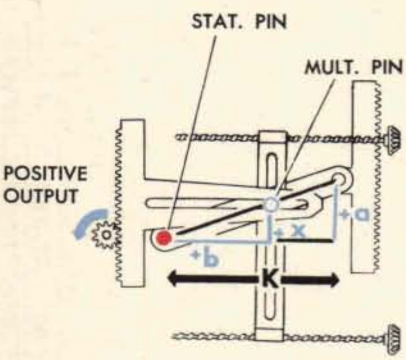
How it handles both



Suppose the rack input is to be a rate or an angle which can have *negative* values as well as *positive* ones. The arrangements of the parts must then be changed slightly to allow for this. The *stationary pin* must be located so that the zero position of the input rack is in the *middle of the rack travel.* That is, the input rack can be moved UP OR DOWN from its zero position. This is the usual location of the stationary pin.

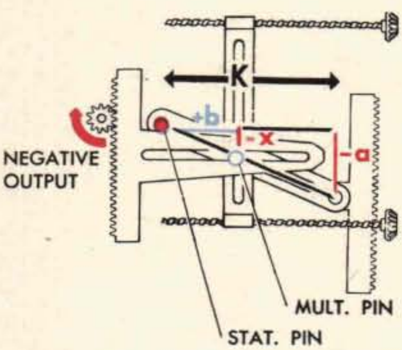
Now, if the input is considered to be *positive when the rack is above its zero position,* the input must be *negative when the rack is below its zero position.*

The same rule must also apply to the output rack. That is, a position of the *output rack above zero represents a positive output* and a position of the *output rack below zero represents a negative output.*



Here both inputs are positive so the output is positive

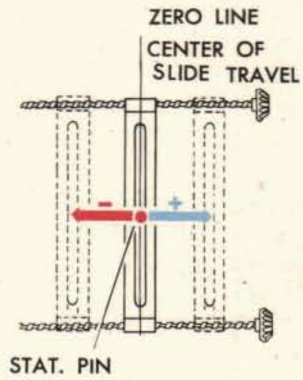
$$x = \frac{(+a)\ (+b)}{K} \qquad x = +\frac{ab}{K}$$



Here the screw input is positive but the rack input is negative so the output is negative

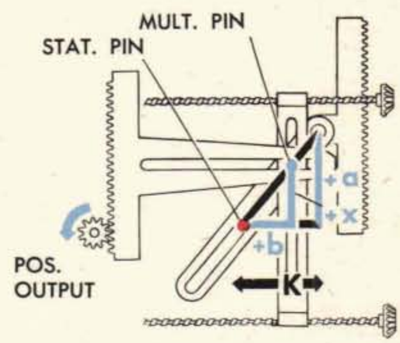
$$x = \frac{(-a)\ (+b)}{K} \qquad x = -\frac{ab}{K}$$

POSITIVE and NEGATIVE values



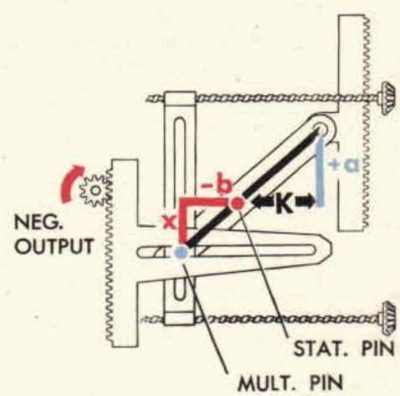
In the same way the multiplier can be arranged to handle a positive or negative *input* to the slide. This is accomplished by locating the stationary pin toward the middle of the screw travel. The slide may now travel in either direction from the zero position.

Then, if positions of the slide to the right of the pin represent *positive* input values, positions of the slide to the left of the stationary pin represent *negative* values of that input.



Here both inputs are positive:
The output is positive

$$x = \frac{(+a)\ (+b)}{K} \quad \text{or} \quad x = +\frac{ab}{K}$$

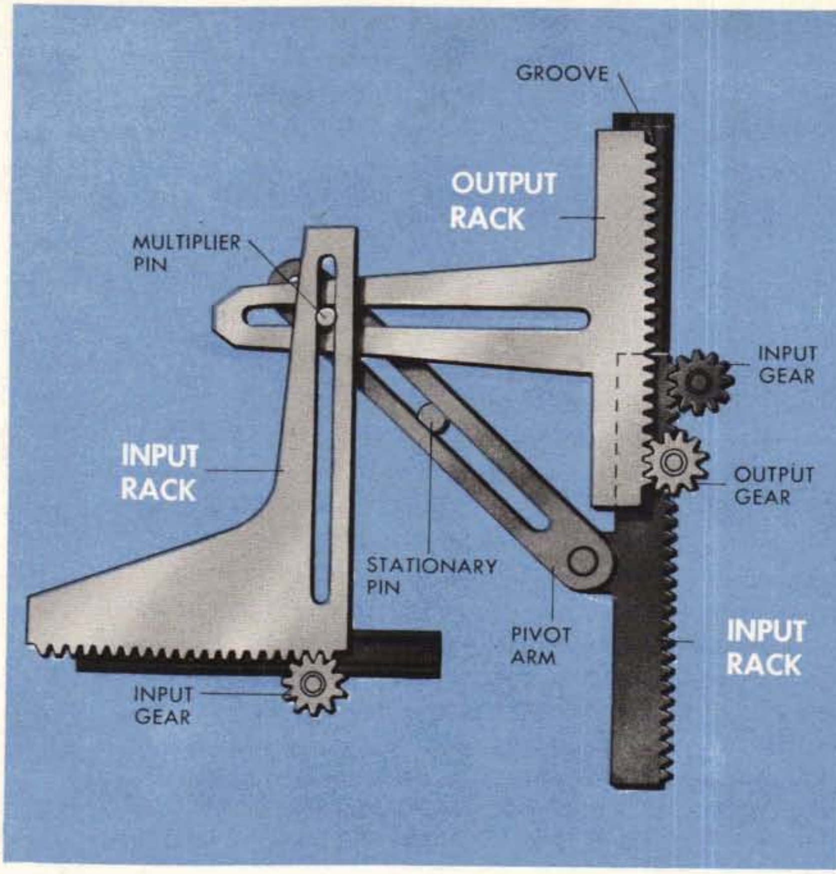


Here the rack input is positive,
The slide input is negative,
So the output is negative

$$x = \frac{(-b)\,(+a)}{K} \quad \text{or} \quad x = -\frac{ab}{K}$$

From these examples it can be seen that the *stationary pin may be located any convenient place* on the multiplier. For any particular multiplier the exact location of the stationary pin depends mainly upon the values that must be handled by the two inputs.

It is important to note that *the zero position of the input slide is always directly over the stationary pin wherever the stationary pin is located.*



The RACK TYPE MULTIPLIER

There are two major differences between the rack type and the screw type:

1 The input slide and the lead screws of the screw type have been replaced by a rack like the output rack. This is one input rack. It is mounted in guide rails so that its slot is always at right angles to the slot in the output rack.

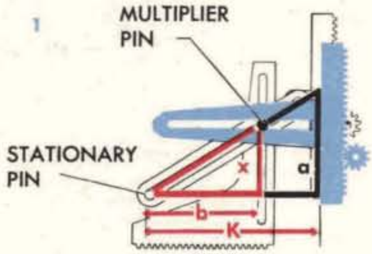
2 The output rack is generally mounted on the same side of the multiplier as the second input rack. However, the position of the slot is still the same as in the screw type and the operation is the same.

1 This multiplier works just like the screw type. The same triangles are formed and the same equations apply to those triangles.

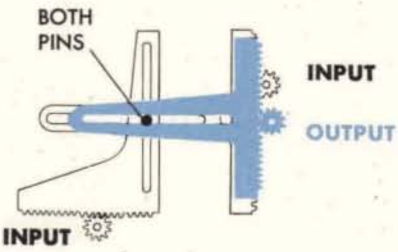
$$\frac{x}{b} = \frac{a}{K} \quad \text{or} \quad x = \frac{ab}{K}$$

In other words, the output is always PROPORTIONAL to the product of the two inputs, just as it was in the screw type multiplier. Here the stationary pin is shown at one end of the pivot arm.

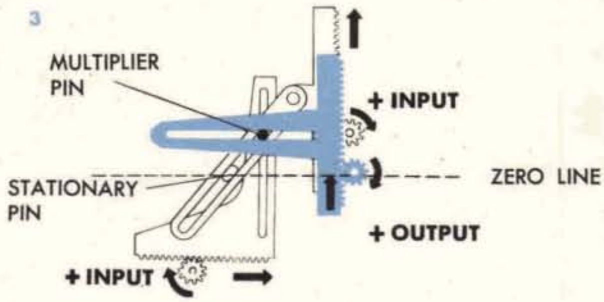
In the rack type multiplier the stationary pin is often in the CENTER of the pivot arm, but not always. It may be located anywhere along the pivot arm. In all diagrams except the first it is shown in the center of the pivot arm slot.



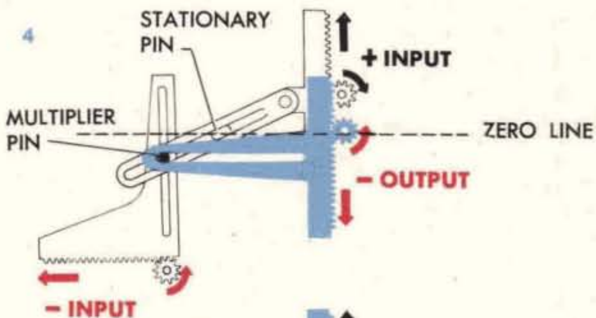
2 Here are all the parts in zero position. The multiplier pin is right on top of the stationary pin. Movement of any *one* input will leave the output at zero.



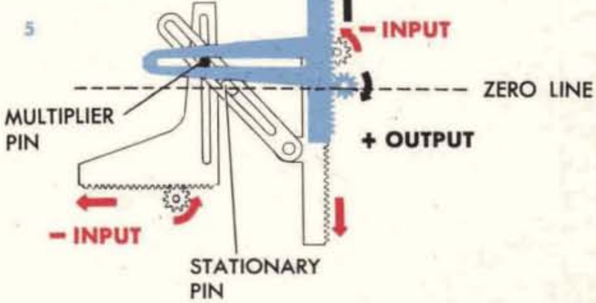
3 Here both racks move in a POSITIVE direction. The output is POSITIVE.



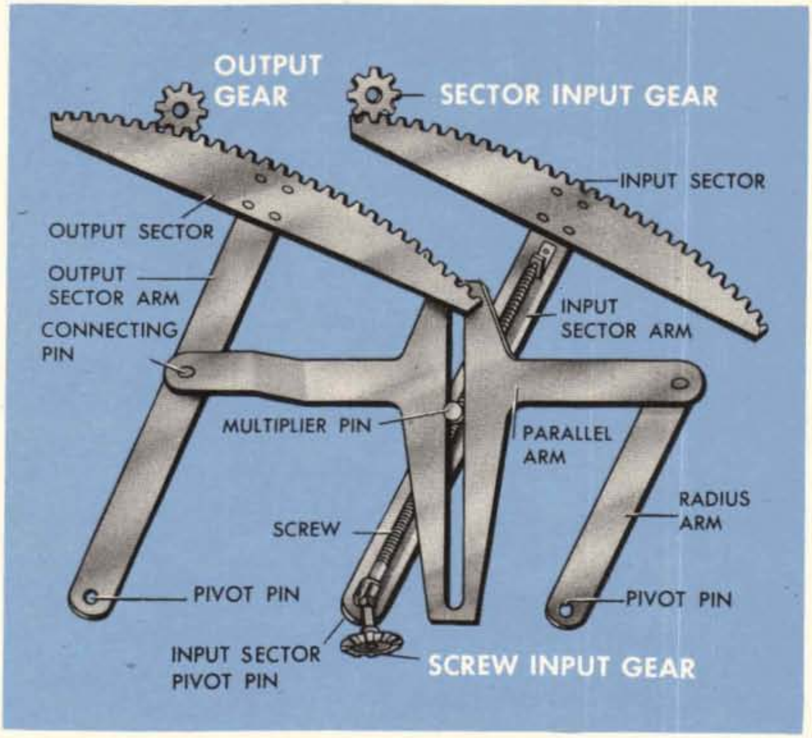
4 Here one input is POSITIVE, the other is NEGATIVE. The output is NEGATIVE.



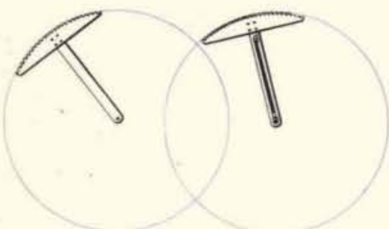
5 Here both inputs are NEGATIVE, so the output is POSITIVE.

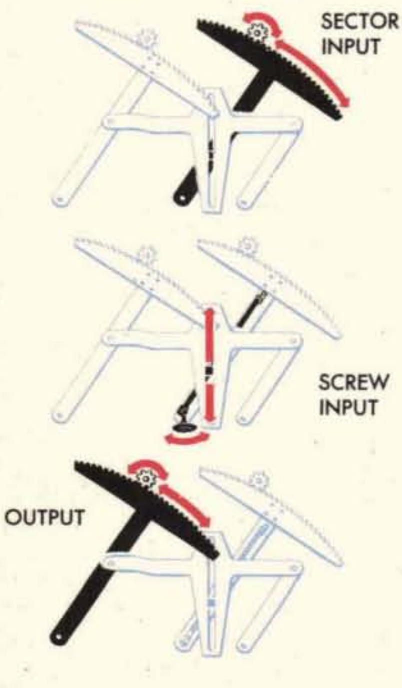


IN THE RACK TYPE MULTIPLIER, THE DISTANCE MOVED BY THE OUTPUT RACK IS PROPORTIONAL TO THE PRODUCT OF THE DISTANCES MOVED BY THE TWO INPUT RACKS.



The SECTOR TYPE MULTIPLIER





This multiplier is called the sector type because the long geared parts are sectors of circles. The centers of these circles are the pivot pins around which the sector arms swing.

There are two inputs:

One input positions the input sector arm.

The other input turns a long screw that is mounted on the input sector arm. The bevel gear turns this screw through a universal joint, so that it can drive the screw as the sector arm changes its angular position.

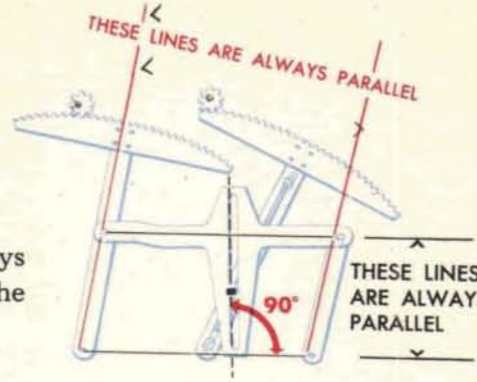
The multiplier pin is driven up and down the sector arm by the screw.

The position of the input sector arm and the position of the pin on the screw represent the two values to be multiplied.

One end of the parallel arm is mounted on the output sector, the other end is mounted on the radius arm.

The multiplier pin moves in the slot in the parallel arm and positions this arm. As the parallel arm is moved from side to side, it swings the output sector to a position representing the output.

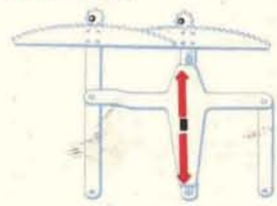
How the parts move



The slotted piece is called the parallel arm because it always moves parallel to a line through the three lower pivot pins. The slot is always PERPENDICULAR to that line.

The sector arms are in zero position when the lead screw on the input sector is parallel to the slot in the parallel arm. With the input sector arm at zero, movement of the pin will not move the output sector arm.

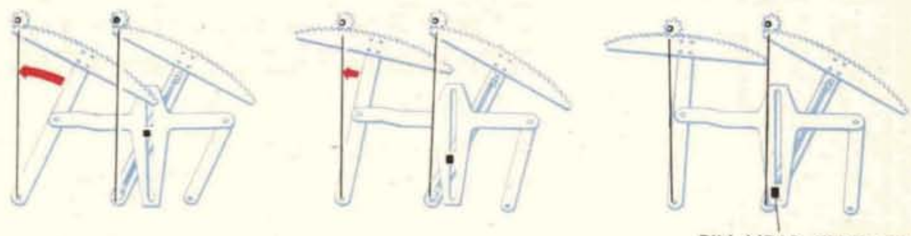
NO MOTION



INPUT SECTOR ARM IN ZERO POSITION

When the input sector arm is moved away from zero, any movement of the pin will move the output sector arm. The amount of output motion depends on the position of the multiplier pin along the screw.

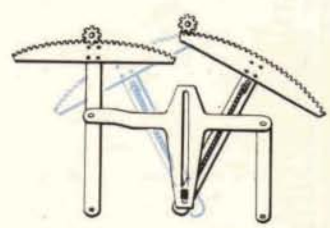
AS PIN MOVES DOWN, OUTPUT ARM MOVES TO ZERO POSITION



PIN NEAR ZERO POSITION

As the multiplier pin is moved down the screw toward the sector arm pivot pin, the output arm straightens up towards its zero position.

Zero position for the multiplier pin is right over the sector arm pivot pin. When the pin is at zero, motion of the input sector arm will not move the output arm.



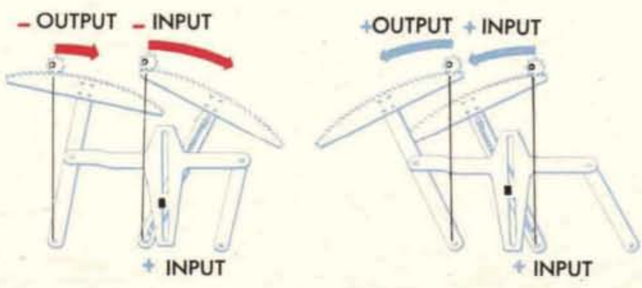
INPUT ARM MOVES IN EITHER DIRECTION FROM ZERO POSITION

The sector arm input moves in either direction from zero position. These two directions represent positive and negative inputs.

Since the pin moves only one way from its zero position, it can handle only positive inputs, or only negative inputs, but not both.

SECTOR INPUT CAN HANDLE BOTH POSITIVE AND NEGATIVE INPUTS

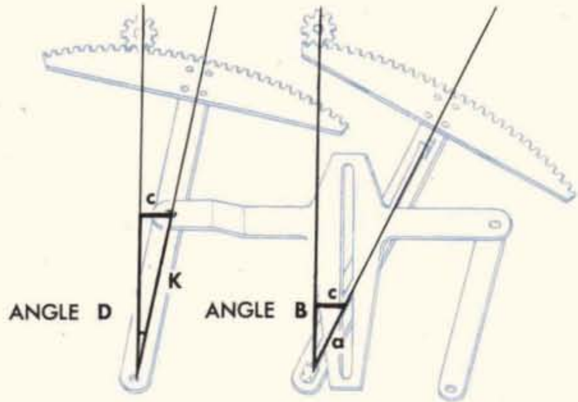
SCREW INPUT TAKES VALUES OF ONLY ONE SIGN



NOTE:

In some installations, the screw-type multiplier is constructed to allow the pin to travel a little below the zero position.

How the sector type works



Like the screw type multiplier, the sector type uses the relationship between triangles in performing a multiplication. These triangles are formed by movement of the sectors in response to changing inputs.

Assume that a combination of two inputs has caused the sectors to take the positions shown in the diagram. Two right triangles are formed. Each has one side of the same length, c.

In the LEFT HAND TRIANGLE the hypotenuse K is the fixed length between the pivot pin and the connecting pin.

In the RIGHT HAND TRIANGLE the hypotenuse is the distance, a, that the multiplier pin has moved away from the pivot pin.

Since the sine of an angle $= \dfrac{\text{opposite side}}{\text{hypotenuse}}$

then in the LEFT HAND TRIANGLE

$$\text{the Sine of angle } D = \frac{\text{side c}}{\text{hypotenuse } K}$$

Multiplying both sides of the equation by K produces:

$$K \text{ Sine } D = \frac{cK}{K} \quad \text{or, } K \text{ Sine } D = c$$

In the RIGHT HAND TRIANGLE

$$\text{the Sine of angle } B = \frac{\text{side c}}{\text{hypotenuse } a}$$

Multiplying both sides of this equation by a produces:

$$a \text{ Sine } B = \frac{ca}{a} \quad \text{or, } a \text{ Sine } B = c$$

Reviewing both equations,

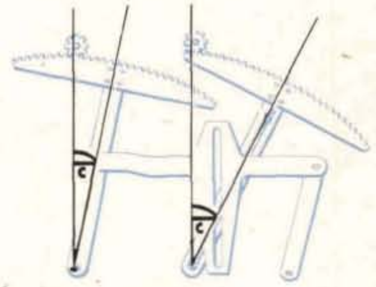
since K Sine $D = c$ and a Sine $B = c$

then K Sine $D = a$ Sine B

Dividing both sides of this new equation by K produces:

$$\text{Sine } D = \frac{a \text{ Sine } B}{K}$$

Now to get rid of the Sines:

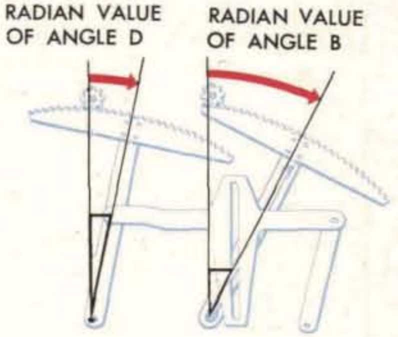


LINE C IS NEARLY EQUAL TO RADIAN ARC

As shown in the Basic Mathematics chapter it is permissible to substitute the value of an angle in *radians* for the sine of the angle, when the angle is small. Here the angle may be as large as 20°. Such an angle is larger than is usual when the radian value is substituted for the sine. However, the resulting error is still considered acceptable.

The equation now becomes:

$$\text{Angle } D \text{ in radians} = \frac{a \times \text{angle } B \text{ in radians}}{K}$$



LINEAR VALUES CAN BE SUBSTITUTED FOR ANGLES B AND D

Since these angles are expressed in radians, the radian values of angles B and D, which represent motion of the sectors, can now be substituted for the angles in each case.

Therefore, output D is the product of input a, multiplied by input B, and divided by constant K.

$$D = \frac{aB}{K}$$

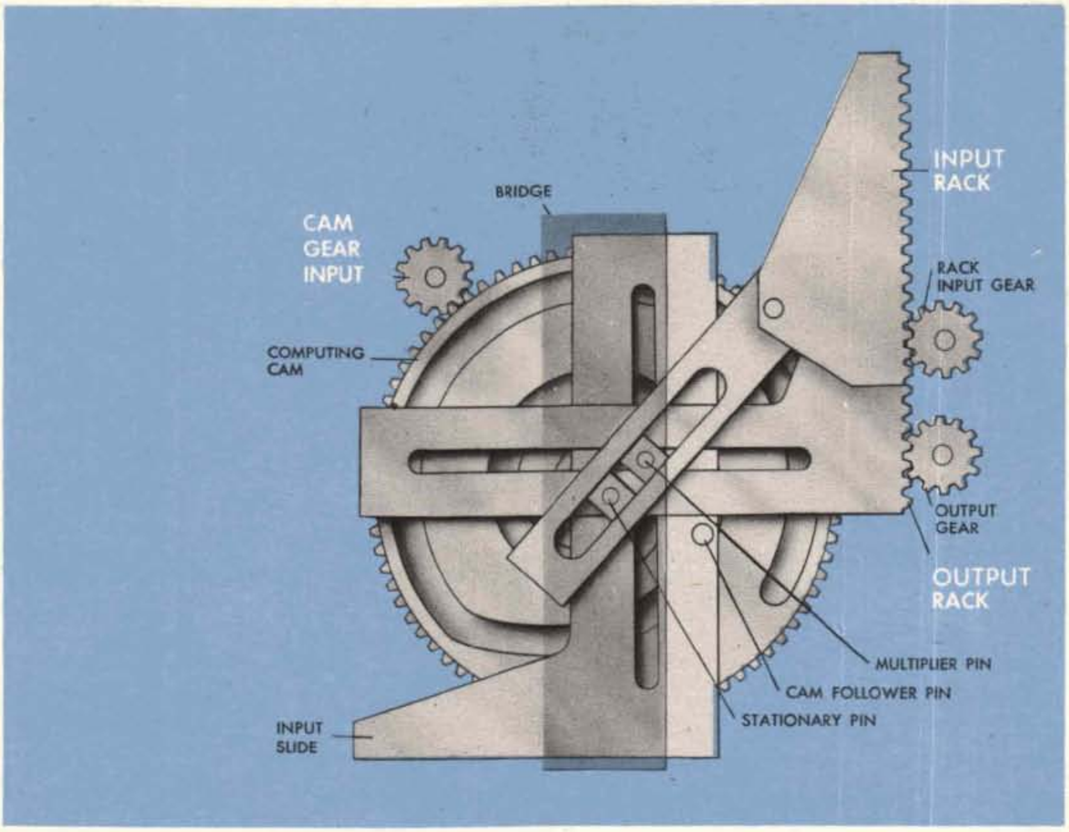
THE OUTPUT, THEN, IS PROPORTIONAL TO THE PRODUCT OF THE TWO INPUTS.

The constant K is taken into consideration by giving a suitable value to the output shaft, or by appropriate gearing.

Thus:

Output D is the product of input a, multiplied by input B

or: $D = aB$



SINGLE CAM COMPUTING MULTIPLIER

The cam type multiplier does more than just multiply two values together.

IT COMPUTES A FUNCTION OF ONE VALUE AND MULTIPLIES THAT FUNCTION BY A SECOND VALUE.

This multiplier is like the rack type multiplier except that one of the inputs is positioned by a cam instead of a rack.

The cam follower pin is mounted directly on the multiplier input slide. The cam used may be cut to compute any desired function of the cam input.

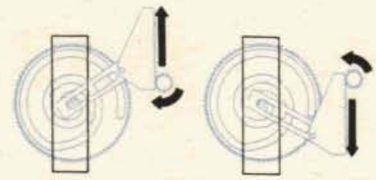
The mechanism works this way:

1 One input drives the input rack.

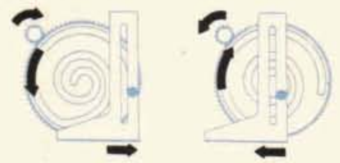
2 The other input drives the cam directly.

3 The cam positions the input slide according to the function for which the cam was cut. Thus the cam *output* becomes the slide *input*.

4 The position of the output rack represents a value which is proportional to the product of the cam output and the rack input.

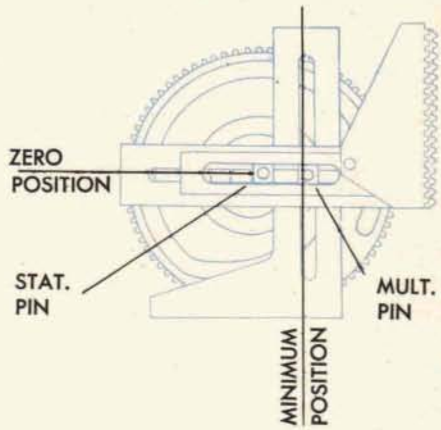


The racks move in the same directions as they did in the rack type multiplier.



The input rack is pinned to an arm which pivots around the stationary pin.

The cam follower pin is fixed to the input slide so that this slide is positioned by the cam.



When the output rack and the pivot arm are parallel, they are in their ZERO positions.

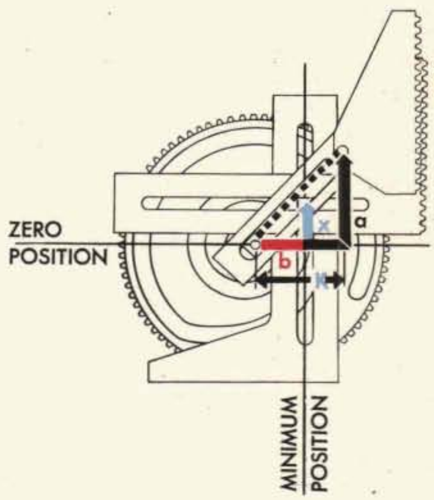
The slide is in its zero position when the multiplier pin is directly over the stationary pin.

In some cam multipliers there is a "minimum" position but no zero position, since the grooves of some of the cams compute functions which do not go to zero. A secant cam is an example.

Suppose both input gears are turned:

1 The cam turns and moves the slide a distance b. Distance b is then the *output of* the cam and the *input* to the multiplier.

2 The input rack moves upwards from its zero position an amount a.



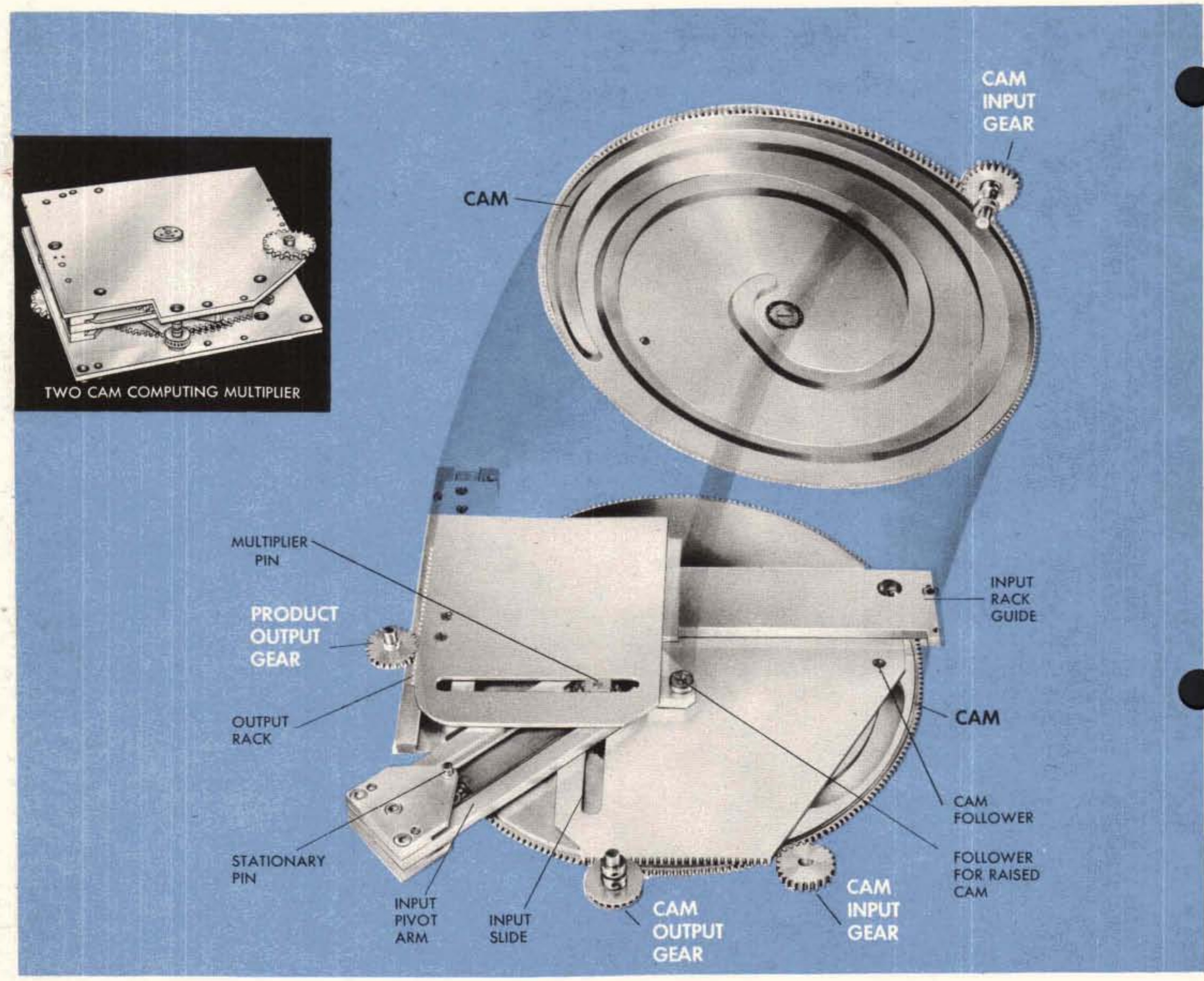
These two inputs make the output rack move up a distance x from zero position.

These distances form two right triangles. These triangles are just the same as those used for the rack or screw type multiplier.

$$\frac{x}{b}=\frac{a}{K} \quad \text{or} \quad x=\frac{ab}{K}$$

Distance K is a constant. Distance b is the cam output.

THE MULTIPLIER OUTPUT, *x*, IS PROPORTIONAL TO THE OUTPUT OF THE CAM MULTIPLIED BY THE RACK INPUT.



The TWO CAM COMPUTING MULTIPLIER

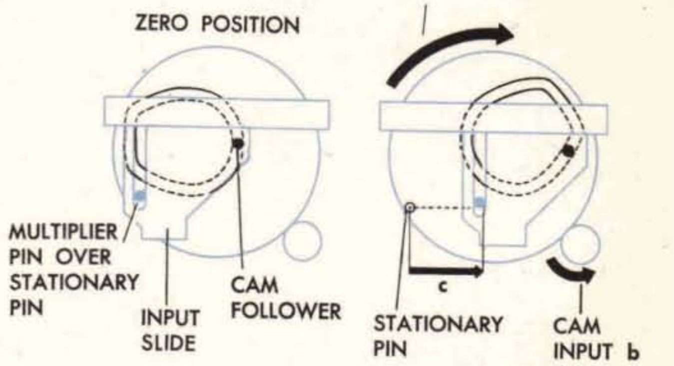
The two-cam multiplier computes a function of each of the two input values, then multiplies one function by the other.

In this multiplier, BOTH input racks are replaced by cams. The cams position the input slide and pivot arm.

The product output value is always the product of the two cam outputs.

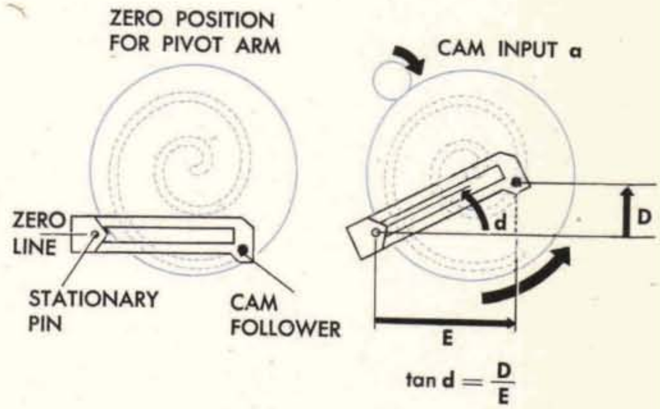
The cam follower in the groove of one cam moves the input slide from side to side. The position of the slide always represents the cam output. The slide can be used to turn a *cam output gear,* and thus make the *cam* output available as another output in addition to the *product* output.

Zero position of the slide is at the left with the multiplier pin over the stationary pin.



The cam follower in the groove of the second arm swings the input pivot arm on the stationary pin.

The second cam is always cut in such a way that the output is the tangent of the angle which the pivot arm forms with the zero line.



The multiplier pin is mounted in the pivot arm, and passes through the input slide and the output rack.

Two triangles are formed, just like the triangles formed in the screw type multiplier.

The tangent of angle *d* is equal to a function of the cam input *a.*

$$f(a) = \tan d = \frac{D}{E}$$

Side c of the small triangle is equal to a function of the cam input *b.*

$$f(b) = c$$

Since the two triangles are similar triangles,

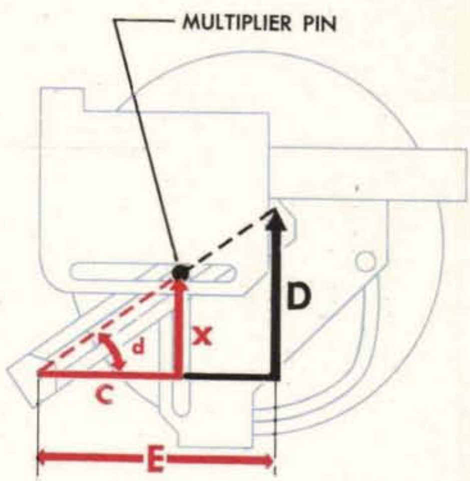
$$\frac{D}{x} = \frac{E}{c}, \qquad \text{or } \frac{D}{E} = \frac{x}{c}$$

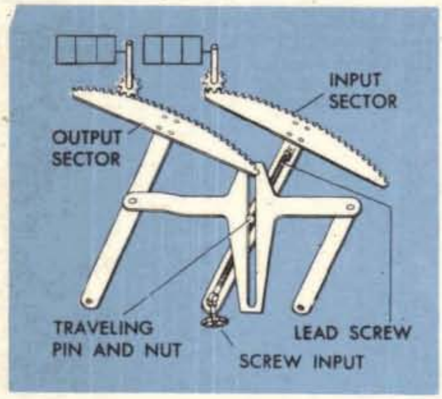
Also, since

$$\frac{D}{E} = f(a), \quad \text{and} \quad c = f(b)$$

$$f(a) = \frac{x}{f(b)}, \quad \text{or } f(a) \times f(b) = x.$$

Each cam output is a function of the cam input and the multiplier's output is the product of these two functions.





Setting the SECTOR TYPE

The parts of the sector type multiplier to be set are:

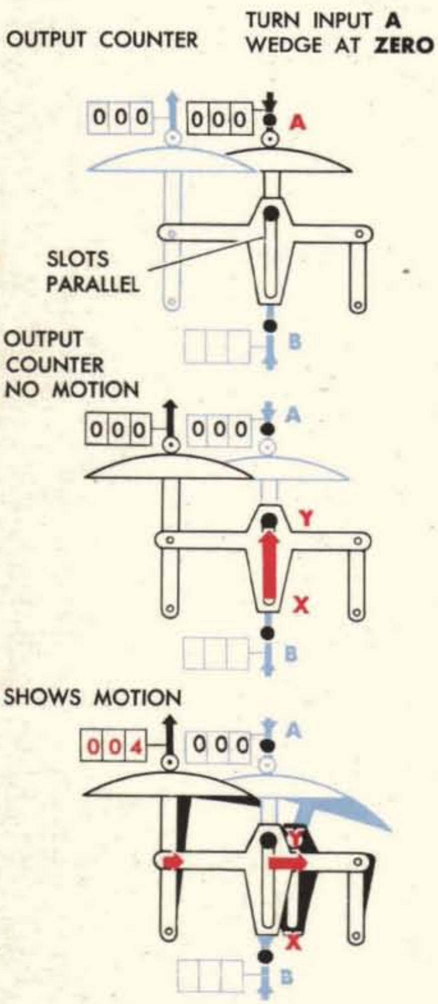
1. The Input Sector
2. The Lead Screw

And the Parts which aid in setting are:

1. The Traveling Nut and Pin
2. The Output Sector

The *INPUTS* go to the Input Sector and the Lead Screw. The *OUTPUT* comes off the Output Sector.

The input shaft *A* positions the Input Sector and also positions the counter. When setting, the purpose is to join the input sector and the counter through the setting clamp so that the position of the sector is exactly indicated by the counter.

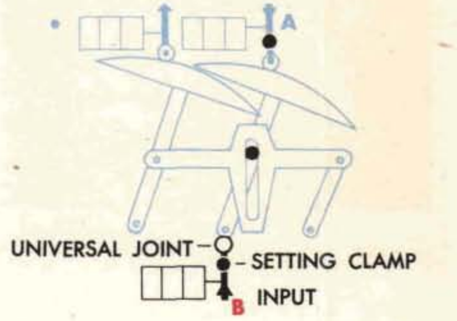


To set the input sector:

1. Turn Input Shaft *A* until counter is at zero. Wedge the Input.
2. Position the Input Sector so that its slot is parallel to the slot in the parallel arm. This is the Zero position for the Input Sector.
3. Slip-tighten the setting clamp.
4. Starting with the Multiplier Pin over the Input Sector pivot pin at *X*, run it to *Y*. Observe the amount of movement of the output counter.
5. Here there is no motion. The Input Sector is set correctly. Since the slots are parallel, the pin can travel along the slots without moving the Output.
6. Here the Input Sector setting is incorrect. The indicator shows the distance the Output Sector moved. This distance represents the amount of error in setting.
7. To correct the error, push the Input Sector, slipping through the setting clamp until the Output indicator returns to its original position.

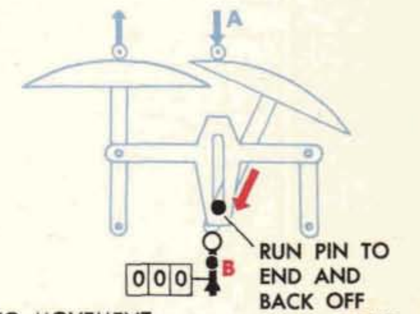
   Always correct with the pin at point *Y*, because this position will give the maximum movement on the indicator.
8. Repeat 4 and 7 as often as necessary to eliminate the movement of the indicator.
9. Tighten the setting clamp.
10. Remove wedge.

MULTIPLIER



The Input shaft *B* turns the lead screw which positions the multiplier pin. This Input shaft also positions the counter. The purpose, when setting, is to join the pin and the counter so that the position of the pin is exactly indicated by the counter.

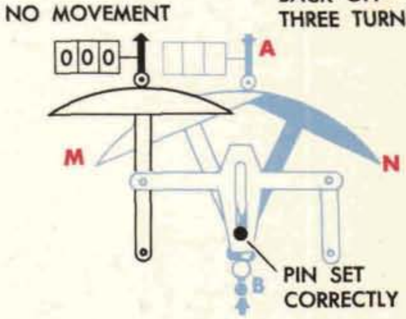
To set the lead screw:



1 Turn the Input shaft *B* until the counter is at Zero. Wedge the Input.

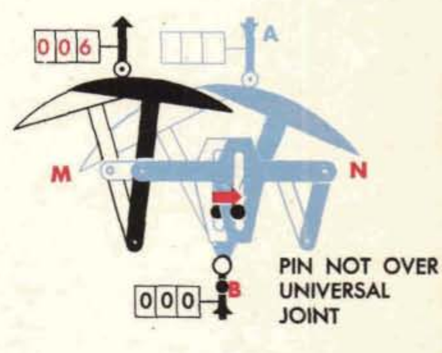
2 Run the pin to the end of the screw near the Input Sector pivot pin, then back off three turns. This is approximately zero for the pin.

3 Slip-tighten the setting clamp.



4 Starting with the input sector at *M* turn input *A* to bring it to *N*. Observe movement of the output indicator.

5 Here there is no movement. The lead screw is set correctly. The pin is right over the universal joint in the screw, and motion of the input sector causes no output.



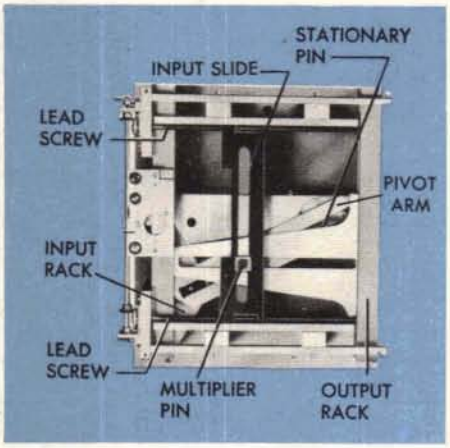
6 Here the lead screw setting is incorrect. The indicator shows the distance that the output sector moved. This distance represents the amount of error in setting.

7 To correct this error, move the pin by slipping the lead screw shaft through the setting clamp. The input shaft *B* should still be wedged. Turn the lead screw shaft until the indicator returns *halfway* to its original reading.

Always correct at *M* or *N* because these positions give the maximum movement on the indicator.

8 Repeat 4 and 7 until there is no movement of the output indicator.

9 Tighten setting clamp. Remove wedge.



Setting the SCREW TYPE

The method of setting the screw type multiplier is very similar to that of the sector type.

The parts to be set are:

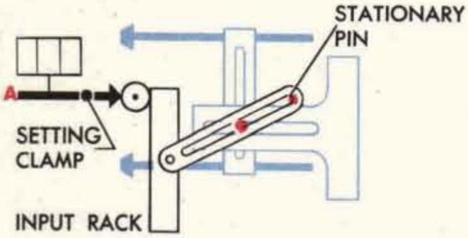
1. The Input rack
2. The Lead screws.

And the parts which aid in setting are:

1. The Input slide
2. The multiplier pin
3. The stationary pin
4. The output rack.

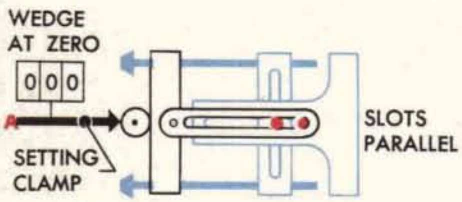
The *INPUTS* go to the Input rack and the Lead screws.

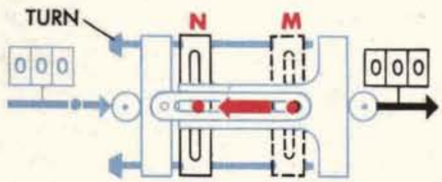
The *OUTPUT* comes off the Output rack.

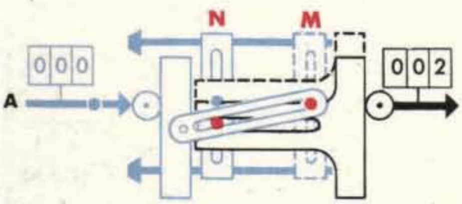


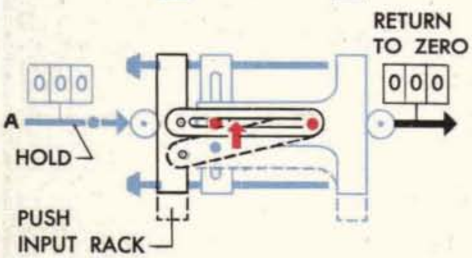
The INPUT shaft *A* positions the Input rack and also positions the counter. The purpose of the setting is to join the Input rack and the counter through the setting clamp so that the position of the Input rack is indicated by the counter.

To set the input rack:



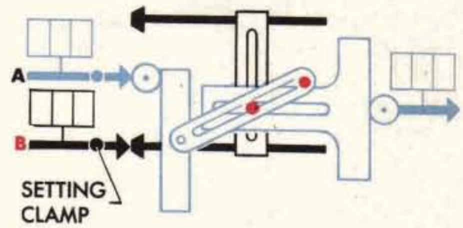






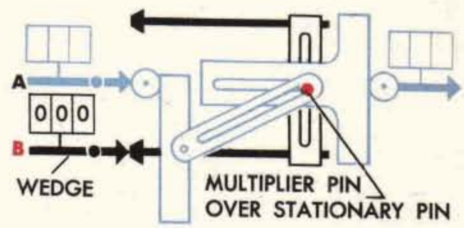
1. Turn Input shaft *A* until the counter is at zero. Wedge the Input.
2. Position the Pivot arm slot of the Input rack so that it is parallel to the Output rack slot. This is approximately zero position for the Input rack.
3. Slip-tighten the setting clamp.
4. Starting with the Input slide at *M* where the multiplier pin is over the stationary pin, run the slide to *N*. Note the movement of the Output indicator.
5. Here the input rack is set correctly. The two slots are parallel and the multiplier pin travels along the pivot arm slot without moving the output rack. There is minimum motion on the output indicator.
6. Here the Input rack setting is incorrect. The slots are not exactly parallel. Moving the Input slide produces an output. The distance the indicator moved represents the amount of error in setting.
7. To correct this error, push the Input rack until the indicator returns to its original position. Always correct with the Input slide at *N* because this position will give the maximum movement of the indicator.
8. Repeat 4 and 7 as often as necessary to reduce the movement of the indicator to minimum.
9. Tighten the setting clamp.
10. Remove wedge.

MULTIPLIER



The Input shaft *B* turns the lead screws which position the Input slide. This Input also positions a counter. When setting, the purpose is to join the lead screw and the counter through the setting clamp so that the position of the slide is exactly indicated by the counter.

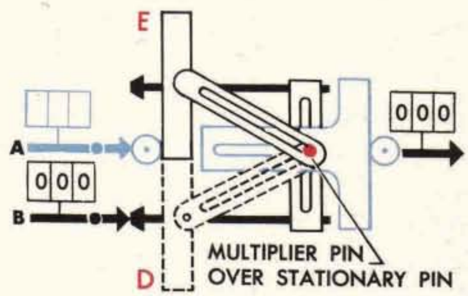
To set the lead screw:



1 Turn Input shaft *B* until the counter reading is zero. Wedge the Input.

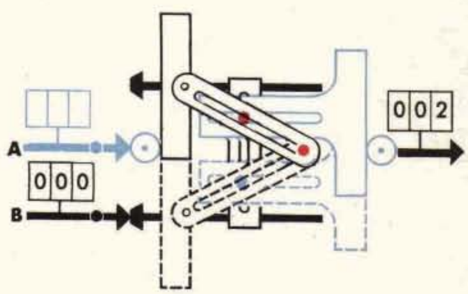
2 Run the Input slide to the point where the multiplier pin is directly over the stationary pin. This is the approximate zero position of the Input slide.

3 Slip-tighten the setting clamp.

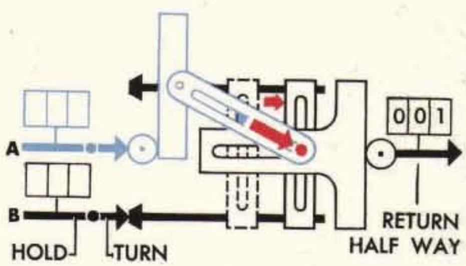


4 Starting with the Input rack at *D,* run it to *E.* Note amount of movement of the output indicator.

5 Here the lead screw is set correctly. Because the multiplier pin in the Input slide is directly over the stationary pin, the Input rack can move without moving the output rack. There is minimum motion on the output indicator.



6 This setting of the lead screw is incorrect. The multiplier pin is not exactly lined up over the stationary pin, so that moving the Input rack causes an output. The distance the indicator moved represents the amount of error in setting.

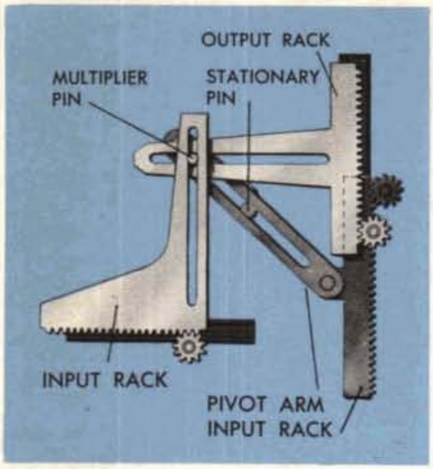


7 To correct the error, move the Input slide by slipping through the setting clamp until the indicator returns *half-way* to its original position.

Always correct at *E* or *D* because these are the maximum positions.

8 Repeat 4 and 7 until there is minimum movement.

9 Tighten the setting clamp. Remove wedge.



Setting the RACK TYPE

The Parts of the Rack Type Multiplier to be set are:

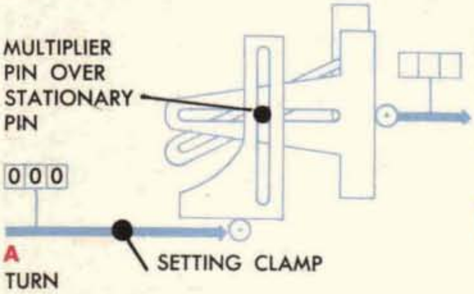
1. The Input Rack
2. The Pivot Arm Input Rack

and the parts which aid in setting are:

1. The Multiplier Pin
2. The Stationary Pin
3. The Output Rack

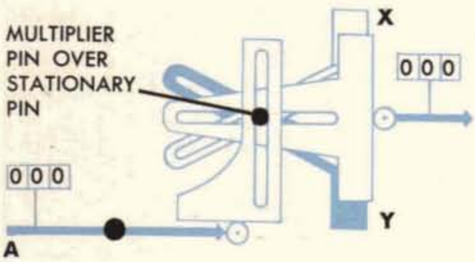
The *Inputs* go to the Input rack and the Pivot Arm Input Rack.

The *Output* comes off the Output Rack.



The input shaft *A* positions the input rack and also positions the counter. The purpose of the setting is to join the input rack and the counter through the setting clamp so that the position of the input rack is indicated by the counter.

To set the input rack:



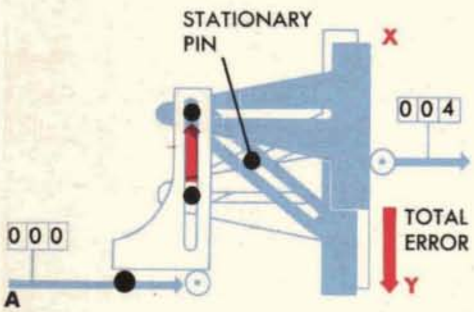
1 Turn the input shaft *A* until the counter is at zero. Wedge the input.

2 Position the input rack so that the multiplier pin is directly over the stationary pin. This is the approximate zero position of the input rack.

3 Slip-tighten the setting clamp.

4 Starting with the pivot arm input rack at *X*, run it to *Y*. Note the motion of the output rack indicator.

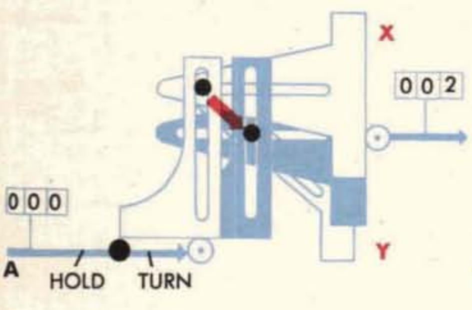
5 Here the input rack setting is correct, because the multiplier pin is directly over the stationary pin and movement of the pivot arm rack causes no motion on the output indicator.



6 Here the input rack setting is incorrect. The pins are not lined up, so when the pivot arm rack is moved there is an output. The distance the indicator moves represents the amount of error in the setting.

7 To correct the error, push the input rack until the indicator returns halfway to its original position.

Always correct with pivot arm input rack at *X* or *Y* because these positions will give the maximum movement on the indicator.



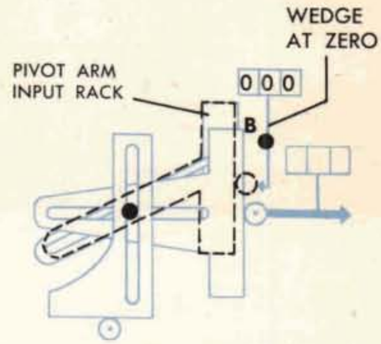
8 Refine the setting until the error is minimum and evenly split.

9 Tighten the setting clamp.

10 Remove wedge.

MULTIPLIER

The input shaft *B* moves the pivot arm input rack. This input also positions the counter. When setting, the purpose is to join the rack and the counter through the setting clamp so that the position of the rack is exactly indicated by the counter.



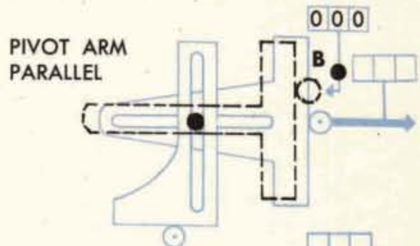
To set the pivot arm input rack:

1 Turn input shaft *B* until the counter is at zero reading. Wedge the input.

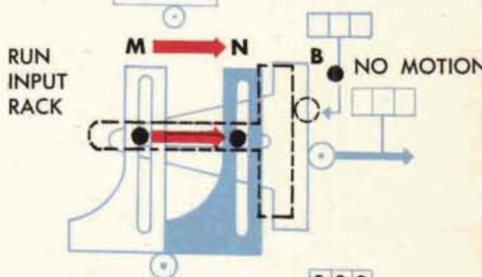
2 Position the pivot arm input rack so that its slot is parallel to the slot in the output rack.

3 Slip-tighten the setting clamp.

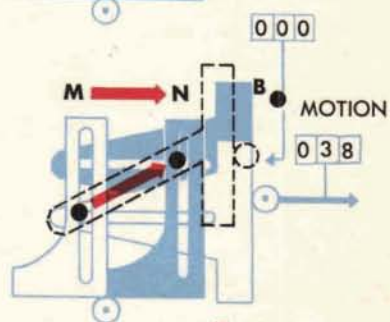
4 Starting with the input rack at *M* turn *INPUT A* and run it to *N*. Note the motion of the output indicator.



5 Here the Pivot-Arm Input Rack setting is correct. The slots are parallel and movement of the Input Rack causes zero or minimum motion on the output indicator.



6 Here the setting of the Pivot Arm Input Rack is incorrect. The slot of the Pivot Arm Input Rack is not exactly parallel, so that when the input rack is moved there is an output. The distance the indicator moves represents the amount of error.

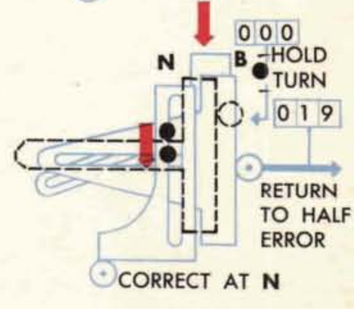


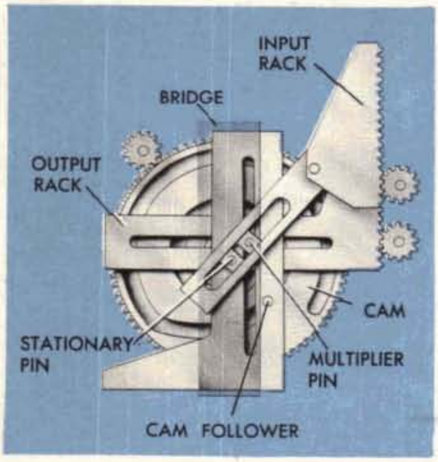
7 To correct this error, push the pivot arm input rack through the clamp until the indicator returns halfway to its original position.

8 Refine the setting until the error is minimum and evenly split.

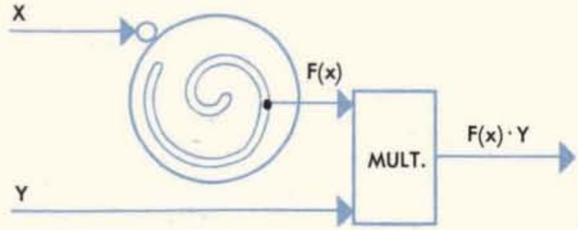
9 Tighten setting clamp.

10 Remove wedge.





Setting the SINGLE CAM



The single Cam Type Multiplier is a combination of a Rack Type Multiplier and a Cam.

Notice here that one *input* to the multiplier is the *output* from the cam.

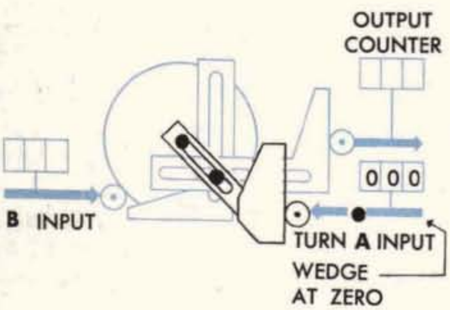
The parts to be set are:
1. The Input Rack
2. The Cam

And the parts which aid in setting are:
1. The Multiplier Pin
2. The Stationary Pin
3. The Output Rack

The *INPUTS* go to the input rack and the cam.

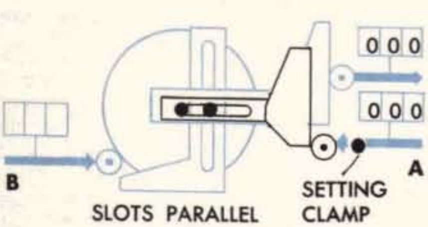
The *OUTPUT* comes off the Output Rack.

Input *A* positions the input rack and also positions a counter. The purpose of the setting is to join the input rack and the counter through the setting clamp so that the position of the input rack is indicated by the counter.

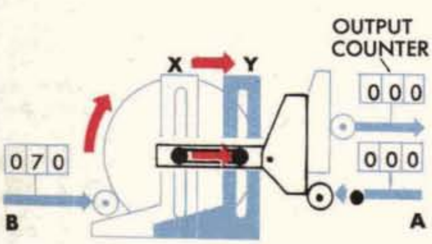


To set the input rack:

1. Turn the input shaft *A* until the counter is at zero. Wedge the input.



2. Position the input rack so that its slot is parallel to the output rack slot. This is the approximate zero position of the input rack.
3. Put the output counter on zero.
4. Slip-tighten the setting clamp.



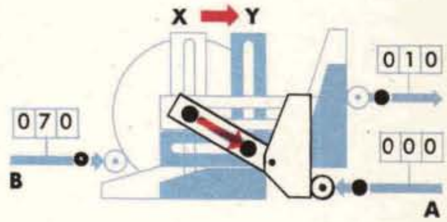
5. Starting with the pin at *X*, where the multiplier pin is at its minimum position, turn the input *B* and run the pin to *Y*. Note movement of the output counter.
6. Here the input rack is set correctly. The two slots are parallel and the pin can travel along its groove without moving the output rack. There is minimum or no motion on the output counter.

COMPUTING MULTIPLIER

7 Here the input rack is set incorrectly. The slot in the input rack is not exactly parallel with the output rack, so that moving the pin causes an output. The change of output counter reading represents the amount of error in setting.

8 To correct this error push the input rack through the setting clamp until the output counter returns to its original position. Always correct at *Y* because this position will give the maximum movement on the output counter.

9 Refine the setting until there is minimum or no motion of the output counter.

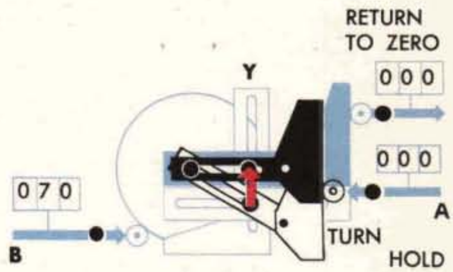


10 With input A counter at 0 and output counter at 0 tighten the setting clamps.

11 Remove the wedge.

Input *B* turns the cam which positions the multiplier pin. This input also positions a counter.

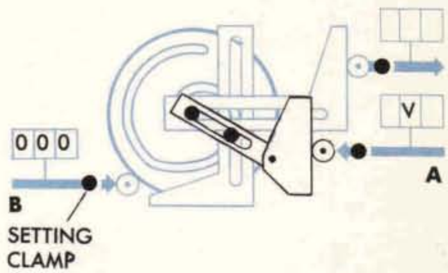
When setting, the purpose is to join the cam and the counter through the setting clamp so that the position of the cam is exactly indicated by the counter.



To set the cam:

1 Position the input rack at *V*. Wedge the input. This is a maximum position. The counter reading, *V*, is given in each Computer's setting notes.

Assume that with a cam input of 60 and with the input rack at position *V* the output will be 135.

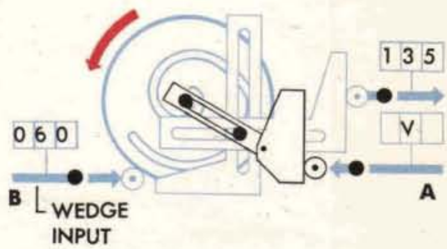


2 Now turn input *B* until the input counter reads 60 and wedge the input.

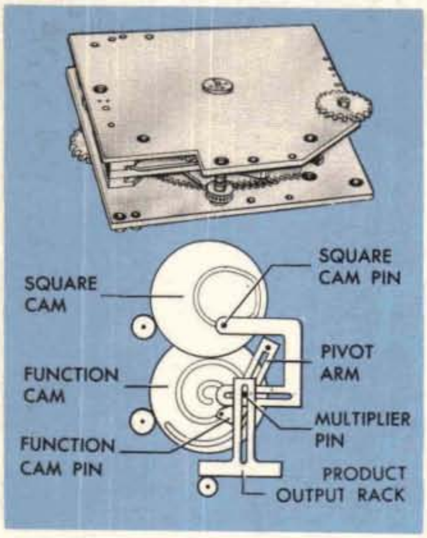
3 Turn the cam until the output counter has the correct output reading 135 for the given input reading 60.

NOTE: The Computer's setting notes give the output reading for the input value to be used as the setting position.

4 Tighten the setting clamp. Remove the wedges.



Setting the TWO CAM



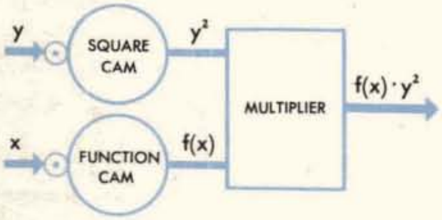
The double cam multiplier is a combination of a rack type multiplier and two cams. Usually one of these is a square cam, and the other a function cam.

The parts to be set are:

1. The Square Cam
2. The Function Cam
3. The Output Counter

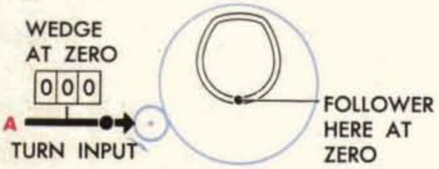
The parts which aid in setting are:

1. The Function Cam Pin
2. The Square Cam Pin
3. The Output Rack
4. The Pivot Arm



Inputs go to the square cam and the function cam. Outputs come off two racks, but only the output which gives the *product* of the cam outputs is used in setting.

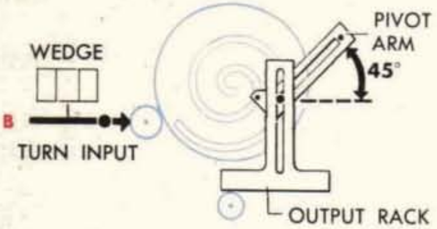
The square cam is positioned by input *A* which also positions the counter. In setting, the purpose is to join the square cam and the counter through the setting clamp so that the position of the square cam is exactly indicated by the counter. The method consists of turning the square cam input exactly the same amount above zero and below zero, and adjusting the setting clamp until the cam gives the same positive output for each of these two inputs.



Setting the square cam

1. Turn the input *A* until the counter setting is zero. Wedge the input.
2. Position the square cam at its estimated zero position.
3. Slip-tighten the setting clamp. Remove the wedge. The cam is now approximately set to the counter.
4. Position the function cam so that the pivot arm is at approximately its maximum position which is near the center.

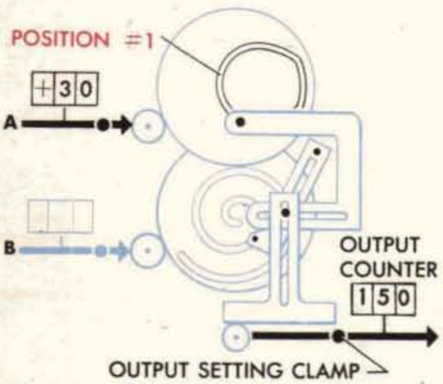
   At this position of the cam the pivot arm is at a 45° angle to the output rack, so any motion of the square cam follower will cause maximum motion of the output rack.



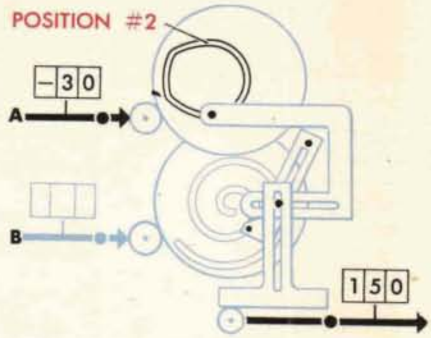
5. Put the output rack counter on zero.
6. Slip-tighten the output clamp.
7. To check how closely the square cam was set at the zero position, set up a table like this:

	SQUARE CAM INPUT COUNTER READING	OUTPUT COUNTER READING
POSITION #1	**plus 30**	**output #1**
ZERO	**0**	**0**
POSITION #2	**minus 30**	**output #2**

8. Turn input *A* to run the square cam to Position #1 (exactly plus 30 in this example).
9. Record the reading of the output counter.



COMPUTING MULTIPLIER

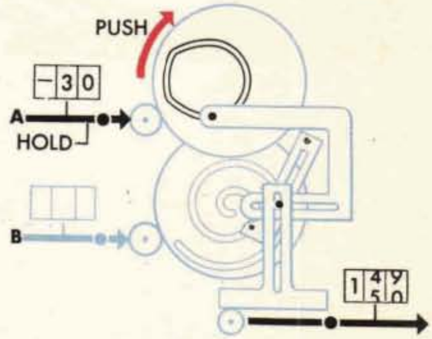


10 Now turn input *A* to run the square cam to Position #2 (exactly minus 30 in this example).

11 Record the reading of the output counter. If the setting is correct, output #1 will equal output #2.

12 Here the square cam is set correctly:

POSITION #1	**plus 30**	**plus 150**
ZERO	**0**	**0**
POSITION #2	**minus 30**	**plus 150**



13 Here the setting is incorrect; the readings do not agree.

POSITION #1	**plus 30**	**plus 125**
ZERO	**0**	**0**
POSITION #2	**minus 30**	**plus 175**

14 To correct, first find the average output counter reading. To do this add output #1 and output #2, and divide by 2:

Output #1	125
Output #2	175
	$300 \div 2 = 150$

15 Then with the square cam input counter held at its reading for either Position #1 or Position #2, slip the square cam until the output counter is at the average reading.

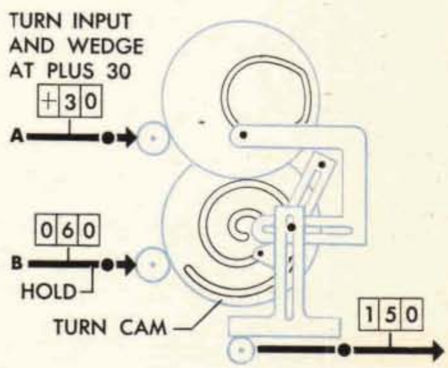
16 Return the input counter to zero by turning input *A* and reset the output counter on zero.

17 Repeat until equal output readings are obtained.

18 Tighten the setting clamp.

Setting the function cam

NOTE: These readings are samples. The actual values are given in each Computer's setting notes.



1 Turn input *A* to bring the square cam to Position #1 (plus 30). Wedge input *A*.

2 Put input *B* counter on 60. Wedge the counter.

3 Turn the function cam until the output counter reading is 150. The cam follower is near the inner radius of the cam.

4 Tighten the setting clamp.

5 Remove the wedges.

COMPONENT SOLVERS

To solve a fire control problem, it is not enough to know the speed and direction of own ship, the target, the wind, and other variables.

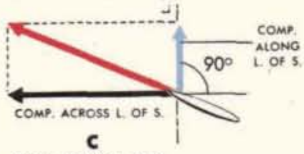
These velocities must be broken down into their COMPONENTS along and across the line of sight.

Finding the components of velocities is a simple enough mathematical job, but it takes too much time to do it with pencil and paper under combat conditions.

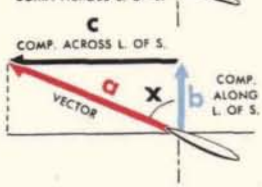
Component solvers break down these velocities or other variables, giving their components instantly, accurately, and continuously.

Remember? A velocity vector looks like this. It is an arrow that represents a speed in a certain direction. The length of the arrow represents speed. The angle between the arrow and a reference axis represents direction.

In fire control this axis is usually the line of sight. The components of the vector are represented by two arrows: one along the axis, and the other at right angles to the axis.



By drawing the component across the line of sight in this position, the vector and two components make a right triangle. This is the way components are usually shown.

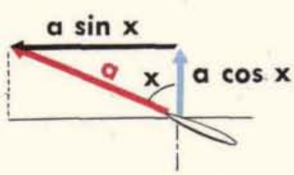


The values of the two components are easily figured from this triangle.

$$\text{Cos}\, X = \frac{b}{a} \qquad b = a\, \text{Cos}\, X$$

So the component *along the line of sight* will always have the value of the vector *times the cosine of the vector angle.*

$$\text{Sin}\, X = \frac{c}{a} \qquad c = a\, \text{Sin}\, X$$

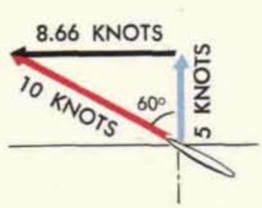


So the component *across the line of sight* will always have the value of the *vector times the sine of the vector angle.*

Here's an example: A ship is traveling at 10 knots at 60° to the line of sight.

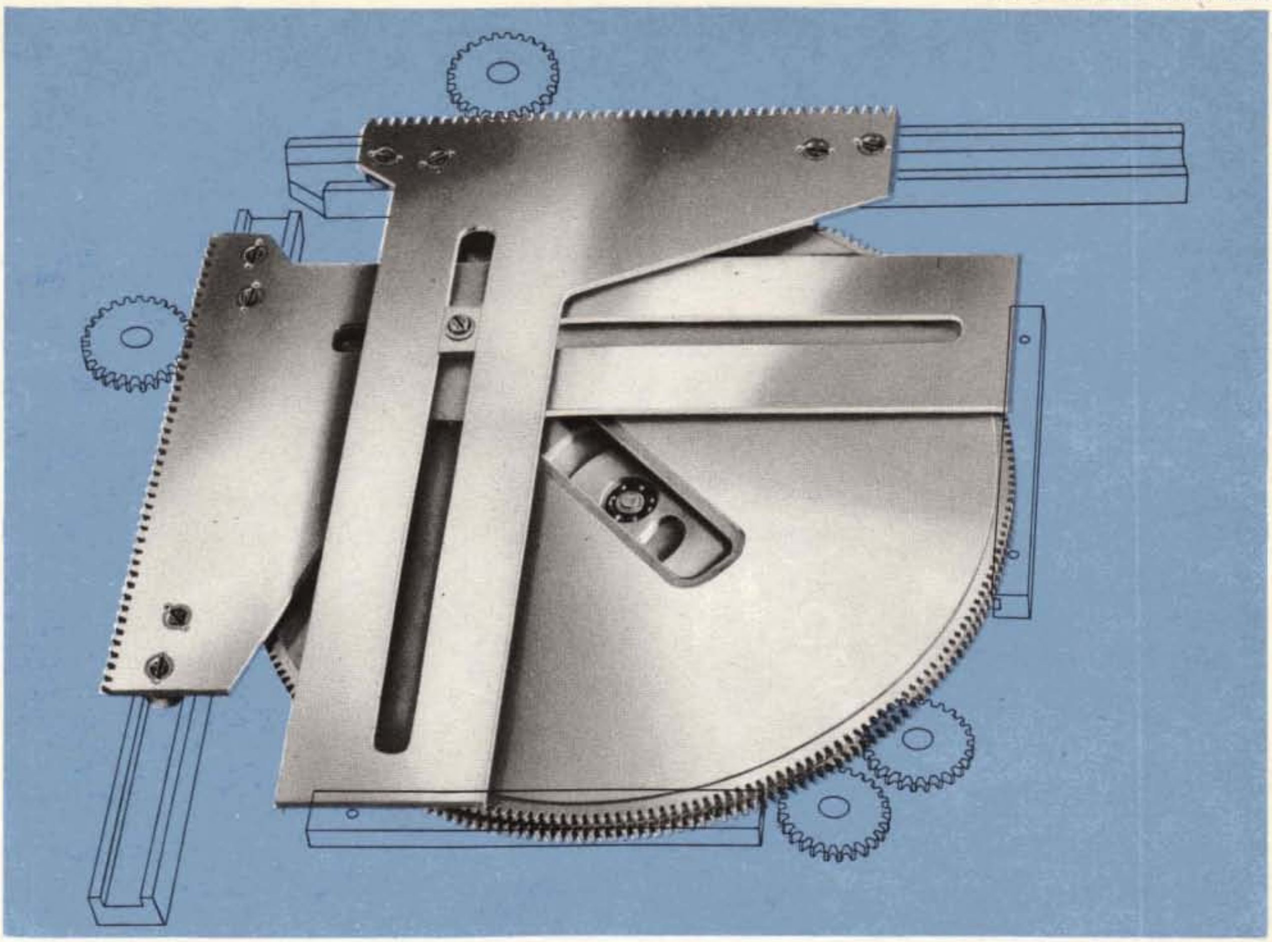
The cosine of 60° is .5. The sine of 60° is .866.

The component along the line of sight = 10 knots × .5 = 5 knots. The component across the line of sight = 10 knots × .866 = 8.66 knots.



SO THE SPEED OF 10 KNOTS AT 60° HAS THE SAME EFFECT AS SIMULTANEOUS SPEEDS OF 5 KNOTS ALONG THE LINE OF SIGHT AND 8.66 KNOTS ACROSS IT.

There are other kinds of vectors besides velocity vectors. A distance in a given direction is a vector, and can be broken down into components exactly like a velocity.



This is a CAM TYPE COMPONENT SOLVER

Cam type solvers are used to resolve many different vectors in the fire control problem.

The own ship component solver is typical.

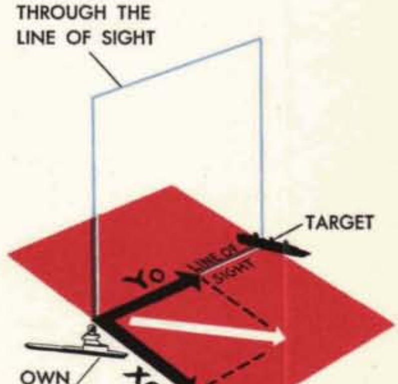
It breaks down own ship speed along her course into:

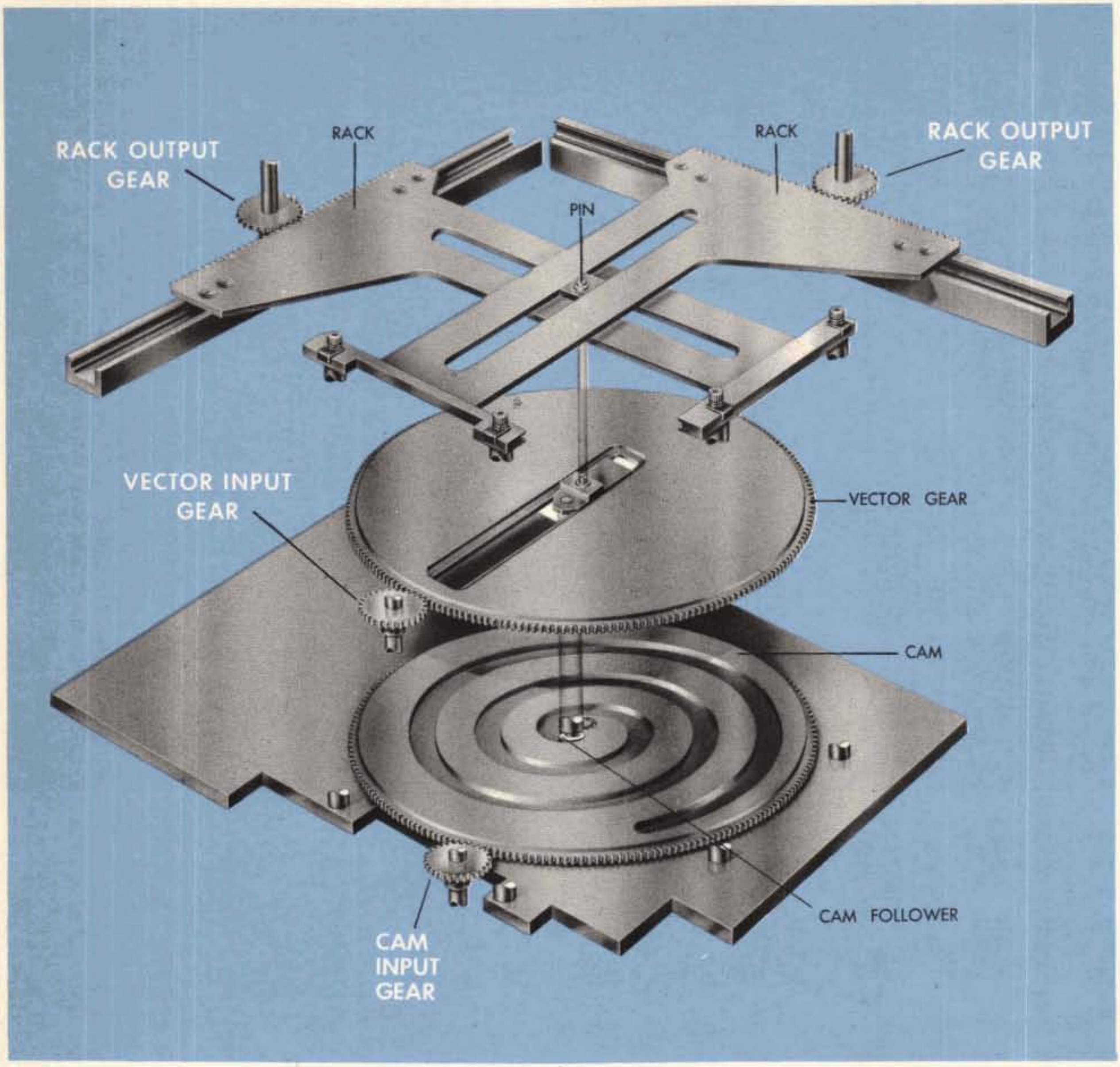
1 The speed at which she is moving on a line straight toward the target—along the line of sight. (More accurately, the horizontal component of own ship velocity in vertical plane containing the line of sight, *Yo*.)

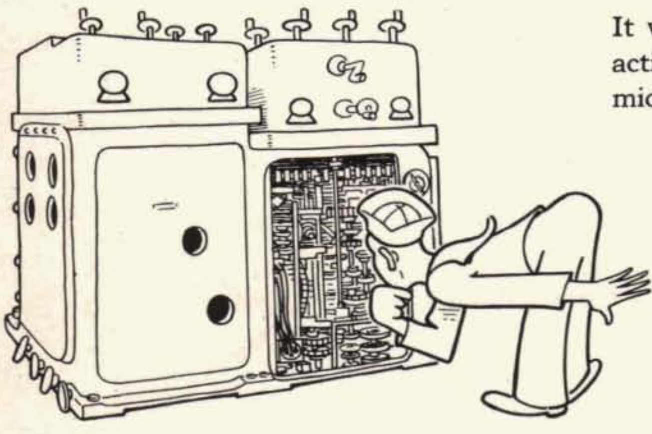
2 The speed at which she is moving at right angles to the line of sight. (More accurately, the horizontal component of own ship velocity at right angles to the line of sight, *Xo*.)

The ship's speeds in these two directions are called the COMPONENTS of her actual speed along her course.

Her actual speed along her course is the VECTOR which the ship's component solver resolves.







It will be difficult to see a component solver in action because most of them are buried in the middle of a lot of other mechanisms and gears.

Take a look inside the solver

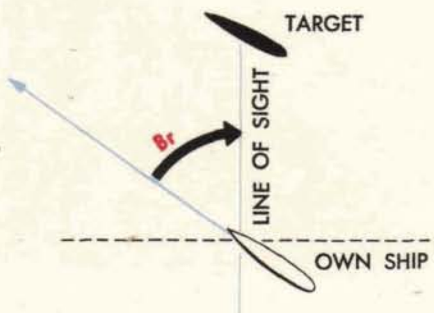
The ship component solver has five main parts:

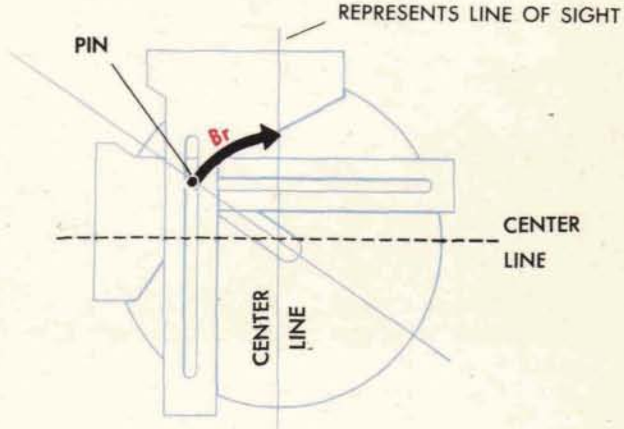
- a cam
- a vector gear
- a pin and follower
- two racks

The cam generally has a "constant lead" spiral groove. It is called the speed gear because it is turned amounts corresponding to changes in speed of the ship. It turns in one direction when the ship is picking up speed, and in the opposite direction when the ship slows down.

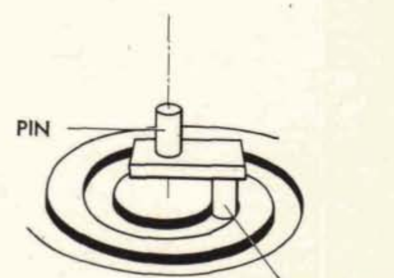
The vector gear has a straight slot, passing through its center. The vector gear is turned by its input gear in such a way that:

The angle between one center line of the component solver and the slot in the vector gear is always equal to the angle between the fore and aft axis of own ship and the line of sight, measured clockwise from the bow. This angle is called *Br,* relative target bearing in the horizontal plane.





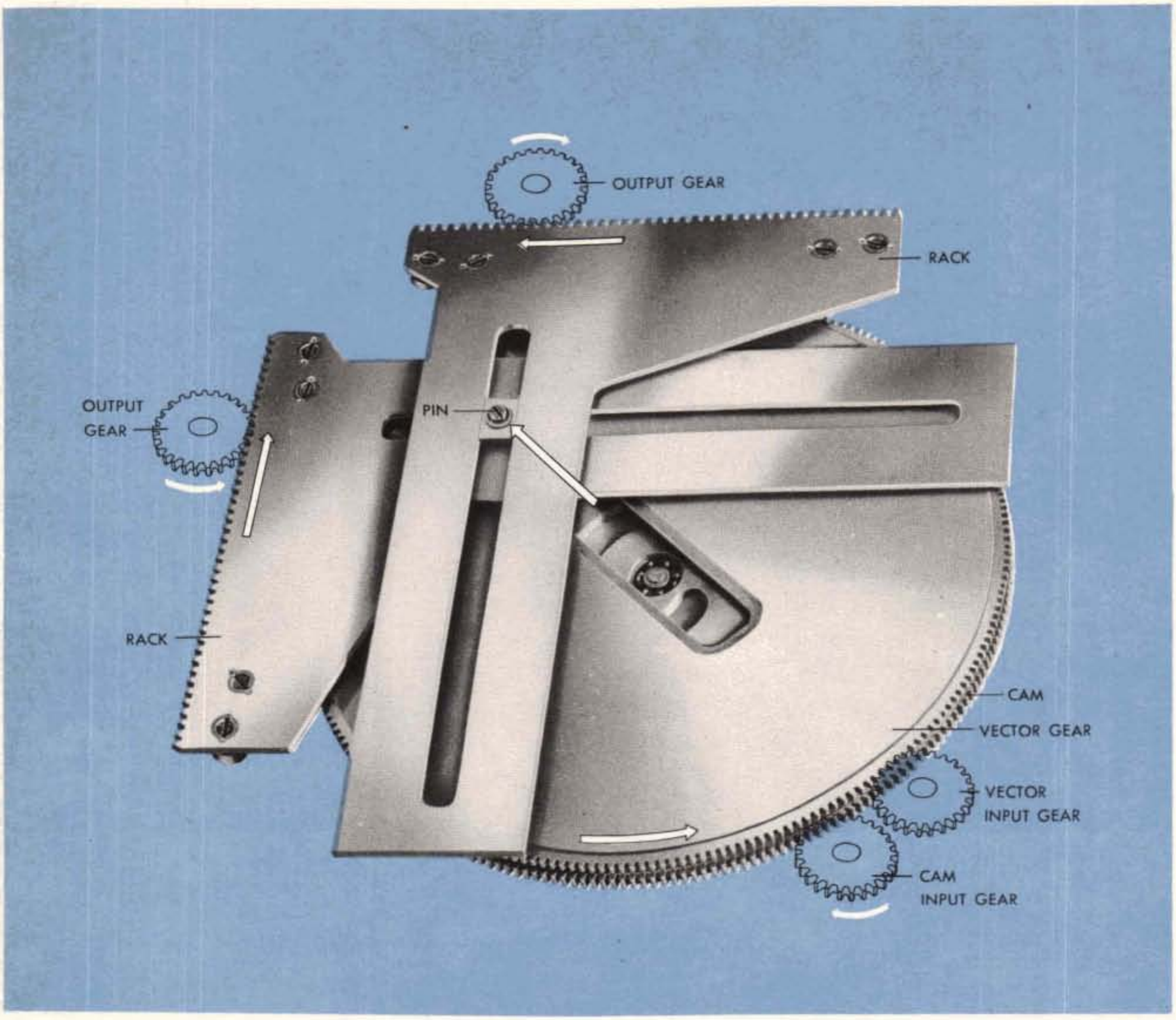
The vector slot represents the fore and aft axis of own ship. One of the center lines represents the line of sight.



The pin is joined to a block which also carries the cam follower. The follower is offset a little from the pin so that the pin is over the center of the cam when the follower is near the inner end of the cam groove.

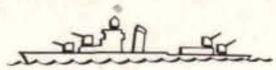
The follower rides in the cam groove and the pin comes up through the slot in the vector gear, so the pin is moved by both the cam and the vector gear, radially by the cam, and angularly by the vector gear.

The two racks are pushed back and forth along their guides by the pin. This movement in turn rotates the two output gears which deliver the components to other mechanisms.



A quick run through the actions

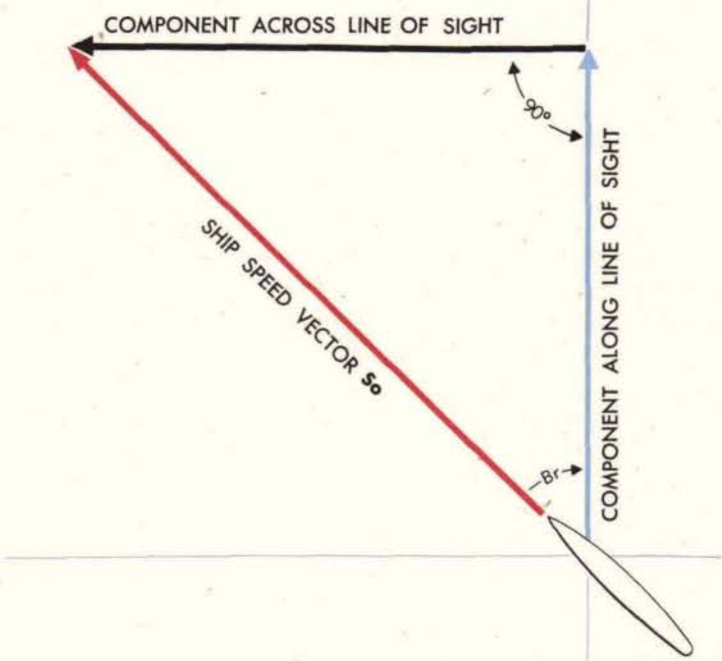
The input gears turn the cam and vector gear.
The cam and the vector gear move the pin.
The pin pushes the racks into position.
The racks turn the output gears.



Knowing how the solver's parts move, the next step is to find out what all this has to do with speed vectors.

Before the mechanism can start to solve any components there must be a vector. The vector is going to be the speed of own ship along its course in relation to the line of sight. The component solver's work can be divided into two parts:

- **A** It must set up a vector of the ship's motion.
- **B** It must solve the components of that vector.

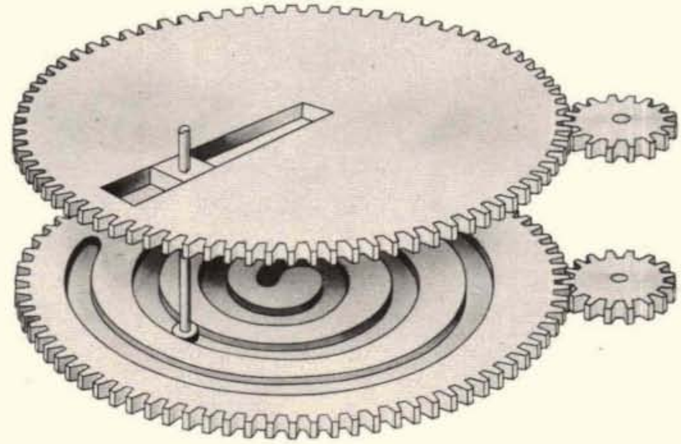


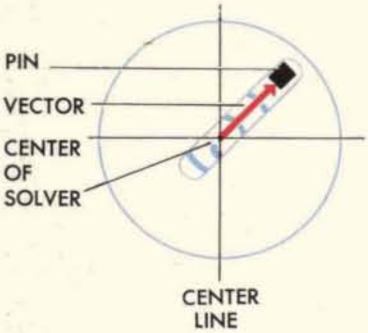
The two components needed are:

1. Speed along the line of sight for range changes.
2. Speed across the line of sight for deflection changes.

These linear motion components are used by other mechanisms which compute deflection prediction and range prediction.

How the VECTOR

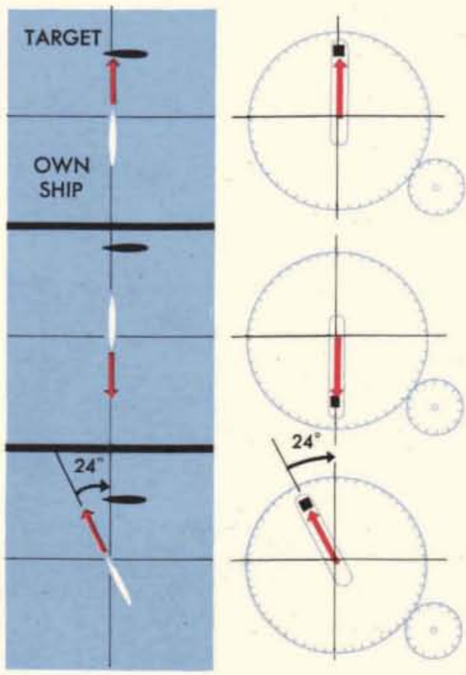




Just this much of the mechanism—the cam, the vector gear, and the pin—establish the vector.

THE VECTOR WILL BE THE LINE FROM THE CENTER OF THE SOLVER TO THE PIN.

The direction of the vector is controlled by the vector gear. The vector gear input turns the vector gear so that the angle between its slot and the center line of the solver corresponds to the angle between the fore and aft axis of own ship and the line of sight.



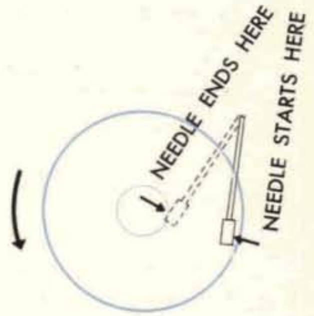
Here the ship is approaching the enemy right along the line of sight. The slot is along the center line of the solver.

Here the ship's course is still along the line of sight but the ship is moving *away* from the target.

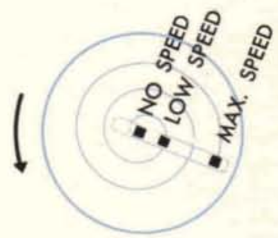
In this case the ship's axis is at 24° to the line of sight. The slot repeats this angle with the center line.

is set up

The *length of the vector* is put into the solver by the speed cam.

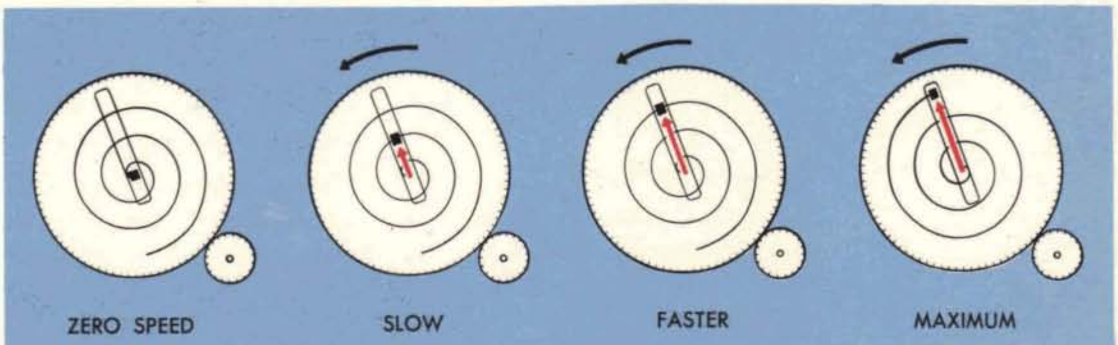


The spiral in the speed cam works like the groove in a phonograph record. As the record turns, the phonograph needle in the groove travels toward the center of the record.

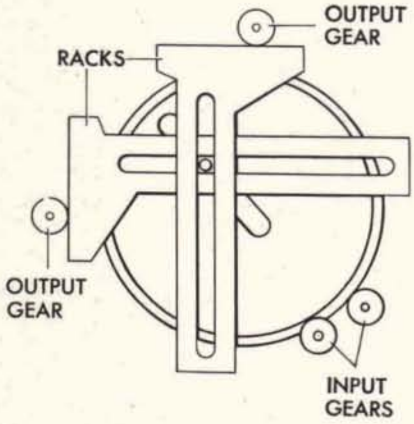


The pin does the same. It moves back and forth in the slot in the vector gear when the speed cam is turned, so that for every speed of the ship there is a definite position of the pin.

This sets up the length of the vector.



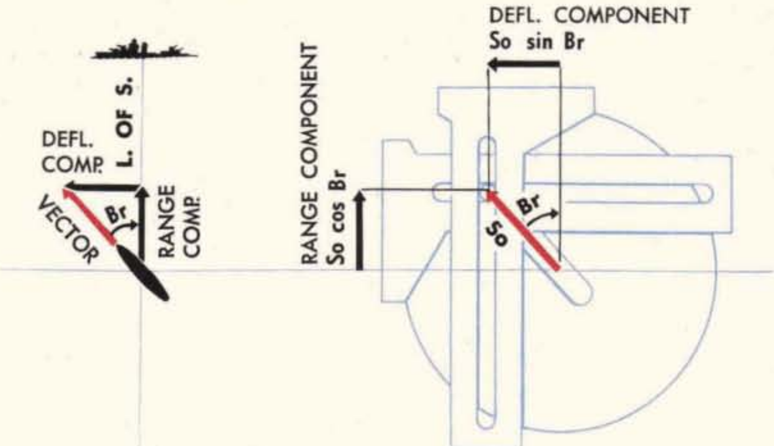
How the components



Up to this point the cam, the vector gear, and the pin have done all the work. Now the output racks come into the picture.

The pin comes up through the slots in the racks, so that every time the pin is moved it will push the racks to new positions. The positions of the racks tell the length of the components.

THE COMPONENTS OF THE VECTOR ARE THE DISTANCES FROM THE CENTER LINES OF THE COMPONENT SOLVER TO THE SLOTS IN THE RACKS.



One rack moves up and down, giving the value of the component along the line of sight, called the RANGE RATE COMPONENT, Yo.

This component will have the value of the speed, So, multiplied by the cosine of Br. (So Cos Br.)

The second rack moves from side to side, giving the components across the line of sight, called the DEFLECTION RATE COMPONENT, Xo.

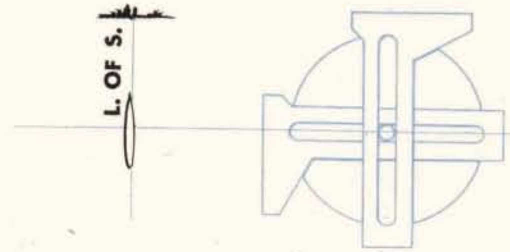
The deflection rate component will equal the speed times the sine of Br. (So Sin Br.)

Every time the rack moves it turns its output gear a proportionate amount. This turning of the output gears positions the output shafts. The positions of these shafts at any moment transmit to other mechanisms the values of the components of ship speed.

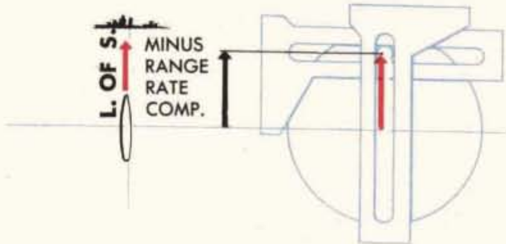
As both racks can move on either side of their center or zero position, both plus and minus values can be obtained.

are SOLVED

Here the ship is not moving at all. The solver is in zero position. The pin is at the center. Both racks lie across the CENTER of the vector gear. Both outputs are zero.



Here the ship is going straight towards the target, so that the range rate component is minus and equal to the whole vector.



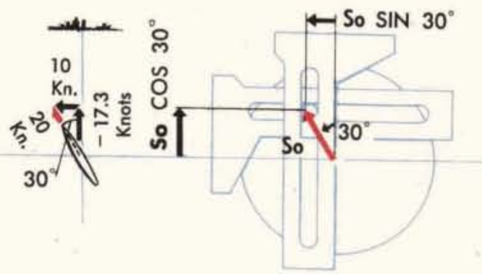
Here the ship is moving at 30° to the line of sight. Its speed is 20 knots.

$\text{Sin } 30° = .5, \text{Cos } 30° = .866$

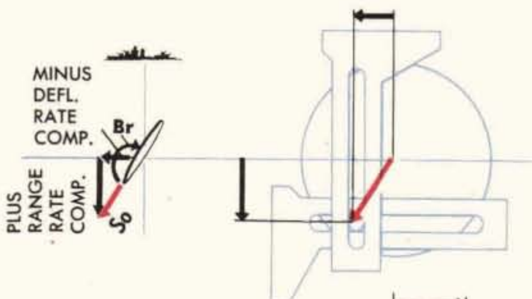
The values of the components are:

Range rate component 20 knots × .866 = 17.3 knots along the line of sight.

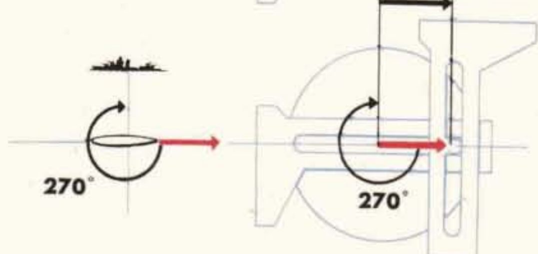
Deflection rate component 20 knots × .5 = 10 knots across the line of sight.



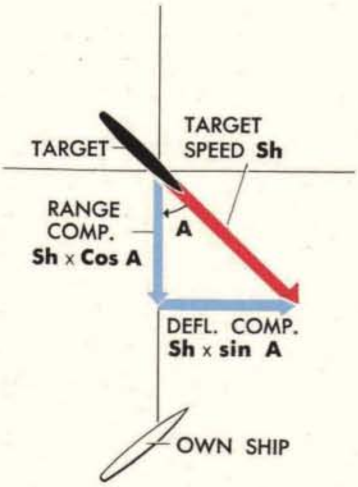
In this example own ship is moving away from the target at 150°. The vector is long, corresponding to 45 knots.

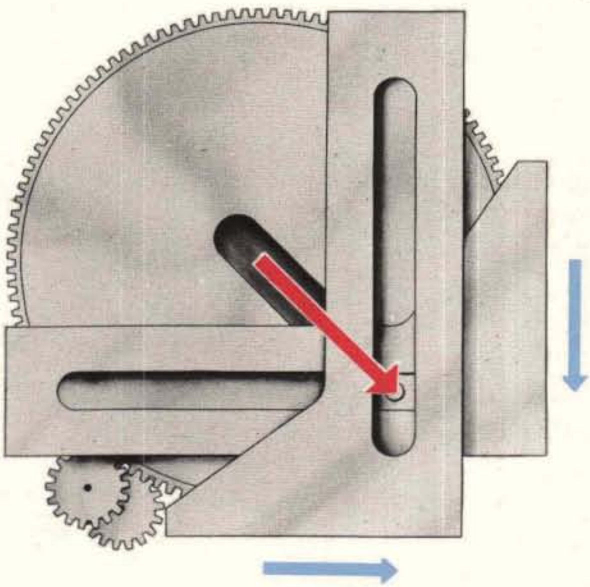


Here the ship moves with a speed of 45 knots across the line of sight, at 270°. The deflection rate component equals the whole vector and is plus. The range rate component is zero.



A cam type solver is also used as the TARGET component solver





The target vector must also be broken down into components along and across the line of sight.

Another cam type solver is used, which is like the ship's solver but often larger.

The vector in this case is target speed and direction. The input to the cam will be Target Speed, *Sh,* horizontally with respect to the earth. The input to the vector gear will be Target Angle, *A,* the angle between the target's direction and the line of sight.

The value of the range component will be: $Sh \times \text{Cos } A$.

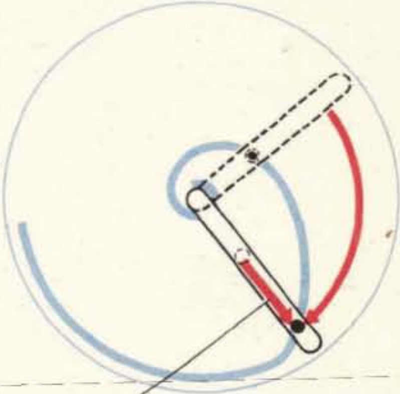
The value of the deflection component will be: $Sh \times \text{Sin } A$.

Why the vector gear input must also go to the cam

So far, the inputs to the speed cam and to the vector gear have been treated as if they were independent of each other.

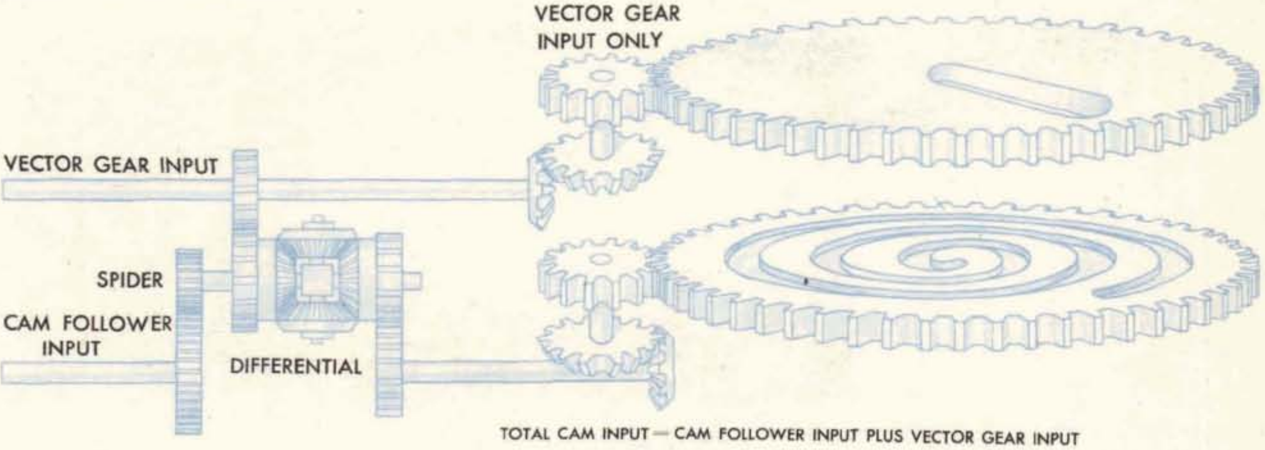
Actually they are not.

If the vector gear should turn while the cam was held stationary, the vector slot would move the pin along the cam groove and disturb its position. *This would give a false value for the length of the vector.*



PIN HAS BEEN MOVED THIS MUCH FARTHER FROM CENTER BY TURNING OF VECTOR GEAR ONLY

Such errors are prevented by a differential in the cam input line. The vector gear input is meshed with one input of the differential; the cam follower input is meshed with the spider. The output of the differential is geared to the cam. This differential is called a "compensating" differential. Every component solver has one.



TOTAL CAM INPUT — CAM FOLLOWER INPUT PLUS VECTOR GEAR INPUT

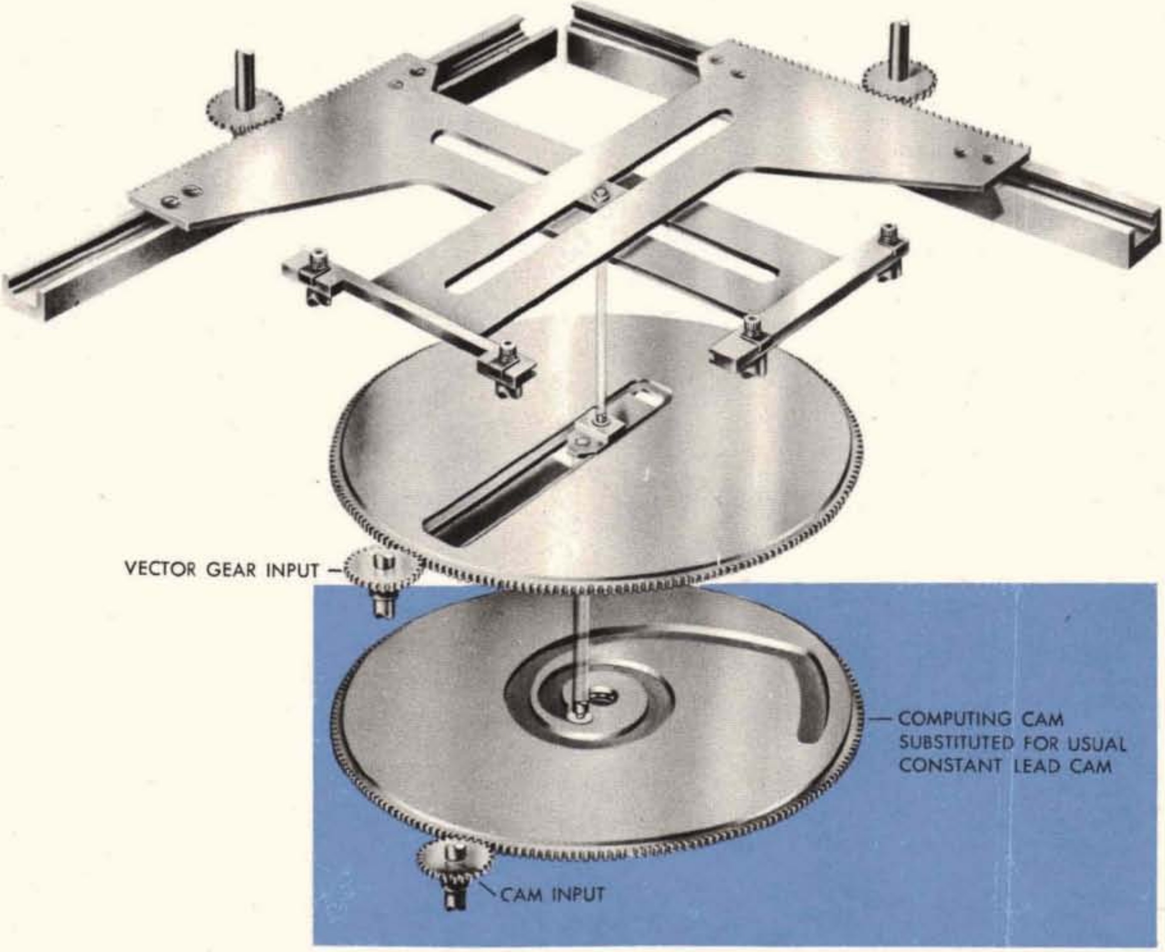
If there is no motion of the cam follower input, the spider is held stationary, and the vector input drives through the differential to turn the cam equally with the vector gear. This prevents the vector slot from pushing the cam follower along the cam groove.

If there is no motion of the vector input, the cam follower input drives through the spider of the differential to turn the cam without disturbing the vector gear.

THE VECTOR GEAR IS TURNED ONLY BY VECTOR INPUTS.

THE CAM IS TURNED BY CAM FOLLOWER INPUTS PLUS VECTOR INPUTS. IN THIS WAY THE VECTOR GEAR CAN BE TURNED WITHOUT DISTURBING THE VALUE REPRESENTED BY THE PIN.

Component solvers sometimes



A component solver's outputs will always be:

The VALUE set in by the CAM times the sine or cosine of the angle set in on the vector gear.

The cam always controls the length of the vector.

Sometimes this vector length is a value which itself must be figured on a computing cam.

THEN INSTEAD OF HAVING THE OUTPUT FROM THE COMPUTING CAM FEED INTO A CONSTANT LEAD CAM IN THE COMPONENT SOLVER, THE COMPUTING CAM ITSELF IS BUILT INTO THE SOLVER.

have COMPUTING CAMS

The parallax component solver is an example.

Some of the parallax corrections need the value:

$$\frac{1}{\text{Predicted Range}} \times \text{sine of train angle}$$

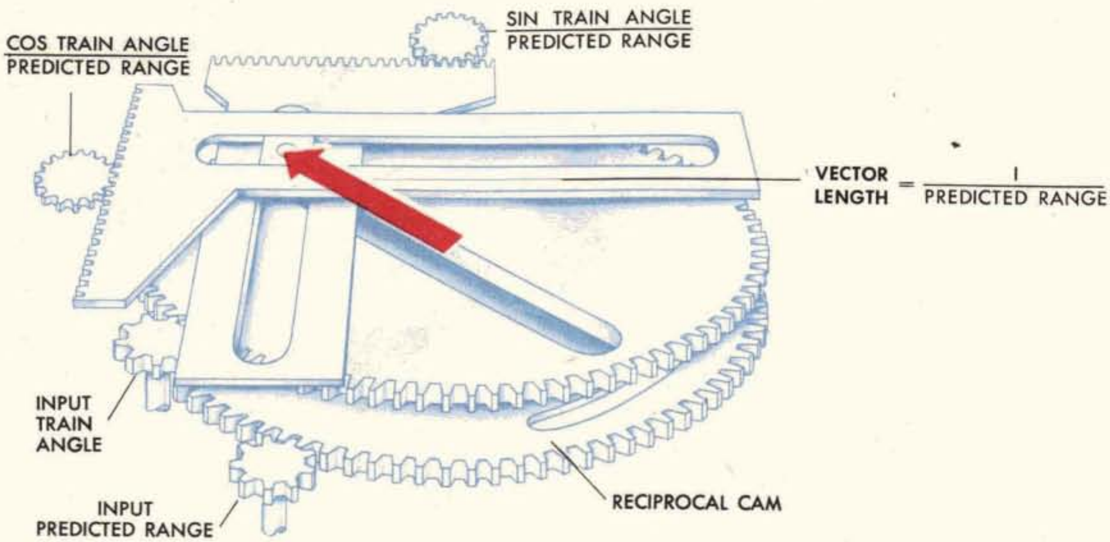
The length of the vector in the parallax solver will be the reciprocal of predicted range.

To compute the reciprocal of predicted range the parallax solver has a reciprocal cam whose input is predicted range.

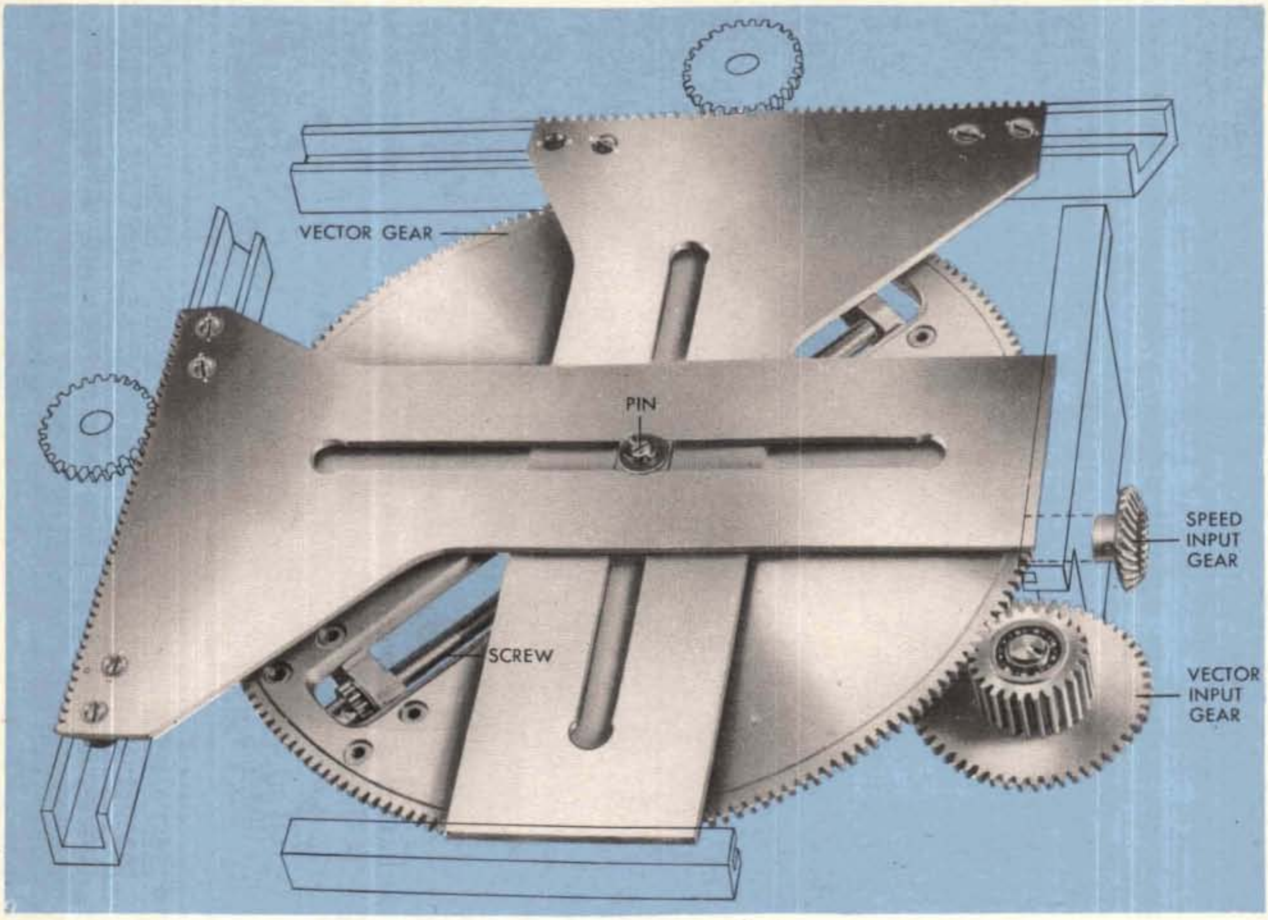
The second input to the solver is train angle (either gun train or director train).

The two outputs will be

$$\frac{\text{Sin train angle}}{\text{Predicted Range}} \text{ and } \frac{\text{Cos train angle}}{\text{Predicted Range}}$$



Several kinds of computing cams are used this way in component solvers.

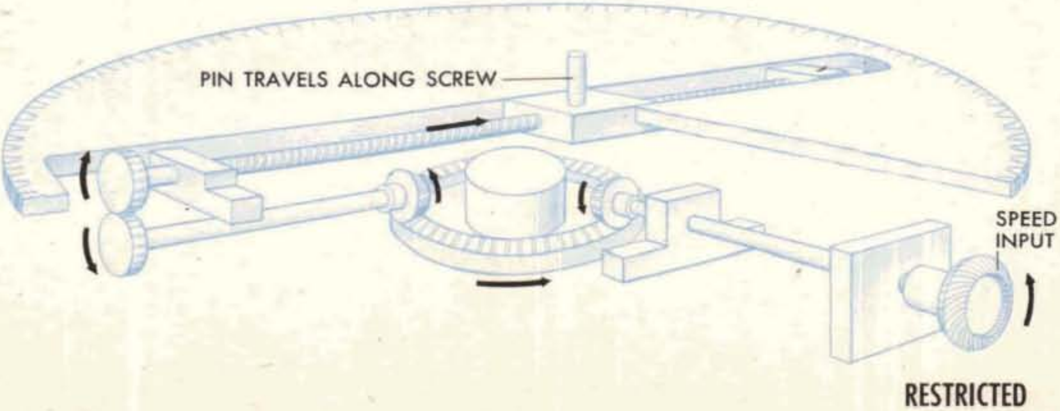


This is a SCREW TYPE component solver

The screw type component solver works very much like the cam type.

It is called the screw type because there is a long screw set in the slot in the vector gear. This screw takes the place of a speed cam—it positions the pin.

The speed input gear drives a line of gearing which turns the long screw. As the screw turns, the pin moves along it, changing the length of the vector.



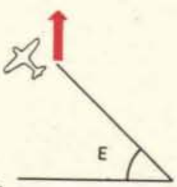
In the cam type component solver the pin can only travel half the width of the cam, i.e., between the center and the circumference.

In the screw type the pin can travel along the screw almost the full width of the vector gear.

The pin can travel along the screw in either of two directions from its center zero position.

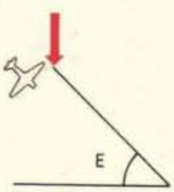
These two directions correspond to positive and negative values.

For any one position of the vector gear the pin can represent vectors in opposite directions. An example is vertical target speed.



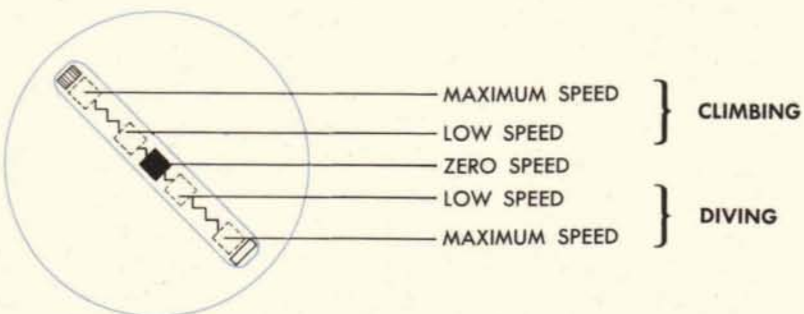
The speed is positive when the target is climbing.

E IS THE SAME IN EACH CASE, BUT THE DIRECTION OF THE VECTOR REVERSES



The speed is negative when the target is diving.

For any angle of the vector slot the pin can show all the speeds from maximum climbing to maximum diving speed:

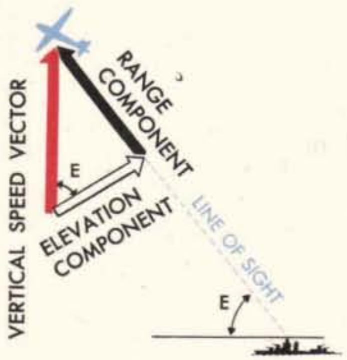


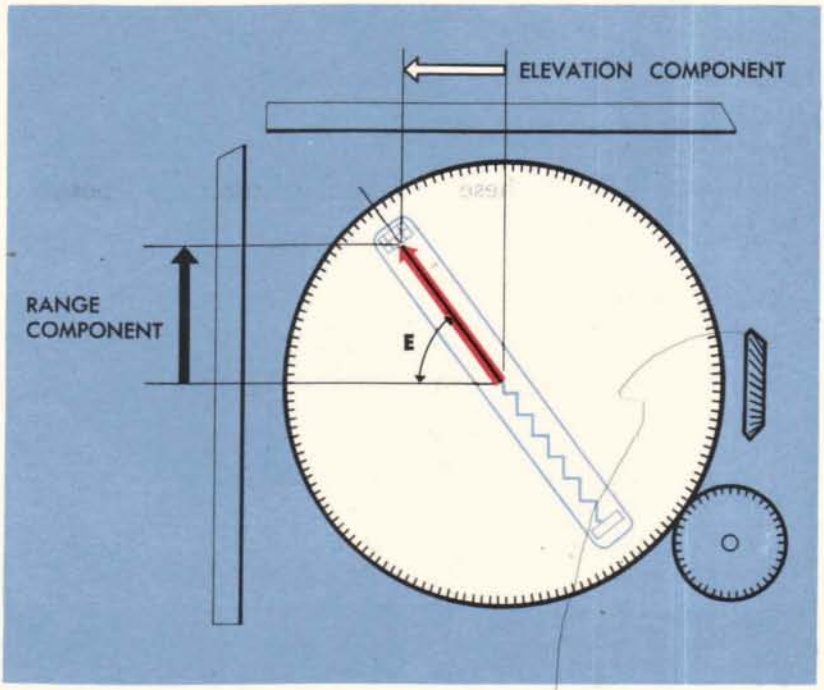
Screw type component solvers

In breaking up the vertical target speed vector, the direction of the slot in the plate must correspond to the angle of elevation, because components are needed:

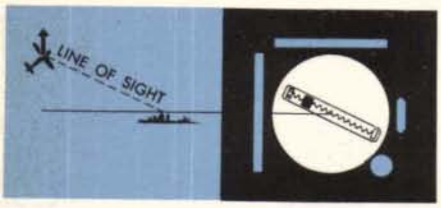
A Along the line of sight for range rate.

B Perpendicular to the line of sight in the vertical plane containing the line of sight, for elevation rate.

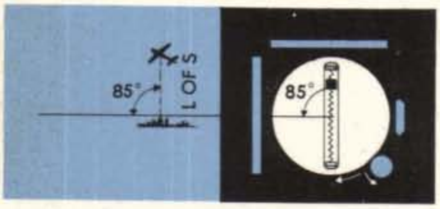




The elevation angle, E, usually varies from a low limit of $-25°$ to a high limit of $+85°$. The vector gear, therefore, need only move between these limits.



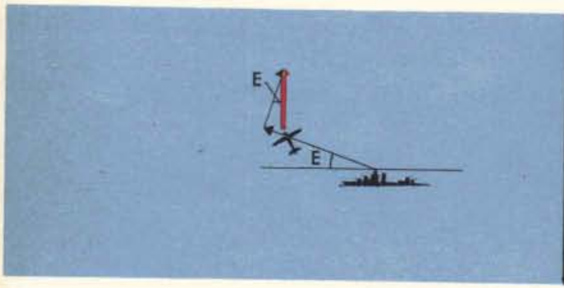
Here the slot is almost horizontal because the target is very near the water.

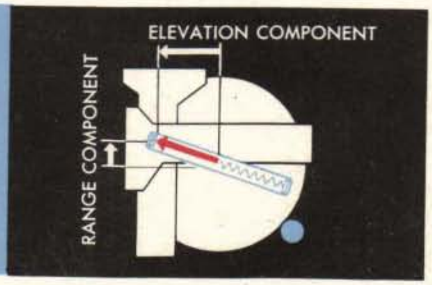


Here the slot is at 85° because the target is almost directly overhead.

But because the slot goes right across the vector gear, the components can be in either direction, in spite of this limited movement of the vector gear.

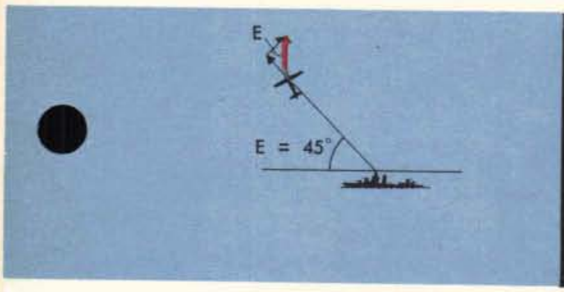
Here's how the solver follows the movement of a target . . .

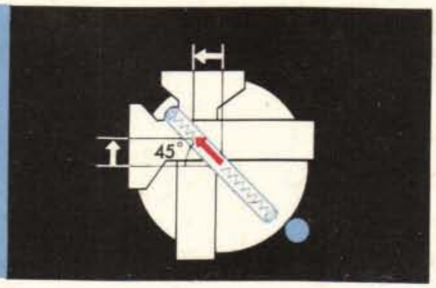




The plane is near the water but rising fast.

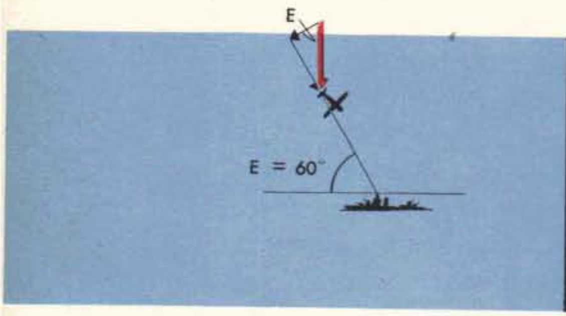
The vector is long, with most of the speed in the elevation component.

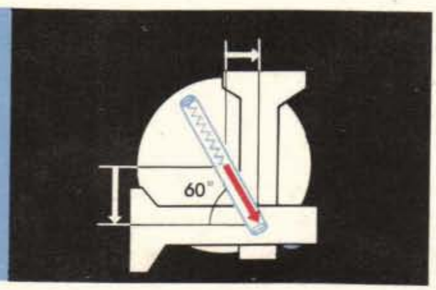




The plane is still climbing. Its elevation now is 45°, the vertical speed is slower and the plane is preparing to go into a dive.

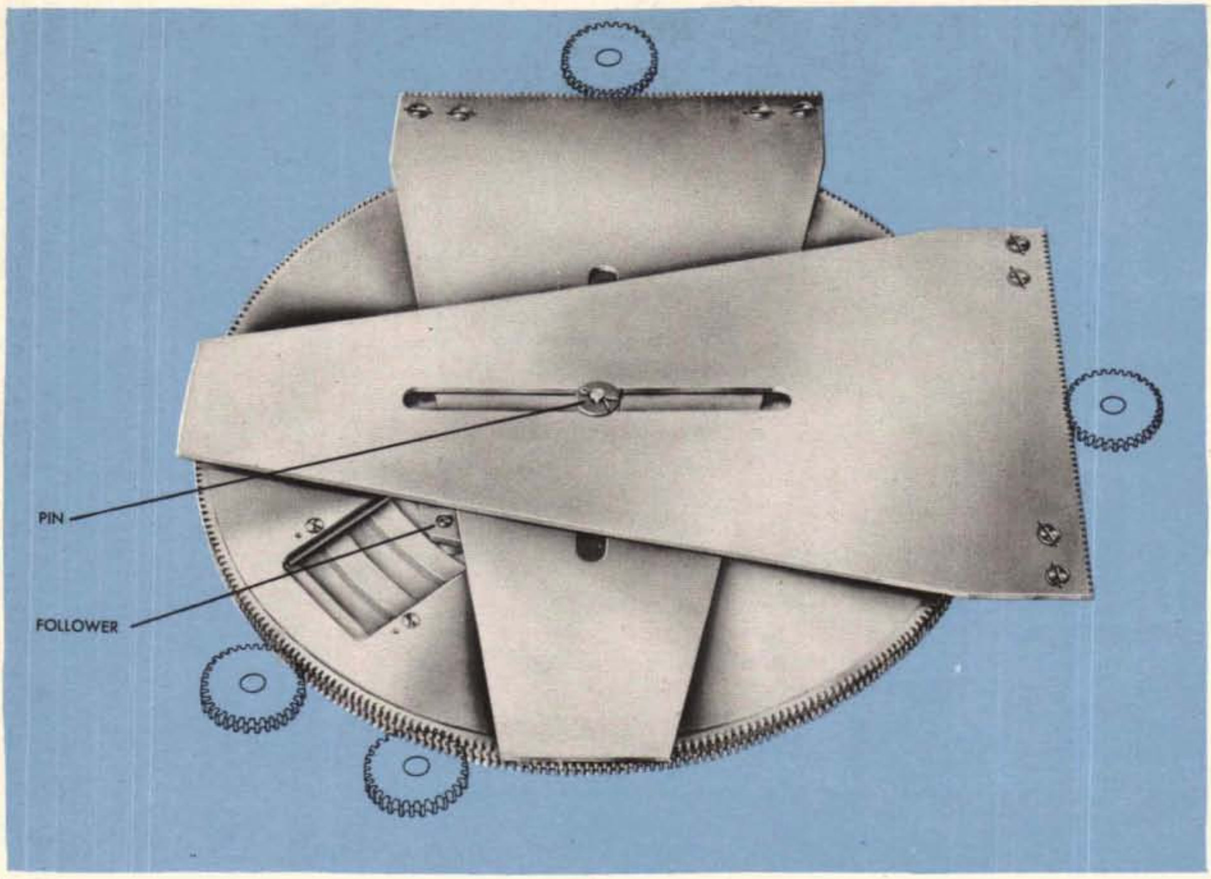
The vector is small and the components are equal.



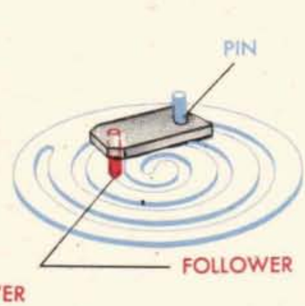


The plane is at 60° elevation, DIVING fast.

THE VECTOR IS IN THE LOWER HALF OF THE PLATE. THE COMPONENTS HAVE REVERSED THEIR DIRECTIONS.



The OFFSET PIN component solver



The offset pin solver is a CAM type designed to give both positive and negative vector lengths for any one position of the vector gear.

In this respect it is like the screw type component solver, but since a cam wears somewhat better than a screw, the offset pin type is often used when the cam input is changing constantly and fast.

The offset pin type has an ordinary constant lead cam.

The cam follower can only move outwards and back from the center to the edge of the cam. In order to use half the motion as positive and half as negative, the pin which moves the racks is offset half this distance from the follower itself.

The follower and the pin are mounted on opposite ends of a steel plate which slides in the vector slot.

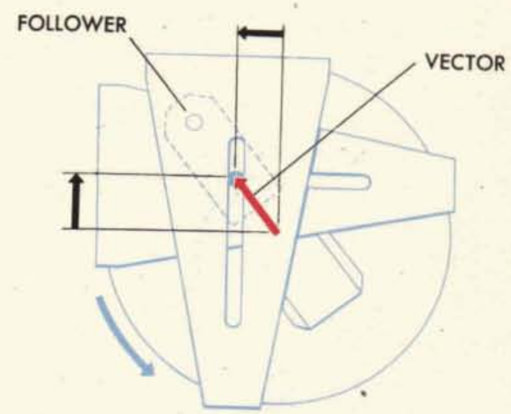
Although the follower only travels from the center to the edge of the cam, the pin travels half this distance EACH SIDE OF THE CENTER.

So for any one position of the vector gear, the outputs on the racks can be positive or negative.

Positive values

When the cam is turned one way the follower moves from zero position towards the edge of the cam. The vector is positive and the racks move in one direction.

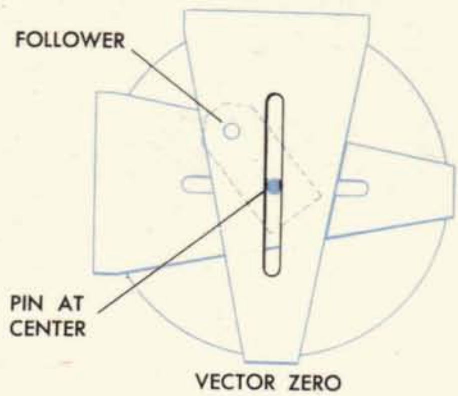
At maximum POSITIVE position, the follower is at the outer end of the cam groove.



Zero position

When the pin is over the center of the solver the racks are at zero. THE FOLLOWER IN THE CAM GROOVE IS ABOUT HALF WAY BETWEEN THE CENTER AND THE EDGE OF THE CAM.

Any one rack is at zero position when its slot is parallel to the slot in the vector gear.

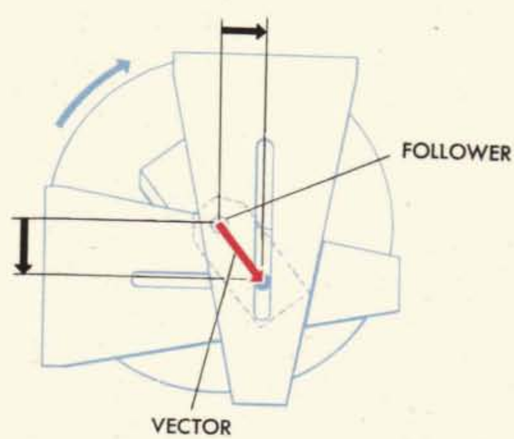


Negative values

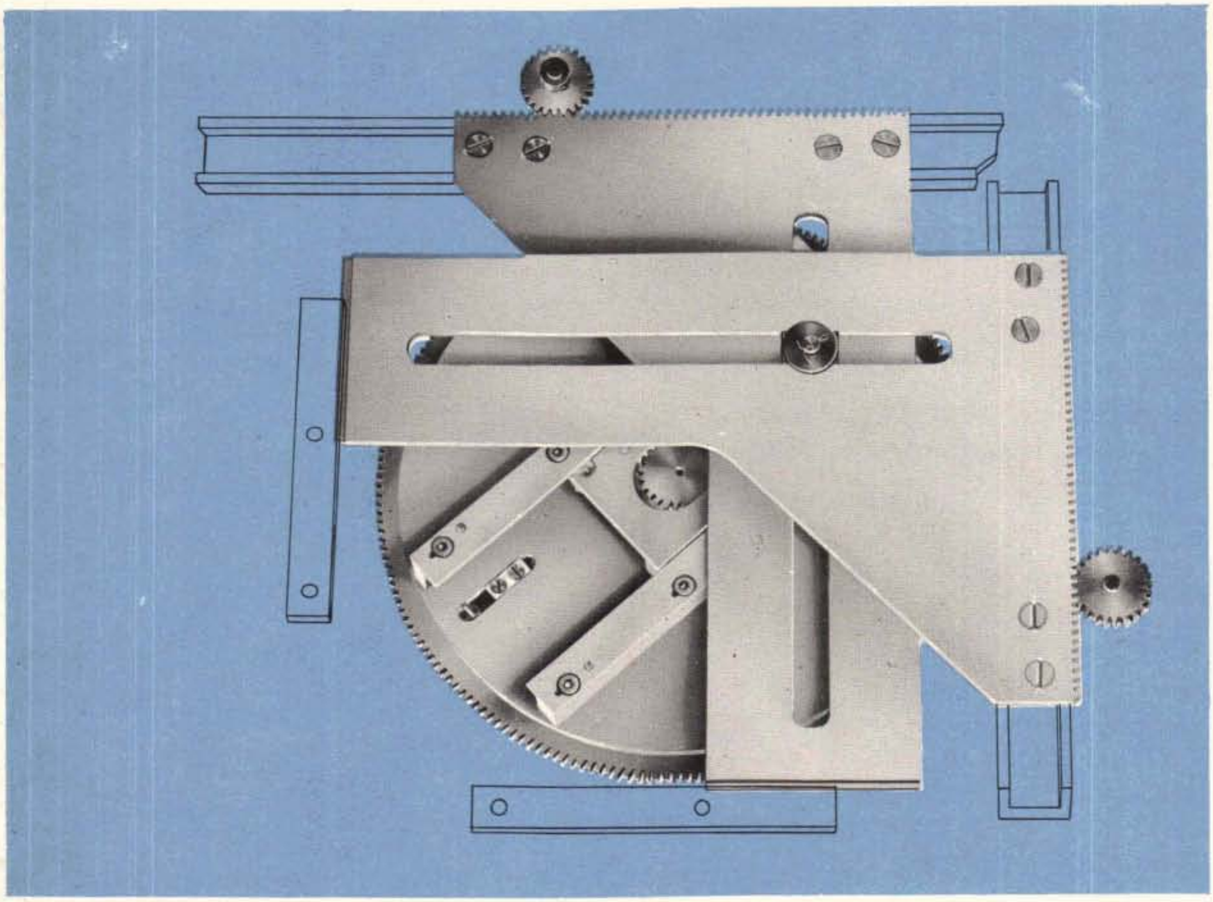
When the cam is turned the other way from zero position, the follower moves toward the center of the cam. The vector is negative and the racks move in the OPPOSITE direction.

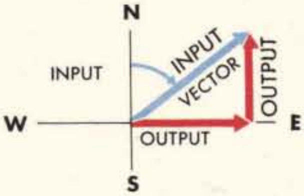
At maximum NEGATIVE position, the follower is at the inner end of the cam groove.

Obviously, either end of the vector slot can be used for positive values—the choice depends on mechanical convenience.

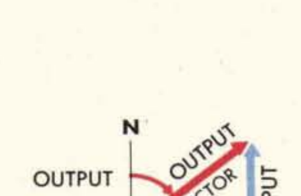


The VECTOR SOLVER





COMPONENT SOLVER



VECTOR SOLVER

The Vector Solver is like a Component Solver working in reverse.

The Component Solver takes as inputs a speed or distance and an angle and forms a vector. It solves for two components of this vector at right angles to each other.

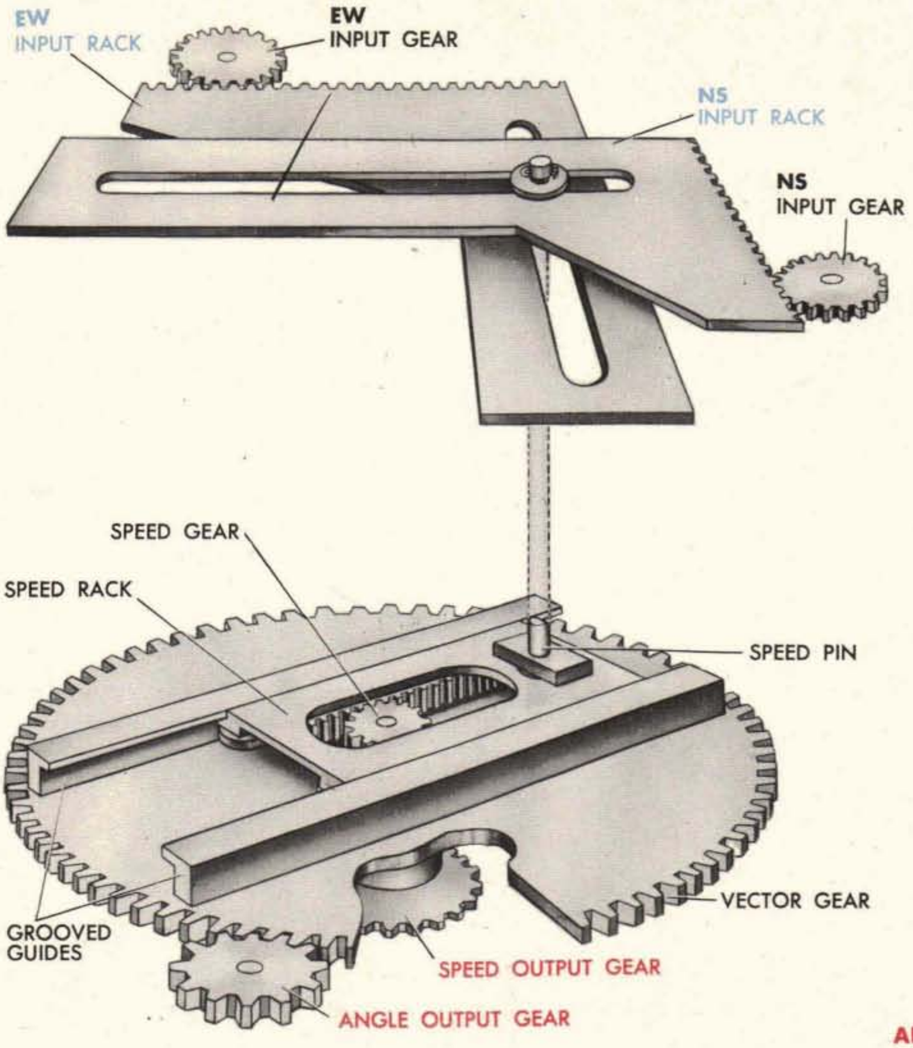
BUT THE VECTOR SOLVER TAKES AS INPUTS TWO COMPONENTS AT RIGHT ANGLES TO EACH OTHER. WITH THESE COMPONENTS IT FORMS A VECTOR.

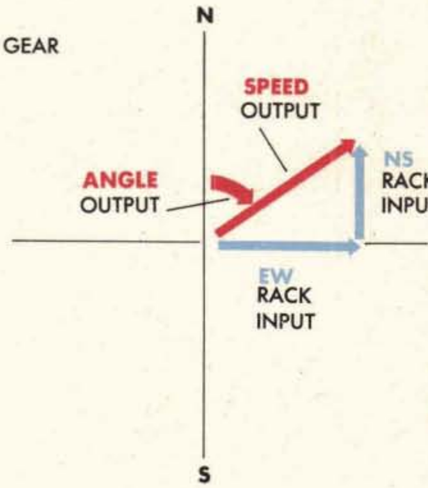
The two outputs of the Vector Solver are:

The length of the vector, (usually a speed)
The direction of the vector, (always an angle)

Usually an *approximate* vector is first set into the Vector Solver by positioning the speed pin and the vector gear. When this is done all the vector solver parts move as in a Component Solver.

The *approximate* vector is then corrected by the movement of the two input racks. The input racks push the speed pin and rotate the vector gear to new positions to form a new vector of correct length and direction.





How the INPUT RACKS set up a VECTOR

A speed pin comes up through the slots in these two racks so that the position of the pin changes with every input movement of either or both racks.

The other end of the speed pin is anchored to a speed rack.

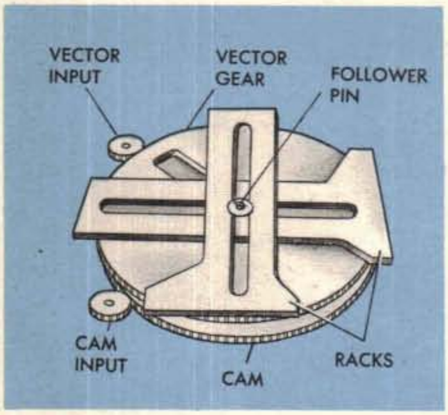
The speed RACK slides between the two grooved guides fastened to the vector gear, whenever the speed PIN moves across the vector gear.

The speed gear at the center of the vector gear meshes with the speed rack. Movement of the speed rack along its guides rotates the speed gear.

The speed gear turns an output gear below the vector plate.

Movement of the input racks and the speed pin also causes the VECTOR GEAR to TURN.

The vector gear turns the angle output gear.



Setting a CAM TYPE COMPONENT SOLVER

Here are the parts of a Cam Type Component Solver to be set

1. The vector gear
2. The cam

and the parts of the solver which aid in setting

1. The follower pin
2. The racks

The *inputs* go to the vector gear and the cam, which together position the pin. The pin, in turn, positions the racks.

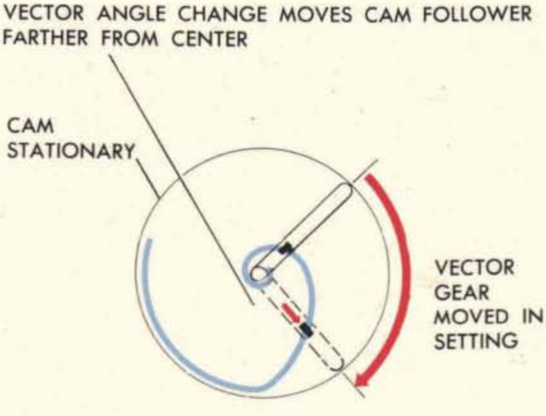
The *outputs* come off the racks.

CAUTION

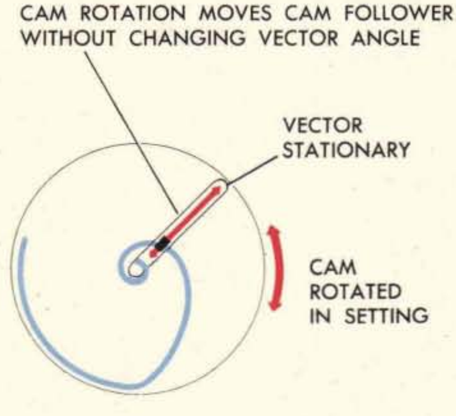
ALWAYS TURN THE CAM OR VECTOR GEAR SLOWLY AND CAREFULLY WHEN SETTING.

Spinning the vector gear or cam before setting is completed will drive the cam follower against the end of the cam groove and damage the cam follower pin.

ALWAYS MAKE THE VECTOR GEAR SETTING FIRST.



THE VECTOR GEAR SETTING CHANGES THE CAM SETTING WHEN THE CAM IS STATIONARY



THE CAM SETTING DOES NOT CHANGE THE VECTOR GEAR SETTING

The vector gear

ROUGH SETTING

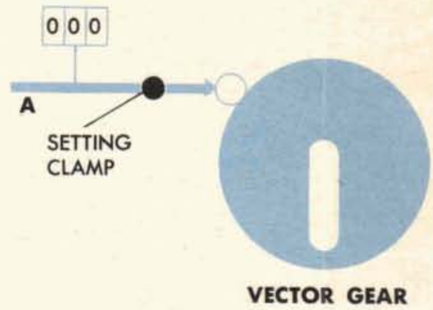
The *vector gear* is positioned by input shaft A, which also positions the counter.

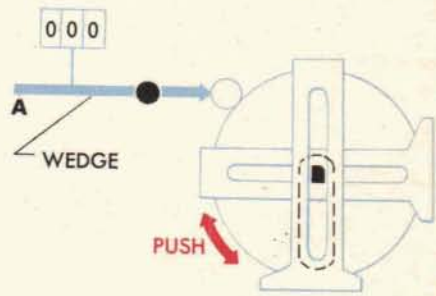
The purpose of setting the vector gear to the counter is to join them so that the position of the slot will be exactly the position indicated on the counter.

1. Turn input A until the counter reads zero. Wedge the input.
2. Push the vector gear until the vector slot points in the right direction for the zero setting. The vector slot should be parallel to one output rack.

   NOTE: A computer's setting notes give the readings and the vector gear directions for its component solvers.
3. Slip-tighten the setting clamp.
4. Remove the wedge.

The fine setting of the vector gear will be made later.





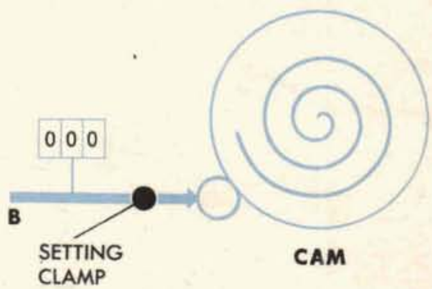
The cam

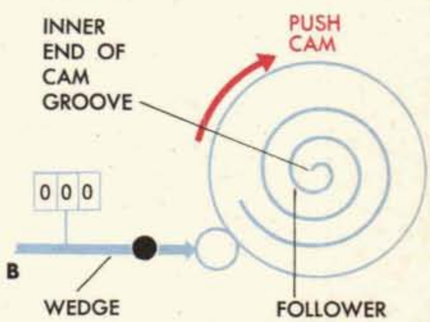
ROUGH SETTING

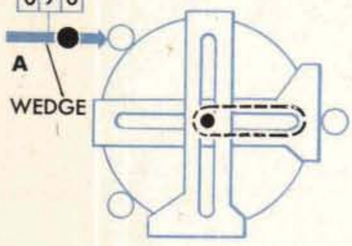
The *cam* is positioned by input shaft B which also positions the counter. In setting, the purpose is to join the cam and the counter through the setting clamp so that the position of the cam is exactly indicated by the counter.

1. Turn cam input B until the counter reads zero. Wedge the input.
2. Push the cam until the follower goes to the inner end of the cam groove; then back it off a little so that the follower will not hit the end of the groove.
3. Slip-tighten the setting clamp.
4. Remove wedge.

The fine setting of the cam will be completed later.



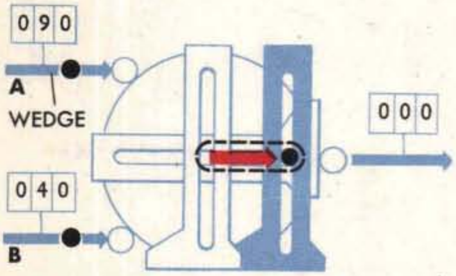




SLOTS PARALLEL

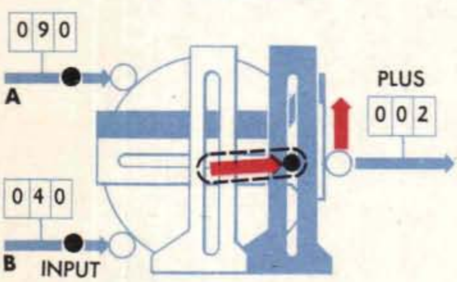
To refine the setting of the vector gear

1 Turn the vector gear until its slot is parallel with the slot in one of the output racks. Wedge the input.

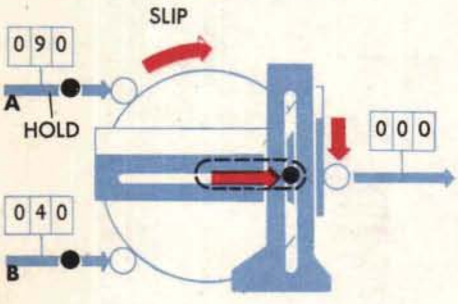


2 Starting with the pin at the center of the cam, turn the cam to bring the pin to the outer radius of the cam. As the pin moves, observe any motion of the output rack with the counter indicator on it.

3 Here there is *no* motion.... The vector gear is set correctly because the slots are exactly parallel and the pin can travel along the slots without moving the output rack.



4 Here the vector gear setting is incorrect. The vector gear slot is not parallel to the slot in one of the output racks, and as the pin travels along the slots the output rack moves. The distance the counter indicator moves represents the amount of error in the setting.



5 To correct this error: With the input still wedged, slip the vector gear until the output rack with the counter indicator on it returns to its original position.

The movement of the output rack is always proportional to the distance the pin moves from the center.

Always correct with the pin at the outer radius because this position will give the maximum movement of the output rack which has the counter indicator on it.

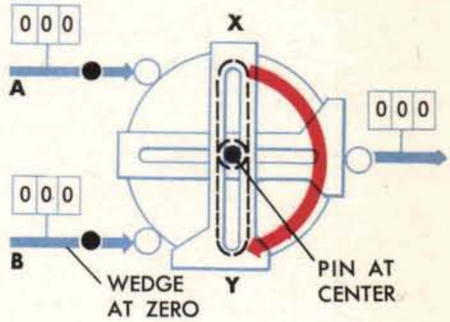
6 Repeat steps 2 and 5 until there is a minimum motion on the counter indicator.

7 Tighten the setting clamp.

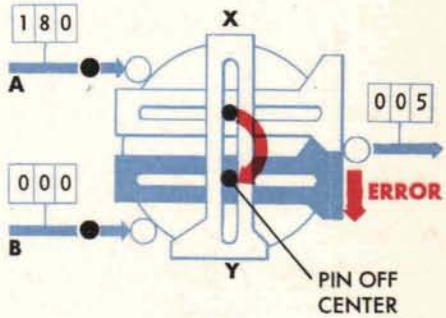
8 Remove wedge from input shaft.

To make the **fine** setting of the cam

1. Turn cam input *B* until the counter reads zero. Wedge the input.
2. Starting with the vector slot in position *X* turn it to position *Y*. As the vector gear moves, observe any motion of the output rack with the counter indicator on it.
3. Here there is *no* motion . . . The cam is set correctly because the pin is right over the center and the vector gear slot can turn around without moving the output rack.

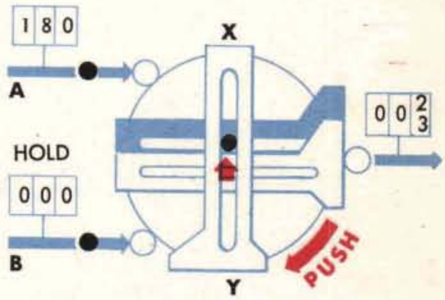


4. Here the cam setting is incorrect. The pin is a little way from the center, so when the slot is turned around, the pin is moved and the pin, in turn, moves the output rack with the counter indicator on it.



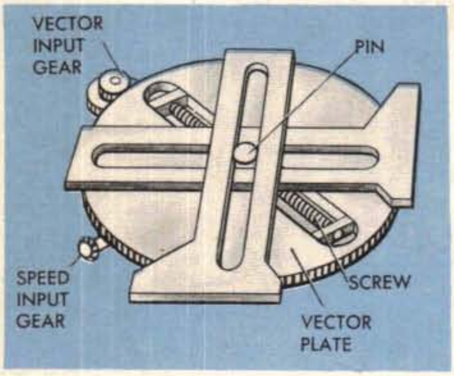
5. To correct the setting, slip the cam in the direction which returns the output rack halfway to its original position.

   Always correct with vector slot at *X* or *Y* because these positions give the maximum movement on the output rack.



6. Repeat steps 2 and 5 until there is minimum movement of the output rack with the counter indicator on it.
7. Tighten the setting clamp.
8. Remove wedge.

Setting a SCREW TYPE

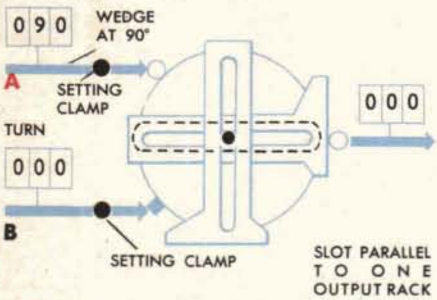


The screw type component solver is very similar to the cam type. The only difference is that the pin travels along a *screw* instead of *in a cam groove.*

In the screw type component solver the vector slot extends across almost the whole gear. So the pin can travel either side of the center and it can move the whole length of the vector gear slot for any given vector setting.

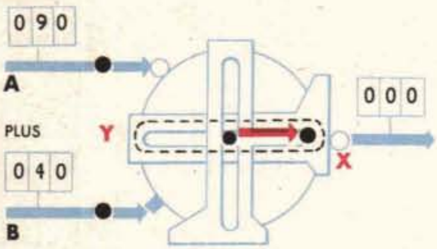
CAUTION: Set the vector gear first.

To set the vector gear

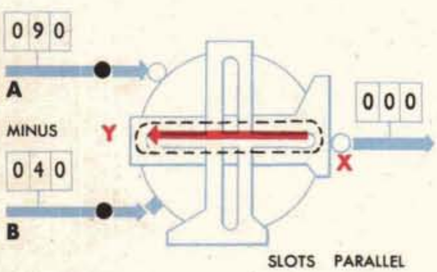


1. Turn input shaft *A* until the counter reads ninety degrees. Wedge this input.
2. Push the vector gear until the slot points in the right direction for the ninety degree setting. In this example the vector gear slot is parallel to the slot on the output rack with the indicator counter.

   NOTE: A Computer's setting notes give the readings and the vector gear directions for its component solvers.

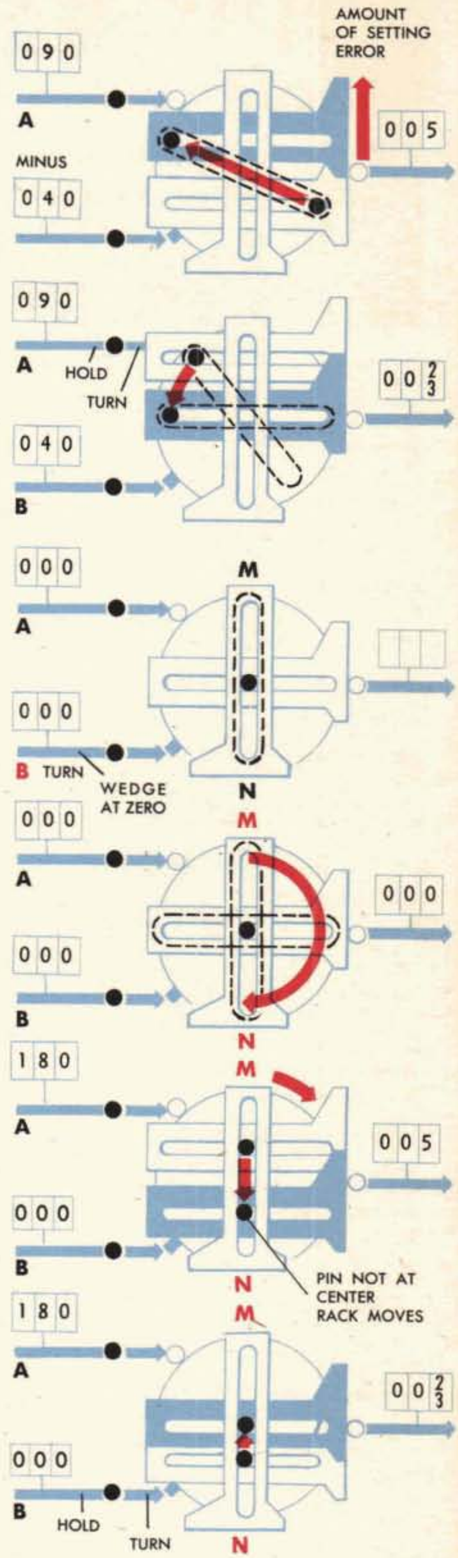


3. Slip-tighten the setting clamp.
4. Turn input shaft *B* to move the pin from the *center* to the *X* end of the screw.



5. Now run the screw from *X* to *Y*. Observe the motion of the output rack indicator counter.
6. Here there is *no* rack motion . . . the vector gear is set correctly . . . the two slots are parallel.

COMPONENT SOLVER



7 Here the vector gear setting is incorrect. The two slots are not parallel, so the motion of the pin causes the output rack to move. The distance the counter indicator moves represents the amount of error in setting.

8 To correct this error, slip the vector gear until the output rack with the counter indicator returns to a position half way back to its original position.

9 Repeat 5 and 8 until there is minimum motion of the indicator.

10 Tighten the setting clamp.

11 Remove wedge.

To set the screw

1 Turn input shaft *B* until the counter reads zero. Wedge the input.

2 Turn the screw until the pin is at the center of travel. This is the approximate zero position of the pin.

3 Slip-tighten the setting clamp.

4 Using input shaft *A*, turn the vector gear so that its slot moves from *M* to *N*. Observe the motion of the output rack with the counter indicator on it.

5 Here there is *no* motion . . . the screw is set correctly. The pin is at the center and the vector gear slot can turn around it without moving the output.

6 Here the screw setting is incorrect. The counter indicator shows the distance the rack moved. This distance represents the amount of error in setting.

7 To correct the error, slip the input B to the screw until the pin moves enough to bring the output rack with the counter indicator half way back to its original position.

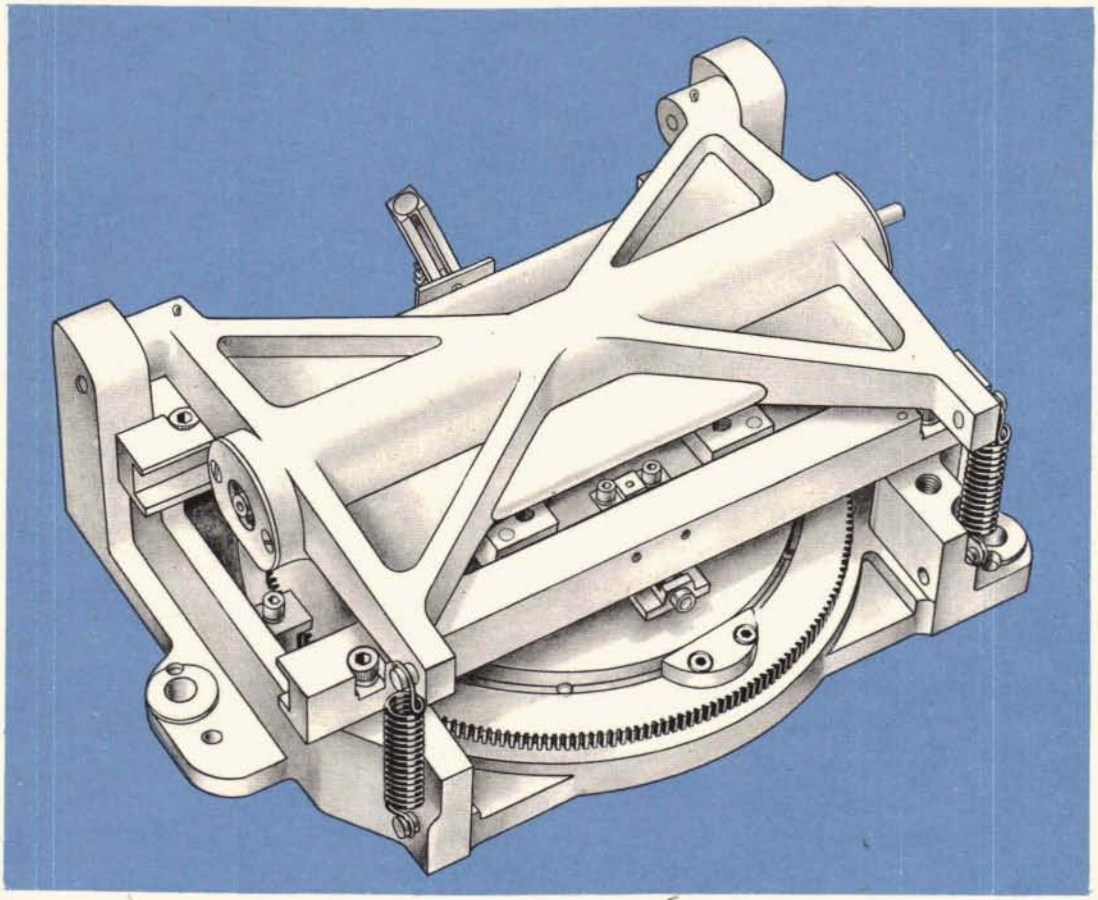
Always correct with the vector slot at *M* or *N* because this position gives the maximum movement on the indicator.

8 Repeat 4 and 7 until there is minimum motion of that indicator.

9 Tighten the setting clamp.

10 Remove wedge.

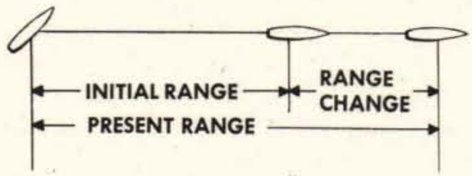
DISK TYPE INTEGRATORS



Disk integrators can do a variety of jobs, some of them quite complicated. One of their simplest uses is "keeping the range." By seeing how the integrator does this simple job, it is possible to get a pretty good idea of how it works.

It must be remembered though, that while a description of an integrator keeping the range is a good introduction, it is not the whole story of what integrators can do.

The integrator acts like a variable gear ratio



A Rangekeeper or computer keeps the range by computing the *changes of range* as they occur, and adding them to the initial observed range.

Change of range for a constant range rate is computed by multiplying the *Rate* at which range is changing by *Time*.

Range rate $\times$ time $=$ change of range during that time.

5 yds. per sec. $\times$ 1 sec. $=$ 5 yds. change of range in one second.

5 yds. per sec. $\times$ 60 sec. $=$ 300 yds. change of range in one minute.

This multiplication could be done by a gear ratio. The larger gear could represent *time*. Let the ratio be 5 to 1.

If the time gear is turned once per second the output gear will turn 5 revolutions per second. Let each revolution of the output shaft represent one yard and the simple change of range problem above is solved:

The large gear represents *time*

The ratio represents *range rate*

The output represents *change of range*

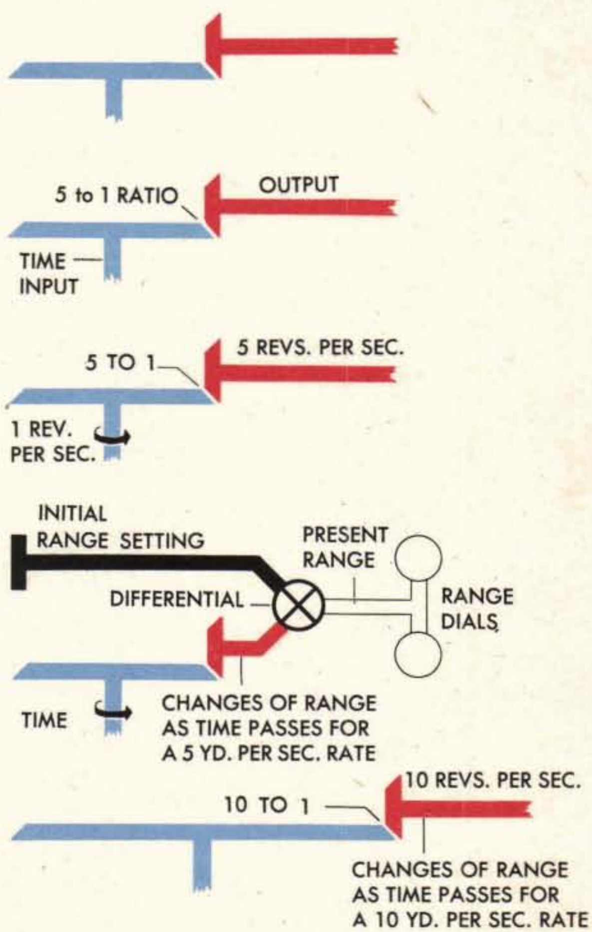
Connect the output shaft to a range dial by reduction gearing, and the moving range dial will indicate the range at any instant AS LONG AS THE RANGE RATE STAYS AT 5 yds. per sec.

Suppose the range rate changes to 10 yds. per sec. The time input gear must continue to turn at the same speed, because it represents time. So another set of gears would be needed with a ratio of 10 to 1.

EVERY DIFFERENT RANGE RATE REQUIRES A DIFFERENT GEAR RATIO TO COMPUTE RANGE CHANGE. The problem then is to set up a

VARIABLE GEAR RATIO

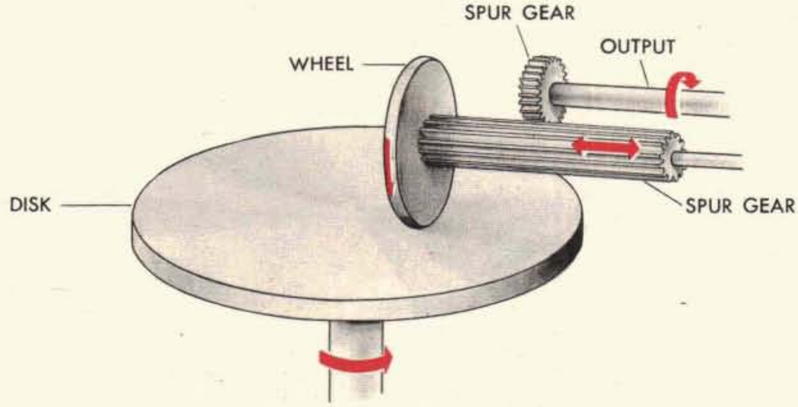
The disk integrator is one answer to this problem.

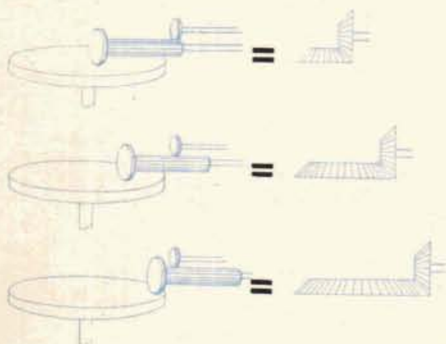


TWO TYPES OF

The WHEEL type

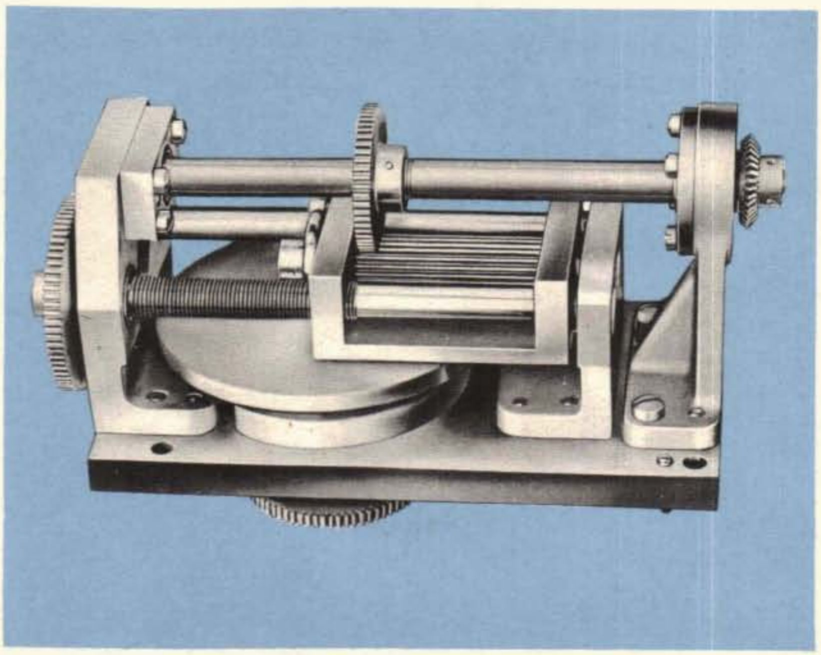
Here is one way to construct a variable gear ratio.





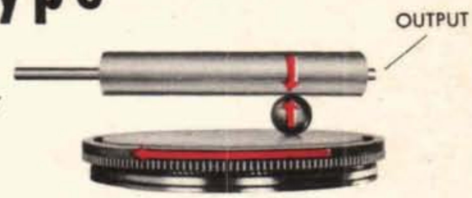
The disk takes the place of the large time input bevel gear. The wheel replaces the small output bevel. The wheel can be positioned at different distances from the center of the plate to get different output ratios.

One of the integrators in actual use is constructed this way.



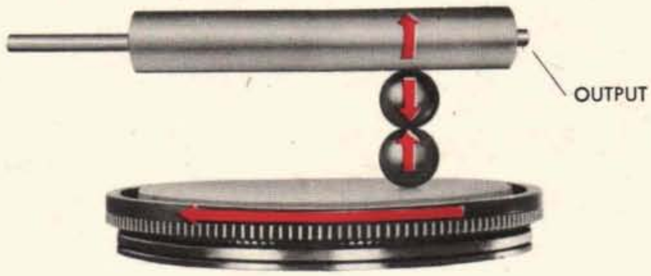
INTEGRATORS

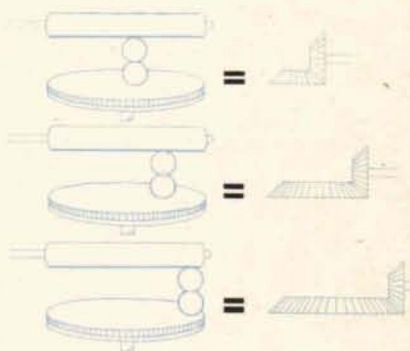
The BALL and ROLLER type



A ball and roller may be used instead of the wheel and spur gears.

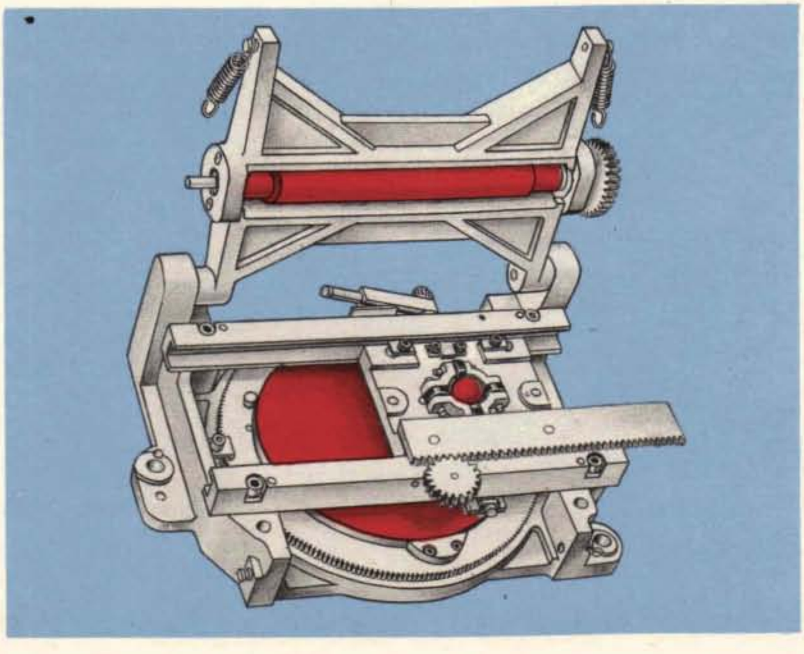
If two balls are used they will move across the face of the disk more easily than one.



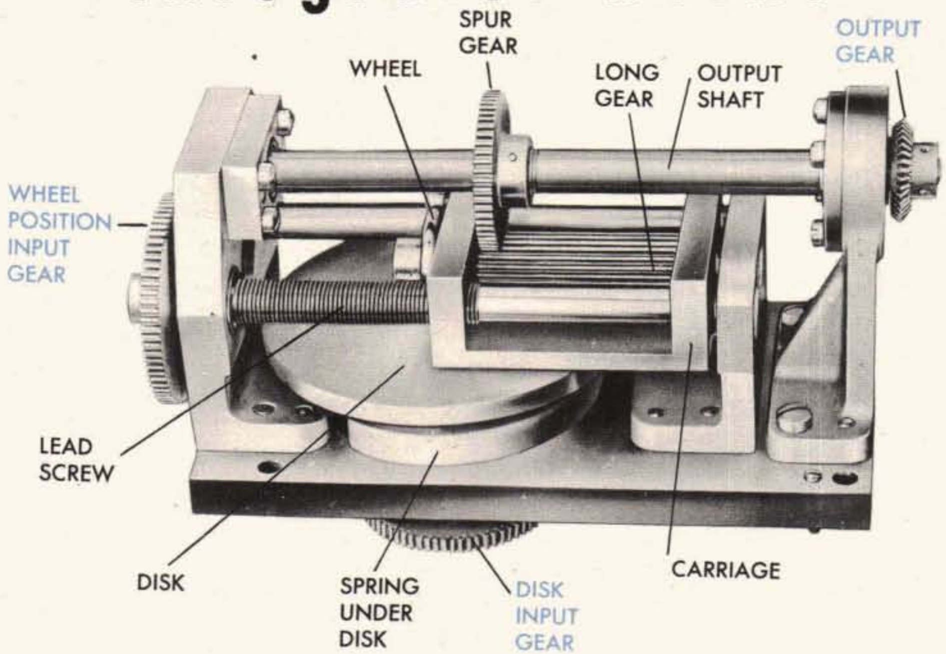


In this case the two balls take the place of the small bevel.

This is the ball and roller type opened up for a look inside.



How the wheel type integrator works



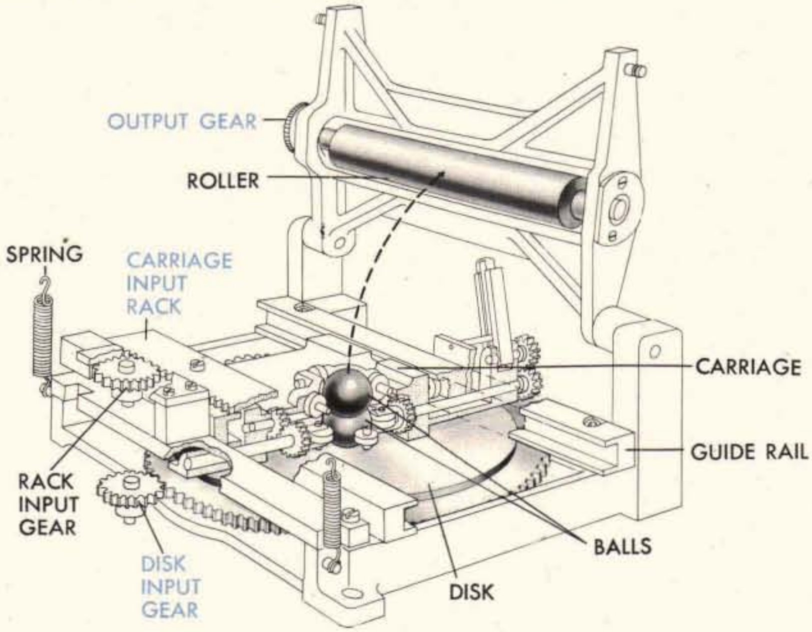
The disk is turned by a gear.

The wheel is positioned by a lead screw. In the unit shown above the wheel will move only half the width of the disk.

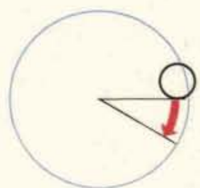
The output is transmitted to a shaft by a spur gear which stays in mesh with the long gear as it moves back and forth with the carriage.

The disk and wheel must be held together tightly to prevent the wheel from slipping. The necessary pressure comes from a spring under the disk.

How the ball and roller type integrator works



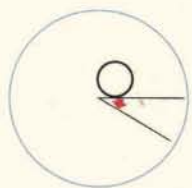
In the ball and roller type, the disk is mounted on a gear and is turned directly by an input gear in mesh with it. In this integrator the disk is 5″ across.



The two steel balls, one on top of the other, are held in position by a carriage which runs along a pair of guide rails across the face of the disk.

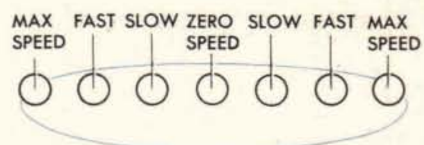
The balls turn the roller, which has an output gear at one end.

The balls can be positioned by the carriage anywhere along a straight line from one edge of the disk across the center to the other edge.

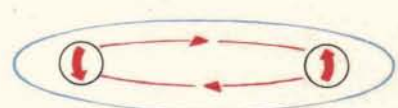


The circumference of the circle passing under the balls is greater when the balls are near the edge of the disk than when they are near the center.

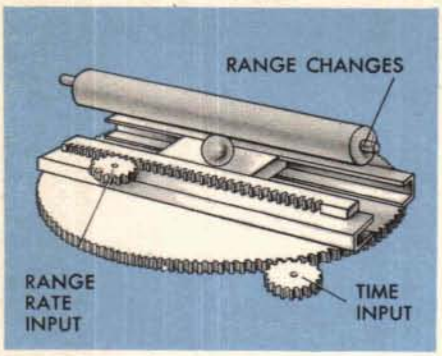
So the balls rotate fastest when they are at the edge of the disk, slower towards the center.



On one side of the center the balls turn in one direction, on the other side of the center in the opposite direction.



The pressure needed to hold the balls against one another, and against the disk and roller comes from two springs. Each of them exerts about a nine pound pull.



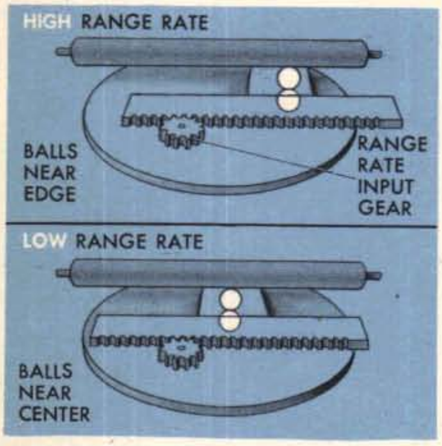
NOTE:
It is assumed in this description that the speed of rotation of the bottom ball is determined only by its distance from the center of the disk. Actually its speed of rotation is affected also by two tiltable rollers. See pages 128-129.

How an INTEGRATOR

Time Input

When the target is picked up, the Initial Range is set into the range dial. At that moment, the Time Motor is turned on, setting the disk in motion. The rotating disk, then, can be compared to a clock which is constantly ticking away the passage of time from the instant the target is first sighted up to each new range reading.

In the range problem the disk always rotates in the same direction at a constant speed. This is a mechanical way of saying that TIME, which the disk represents, always goes by and never backs up.



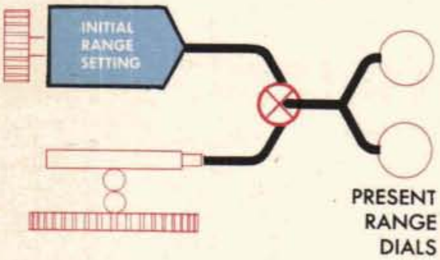
Range rate input

Range rate is fed from component solvers into the carriage input gear, which positions the carriage and the balls according to this rate.

If the range rate is fast, the carriage will locate the balls away from the center near one edge of the disk.

If the rate is slow, it will locate them near the center of the disk.

The speed of the balls depends on their distance from the center of the plate SO THE SPEED OF THE BALLS IS ALWAYS PROPORTIONAL TO THE RANGE RATE.



Output

The output roller is constantly being turned by the balls. Sometimes it turns rapidly, sometimes slowly, according to the rate input.

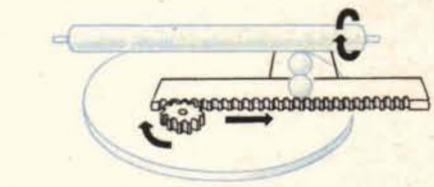
THE POSITION OF THE ROLLER AT ANY MOMENT, THAT IS, THE NUMBER OF REVOLUTIONS IT HAS MADE FROM ITS INITIAL POSITION, TELLS THE ACTUAL CHANGE IN RANGE DURING THE TIME THE DISK HAS BEEN TURNING.

The output roller is geared to the range dial through a differential, so that this change in range is constantly being added to the initial setting to give present range at any moment.

keeps the range

Plus and minus RANGE RATES

When Range is increasing, changes of Range are being ADDED to Initial Range. The Range rate is PLUS.

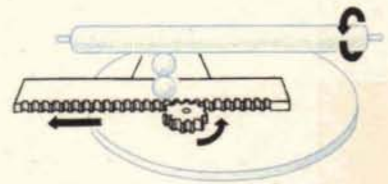


When Range is decreasing, changes of Range are being SUBTRACTED from Initial Range. The Range Rate is MINUS.

A PLUS range rate will turn the rate input gear in one direction positioning the carriage toward one side of the disk.

The balls and roller turn in the direction to ADD range changes.

The MINUS range rate will turn the rate input in the opposite direction, moving the carriage toward the opposite side of the disk. The balls and roller will *reverse* and start subtracting range changes.



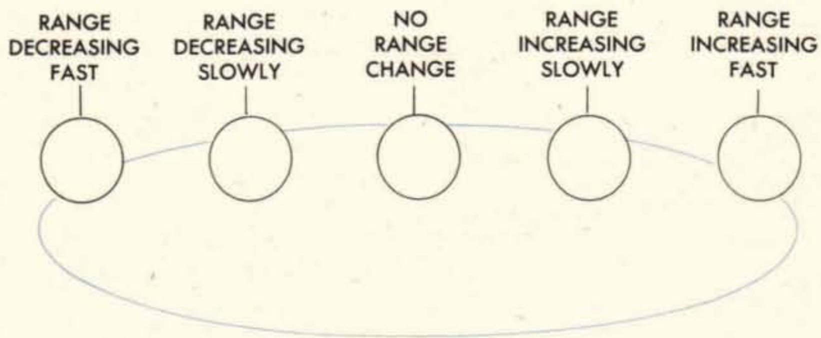
Always remember this:

The DISTANCE of the balls from the center depends on the value of the range rate.

The balls are on one side of the center or the other, depending on whether the range rate is PLUS or MINUS.

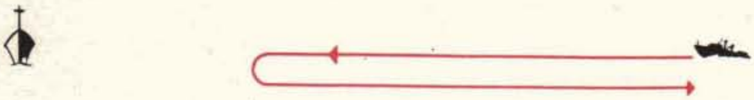
The rate will be PLUS if range is INCREASING.

The rate will be MINUS if range is DECREASING.

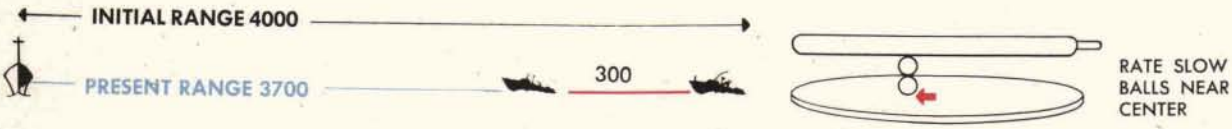


A simple RANGE PROBLEM

Suppose that a torpedo boat attacks own ship, increasing its speed as it comes closer. To simplify the problem the speed of the torpedo boat is assumed to change instantly and remain at the new speed until changed again. Own ship does not move.



Torpedo boat picked up at 4000 yards range. Speed 300 yds. per min. It proceeds at this speed for one minute.

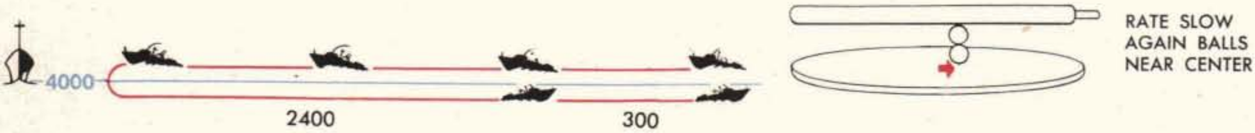


Then its speed increases to 600 yds. per min., and it runs at this speed for two minutes, covering 1200 yards.

Then the speed increases to 1200 yds. per min., and it runs at this speed for one minute.

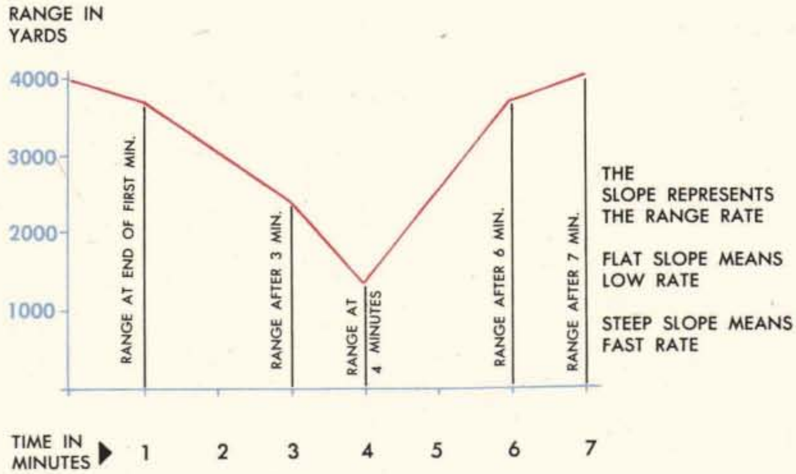
Then the boat releases the torpedoes and reverses its course. It travels for two minutes at 1200 yds. per min.

The speed is then reduced to 300 yds. per min., and after one minute the torpedo boat is back at its starting range.



This problem can be summarized in a chart:

300 yds./min. × 1 min. — 300 yds. range change (less)
600 yds./min. × 2 min. — 1200 yds. range change (less)
1200 yds./min. × 1 min. — 1200 yds. range change (less)
1200 yds./min. × 2 min. — 2400 yds. range change (more)
300 yds./min. × 1 min. — 300 yds. range change (more)



Of course no ship behaves so simply. The speed of a ship does not increase in jumps, it increases gradually. But the position of the balls, which represents range rate, can also be changed gradually, while the time disk is running.

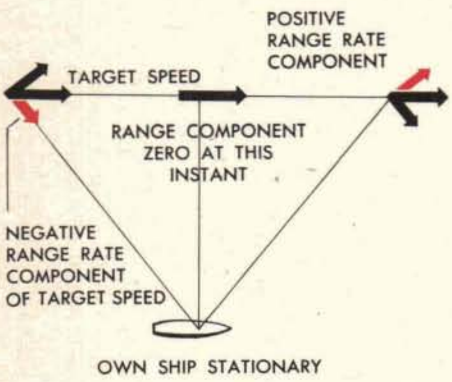
The balls do not wait until they have reached a fixed position before they start registering changes of range for the new rate.

AS THE BALLS MOVE THEY WILL CONTINUOUSLY CHANGE IN SPEED OF ROTATION IN DIRECT PROPORTION TO THEIR CHANGING DISTANCE FROM THE CENTER OF THE DISK.

In this way the integrator keeps on multiplying continuously as the balls move. It can multiply a continuously changing rate by time, and the roller will accurately accumulate the resulting changes of range.

A charted line showing present range during any actual torpedo boat attack would be straight when speed was constant and *curved* during changes of speed.

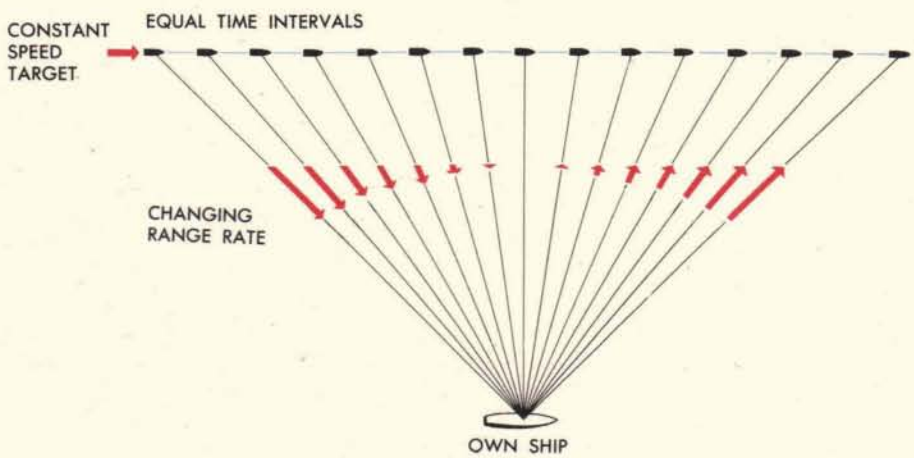
A range rate that continually

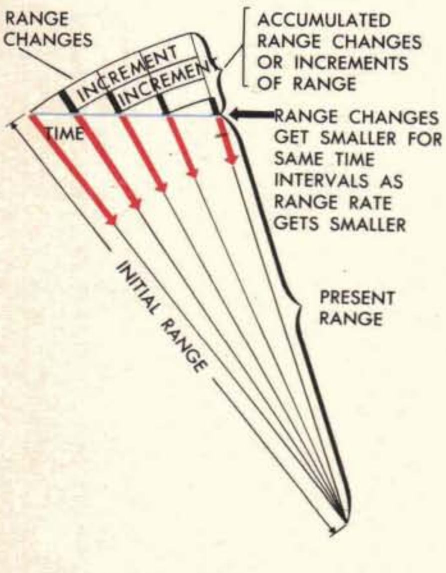


No matter how often or how gradually the range rate changes, an integrator can keep track of the change of range. It accumulates changes of range even when the range rate is continually changing. A changing range rate is the *usual* situation.

Take the case where a target passes by own ship traveling a straight line course at a constant speed. Own ship is stationary.

Although target speed remains constant, the component along the line of sight, which is the whole range rate in this case, will gradually change from a negative rate through zero to a positive rate.

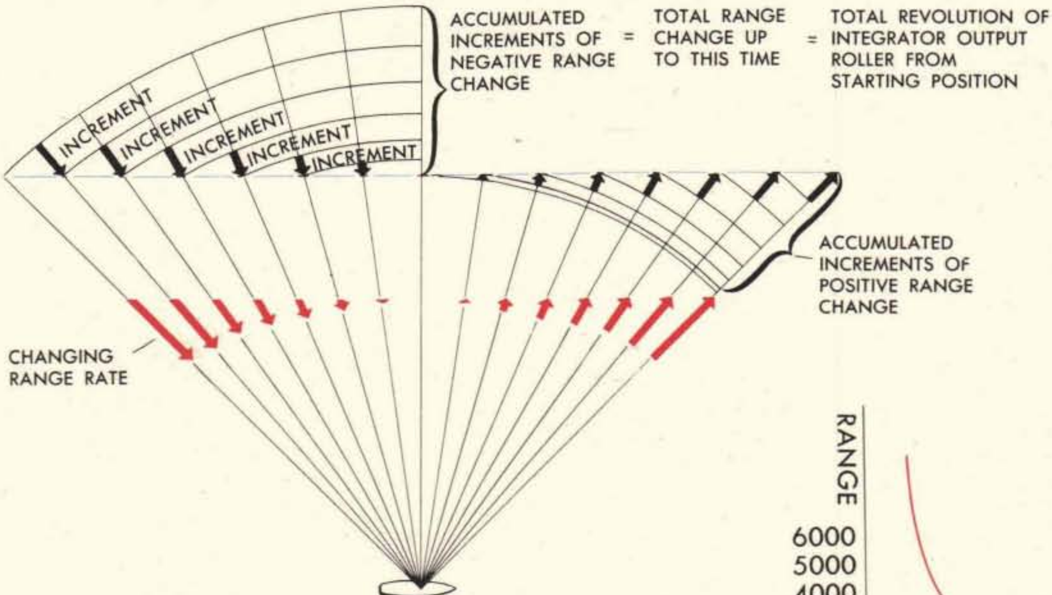


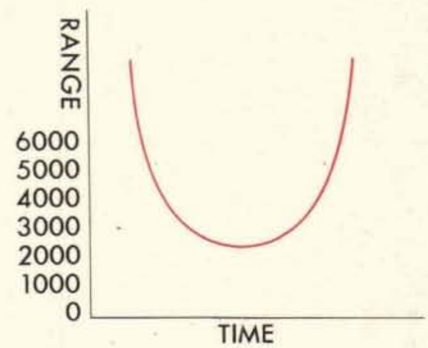


The range *rate* keeps changing as the target goes past own ship at a constant speed.

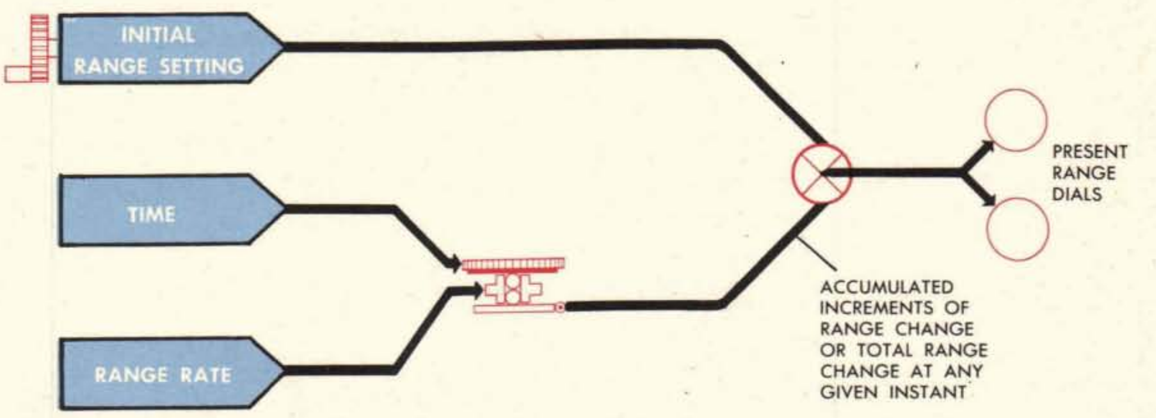
The integrator takes the range rate at a given instant and multiplies it by a small time interval. The computed change of range during that time is called an INCREMENT of range. The roller accumulates these increments by turning to new positions. Actually the increments do not accumulate as little jumps of the roller. The roller movement is as smooth as the changes in range rate.

changes





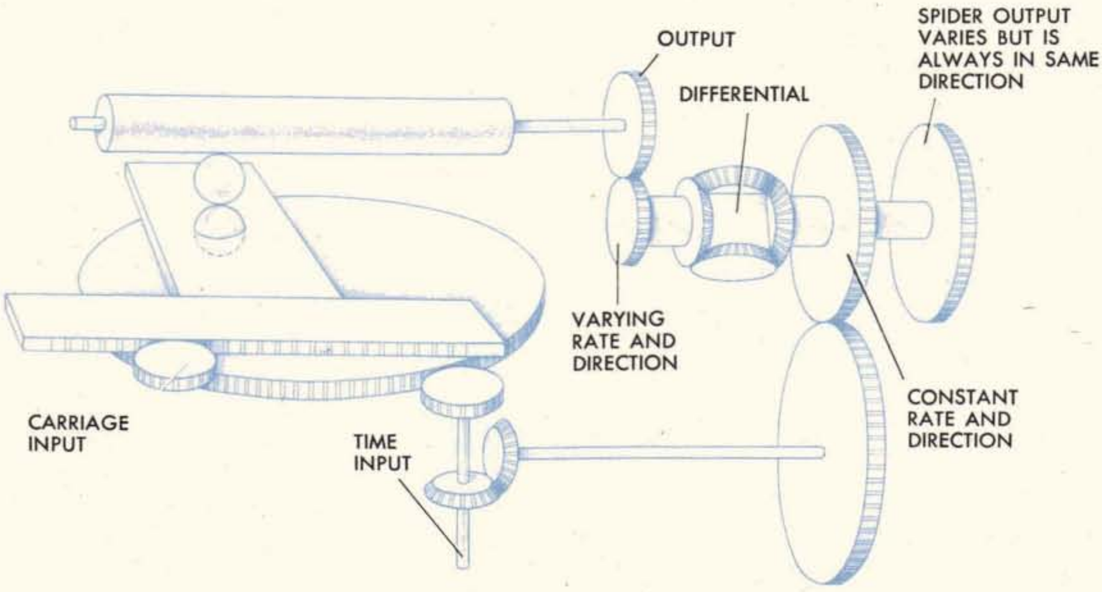
IF CHARTED, THE INTEGRATOR OUTPUT WOULD BE A SMOOTH CURVE—NOT A SERIES OF STRAIGHT LINES



Using the integrator to give an OUTPUT in only ONE direction

Sometimes the input and output of an integrator are values that can only be plus, never minus. In this case it would seem that only the plus half of the integrator disk could be used while the minus side would be wasted.

To avoid this waste, and to increase accuracy, a method of using the whole width of the disk for plus values has been worked out by adding a differential to the integrator output gearing.

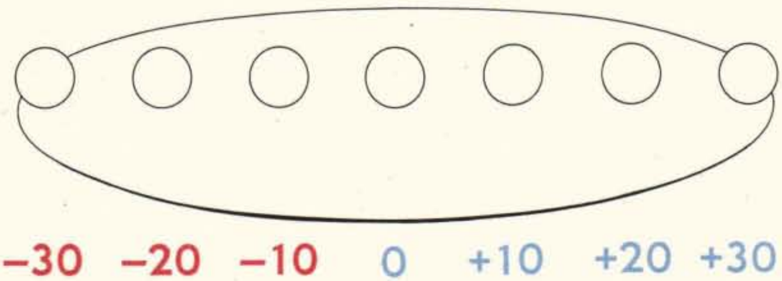


One side of the differential is driven by the output roller from the integrator. The other side is driven at a constant rate through a gear line by the time input.

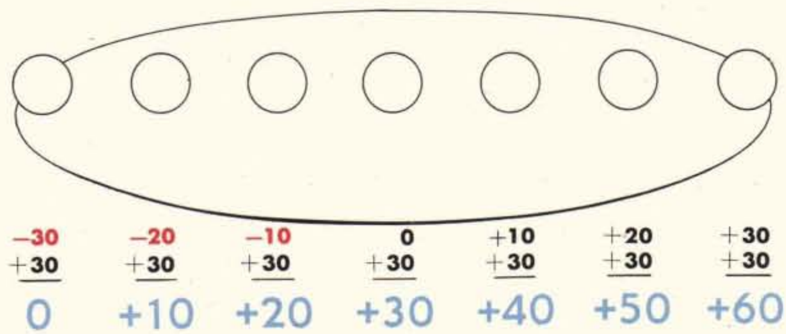
Assume that this constant rate from the time line is equal to the maximum plus rate of the output roller. With this setup, the carriage input can be set so that the zero value will position the balls at one edge of the plate, and the maximum input will bring them across to the other edge of the plate.

here's what happens

Suppose positions of the ball across the disk normally gave these output values ranging from minus 30 revolutions per minute to plus 30 revolutions per minute on the output roller.



If plus 30 revolutions are added per minute to each of these plus or minus outputs, the result will be a set of outputs running from zero to plus 60 instead of from minus 30 to plus 30.

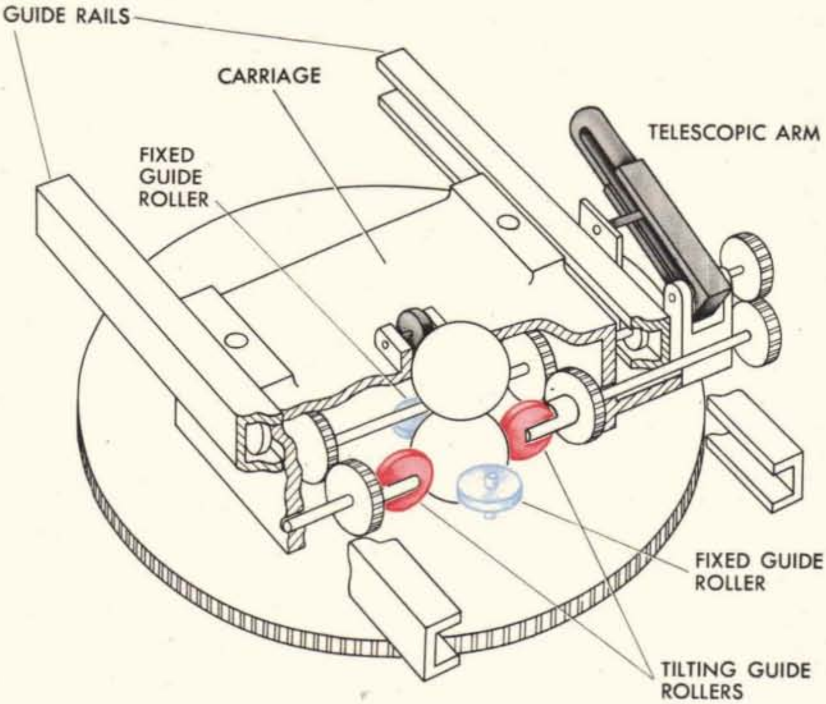


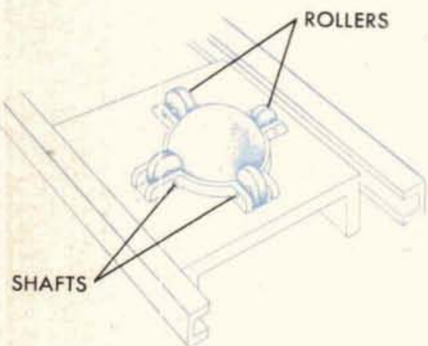
This is done in the differential by driving the second side at a speed equal to the maximum positive value of the output roller, and in the direction of the positive outputs from the roller.

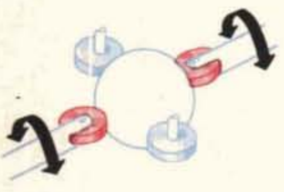
The outputs from the spider will now always be plus, whichever way the output roller is turning.

NOTE: For design reasons, the constant rate which is chosen is usually greater than the maximum plus rate of the output roller. Therefore, there is usually some positive movement of the output roller when the carriage is at its minimum position.

The GUIDE ROLLERS and







Each of the two balls is held in the carriage by four guide rollers. The guide rollers keep the balls positioned in the center of the carriage—yet allow them to roll. This arrangement enables the balls to do two things at the same time:

1. To move across the face of the rotating disk.
2. To deliver a smoothly changing output to the roller.

The TOP BALL guide rollers

The four top ball guide rollers are vertical and turn on shafts fixed to the carriage.

The BOTTOM BALL guide rollers

Two of the bottom ball guide rollers are fixed and horizontal. The other two rollers can be tilted.

When the ball is in the center of the disk all four rollers are horizontal. With the rollers horizontal the ball and disk can turn together and prevent the ball from wearing a hole in the center of the disk.

As the ball is moved away from the center of the disk, the telescopic arm turns the two tilting rollers from their horizontal position toward a vertical position.

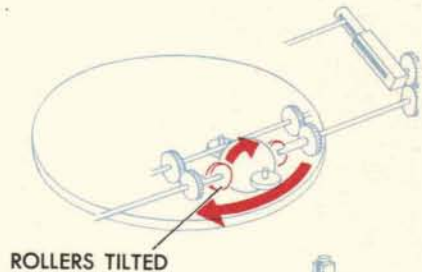
the TELESCOPIC ARM

The telescopic arm tilts the movable guide rollers as the balls move away from the center of the disk.

The slotted bar inside the arm slides in and out at the top like a telescope. The slot rides on a pin fixed to the center of the back guide rail.

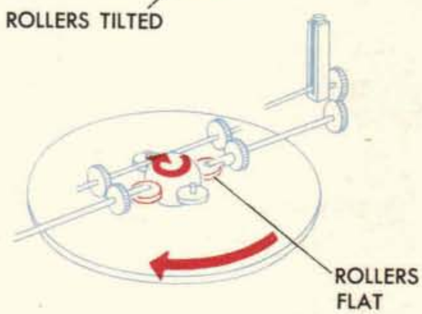
The angle made by the telescopic arm and the disk fixes the tilt of the movable guide rollers holding the bottom ball. The axis of the bottom ball is therefore always pointing toward the center of the disk.

At one side of the disk the angle between arm and disk is small.

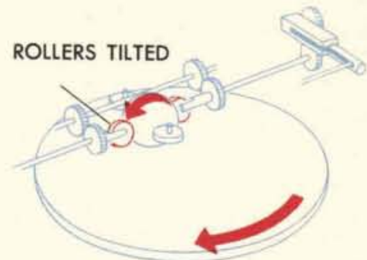


As the angle between the arm and the disk approaches 90° the balls are getting near the center of the disk.

When the balls are in dead center, the telescopic arm is at right angles to the disk. It holds the movable guide rollers so that their position matches the position of the stationary guide rollers. The bottom ball then turns WITH the disk. This keeps the ball from wearing a hole in the disk.



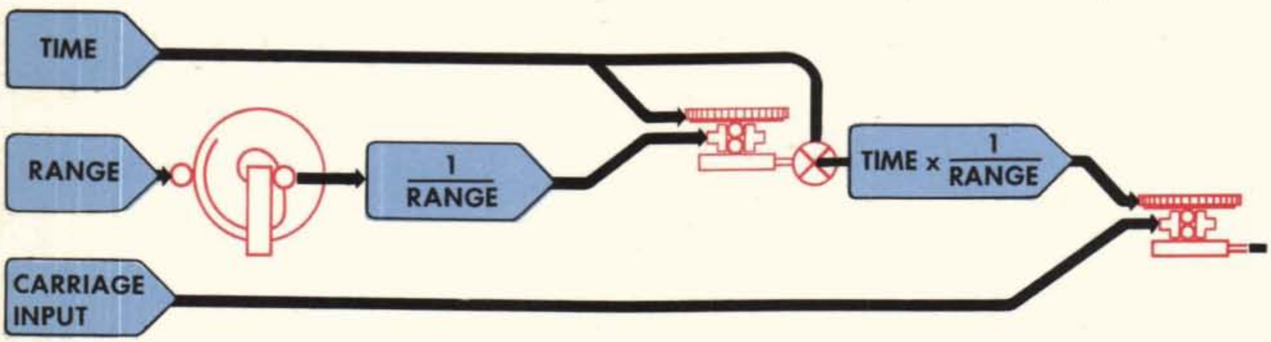
At the other side, the angle between arm and disk is small.



OTHER USES for the INTEGRATOR

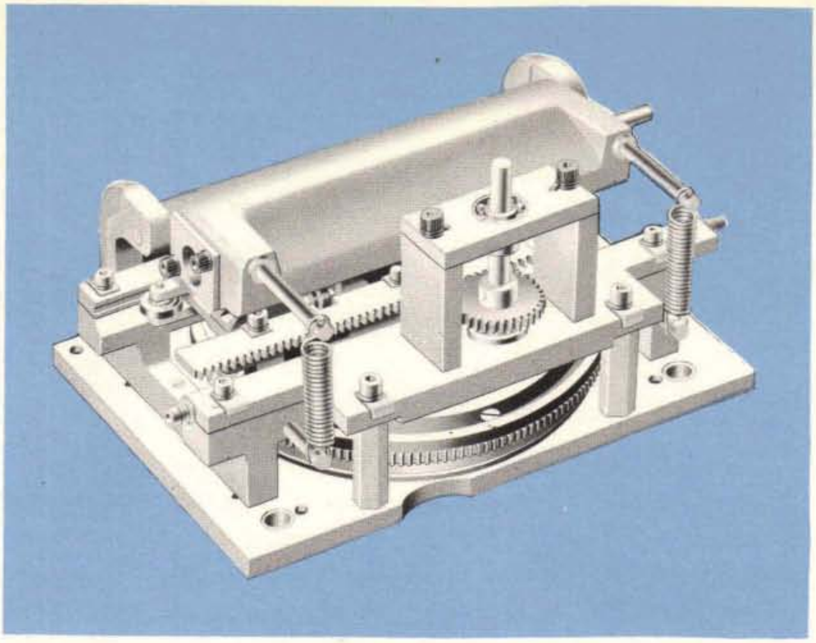
When an integrator is used to keep the range, the only input that varies is the range rate, which positions the carriage. The disk is turned at an unvarying speed representing the passage of time.

But the disk can also be used to represent a varying quantity, such as Time multiplied by the reciprocal of range. In such a case the varying input to the disk comes from another integrator. This other integrator has for its two inputs *time*, and *1/range* from a reciprocal cam.

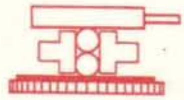


The output of the first integrator is fed into the disk of the second integrator. At high ranges the disk of the second integrator will turn more slowly. As range decreases it will turn faster.

These more complicated ways of hooking up integrators are explained in the computer OP's. It is enough here to know that the disk may turn at a varying speed representing one or more varying quantities.



The FOUR INCH integrator



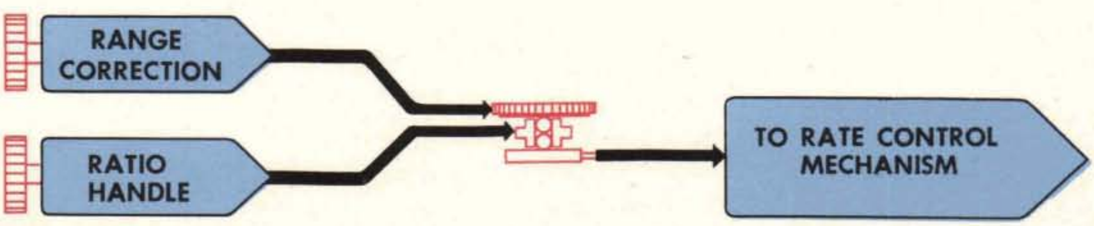
In addition to being smaller, this integrator differs from the five-inch integrator in several ways. The basic principle is the same.

1 The two springs holding the roller bracket of the four-inch integrator exert together only a $5\frac{1}{2}$ pound pull compared with the $18\frac{1}{2}$ pound pull of the two springs on the five-inch integrator.

2 On this account the output load which the four-inch integrator can drive without slippage between the balls and the roller is much smaller.

3 The lighter pressure reduces wear on the center of the disk to the extent that the tilted rollers are not needed.

The four-inch integrator is often used simply as a variable ratio gear. In one of the computer hook-ups it is used to vary the fraction of range correction which is fed into a rate control mechanism.



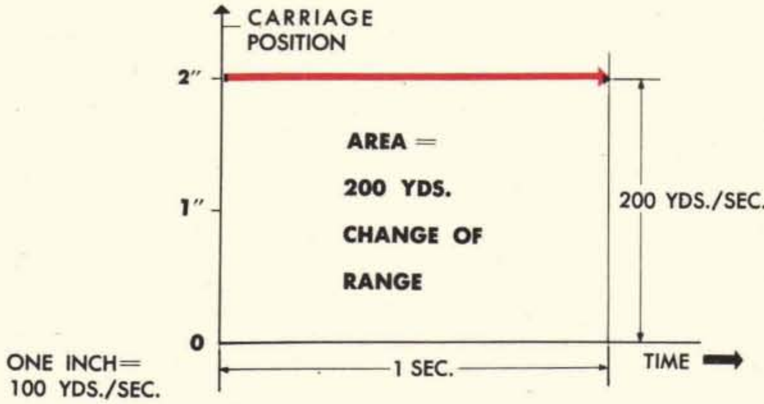
A more exact explanation of how an integrator handles a varying rate

Here is another more exact way of picturing what an integrator does when it keeps the Range.

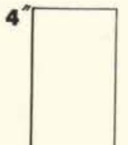
The output of a Range Integrator may be represented by the area of a rectangle. The height of the rectangle represents the distance of the carriage from the center of the disk, or the *Range Rate*. The base of the rectangle represents the amount of rotation of the disk, or the *Time*. The area of a rectangle equals the *height* × *the base*. The total change of Range equals the *Range Rate* × *Time*.

Because the height equals a given Range Rate and the base equals a given Time, the area of the rectangle formed by the height and the base *equals the total Range Change*.

For this example the carriage is held fixed 2″ away from the center of the disk for one second. If 1″ on the carriage equals 100 yards per second Range Rate, the output is 200 yards per second times one second, or 200 yards total Range Change.



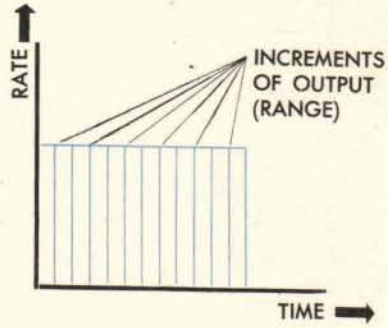
If the disk were to be turned for two seconds instead of one, the output would be twice at great. So would the area.



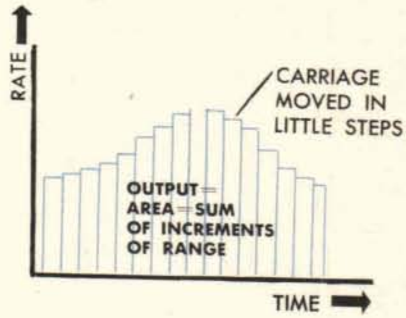
If the carriage were twice as far from the center throughout the time interval, the output would again be twice as great. So would the area.

This graphical interpretation of the output can be extended to explain how the output varies if the carriage is moving during the process.

We can think of the area of a rectangle as the sum of the areas of a large number of thin rectangles, as shown here.



Similarly, the area under a curve may be regarded as the sum of the area of an infinite number of infinitely thin rectangles. Each rectangle is as high as the curve at that point.

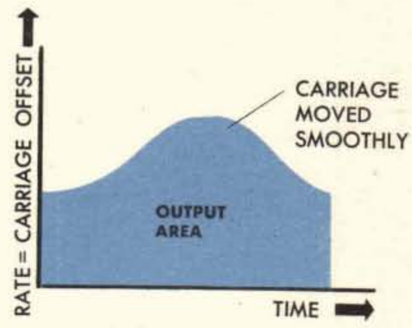


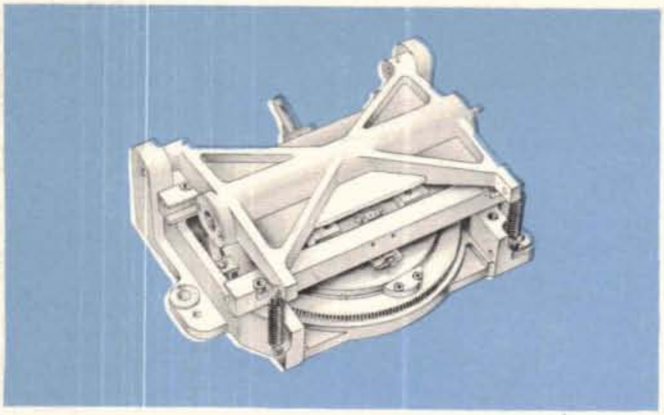
If the rectangles are thin enough, the sum of their areas will be *almost exactly* equal to the area under the curve.

Moreover, the disk type integrator adds up the outputs, by changing the output counter reading continuously.

Hence the integrator generates the area under a curve, if the height of the curve positions the carriage.

If range rate is put on the carriage, the integrator will therefore generate continuously "up to date" values of range, regardless of how range rate varies.





Setting the

The part of the Disk Integrator to be set is:

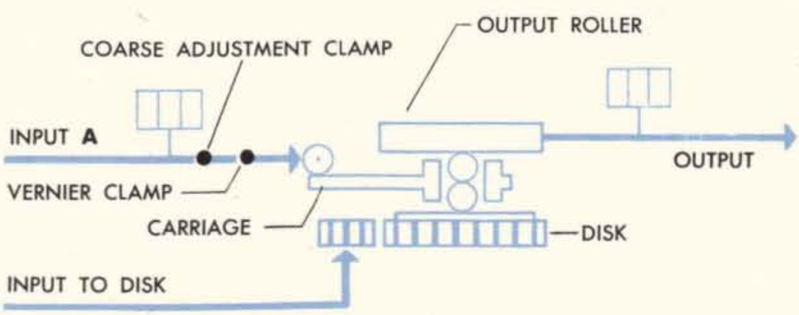
THE CARRIAGE

The parts which assist in the setting are:

1. The Disk
2. The coarse adjustment clamp.
3. The Vernier Clamp
4. The Output Roller

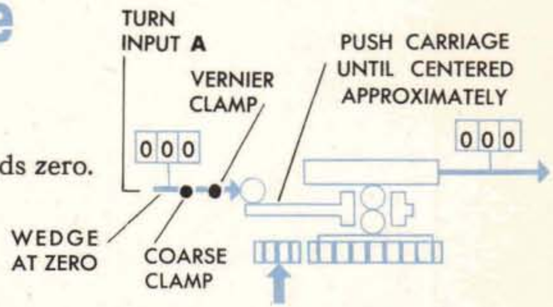
The *inputs* go to the Disk and the Carriage
The *output* comes off the Roller.

The carriage is positioned by input shaft "A" which also positions the counter. In setting the purpose is to join the carriage and the counter through the vernier clamp so that the position of the carriage is exactly indicated by the counter.

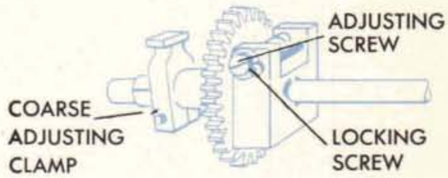


DISK INTEGRATOR

To set the carriage

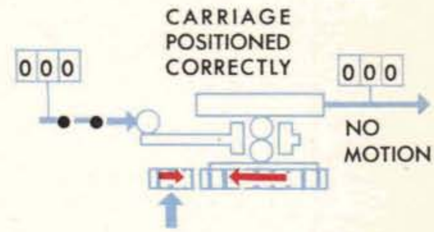


1 Turn the input to the carriage until the counter reads zero. Wedge the input.



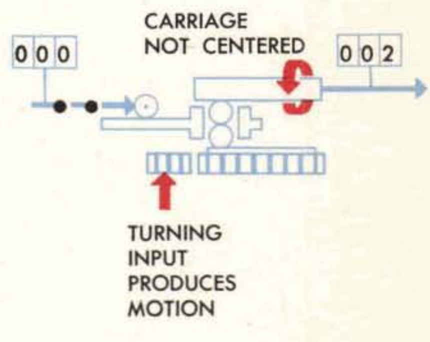
2 Slip-tighten the coarse adjustment clamp and push the carriage until it is approximately centered on the disk. This is the approximate zero position of the carriage. Tighten the coarse clamp.

3 To refine the setting, turn the adjusting nut of the vernier clamp to bring the carriage to the center of the plate.



4 Check the setting by running the disk and adjusting the position of the carriage through the vernier clamp until there is no motion of the roller when the disk turns.

5 Here the carriage is centered exactly at its zero position. Turning the disk produces no motion of the output roller.



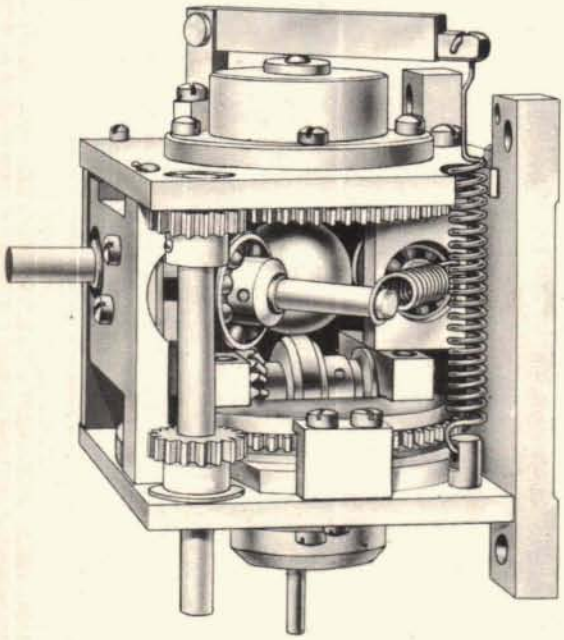
6 Here the carriage setting is incorrect. The carriage is not in the center of the plate. Turning the disk causes motion of the output roller.

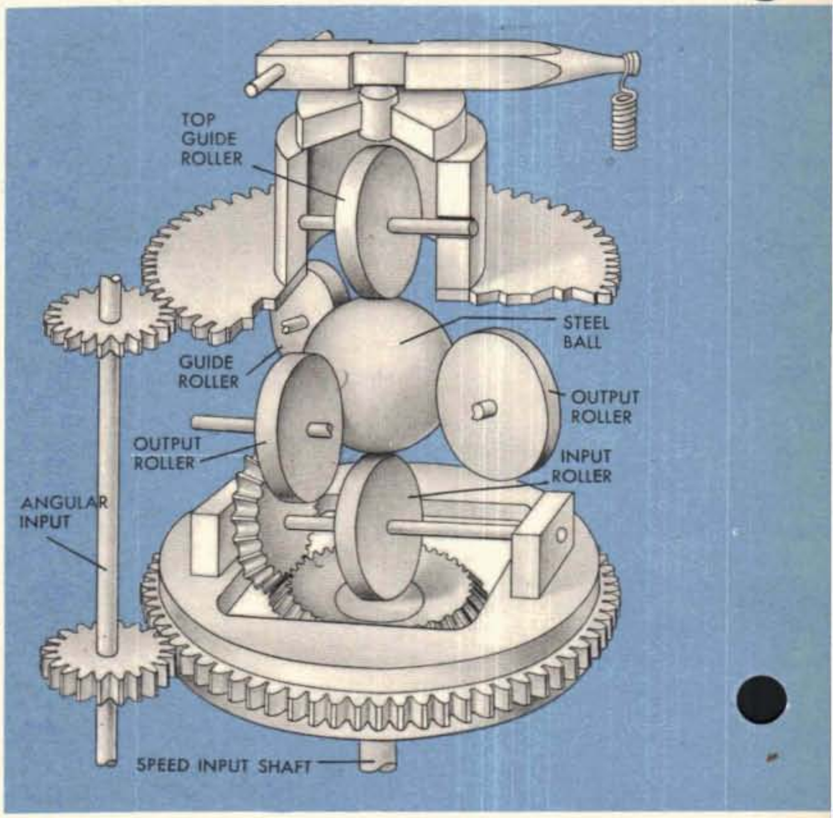
The rate at which the indicator counter moves represents the amount of error in setting.

7 To correct this error repeat 3 and 4 until there is no motion on the indicator.

8 Tighten the locking screw in the vernier clamp. Be careful not to change the setting while tightening the locking screw.

The COMPONENT INTEGRATOR





The component integrator receives the increments of change of a vector's length and computes the increments of change of this vector's length in two directions, at right angles to each other. These increments are continuously accumulated as in the disk integrator.

There are two inputs to the component integrator. Usually one input is a changing linear value and the other input is a changing angular value.

1 One output would then be the product of the linear input and the **SINE** of the angular input.

2 The other output would be the product of the linear input and the **COSINE** of the angular input.

THE TWO INPUTS FORM A CONTINUALLY CHANGING VECTOR; THE OUTPUTS ARE THE CONTINUALLY CHANGING COMPONENTS OF THAT VECTOR.

The component integrator has one steel ball and five rollers. The ball is *driven* by the INPUT ROLLER mounted under the ball.

The ball itself *drives* two OUTPUT ROLLERS, which are mounted in the frame on horizontal shafts at right angles to each other.

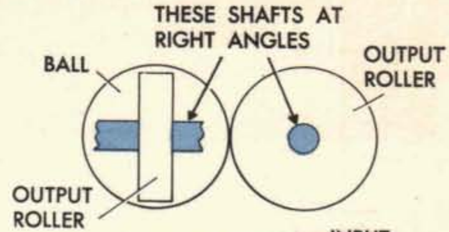
The other two rollers are GUIDE ROLLERS which hold the ball in firm contact with the input roller and the two output rollers.

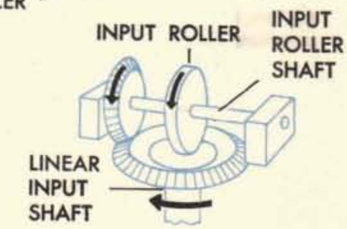
The ball and all five rollers usually have the same diameter.

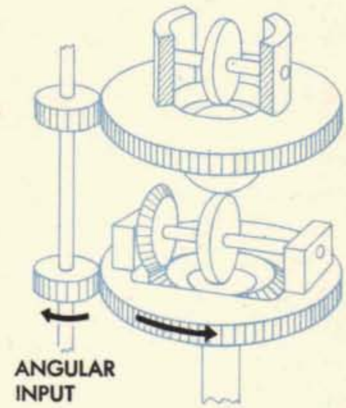
The input roller is driven by the LINEAR INPUT shaft through a pair of bevel gears.

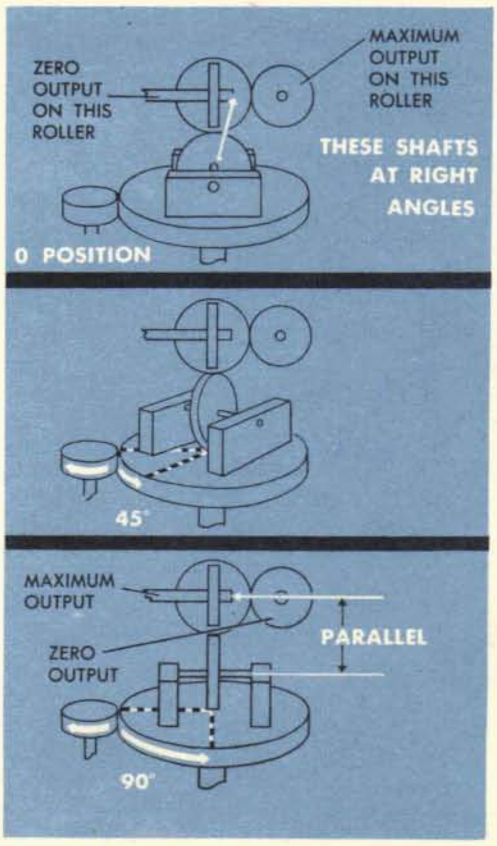
The ANGULAR INPUT drives the big spur gear on which the input rcller is mounted, so that the angular input controls the angular position of the input roller in relation to the two output rollers.

The angular input also turns the upper big spur gear on which one of the guide rollers is mounted, so that the axis of this roller is held parallel to the axis of the input roller.









Zero position for the angular input is with the input roller shaft at right angles to the shaft of either one of the output rollers, depending on the particular installation.

Here the angular input has turned the input roller 45° from its zero position.

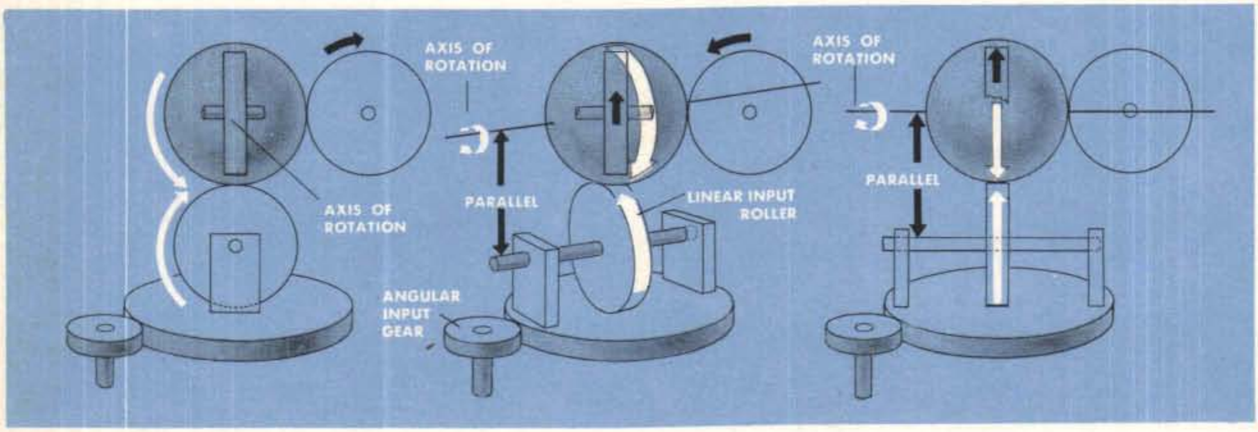
Here the angular input has turned the input roller 90° bringing the input roller shaft parallel to the shaft of the other output roller.

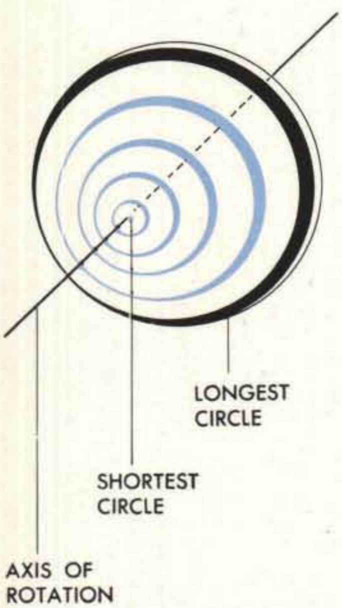
How the two inputs affect

The ANGULAR input gear turns the axis of rotation of the linear input roller.

This changes the axis of rotation of the ball in relation to the output rollers.

THE BALL ALWAYS TURNS AT THE SAME SPEED AS THE INPUT ROLLER. THE AXIS OF ROTATION OF THE BALL IS PARALLEL TO THE INPUT ROLLER SHAFT.





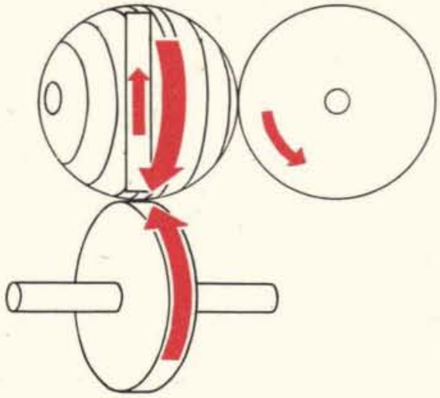
If lines are drawn around the ball at right angles to its axis of rotation, these lines will be circles of different sizes.

The largest circle is the circumference of the ball, and the smallest one is just a dot on the axis itself.

These circles actually represent the *distances* that points on the surface of the ball travel for each revolution of the ball.

Since each point moves in a circle when the ball makes one revolution, the speed of any point on the ball is proportional to the size of the circle on which that point lies.

the ball and output rollers



The point at which each output roller touches the ball lies on one of these circles.

This circle of contact represents the distance through which a point on that roller will travel during one revolution of the ball.

At different positions of the axis of rotation of the ball, circles of different sizes will touch the output rollers, so that the ROTATION OF THE ROLLERS will depend on the position of the AXIS OF ROTATION of the ball, as well as on the ball's rotation.

This becomes clearer if the ball and output rollers are viewed from above.

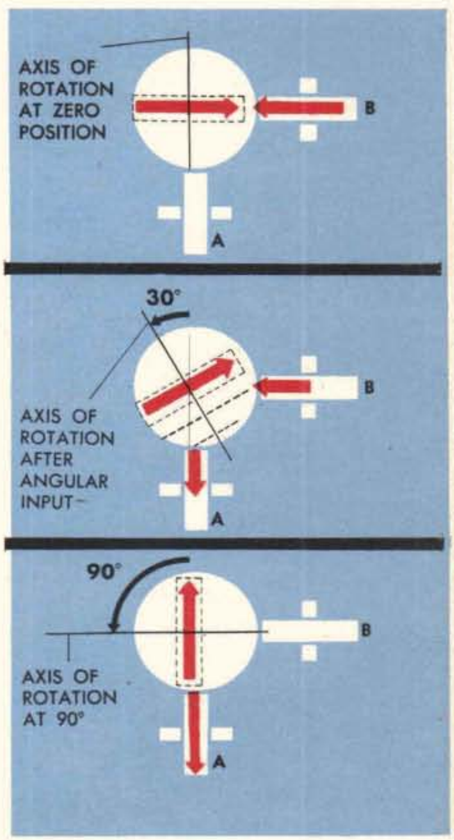
1 In zero position for output roller, *A*, the ball rotates on an axis at right angles to the shaft of output roller, *A*.

   Roller *A* touches the ball on the axis of rotation, and DOES NOT TURN AT ALL.

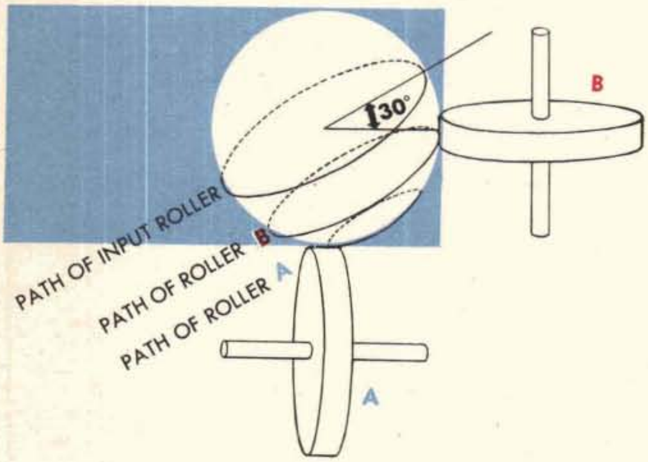
   Roller *B* is touching the biggest circle on the ball and turns at its maximum speed, equal to the speed of the input roller and the ball.

2 Here the angular input has moved the axis of rotation away from the zero position.
   Both rollers touch medium size circles and turn more slowly than the input roller and ball.

3 Here the angular input has moved the axis of rotation 90°.
   Roller *A* moves at maximum speed in this position.
   The roller *B* now touches the axis of rotation and doesn't move.



Finding out how much

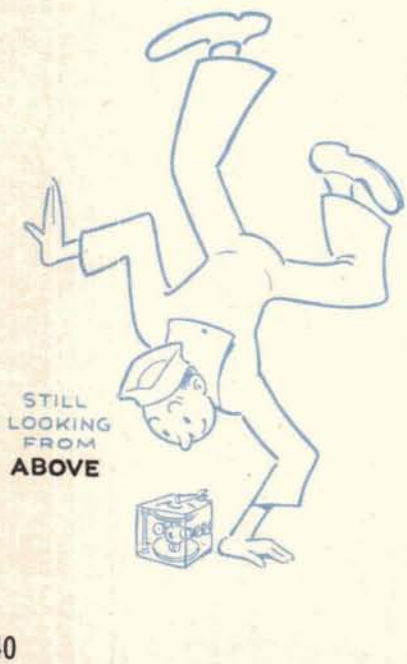


Suppose that the angular input is rotated from zero position through an angle of 30°, and that the input roller is then revolved one complete turn.

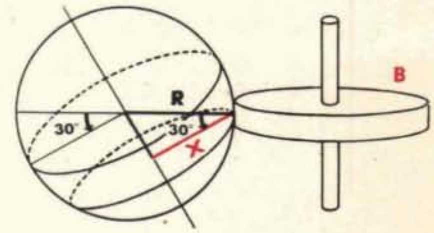
This sketch shows the paths on the ball which will be in contact with the rollers during this revolution of the input roller. The path of the input roller is the circumference of the ball itself; the other two paths are smaller circles.

The lengths of these smaller circles, compared with the circumference of the ball itself will show the relationship between the speed of the output rollers and the speed of the input roller.

For convenience, the RADII of these circles will be compared, since the radii are always proportional to the circumferences.



the OUTPUT rollers actually turn



Here X is the radius of the path of the output roller B.

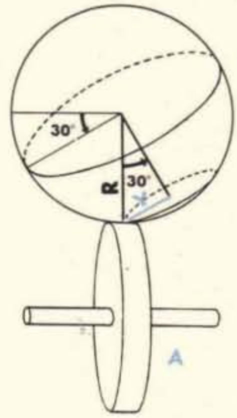
R is the radius of the ball itself, so it is equal to the radius of the path of the input roller.

In the triangle, $\frac{X}{R} = \cos 30°$

$X = R \cos 30°$

Since the ball and output roller have the same diameter, roller B turns cos 30° times one revolution for each revolution of the ball.

The ball travels at the speed of the input roller and 30° is the angular input. THE ROTATION OF OUTPUT ROLLER B EQUALS THE ROTATION OF THE INPUT ROLLER MULTIPLIED BY THE COSINE OF THE ANGULAR INPUT.



Here is the path of output roller A, with its radius marked Y.

In this triangle, $\frac{Y}{R} = \sin 30°$

$Y = R \sin 30°$

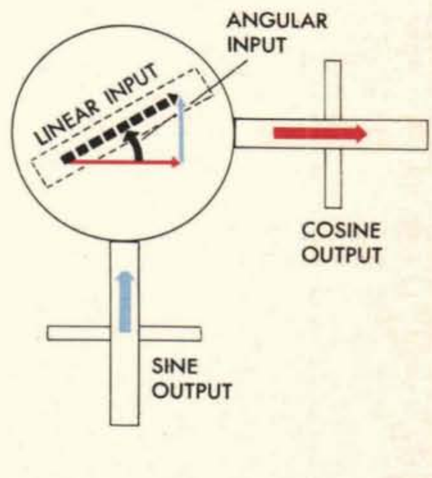
THIS OUTPUT ROLLER ROTATION EQUALS THE INPUT ROLLER ROTATION TIMES THE SINE OF THE ANGULAR INPUT.

The two output values are:

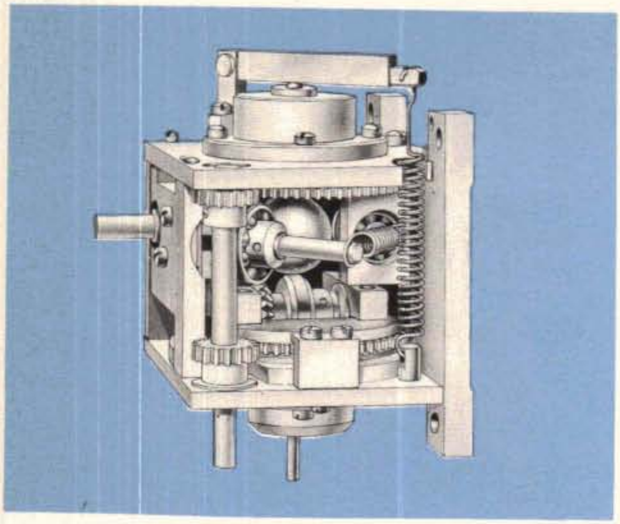
(1) Roller input × cos (input angle)

(2) Roller input × sin (input angle)

The two inputs can be drawn as a vector whose length is proportional to the ROTATION of the input roller. The two outputs are then components of that vector.



By changing the angular input, the component integrator may be used as a variable speed drive in which the output speeds are fractions of the input speed proportional to the sine and cosine of the angular input.



Setting the

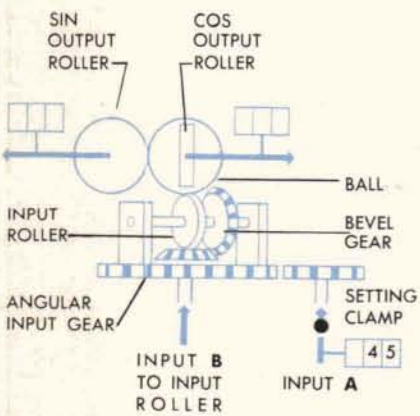
Only one of the Component Integrator's two inputs has to be set. This is the Angular Input Gear which receives the angular input. The parts which assist in the setting are:

The Input roller

The Output rollers

The *INPUTS* go to the Angular Input Gear and the Input roller.

The *OUTPUTS* come off the output rollers.



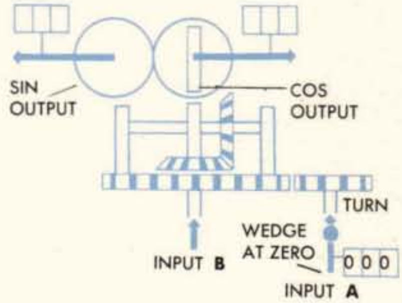
The input roller requires no setting because it is merely a driving roller.

The Angular Input Gear is positioned by input shaft *A*, which also positions a counter. The purpose, when setting, is to join the Angular Input Gear and the counter through the setting clamp so that the position of the Angular Input Gear is exactly indicated by the counter.

COMPONENT INTEGRATOR

To set the angular input gear

1 Turn the input *A* to the Angular Input Gear until the counter reads 0°. Wedge the input.

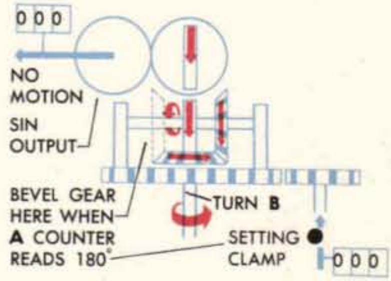


2 Turn the Angular Input until the input roller shaft is parallel to the cosine output roller shaft and the bevel gear on the input roller shaft is in the position described in the Computer's setting notes.

If the setting notes describe a setting for the input angle at 90° instead of zero, the roller shaft should be parallel to the *sine* output roller shaft.

3 Slip-tighten the setting clamp.

4 Turn the roller input *B* and check the motion of the sine output. There should be no motion.

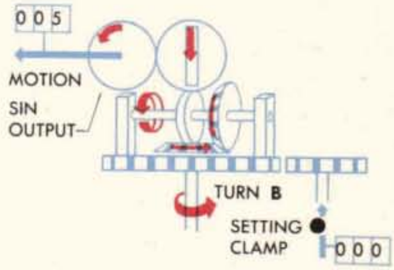


NOTE: The angle used in setting determines which output should be zero:

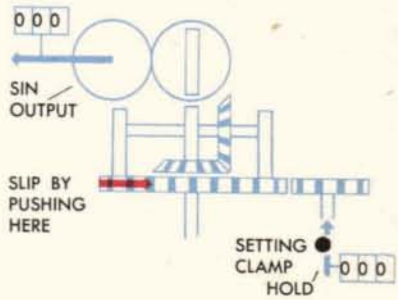
If the setting angle is 0° or 180° there should be no motion of the sine output roller. (Sin 0° or 180° = 0)

If the setting angle is 90° or 270° there should be no motion of the cosine output roller. (Cos 90° or 270° = 0)

5 Here the Angular Input is set correctly for 0°. When the input roller is turned there is *no* motion of the sine output.



6 This setting is incorrect. The input roller is not quite parallel to the cosine output roller. Movement of the roller input causes motion of the sine output. The rate at which the indicator moves represents the amount of error in setting.



7 To correct this error, slip the angular input through the setting clamp until there is no motion of the sine output when the input roller is turned.

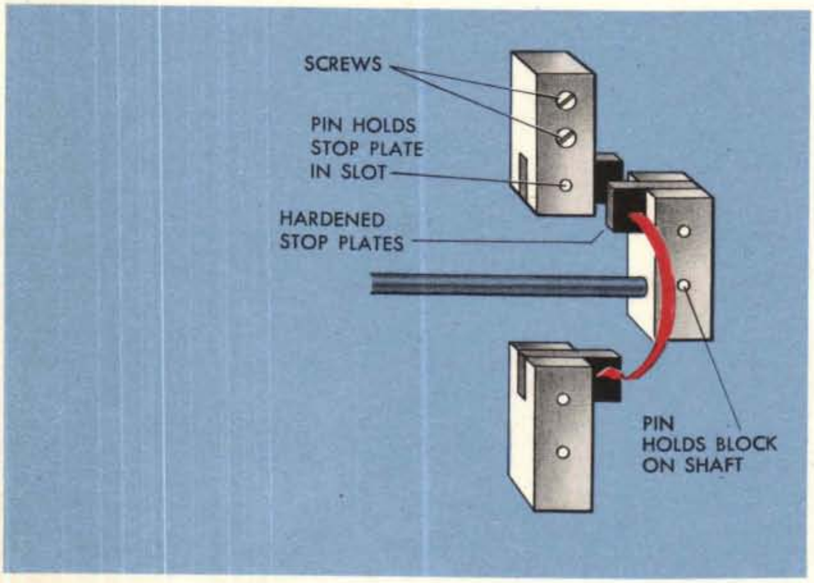
8 Tighten the setting clamp.

9 Remove the wedge.

NON-COMPUTING MECHANISMS

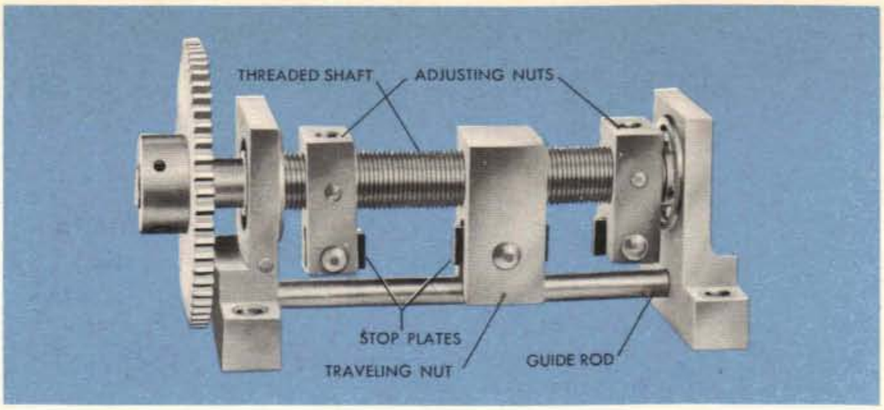
LIMIT STOPS

Limit stops are mechanical safety devices that prevent shafts from rotating farther than they should. They are used to keep hand cranks or electric motors from driving past the limits of the mechanisms to which they are connected. Limit stops protect cams, lead screws, input racks and integrator carriages.



Here is the simplest type

This limit stop permits a shaft to rotate only 180°. It consists of three metal blocks, with inserted steel stop plates. Two of the blocks are fastened to the framework of the machinery close to the shaft that is to be limited. The third block is pinned to the shaft. Every time the shaft makes a half turn in either direction, the stop plate on the block on the shaft touches the stop plate on one of the fixed blocks and prevents the shaft from rotating farther.



Here is the most usual type

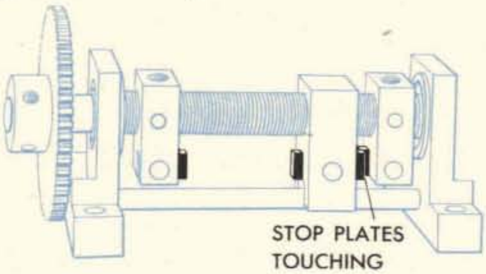
This limit stop consists of a traveling nut on a threaded screw, a guide rod to prevent the traveling nut from rotating, and two adjusting nuts. The adjusting nuts are pinned to the shaft on either side of the traveling nut and turn with the shaft.

The shaft is stopped from turning when the stop plate on one of the adjusting nuts hits against a stop plate on the traveling nut.

The distance between the adjusting nuts is accurately set before the stop is installed in the computer, to correspond with the exact number of revolutions the shaft can make before it must be stopped.

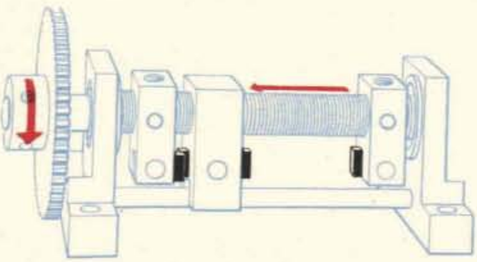
For example, a line is to be limited to 30 revolutions from its zero position:

When the line is at zero the traveling nut will be against one of the adjusting nuts.



After 30 revolutions of the line, the traveling nut will have traveled to the other adjusting nut, and will not be able to turn any farther.

AFTER 30 REVS.



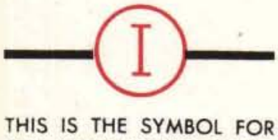
The INTERMITTENT DRIVE

Often in a computer several mechanisms with different limits of operation will be attached to the same line of gearing. For example, the present range line may turn from 0 to 35000 yards, but a reciprocal-of-present-range cam connected to that line may be cut to take values of range only from 750 to 22500 yards.

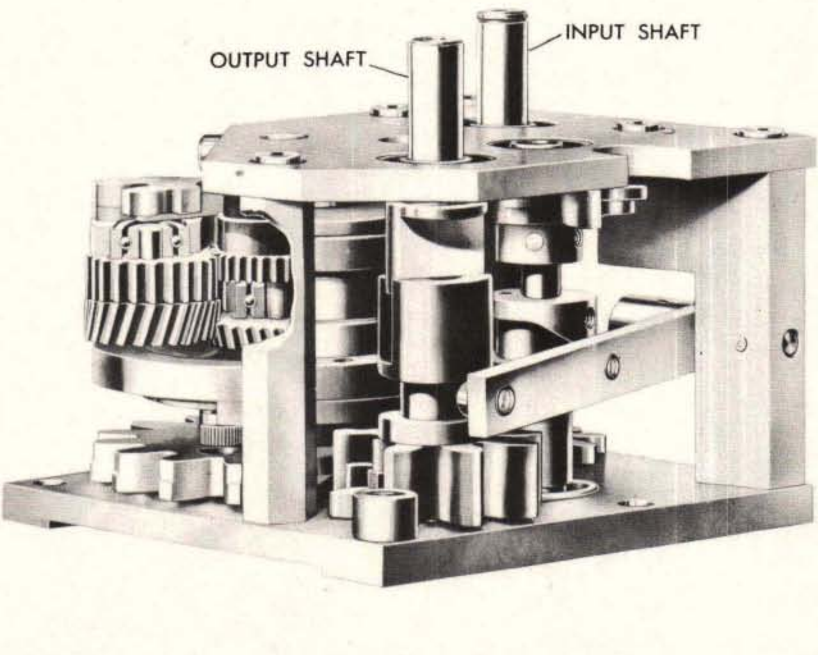
A mechanism is needed which will disconnect the range input to the cam at the instant the input line goes below 750 yards or above 22500 yards. The mechanism that fills this need is the Intermittent Drive.

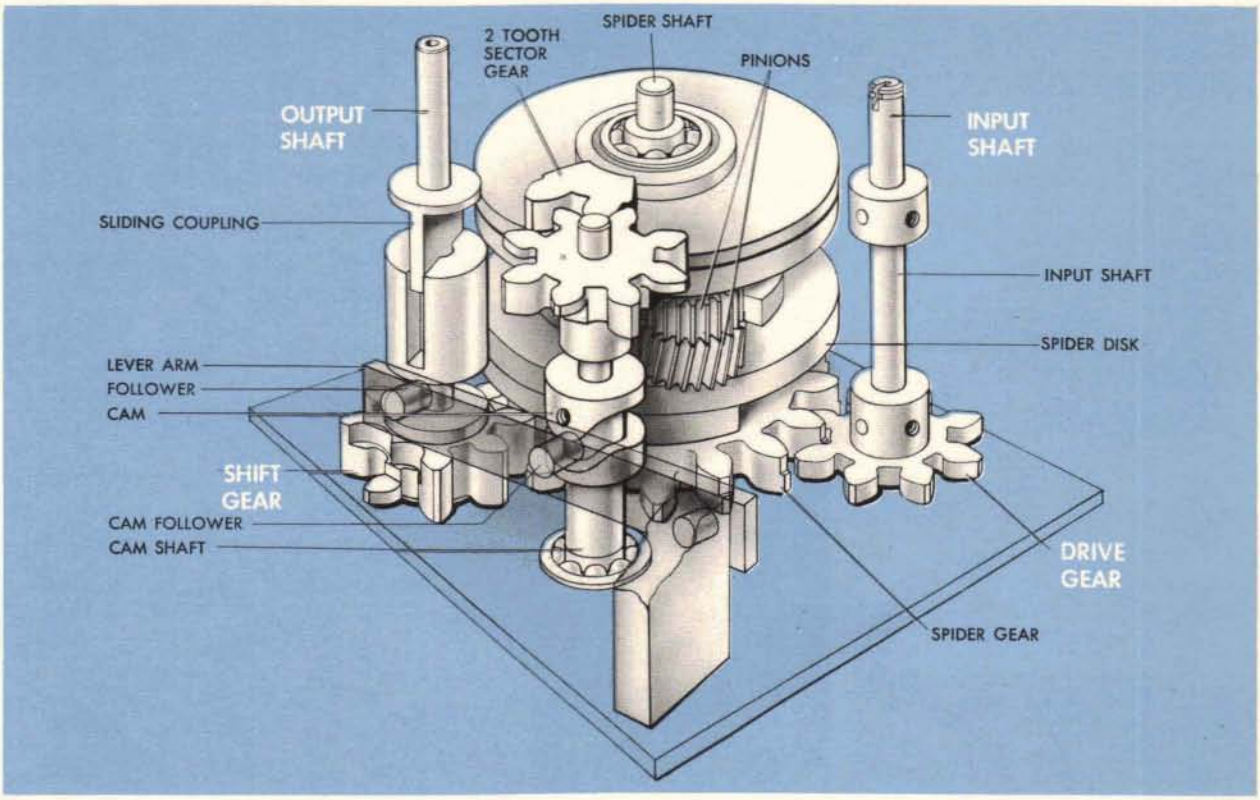
In this example all values of range can turn the *input* to the Intermittent Drive, but only those values between 750 and 22500 will be transmitted to the cam. When the input line turns above or below these limits, the output gear will lock and stay locked until the values coming into the intermittent drive are again within the limits which the cam can handle.

Intermittent Drives are used in this way to connect and disconnect a variety of mechanisms including multipliers, component solvers and transmitters.



THIS IS THE SYMBOL FOR THE INTERMITTENT DRIVE





How the drive looks with the top plate off

On the bottom plate there are three spur gears, the drive gear, the spider gear, and the shift gear.

The drive gear drives the spider gear, which drives the shift gear.

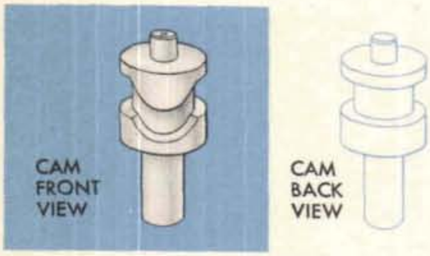
The disks and pinion gears on the spider shaft are there just to reduce the speed, so that the 2-tooth sector gear on the top will drive much more slowly than the spider gear.

The 2-tooth sector gear drives the gear on the cam shaft very slowly.

The cam lifts the lever arm up and down. At the end of the lever arm there is a small follower which fits into the groove on the shift gear. As the lever arm moves upwards it slides the shift gear up along the output shaft, out of mesh with the spider gear.

That's how the intermittent "cuts out." The input can keep on turning after this, but the shift gear will not be meshed, and it will not turn.

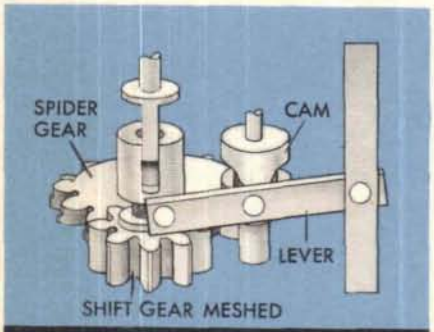
The CAM



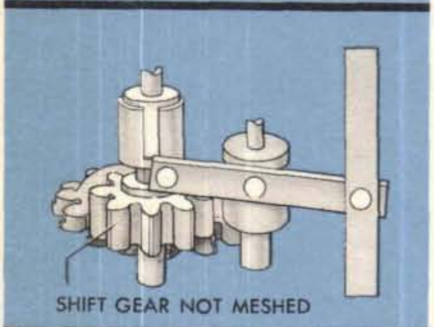
In the intermittent drive the shift gear stays IN mesh for a certain number of revolutions of the drive gear and then moves up OUT of mesh.

The number of revolutions the shift gear stays in mesh is CONTROLLED BY THE CAM AND GEARING.

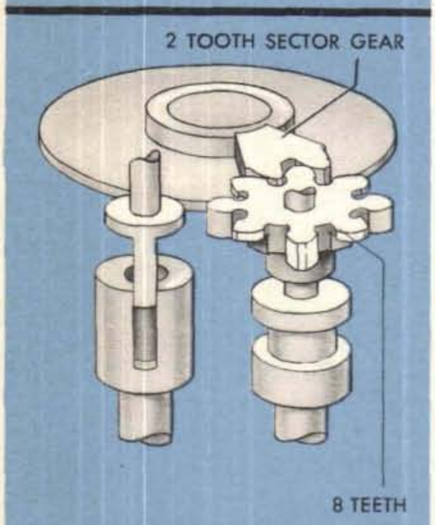
The cam is really a collar with a groove in it.



The groove is low for ¼ of the distance around the collar, and while the lever pin is in this low part, the shift gear meshes with the spider gear.



When the follower is not in this low part of the groove, the lever arm slides the shift gear up its shaft out of mesh.



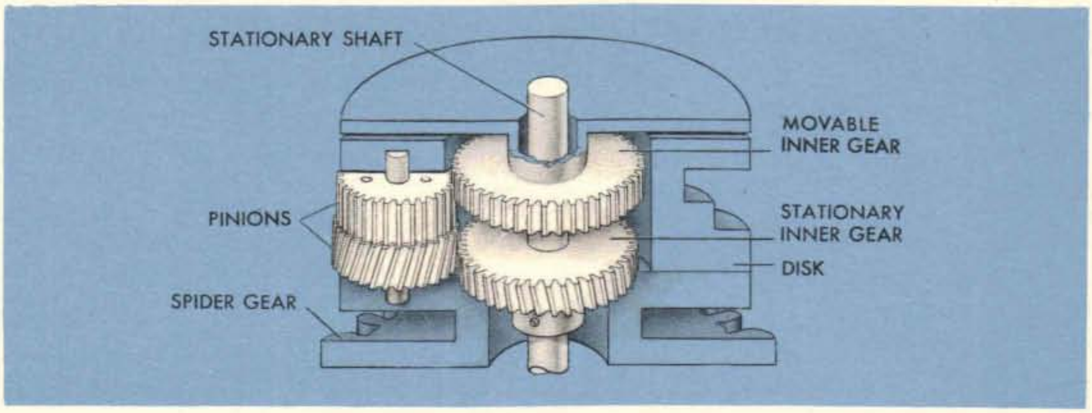
The gear on the top of the cam shaft has 8 teeth, so it will be turned ¼ revolution for each revolution of the 2-tooth sector gear which drives it.

Since the shift gear is IN mesh for only ¼ turn of the cam shaft, the cam will hold the shift gear IN mesh for only ONE revolution of the 2-tooth sector gear.

Obviously, the shift gear must stay in mesh for MANY revolutions of the DRIVE gear, so there has to be a great reduction in speed between the revolutions of the INPUT SHAFT and the revolutions of the 2-TOOTH SECTOR GEAR.

The planetary gearing above the spider gear takes care of this reduction. It gives a ratio of 1 to 29 so that the shift gear will stay meshed for 29 revolutions of the drive gear.

and the PLANETARY GEARING



As the drive gear turns the spider gear, the two pinions of the planetary reduction gearing are carried around on the disk which is screwed to the spider gear.

While being carried around, the two pinion gears rotate on their own shaft.

These pinions are fastened to each other. They mesh with the two inner gears on the stationary shaft, which are housed inside the casing between the disks.

The two pinions have the same number of teeth, but the MOVABLE inner gear has 2 more teeth than the STATIONARY inner gear. As the pinions are carried around, the lower one rolls on the stationary inner gear.

Since the upper pinion is fixed to the lower pinion it turns at the same rate as the lower one, and meshes with the movable inner gear.

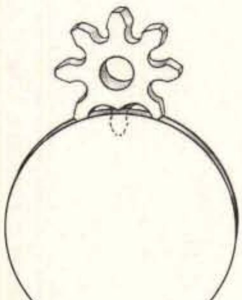
BUT AS THE MOVABLE INNER GEAR HAS THE TWO EXTRA TEETH IT WILL BE DRIVEN AROUND AN AMOUNT EQUAL TO TWO OF ITS TEETH FOR EACH WHOLE REVOLUTION OF THE SPIDER GEAR.

Accordingly, this movable inner gear turns very slowly.

The disk carryng the 2-tooth sector gear is fastened to this movable inner gear. The 2-tooth sector gear will also turn very slowly compared to the spider gear.

In fact, it turns once for 14½ revolutions of the spider gear, or 29 revolutions of the input gear.

LOCKING the SHIFT GEAR



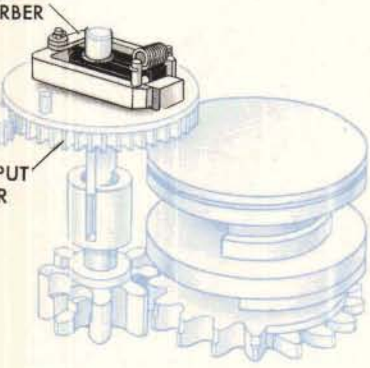
As soon as the shift gear slides out of mesh, it must be locked.

If it were free to turn, the input and output lines might not be synchronized when the output cuts in again.

To make the gear lock, one tooth is partly cut away or "mutilated."

When the gear is raised, the teeth on either side of the mutilated tooth are held against the side of the spider disk, so that the gear cannot turn. The mutilated tooth fits under the edge of the disk. In this position the gear cannot turn and the output is locked.

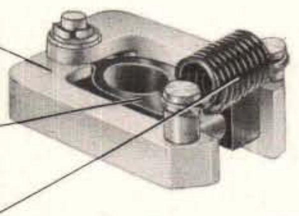
The SHOCK ABSORBER



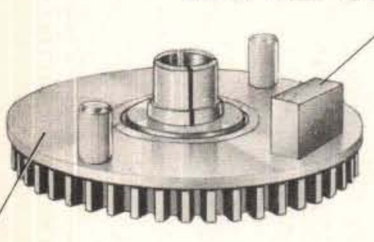
When the cam brings the shift gear down into mesh with the spider gear, the spider gear may be turning rapidly.

The sudden starting of the output shaft could cause damage to the gearing on the output line. To prevent this there is a gear with a shock absorber on the output shaft.

In the shock absorber a disk is fastened to the output gear and both the gear and disk turn freely on a hub on the output shaft. The hub is held tightly to the shaft by a special clamp. Two arms are pivoted on one end of the clamp and are held against the other clamp end by a spring. The two arms straddle a stop block fastened to the gear disk. The shaft motion is transmitted through the clamp assembly and the spring to the stop block on the gear disk, causing the gear to turn as the shaft is turned.



A sudden shaft movement in either direction forces one of the arms away from the stop block and stretches the spring. The spring pressure exerted against the arm remaining in contact with the stop block starts the gear turning and continues to turn the gear until the shaft and gear regain their original position with both the arms touching the stop block. The spring, by stretching, absorbs the first shock of movement and allows the gear sufficient time to pick up speed and so prevent damage to the lines it drives.



THE FIRST MOVEMENT OF SHAFT STRETCHES THE SPRING

THEN THE GEAR AND SHOCK ABSORBER ROTATE TOGETHER

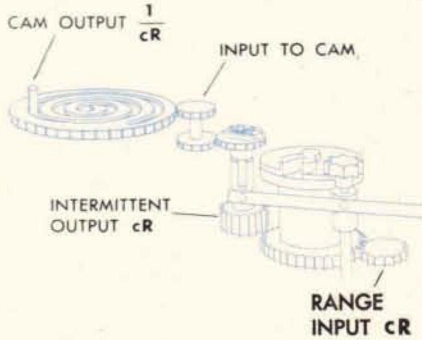
Here's an INTERMITTENT DRIVE in action

An intermittent drive on the range line controls the inputs to the $1/cR$ cam.

This cam calculates the reciprocal of range:

The reciprocal cam may be cut to take range values between 750 yards and 22500 yards only; and the intermittent is connected to the cam input to keep out all other values.

In order to make this clear, consider what happens when a target flies right over own ship:



NOTE:
In the diagrams below, the locking gear has been omitted.

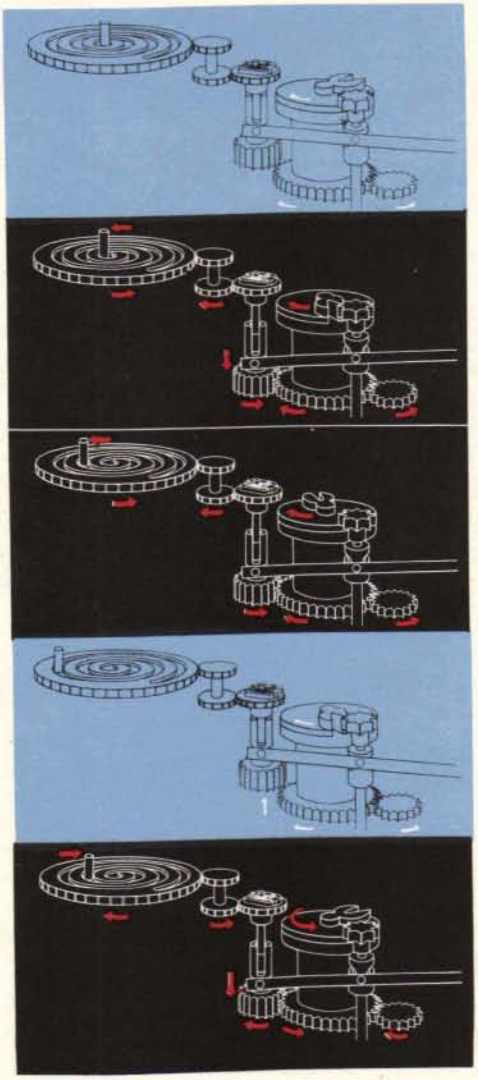
The range input is turning as range decreases. The output is "cut out" and does not drive the $1/cR$ cam. The $1/cR$ cam follower is near the center of the cam.

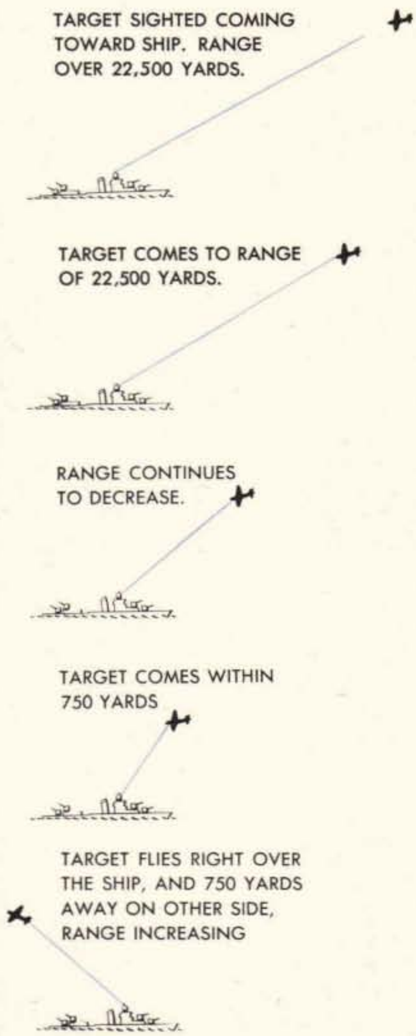
The sector gear turns the "cut-out" cam. The output gear "cuts in." The $1/cR$ cam begins to turn.

All the input values of cR drive through the intermittent to the $1/cR$ cam.

The sector gear has made one complete revolution and now turns the "cut-out" cam again. The output "cuts out" and stops driving the $1/cR$ cam. The $1/cR$ cam follower is at the outside end of the cam groove.

The range input is turning in the other direction as range increases. The sector gear turns the cam back, and the output "cuts in" again and drives the $1/cR$ cam in the opposite direction.





HAND CRANKS

HERE ARE TYPICAL HANDCRANKS

Hand cranks are used as a means of putting values into the computer by hand. They are used to turn lines of gearing which put inputs into various mechanisms.

In some cases a hand crank is the only means by which a quantity is put into a computer. This is true of wind speed, and wind direction.

More often a hand crank is an alternative method of introducing an input when the normal automatic receivers fail, or for some other reason are out of use.

Some of the hand cranks are used mainly as a convenient way to hold certain inputs or outputs at a given value for running tests.

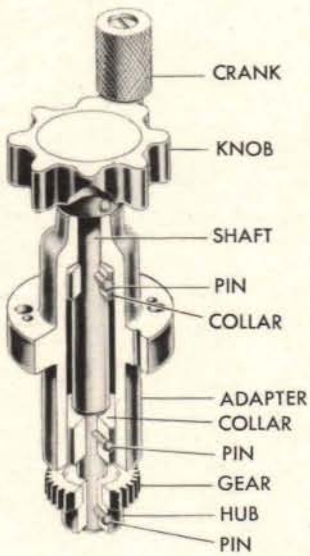
The hand cranks on computers are usually just taken for granted as parts of the covers on which they are mounted. Actually they are themselves important mechanisms requiring care in operation and upkeep.

Here's a simple hand crank

This hand crank consists of a shaft with a knob pinned to one end and a gear pinned to the other.

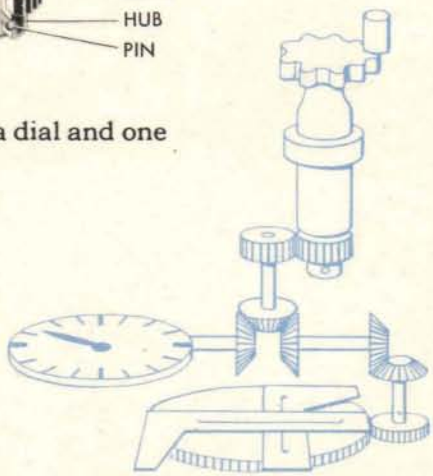
The knob has a crank so that inputs can be cranked in quickly and easily.

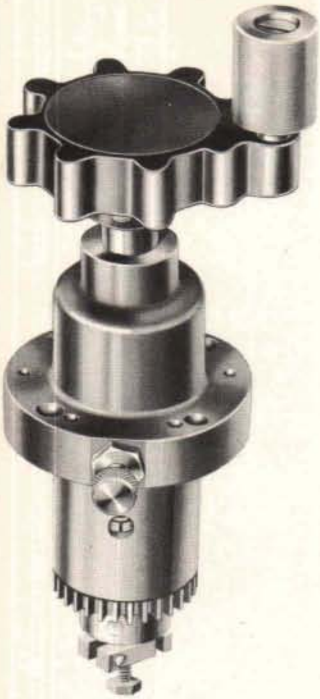
The shaft is mounted in an adapter which is screwed onto the cover of the computer.



This is how the hand crank looks inside.

Here is an example of a hand crank that positions a dial and one of the inputs to a component solver.





What HAND CRANKS can do

Various devices can be added to the simple hand crank to enable it to do other jobs. Different handles have different combinations of these devices according to the work they have to do.

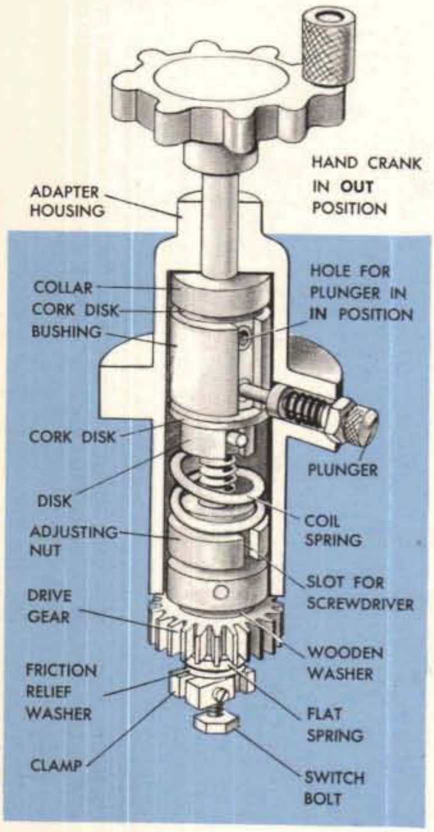
Here's a handle with all the common devices. It has:

Adjustable Holding Friction

Adjustable Friction Relief Drive

Plunger with a locking device to hold the handle in position

Adjustable Push Button Switch-Bolt



The frictions

The HOLDING FRICTION is a friction created by pressure exerted against two cork disks by a collar, a bushing and a metal disk. This friction puts a drag on the hand crank. This keeps the hand crank positioned and thus prevents motion from backing out through the hand crank.

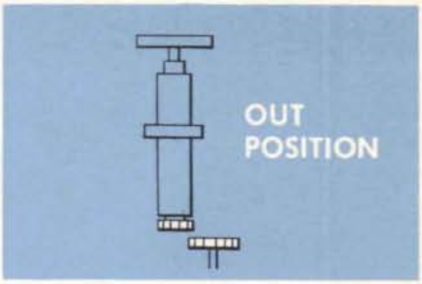
The drive gear is held to the shaft by the FRICTION RELIEF DRIVE consisting of a flat spring, a wooden washer, and a clamp. If the line hits the end of a limit stop or the torque on the line is too great, the friction will slip so that the gearing and mechanisms will not be damaged.

The plunger for changing position of the shaft

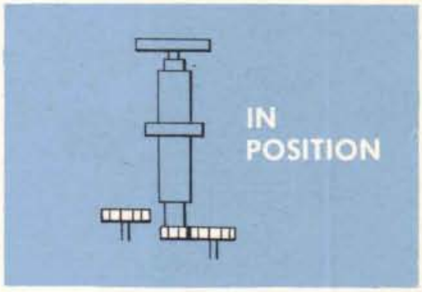
The hand crank usually has two positions: the IN position and the OUT position. In changing position, the shaft and drive gear move in relation to the adapter housing. A plunger is used to hold the shaft in either of these two positions. The plunger is pulled out and the hand crank is pushed or pulled to its new position. The plunger is returned by a spring when released.

in addition to cranking

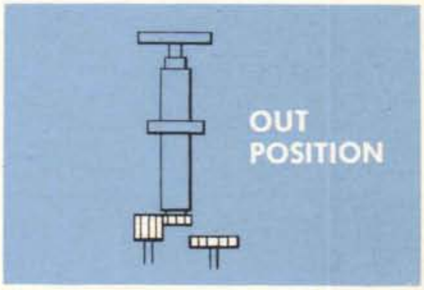
A hand crank may SHIFT GEARS.



With this hand crank in the OUT position, the crank gear is disengaged. When the hand crank is in its IN position, the crank gear meshes with a line of gearing.



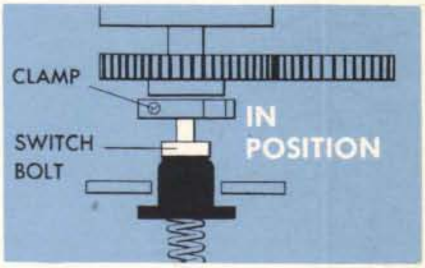
This crank gear is set between two other gears. With the shaft in its IN position, the gear is meshed with one gear. In its OUT position it disengages the first gear and meshes with the second gear.



The gear as attached to this hand crank is set between two gears. One of these gears is wide and is always meshed with the gear on the hand crank. In the OUT position the crank gear engages only the wide faced gear.

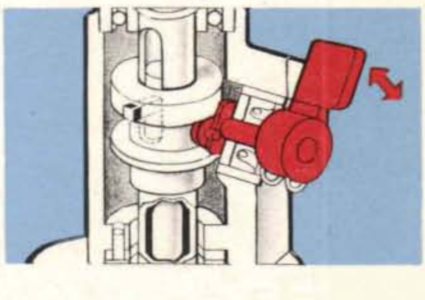
In the IN position the shaft is lowered. The crank gear engages the two gears at once so that the data goes to two mechanisms at the same time.

A hand crank may push SWITCH BUTTONS by changing the position of its shaft.



In the OUT position the crank gear is disengaged; the circuit is closed and a follow-up motor or receiver controls the line.

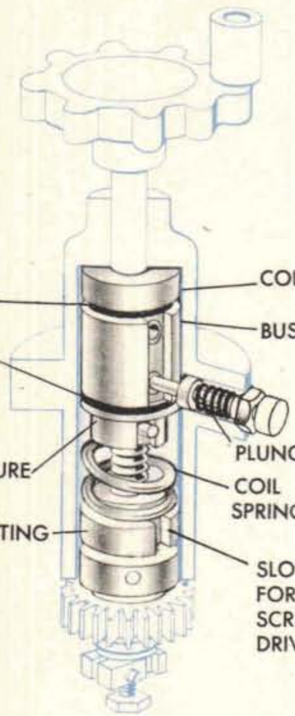
In the IN position the SWITCH BOLT below the gear depresses a push button switch and breaks an electric circuit, usually to de-energize a servo motor. The gear is meshed with a line of gearing and the data is set in by HAND.



In cases where a hand crank is shifted frequently a more convenient method of moving the hand crank from one position to another is needed. A shift lever can be used instead of the plunger and pin. The shift lever mechanism both moves the hand crank and holds it in position once it has been moved.

Details of HAND CRANK FRICTIONS

Holding Frictions



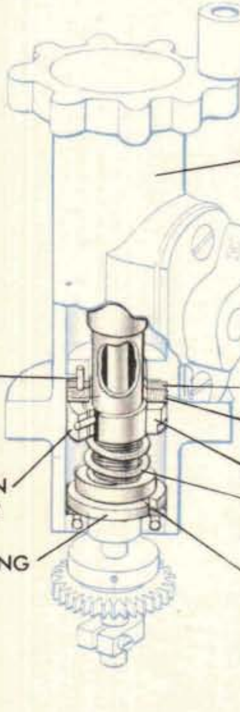
Here is one type of holding friction used on a hand crank:

It consists of a metal bushing that turns freely on the shaft. A plunger prevents the bushing from turning with the shaft. There is a cork disk cemented to each end of the bushing. A coil spring holds the collar and pressure disk tightly against the cork disks.

The tension of the spring against the pressure disk is regulated by turning the adjusting nut.

The friction is adjusted until it is great enough to prevent the value from backing out through the hand crank.

To move the hand crank, the turning force has to be strong enough to overcome the friction between the stationary cork disks and the collar and pressure disk that turn with the shaft.

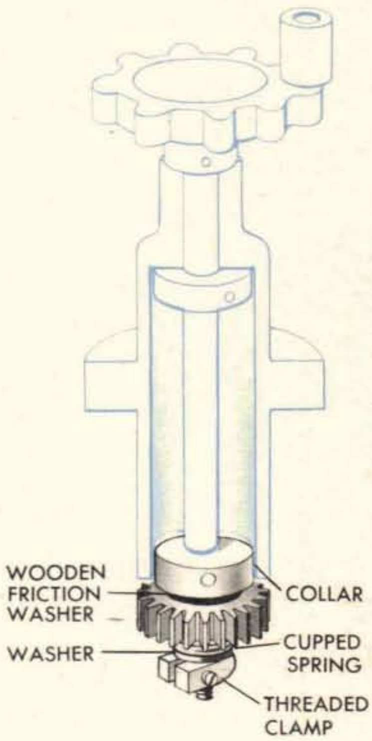


This is another type of holding friction used on hand cranks.

It consists of a cork friction inside an adapter.

There is an adjusting nut which can be screwed up and down on a thread. This nut compresses a spring which bears against a collar. The collar can move up or down and turns with the shaft by means of a pin which slides in a keyway. The collar presses on a cork disk. The cork disk is cemented to a steel disk which is pinned to the adapter.

Turning the adjusting nut either releases or compresses the coil spring increasing or decreasing the friction between the rotating collar and the stationary cork disk.



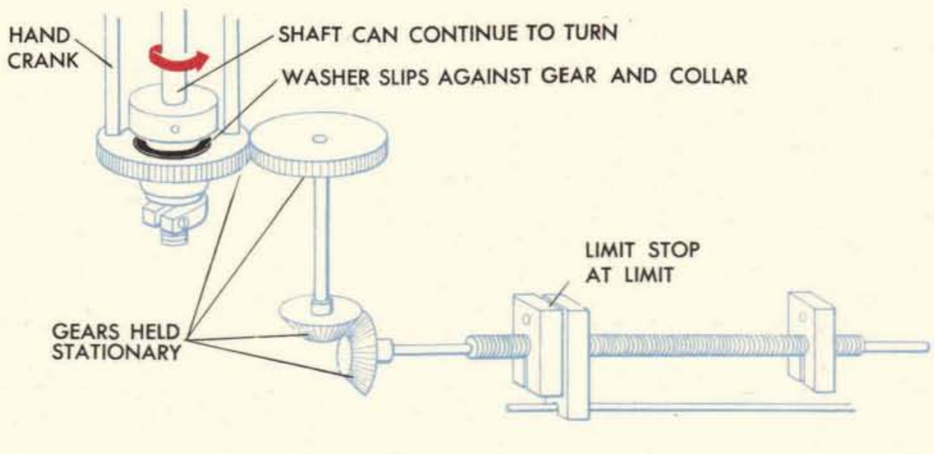
The friction relief drive

On this type of friction drive a wood washer is used.

The gear can rotate on the shaft. A collar is fastened to the shaft and the wooden washer inserted between the collar and the gear. A cupped spring pressing against the other side of the gear creates a friction between the collar, wooden washer and gear. The tension of the cupped spring is regulated by screwing a clamp along the threaded shaft.

When the crank is turned, the collar turns with the shaft, and the friction drive will turn the gear with the collar and shaft. If there is an overload, or the shaft line is stopped by a limit stop, exerting additional force on the hand crank will cause the friction drive to slip. The shaft and collar turn, but the gear remains stationary.

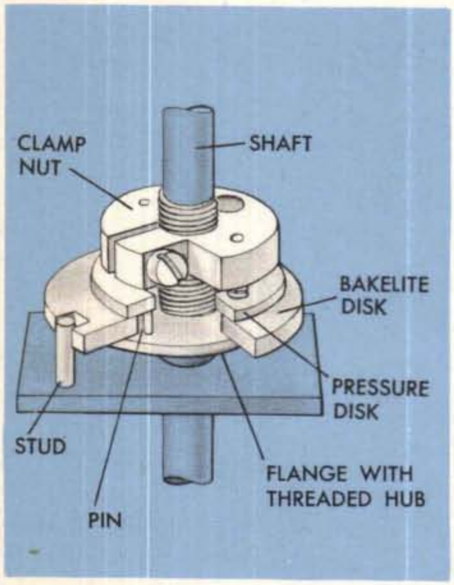
In this way the hand crank and the gearing connected to it are protected when the line runs into a limit stop.



HOLDING FRICTIONS

A Holding Friction holds a shaft. That is, it exerts a drag on a shaft so that a force greater than the drag has to be used before the shaft can turn.

This friction drag prevents shaft values from backing out. It also stops oscillations.



Here is one type

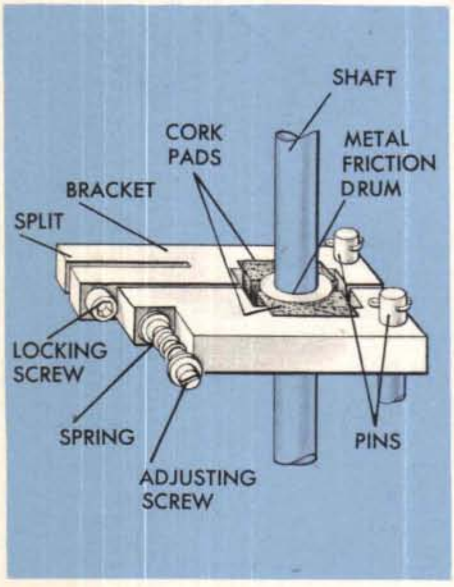
In this type, friction is created between the shaft and a bakelite disk that is held stationary.

A flange with a threaded hub is pinned on the shaft. A bakelite friction disk, which is held stationary by a stud, is held against the flange by a pressure disk. The pressure disk has two pins that fit into the flange, so that the pressure disk is driven by the hub. Two springs between this disk and a clamp nut hold the flange and pressure disk against the bakelite disk.

The springs push against the pressure disk, and create friction between the pressure disk and flange, which turn with the shaft, and the bakelite disk, which is held stationary.

The amount of friction is controlled by turning the clamp nut to change the spring pressure.

After the proper pressure is applied to the friction disk, the screw in the clamp nut is tightened. This holds the clamp nut so that it cannot turn.



Here is a second type

This type consists of two cork-lined metal brackets which press against a metal drum pinned to the shaft. These brackets hinge on two fixed pins in the base plate.

Turning the adjusting screw compresses or releases a spring; the spring pressure presses the brackets together causing the cork pads to press against the friction drum, creating friction between the shaft and the two stationary brackets.

There is a slot and locking screw in one of the brackets. Tightening the locking screw clamps the adjusting screw to prevent it from turning after the spring pressure is adjusted.

To turn the shaft a force has to be strong enough to overcome the friction between the cork-lined brackets and the drum on the shaft.

A DAMPING friction similar in principle to the one illustrated, can be used to reduce oscillation.

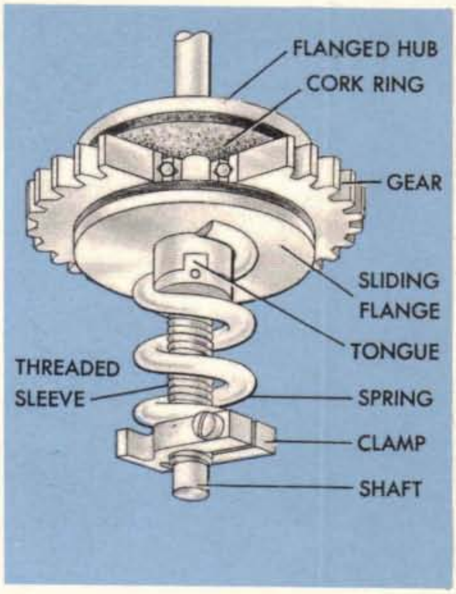
DRIVING FRICTIONS

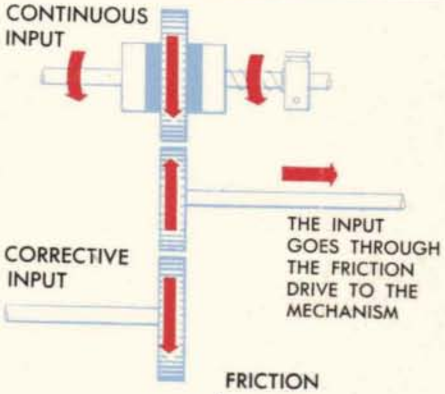
Driving frictions described elsewhere are used to take up shock and to prevent damage. For instance, when a motor overruns enough for the output to hit a limit stop, or when a handcrank is turned with too much force, or when the line driven by the crank has hit a limit and the crank is still turned, the driving friction slips and eases the strain on the mechanism.

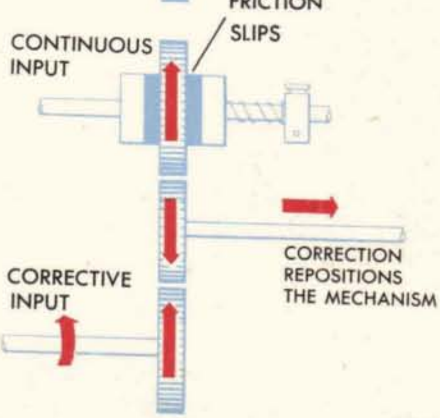
A driving friction can also be used to alter the value of a continuously changing shaft line. The parts of this type of driving friction are arranged as follows:

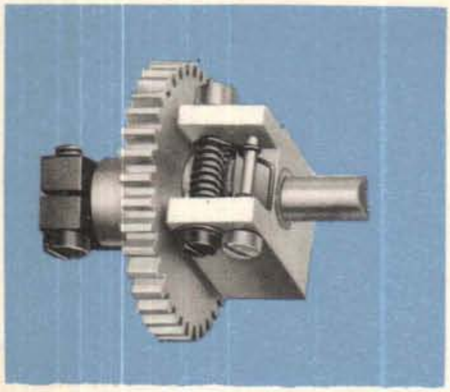
A flanged hub is pinned to the shaft. Then a gear with cork washers cemented to both sides is mounted on a ball bearing to turn freely on the shaft. A sliding flange is added which slides on the shaft and bears against one cork ring. This flange is turned with the shaft by a tongue which is part of a collar pinned to the shaft. A spring is compressed between the flange and a clamp. The clamp screws on a threaded sleeve and controls the spring pressure.

The continuous input turns one of the shafts in a shaft line to a computing mechanism. The input normally drives through the friction to position the shaft line. By slipping through the friction drive, a correction can be made by repositioning the shaft line without disturbing the input. After the correction has been made the input will again turn the shaft line.





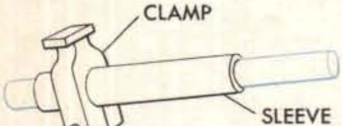




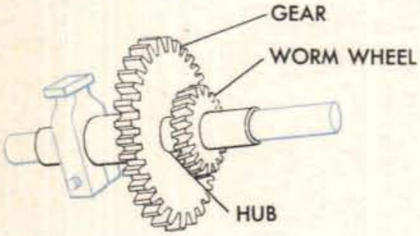
The VERNIER CLAMP

The vernier clamp is used to make a fine adjustment in the position of a gear on a shaft. With the vernier, the gear can be turned very small amounts relative to its shaft.

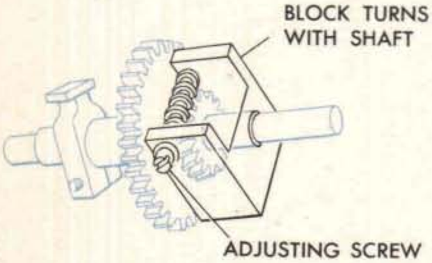
The vernier clamp consists of:



1 A sleeve with an ordinary clamp to hold the sleeve on the shaft.

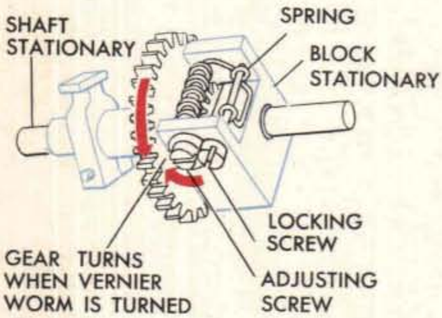


2 A gear that fits over the sleeve is free to turn on the sleeve. This gear has a special very small worm wheel on one end of its hub.



3 A block is pinned to the sleeve and holds a small worm. This worm meshes with the worm wheel on the gear hub. The adjusting screw in this block is turned to rotate the small worm and the gear.

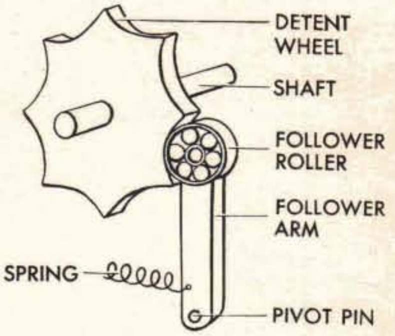
When the worm is turned, the worm wheel and the gear revolve together very slowly on the sleeve, altering the relative positions of the gear and the shaft.



When the gear and shaft have been correctly positioned, the adjusting screw is held in position by a locking screw, which clamps down on a flat portion of the adjusting screw, locking it in place.

The end shake in the worm is removed by a bent washer spring under a collar on the end of the worm. A wire spring acts to hold the worm closely meshed with the wheel to eliminate lost motion, so that any adjustment will be very accurate.

DETENTS



A detent is used to hold a shaft firmly in several definite positions. A detent will pull the shaft to one of the *exact* positions if it is released when *near* that position.

A feature of the detent is that it allows a quantity to be set at definite values quickly and accurately. However, no values can be set between those for which there are detent notches.

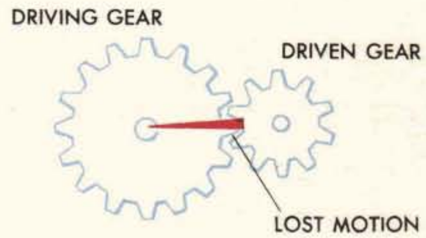
The detent consists of a specially shaped wheel fixed to the shaft and a follower roller on an arm.

The roller is held between the teeth of the wheel by a spring on the follower arm.

When the shaft turns, the roller is forced out to the end of a tooth and the spring pulls the roller back between the next two teeth. The detent always holds the shaft between the teeth.

There are several other kinds of detents, designed for the special places where they work. They all do the same kind of job.

The TAKE-UP SPRING



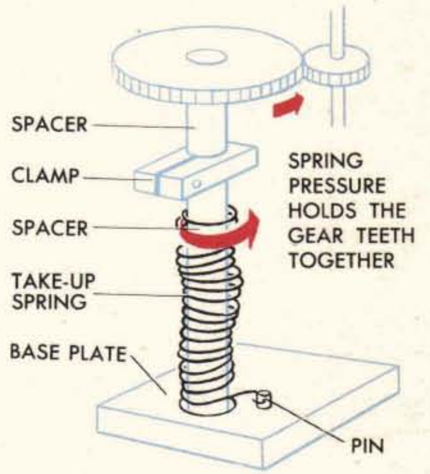
Take-up springs are used to remove lost motion between several pairs of meshing gears.

In each pair of meshing gears there is a small space between the meshing teeth when they are at rest.

When the driving gear begins to turn it must move through this space before it starts to move the driven gear.

The motion of the driving gear before it moves the driven gear is called *lost motion.*

Lost motion adds up to a considerable error on a long shaft line having many meshes.

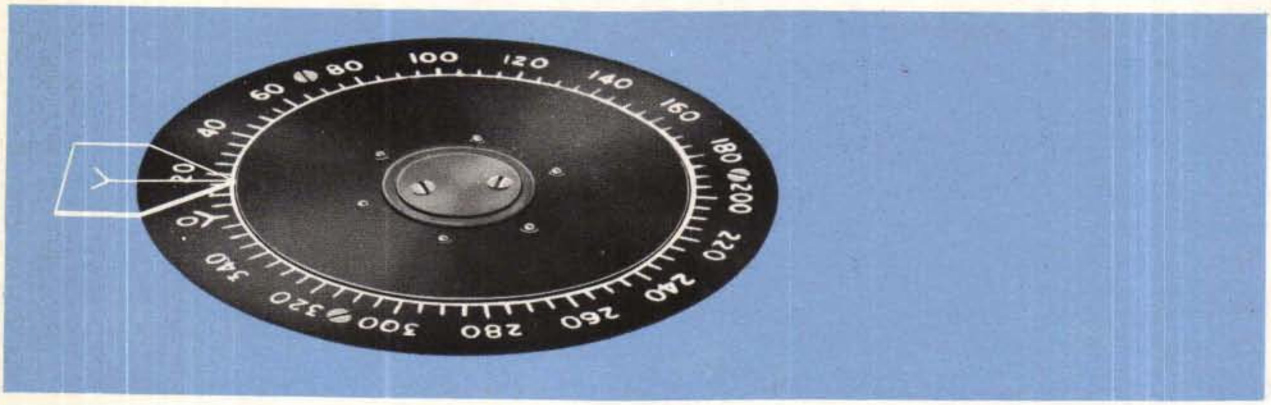


The take-up spring removes lost motion by holding the driving gear teeth firmly against one side of the driven gear teeth all the time, both while the shafts are turning and while they are stationary.

The take-up spring is attached at one end to a mounting plate and at the other end to a clamp on the shaft.

The clamp is held in place by spacers on the shaft. The spacers prevent the clamp from being pulled along the shaft when the spring is adjusted. The spring pressure can be adjusted by loosening the clamp screw and turning the clamp to wind the spring.

DIALS



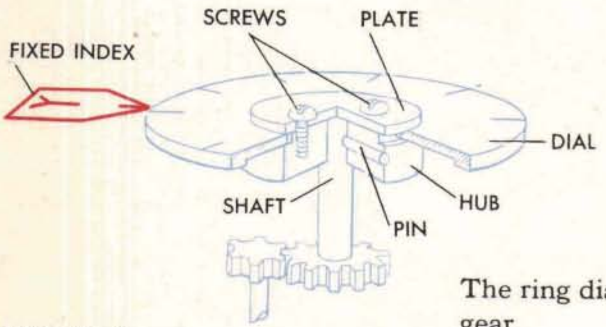
A dial shows the *position* of a line of shafts and the *value* on the line.

It is usually read against a fixed index.

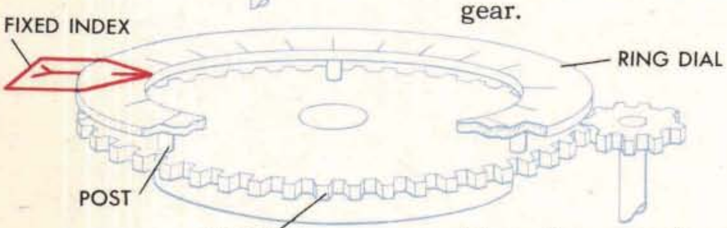
There are two kinds of dials, disk dials and ring dials.

The first consists of a disk which is held to a shaft between a hub on the shaft and a plate screwed to the hub.

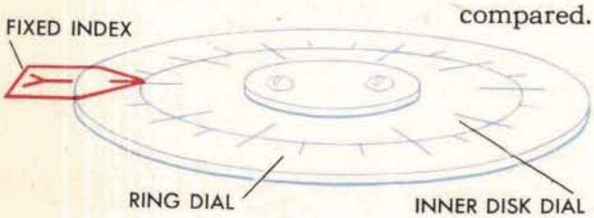
The position of the dial in relation to the shaft can be changed by loosening the screws and moving the dial around by hand.



The ring dial is mounted on posts on a gear, and driven by the gear.



Ring dials are often used together with disk dials, where the inner disk dial and the ring dial have to be matched or compared.



Fine and coarse dials

Where one dial only is needed to show the values on a line, a disk dial is generally used.

For more accurate settings a pair of dials are used so that one turns faster than the other and gives a finer reading of the value on the line.

The fine dial and the coarse dial work together like the minute and hour hands of a watch.

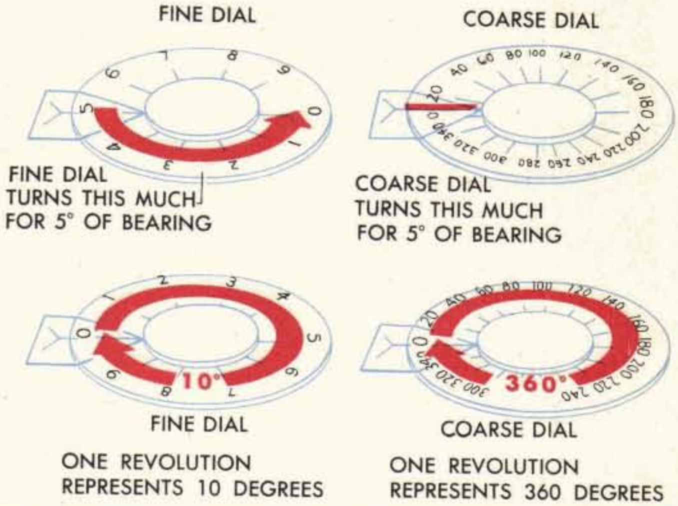
The fine dial turns a whole revolution while the coarse dial turns only part of a revolution.

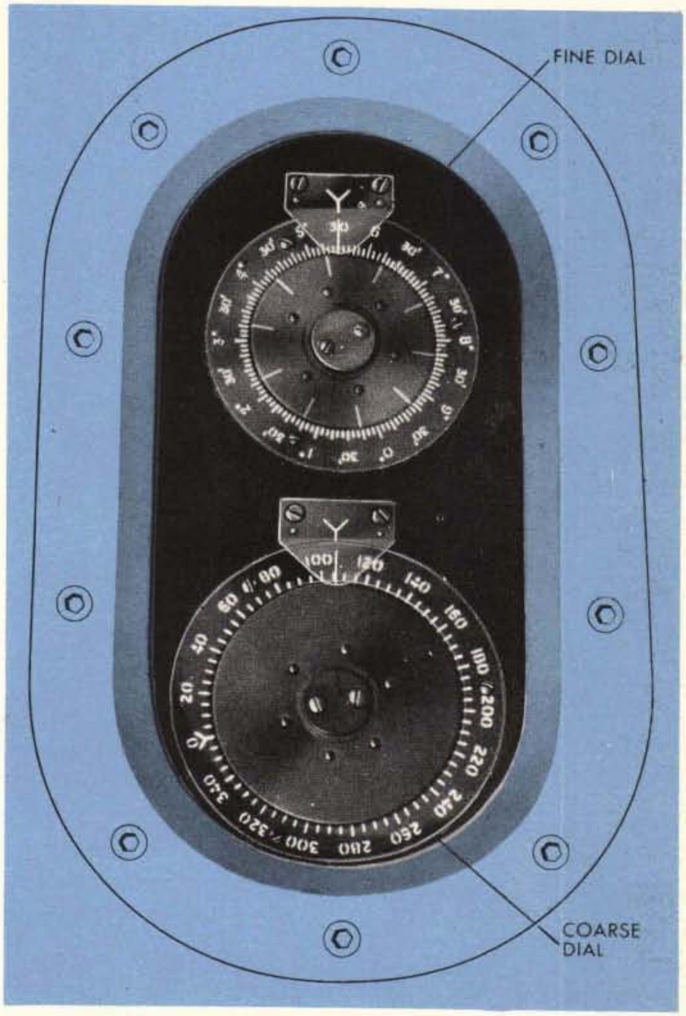
For instance, in the coarse and fine bearing dials of most computers, the coarse dial is graduated every 5°, and turns one whole revolution for 360°.

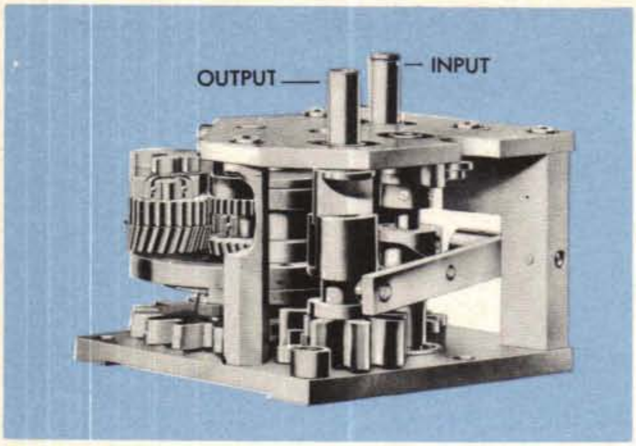
The fine dial is usually graduated every 5′ and turns one whole revolution for only 10° of bearing.

The coarse dial is driven by the fine dial through gearing. In the case of the bearing dials the fine makes 36 revolutions to one of the coarse.

To read these dials, read the coarse dial first. Take the lower 10° mark on the coarse dial and add to it the reading on the fine dial. The dials pictured at the right read 105° 30′.





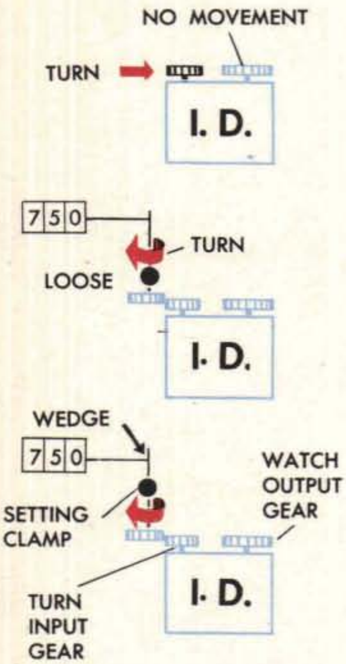


Setting the

The intermittent drive receives a quantity as an input and delivers as an output only that portion of the quantity which can be handled by the mechanism connected to it.

If an input value is within the limits of this mechanism, the intermittent drive allows the value to drive through, but if the value is *above* or *below* the limits, the intermittent drive delivers *no output.*

The purpose, when setting, is to have the intermittent drive set to its input counter so that it will "cut in" and "cut out" at the proper limits as shown on the input counter.



To set the input of the intermittent drive

1 Turn the intermittent drive input gear in a decreasing direction until the output gear "cuts out," that is, until the output stops turning.

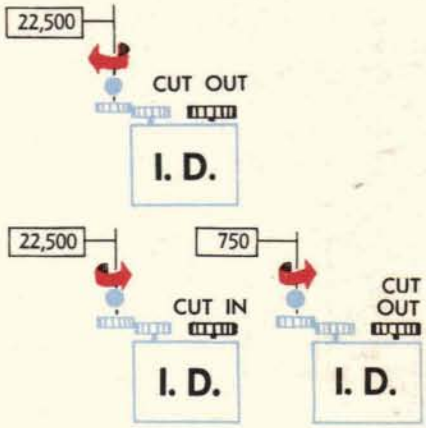
2 Set the input counter at the "cut in" reading for the lower limit. Wedge the input.

NOTE: The limits of the various intermittent drives will be given in each Computer's setting notes. In the examples used here, 750 is the lower limit, and 22,500 is the upper limit.

3 Turn the intermittent drive input gear in the increasing direction until the output gear just starts to move. The intermittent drive is now approximately set to the counter.

4 Slip-tighten the setting clamp.
Remove the wedge.

INTERMITTENT DRIVE



5 Keep turning the input shaft in the same direction until the intermittent drive "cuts out" at its upper limit.

Then start turning it in the *opposite* direction.

It will "cut in" again at the upper limit and "cut out" again at the lower limit.

The observed readings should agree with the true readings if the intermittent drive is set correctly.

6 Observe the input counter and fill the following table while doing step **5**:

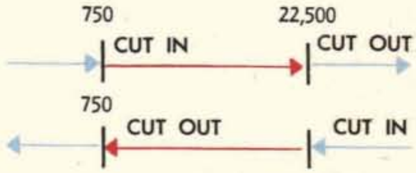
Intermittent drive "cuts in" at lower limit.

Intermittent drive "cuts out" at upper limit.

Intermittent drive "cuts in" at upper limit.

Intermittent drive "cuts out" at lower limit.

TRUE	OBSERVED
750	
22,500	
22,500	
750	



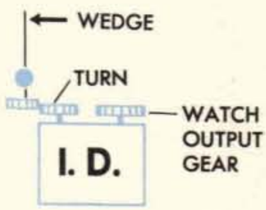
7 Here the intermittent drive is correctly set. The observed readings agree with the true readings. The intermittent drive must have "cut in" when the input counter indicated its "cut in" point.

TRUE	OBSERVED
750	750
22,500	22,500
22,500	22,500
750	750

8 Here the intermittent drive setting is incorrect. The observed readings disagree with the true readings because the intermittent drive "cut in" at the wrong reading.

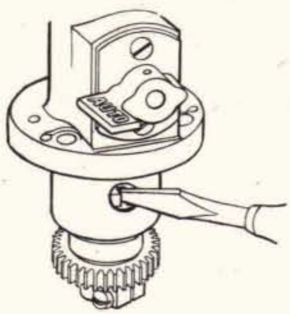
750	745
22,500	22,495
22,500	22,495
750	745

9 To correct the setting, position the input counter at the true reading for "cut in" at lower limit and slip the input gear shaft through the setting clamp until the output gear just begins to move.



10 Tighten the setting clamp.

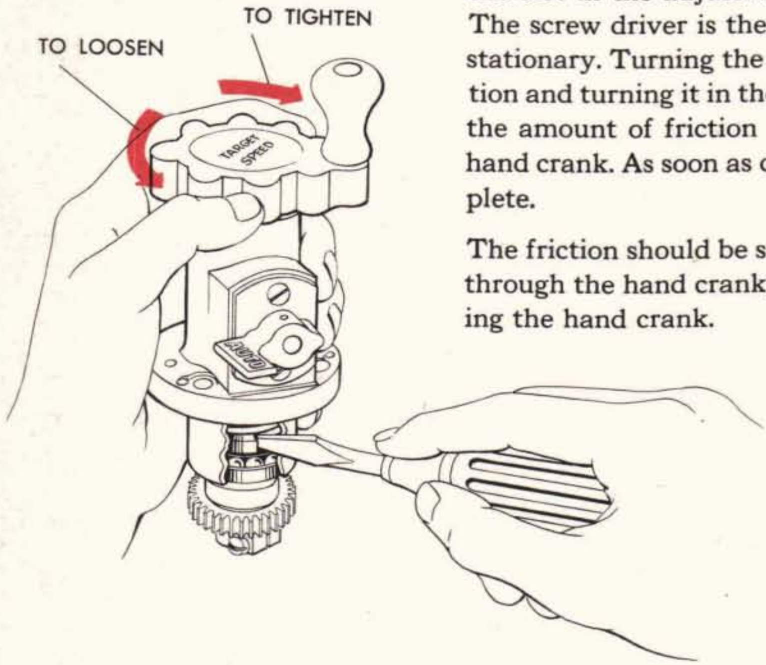
Recheck until the observed readings agree exactly with the true readings.



ADJUSTMENTS OF

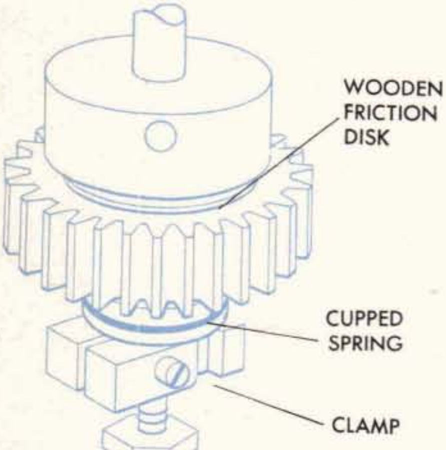
The adjustment of the frictions on hand cranks is very simple and the only tool needed is a screw driver.

The holding friction adjustment



The adapter has a small opening for a screw driver. The hand crank should be put in the OUT position, and then turned until the slot in the adjusting nut is in front of this small opening. The screw driver is then inserted into the slot to hold the nut stationary. Turning the hand crank clockwise tightens the friction and turning it in the opposite direction loosens it. To check the amount of friction remove the screw driver and turn the hand crank. As soon as drag is sufficient the adjustment is complete.

The friction should be sufficient to prevent motion backing out through the hand crank, but not great enough to prevent turning the hand crank.



The friction relief drive adjustment

In this type of friction a cupped spring and clamp are used to hold a maple wood friction disk against the gear on the shaft.

By loosening the screw in the clamp with a screw driver, the clamp can be screwed up on the shaft to increase the pressure of the cupped spring, or turned in the opposite direction to reduce pressure. Tightening the screw in the clamp will hold it in place, when the proper pressure is on the spring.

The friction is adjusted properly when the gear drives under a normal load, but slips when there is an overload.

HAND CRANKS

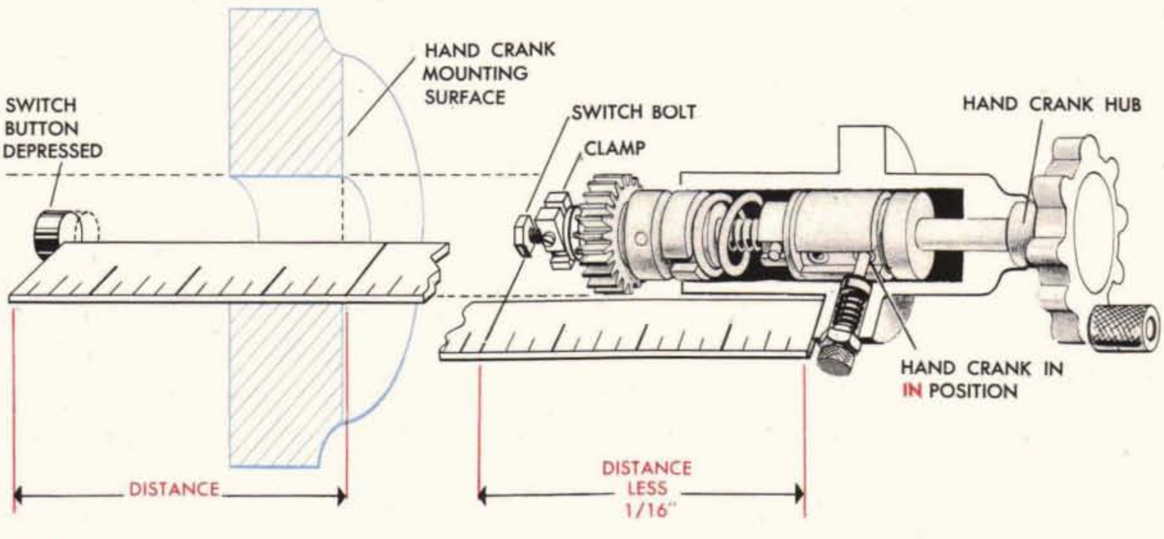
The switch bolt adjustment

On hand cranks having a switch bolt to depress a push button switch, adjustment of the position of the switch bolt is sometimes necessary. Loosening the screw in the clamp will free the switch bolt so that it may be screwed IN or OUT.

THE most accurate way to set the bolt is to remove the hand crank and measure the distance from the switch button when it is depressed to the hand crank mounting surface.

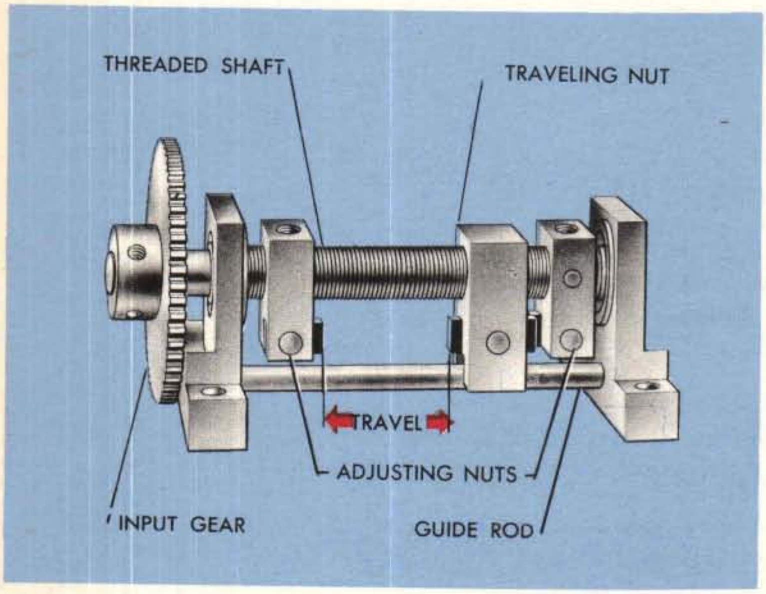
With the hand crank in its IN position, screw the switch bolt IN or OUT until the distance from the mounting surface of the flange to the bottom of the button is 1/16″ less than the first measurement.

The switch bolt is in the proper position when it depresses the push button with the hand crank in its IN position but does not touch the push button when the hand crank is in its OUT position.

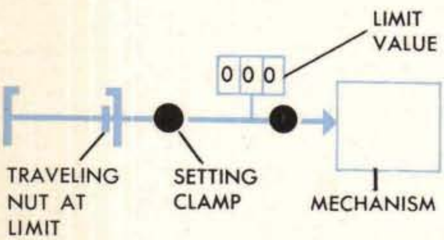


CAUTION:

After adjusting and remounting the hand crank, hold the plunger OUT and move the hand crank IN until the hand crank hub touches the adapter. If the hand crank cannot be moved IN to touch the adapter easily, the switch bolt is too far OUT and forcing the hand crank in may damage the switch.



Setting the LIMIT STOP



A limit stop is a protective device. It *limits the travel* of a shaft and so protects cams, lead screws, integrator carriages and other mechanisms.

The "travel" of a limit stop is determined by the number of turns its shaft can make while the traveling nut moves from one adjusting nut to the other. The travel of the limit stop is fixed when the limit stop is made.

To set the limit stop to the shaft which is to be limited:

1 Turn the limit stop to bring the traveling nut to one end of its travel.

2 Set the counter at the limit value for that point.

3 Tighten the setting clamp.

The counter and the limit stop are set together. Setting a mechanism to *either* the counter or the limit stop will now set the mechanism to *both*.