NAVY DEPARTMENT
BUREAU OF ORDNANCE
WASHINGTON 25, D. C.

To all holders of ORDNANCE PAMPHLET 1140
insert change; write on cover 'Change 1 inserted'
Approved by The Chief of the Bureau of Ordnance

OP 1140 CHANGE 1
9 March 1949

F. I. Entwistle
Acting Chief of Bureau

1 Page ______ Page 1

ORDNANCE PAMPHLET 1140
is changed as follows:

BASIC FIRE CONTROL MECHANISMS

1. Insert this change sheet between cover and title page.
2. Replace page 7 with new page 7 attached.
3. Insert section 7, pages 373 to 424, attached.
4. Cancel INDEX page 372; remove and destroy INDEX pages 373 through 378; cancel INDEX page 379. A corrected index has not been prepared. Delete page numbers but retain distribution list (original page 380) and NOTES (original pages 381 through 384).

DISTRIBUTION

Requests for additional copies of Ordnance Pamphlet 1140 (Change 1) should be submitted on NavExos 158, Stock Forms and Publications Requisition, through the District Publications and Printing Office by which addressee is serviced.

Standard Navy Distribution List No. 56 (Part 1) and Edition No. 14 (Part 2) to Catalog of Activities of the Navy.
2 copies unless otherwise noted:

21; 22; 23; 24A,C,D,E,F,H; 26F,H; 27A,C; 28A,B,C,D,E,J; 29(5 copies) A,H,J,K,L; 29B,C,D,E,M,N,Q,P; 30C; 32A,E,N,S,V,W,DD,HH,JJ; 38A,B*,C*; A3(CNO); A5(BuShips,BuAer,BuOrd); E6(Arlington only); F2; J3,12,37, 60,75,76,83,84,87,95; J(25 copies)91; K5A,B,C,12; L(10 copies)1; R20; BuOrd Special List X1.

*Applicable Groups and Subgroups

The above distribution list inclues the following vessels of the active and reserve fleets: BB,CV,CVB,CVE,CVL,CA,CB,CL,CLAA,DD, DDE,DDR,DDK,CM,AD,AG,AO,AR,ARH,ARL,AS,AV,AVP

PRNC-2288-8-19-49

E 106

RESTRICTED **ORDNANCE PAMPHLET 1140**

BASIC FIRE CONTROL MECHANISMS

SEPTEMBER 1944

PROPERTY OF LIBRARY
U. S. NAVAL SCHOOL (GENERAL LINE)
MONTEREY, CALIFORNIA

This publication is RESTRICTED and will be handled in accordance with Article 76, United States Navy Regulations, 1920.

NAVY DEPARTMENT

BUREAU OF ORDNANCE

WASHINGTON 25, D. C.

September 1944

RESTRICTED

ORDNANCE PAMPHLET 1140

BASIC FIRE CONTROL MECHANISMS

1. Ordnance Pamphlet 1140 explains the mechanical and electromechanical basic mechanisms used by Ford Instrument Company and Arma Corporation in fire control equipment built for the United States Navy. It is bound in loose-leaf form with provision for expansion in case it is desired to add material at a later date.

2. This publication is a basic text and reference book, providing a source of general information on the basic mechanisms of fire control equipment. It is considered that Ordnance Pamphlet 1140 is a prerequisite to the study of any Ordnance Pamphlet on the mechanical computing instruments for fire control equipment.

3. Ordnance Pamphlet 1140 supersedes Ordnance Data 1661, which should be destroyed.

4. This publication is RESTRICTED and should be handled in accordance with Article 76, U. S. Navy Regulations, 1920.

G. F. Hussey, Jr.

G. F. HUSSEY, JR.
Rear Admiral, U. S. Navy
Chief of the Bureau of Ordnance

Prepared For
THE BUREAU OF ORDNANCE
by the
FORD INSTRUMENT COMPANY, INC.
Long Island City, New York

QUICK REFERENCE INDEX

PAGE

FORD MECHANISMS

BASIC INFORMATION

BASIC MECHANICS 10
BASIC MATHEMATICS 26
BASIC SETTING INFORMATION 32

MECHANICAL UNITS

DIFFERENTIALS 38
CAMS 46
MULTIPLIERS 60
COMPONENT SOLVERS 86
DISK INTEGRATORS 114
COMPONENT INTEGRATOR 136
NON-COMPUTING MECHANISMS 144

ELECTROMECHANICAL UNITS

MAGNETISM AND ELECTRICITY 169
SIGNAL, LOCK, AND CLUTCH 188
TIME OF FLIGHT SIGNAL MECHANISM 196
SERVO MOTORS 202
MOTOR REGULATOR 208
FOLLOW-UP CONTROLS 218
SYNCHROS 242
SYNCHRO TRANSMITTERS AND RECEIVERS 278

SUMMARY: A SIMPLIFIED COMPUTING NETWORK

A SIMPLIFIED NETWORK 299
SETTING THE NETWORK 310

TECHNICAL APPENDIX 324

ARMA MECHANISMS

MECHANICAL UNITS

DIFFERENTIALS 350
CAMS 356
RESOLVERS 358
INTEGRATORS 362

ELECTROMECHANICAL UNITS

FOLLOW-UP HEADS 364
TIME MOTOR GOVERNOR 371

CONTENTS

FORD MECHANISMS

BASIC INFORMATION

	Page
BASIC MECHANICS	10
BASIC MATHEMATICS	26
BASIC SETTING INFORMATION	32

MECHANICAL UNITS

DIFFERENTIALS	38
Bevel-gear type	39
Spur-gear type	45
CAMS	46
Flat type: Groove	47
Flat type: Edge	52
Barrel type	54
How to set Cams	56
MULTIPLIERS	60
Simple Multipliers	60
Screw type	61
Rack type	66
Sector type	68
Computing Multipliers	72
Single-cam type	72
Two-cam type	74
How to set Multipliers	76
COMPONENT SOLVERS	86
Cam type	87
Constant lead cam	93
Computing cam	98
Offset pin	104
Screw type	100
Vector Solver	106
How to set Component Solvers	108
DISK INTEGRATORS	114
Wheel type	116
Ball-and-Roller Type	117
How to set Disk Integrator	134
COMPONENT INTEGRATOR	136
How to set Component Integrator	142
NON-COMPUTING MECHANISMS	144
Limit Stops	144
Intermittent Drive	146
Hand Cranks	152
Frictions	156
Vernier Clamp	160
Detents	161
Take-up Spring	161
Dials	162
How to set the Intermittent Drive	164
How to set Handle Frictions	166
How to set Limit Stops	168

There is a detailed ALPHABETICAL INDEX on page 372

ELECTROMECHANICAL UNITS

MAGNETISM AND ELECTRICITY 169
Magnetism 170
Current 176
Electromagnetism 180
Motors 184
Generators 186
SIGNAL, LOCK, AND CLUTCH .. 188
Solenoid Signals 188
Solenoid Clutch 190
Lock 192
Push Button Switch 194
Rotary Switch 195
TIME OF FLIGHT SIGNAL 196
SERVO MOTORS 202
MOTOR REGULATOR 208
How to adjust Motor Regulator . 214
Timing the Motor Regulator 216
FOLLOW-UP CONTROLS 218
Basic Principles 222
Velocity-lag type 232
Compensated type 234
Oscillating type 236
How to synchronize a Follow-up . 240
SYNCHROS 242
Generator and Motor 244
Electrical Operation 248
Differential Generator 254
Differential Motor 260
Control Transformer 262
Sizes and Types 270
How to set Synchros 272
SYNCHRO TRANSMITTERS ... 278
Single Speed Transmission 278
Double Speed Transmission 279
SYNCHRO RECEIVERS 282
Single Speed Receiver 283
The Bearing-Mounted Synchro Motor 286
Double Speed Receiver 288
How to set Transmitters and Receivers 296

SUMMARY: A SIMPLIFIED COMPUTING NETWORK

A SIMPLIFIED NETWORK 299
SETTING THE NETWORK 310

TECHNICAL APPENDIX

MAGNET DRAG 324
MAGNET DAMPER 334
COMPENSATOR 338
SERVO THEORY 342

ARMA MECHANISMS

MECHANICAL UNITS

DIFFERENTIALS 350
CAMS 356
RESOLVERS 358
INTEGRATORS 362

ELECTROMECHANICAL UNITS

FOLLOW-UP HEADS 364
DIVIDER WITH FOLLOW-UP HEAD 370
TIME MOTOR GOVERNOR 371

LINKAGE MECHANISMS

LINKAGE TYPE DIFFERENTIALS 374
LINKAGE TYPE MULTIPLIERS 381
Lever Multiplier 382
Bell Crank Multiplier 382
XY Linkage Multiplier 383
Using a Multiplier as a Divider .. 388
ABSOLUTERS 390
ANGLE RESOLVERS 393
Simple Angle Resolver 393
Compensated Angle Resolver ... 396
Internal Gear Angle Resolver ... 398
NON-LINEAR LINKAGES 402
Function Mechanisms 402
LINKAGE ADJUSTMENTS 408
NON-COMPUTING LINKAGES .. 412
Gear Type Limit Stop 412
Intermittent Drive 414
Relief Drive 419
A LINKAGE NETWORK 421

INTRODUCTION

The basic mechanisms described in this book were especially developed over a period of about 30 years to do a highly specialized job. That job is to *solve mechanically the mathematics for surface and anti-aircraft fire control*. These basic mechanisms make the necessary computations to point the guns and set the fuzes to hit fast moving targets with shells fired from the deck of a ship which is moving, pitching, and rolling. To aim the guns correctly under these conditions about 25 things must be taken into account all at the same time. These include target speed, climb, and direction; target range, elevation, and bearing; own ship speed and course; wind speed and direction; pitch and roll; and initial shell velocity.

If the enemy were to announce six or eight hours beforehand just where the target would be at a particular instant and just how it would be moving, a lightning mathematician would be able to calculate where to point the guns to hit it at that one instant. *But,* the results would be good only for one instant.

Instead of going through the mathematical calculations necessary to make each shot count, a ship might try to throw out enough exploding shells to hit the target almost by pure chance. That is, it might throw out a barrage of shells and let the target fly into them. This type of fire is effective against some types of air attack, but it is far from a satisfactory answer to the problem of aiming the guns.

What is needed is an instrument which will predict quickly and accurately what will happen while the shell is in the air, compute the necessary corrections for the guns, and in addition continuously correct the guns for the effects of pitch and roll of own ship. As soon as a target is picked up, this instrument must be able to solve the fire control problem in a few seconds and thereafter it must keep on solving the problem *continuously* and *accurately* as own ship and target move in relation to each other.

At first it might seem that such an instrument would be far too complex for anyone but an engineer to understand, but that is not true. Actually it is a collection of standard mechanisms and parts assembled together inside a case. Each mechanism or part has a particular job to do in solving the fire control problem. This book is intended to explain what these mechanisms are and what each can do. By studying each unit in turn, learning what it can do and how it does it, and how it can be used with the other units, it is possible to learn many of the fundamental things that one must know to operate and maintain the Computers, Range Keepers and other instruments. These include:

Computer Mark 1, for the 5″ guns, and certain others.
Range Keeper Mark 10, for the 5″ guns.
Range Keeper Mark 8, for main battery guns.
Computer Mark 3, stand-by for the Mark 8.
Torpedo Data Computer Mark 3 and Mark 4.

SECTION 1

BASIC INFORMATION

A certain amount of basic information is necessary to understand fire control mechanisms. This information is summarized in the three chapters which make up this section.

1 The chapter, "Basic Mechanics," introduces a number of mechanical elements common to most of the mechanisms. These mechanical elements include gears, shafts, bearings and clamps. This chapter also explains several basic mechanical ideas such as "gear ratios," "shaft values" and "shaft positions."

2 "Basic Mathematics" briefly summarizes the mathematical operations which are more frequently used in fire control. This chapter does not try to teach mathematics, but assumes that the principles it reviews are already familiar. Later explanations of the computing mechanisms will be based largely on these mathematical principles.

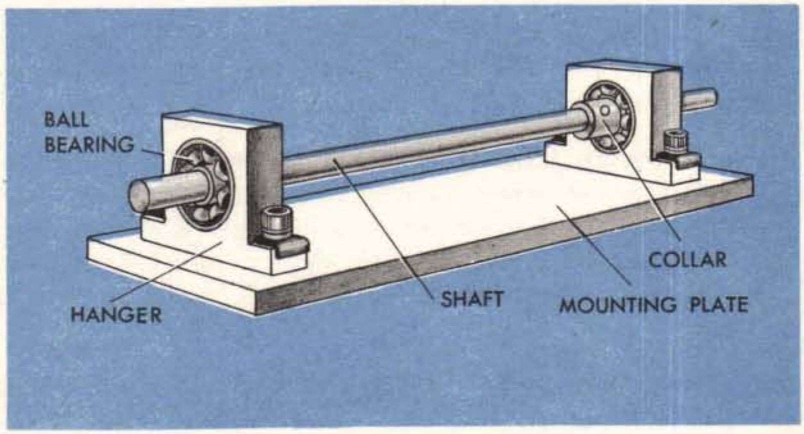
3 "Basic Setting Information" describes the more important setting tools and procedures commonly used in setting the various mechanisms. This chapter supplies the basic information which will be needed to understand the setting instructions included with the description of each mechanism.

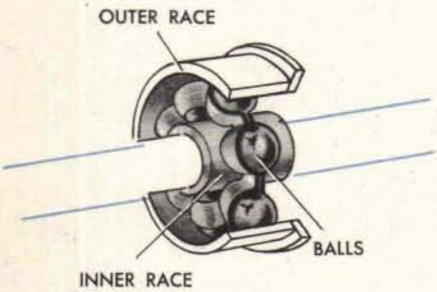
4 The basic information about magnetism and electricity needed for Section 3 on Electromechanical Units is furnished in the first chapter of that section.

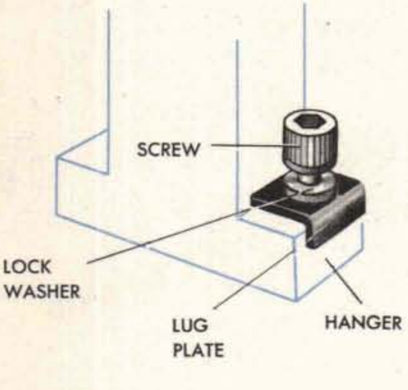
	Page
Basic Mechanics	10
Basic Mathematics	26
Basic Setting Information	32

BASIC MECHANICS

SHAFTS, HANGERS, MOUNTING PLATES, BEARINGS and COUPLINGS







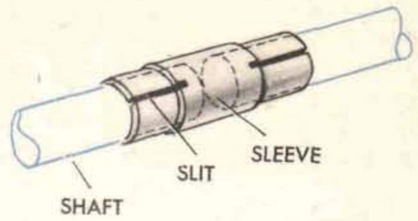
Here is a typical shaft assembly.
The mounting plate is used to support the whole assembly inside the equipment. The hangers are used to support individual shafts.

The hangers are held in place by screws. Lock washers keep the screws from working loose. Lug plates keep the lock washers from digging into the softer hanger metal.
The shaft is free to turn on ball bearings mounted in the hangers.

A ball bearing has an inner race and an outer race. The outer race is fitted snugly into the hole in the hanger. The inner race turns with the shaft. When the shaft turns, the balls roll between the two races. There is no sliding motion between any of the parts, so there is practically no wear and no drag in this kind of bearing.

The shaft is held in position endwise by collars. These are pinned to the shaft so that they can neither turn ON the shaft nor slip ALONG the shaft.

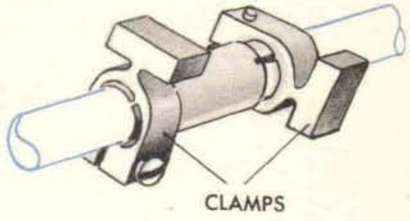
There are three principal devices used to join shafts end to end:



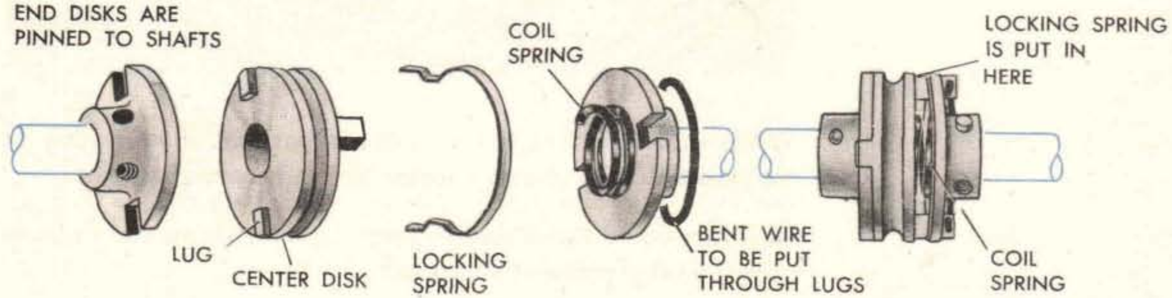
1 A sleeve coupling is used to join two closely aligned shafts usually where an adjustment of the shaft relationship is necessary. It consists of a sleeve over the ends of the two shafts, with a clamp over each end of the sleeve.

The ends of the sleeve are slit so that the clamps can hold the sleeve tightly on the shafts.

When the clamps are tight, the two shafts are held firmly together in the sleeve and will turn as one.



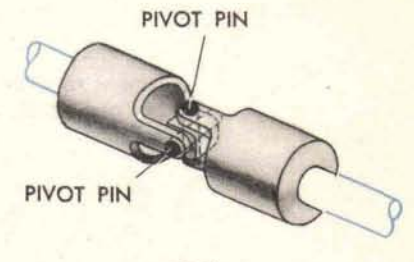
2 An Oldham coupling is used to eliminate the necessity of perfect alignment between two shafts. It is also used between two shafts that must be readily connected or disconnected. Occasionally it is used as an expansion joint in a long shaft.



The Oldham coupling consists of a pair of disks pinned to the ends of the shafts, and a third center disk, with lugs, which fits between the two.

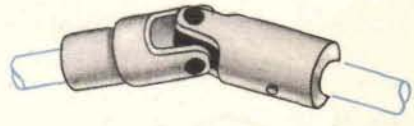
The lugs on the center disk fit into slots in the other two disks, enabling one shaft to drive through the disks to the other shaft.

The center disk is mounted on one of the side disks, and is held away from this disk by a coil spring. The center disk lugs on this side are extended, and a bent wire is run through the ends of the lugs to hold the assembly together.



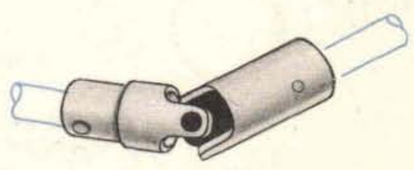
When the coil spring is compressed, the center disk can be moved free of the other side disk, so that the two shafts can be disconnected.

Aboard ship, jarring may occasionally compress these coil springs and disconnect the shafts. To prevent this, a locking spring is used which fills the space between the center disk and side disk. The coil spring cannot be compressed while the locking spring is in place.

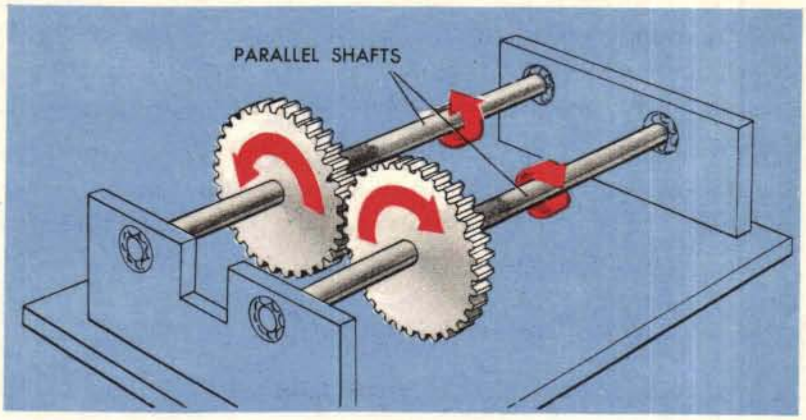


3 A universal joint is often used to connect shafts at an angle to each other.

Because of the two pivot pins in this joint, one shaft can drive the other even though the angle between the two is as great as 25°.

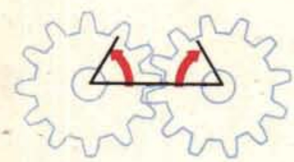


GEARS



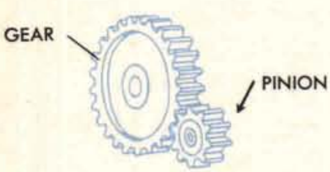
When shafts are not in line, but are parallel, motion may be transmitted from one to another through spur gears.

Gears are wheels with mating teeth cut in them so that one can turn the other without slippage.

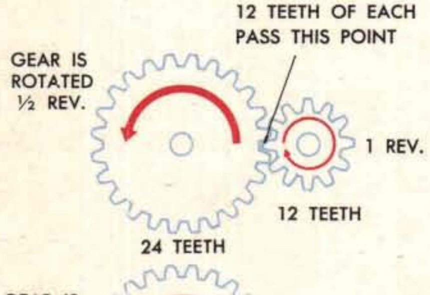


Straight spur gears are used to connect parallel shafts. Their teeth are cut parallel to the axis of rotation.

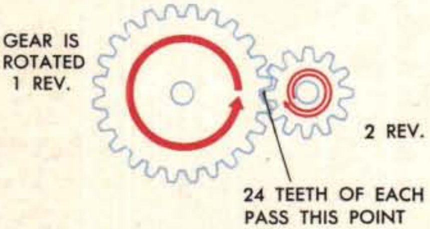
If two mating gears are the same size, they will have the same number of teeth. One revolution of the driving gear will turn the driven gear one revolution, because each tooth of the driving gear will push one tooth of the driven gear across the line between their centers.



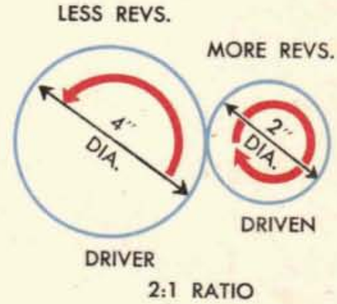
If two gears are of different sizes the smaller one is usually called a pinion.



When a gear and a pinion mesh together, their shafts turn at different speeds.



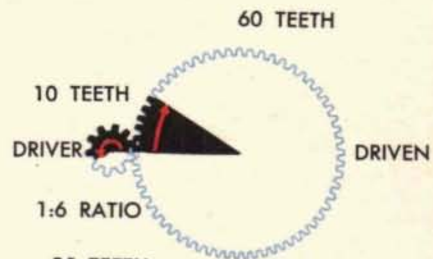
Suppose that a gear has twice as many teeth as its pinion. For instance, the gear has 24 teeth and the pinion 12. If the gear is driving, one revolution of the gear will turn the pinion two revolutions. The pinion will turn TWO WHOLE revolutions for every ONE revolution of the gear.



The ratio between the number of teeth on the driving gear and the number of teeth on the driven gear is called the *gear ratio.* Since it is comparatively easy to count gear teeth, this is perhaps the simplest way to establish the gear ratio.

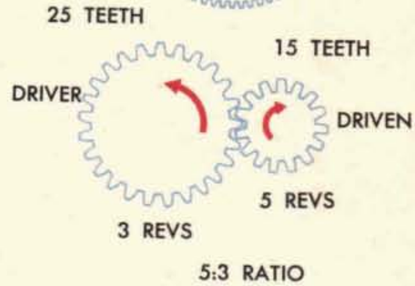
However, since meshing gear teeth are of the same size, dividing the *circumference* of the driving gear by the *circumference* of the driven gear will also provide the gear ratio. Because the corresponding parts of circles are proportional, dividing the *diameter* of the driving gear by the *diameter* of the driven gear will also produce the gear ratio.

$$\text{GEAR RATIO} = \frac{\text{Teeth of } \textit{driver}}{\text{Teeth of } \textit{driven}} = \frac{\text{Diameter of } \textit{driver}}{\text{Diameter of } \textit{driven}}$$



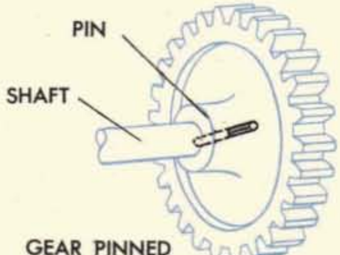
A gear with a 4" diameter driving a gear with a 2" diameter will have a ratio of 2:1. The pinion will rotate twice as fast as the driver.

Here are a pair of gears with a 1:6 ratio. The driving pinion has 10 teeth, and the gear 60. The pinion shaft turns 6 times as fast as the gear shaft it drives.

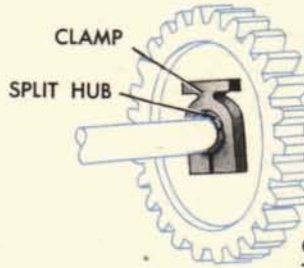


Here are a pair of gears with a 5:3 ratio. The driving gear has 25 teeth, and the driven pinion has 15. The gear shaft makes 3 revolutions, while the pinion shaft is driven 5 revolutions.

There are several ways of holding a gear to its shaft. To permanently join the two parts, a pin can be put through the hub and the shaft. To permit adjustment or simplify assembly, the gear may be held by a clamp which tightens a split gear hub on the shaft.



GEAR PINNED TO A SHAFT



GEAR CLAMPED TO A SHAFT

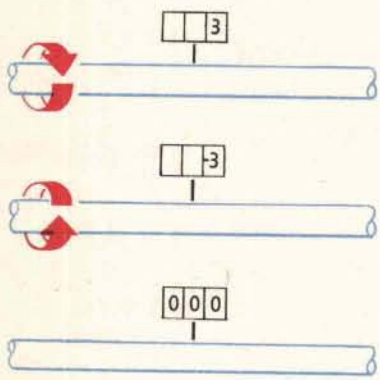
SHAFTS CARRY VALUES

A computer needs a variety of information to help it solve the fire control problem. It receives this information as *values of various quantities* such as yards of Range, degrees of Elevation, and knots of Ship Speed. Most of these quantities are continually changing in value. At every instant, however, each of these quantities has a definite numerical *value*. These values are used in a computer to position the computing mechanisms.

As each of the input values changes, the values of several of the computed quantities will also change. All of these changing values must be carried instantaneously and continuously to all the mechanisms affected by that particular quantity.

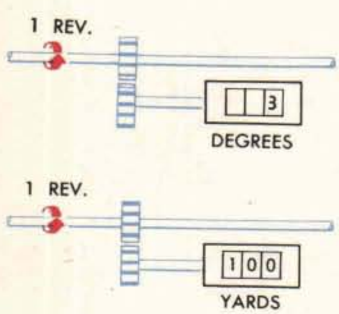
THE FUNCTION OF SHAFTS IN A COMPUTER IS, BY TURNING, TO CARRY THESE CHANGING VALUES FROM ONE MECHANISM TO ANOTHER INSTANTANEOUSLY AND CONTINUOUSLY.

Shaft value



Any turning of a shaft changes the value of the particular angle, speed, or distance, represented by that shaft. Rotation in one direction increases the value on the shaft. Rotation in the opposite direction decreases the value. Usually a shaft will make many revolutions when there is a large change in the value of the quantity it is carrying.

Almost every shaft has a zero position. *Zero position for a shaft is the position where the value of the quantity represented by that shaft is zero.*



One revolution of a shaft can represent any convenient amount of value. For example, on some of the elevation shafts one revolution represents 3° of elevation. These shafts have a shaft value of 3°. On some of the range shafts one turn may represent 100 yards of range. These range shafts then have shaft values of 100 yards.

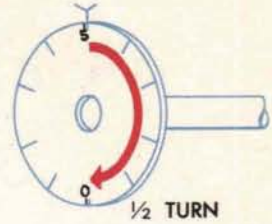
SHAFT VALUE IS THE VALUE THAT A SHAFT CARRIES IN ONE REVOLUTION, THAT IS, THE VALUE PER REVOLUTION.

In most other machines, shafts and gearing are used mainly to carry power, and gear ratios are usually chosen to vary the shaft speed and torque. However, in mechanical fire control computers, the shafts' main job is *to carry throughout the computer the changing values of all the needed quantities.*

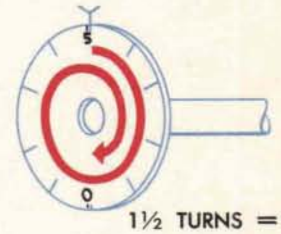
The total value on the shaft

A dial fixed directly to a shaft with its zero position matched to the shaft zero position will only show the total value carried by that shaft during one revolution. If the shaft has a shaft value of 10° and is turned one half a revolution away from the zero position, the *total value* carried by that shaft will be 5°. If the shaft is now turned one complete revolution in the same direction, the dial will again read 5° although the shaft is one and one-half revolutions *away from the zero position and the total value on the shaft is now 15°*. The total value always depends on the number of revolutions the shaft is away from its zero position.

TOTAL VALUE IS THE SHAFT VALUE MULTIPLIED BY THE NUMBER OF REVOLUTIONS THE SHAFT IS POSITIONED AWAY FROM ITS ZERO POSITION.



½ TURN

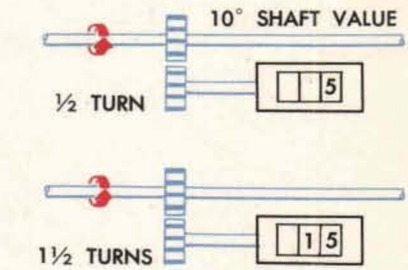


1½ TURNS = 15°
DIAL AT 5°

How total values are read

Total value can be read on a counter because a counter geared to the shaft can show both the number of turns and the fraction of a turn the shaft is away from its zero position.

Suppose a counter is geared to a shaft with a 10° shaft value. The counter is adjusted to read zero at the shaft zero position. When the shaft is turned one-half a revolution to increase the value, the counter will read 5°. If the shaft is now turned one complete revolution in the same direction, the counter will read 15°. If the shaft is turned one and one-half revolutions in the opposite direction to decrease the total value, the counter will again read zero, because the shaft has been returned to its zero position.



How the shafts carry total values

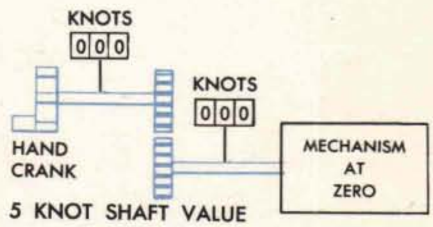
Here is a simple shaft line for putting values of Ship Speed into a computing mechanism.

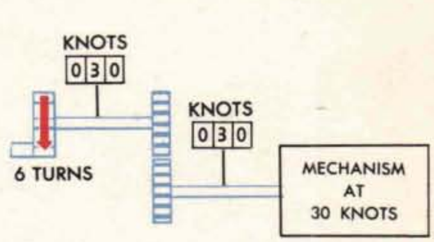
A handcrank positions a shaft and counter. The value on the handcrank shaft is transferred by a pair of equal spur gears to the input shaft which positions the mechanism. The mechanism is set at its zero position. This positions the shaft at its zero position and the counter is adjusted to read zero. The shaft value in this example is 5 knots, so that every time the operator turns the handcrank one revolution he increases or decreases the input value to the mechanism by 5 knots.

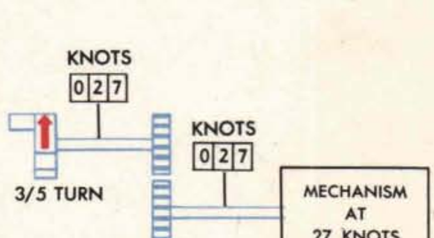
The total value put into the mechanism may be read on the counter. This value may be increased or decreased simply by turning the handcrank until the desired total value appears on the counter.

Suppose Ship Speed increases from 0 to 30 knots. The operator turns the crank until the counter shows 30 knots. This will require 6 turns of the handcrank. The shaft is now 6 turns away from its zero position. Therefore: 6 turns from zero position x 5° shaft value = 30° total value.

If ship speed decreases by 3 knots the handcrank must be turned 3/5 of a revolution in the opposite direction, to reduce the total value on the shaft, counter and mechanism to 27 knots.

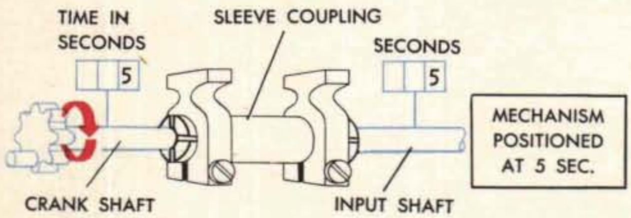




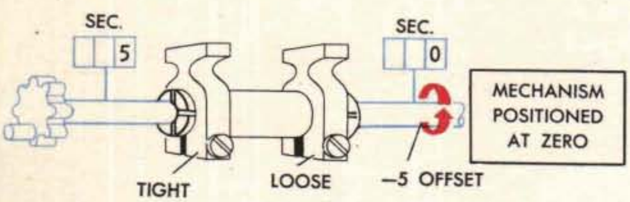


Using CLAMPS to ADD and SUBTRACT a CONSTANT

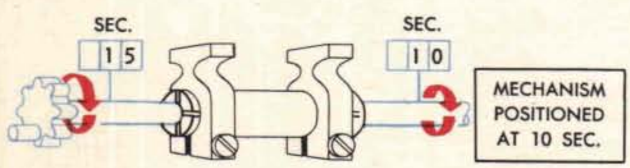
In solving a fire control problem it is sometimes necessary to add or subtract a constant from a value going into a mechanism. For example, some of the multipliers must be positioned by the values of the Time of Flight, *minus a constant*. In a case like this, the crank input is Time of Flight, but the mechanism is positioned for Time of Flight minus *K*. The constant *K* can be set into the transmission line by a sleeve coupling or a clamp gear.



Here is a sleeve coupling joining two shafts which must put Time of Flight in seconds, *minus a constant 5 seconds,* into the mechanism. Each shaft has a counter showing its position. Both shafts are positioned at 5 seconds.

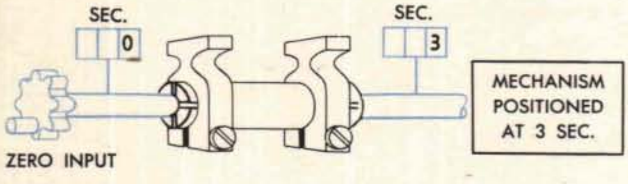


Now if one clamp is loosened, the unit input shaft can be turned till its counter reads zero, without moving the crank shaft. If this clamp is now tightened, with the value of 5 seconds on the crank shaft and zero on the input shaft, the two shafts will turn together when the crank is turned. But the input to the mechanism will always be five seconds *less* than the crank input.

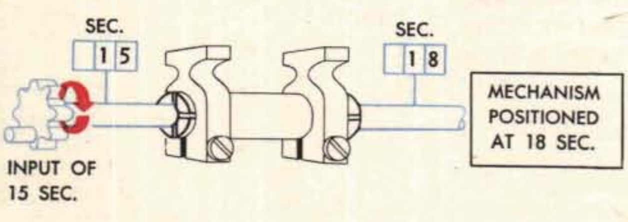


If the crank is turned to the position for a value of 15 seconds, the input to the mechanism will be 10 seconds, and so on.

This use of a clamp is called *putting a constant offset on the line*. The offset can be plus or minus.



Here's an example with a plus offset. The clamp is tightened when the crank shaft is in zero position and the input shaft at 3. The input to the mechanism will always be 3 more than the crank input value.



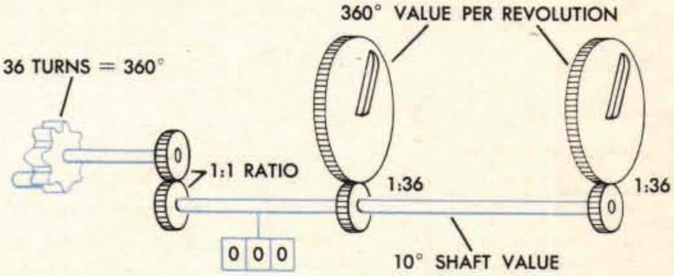
Using GEARS to MULTIPLY by a CONSTANT

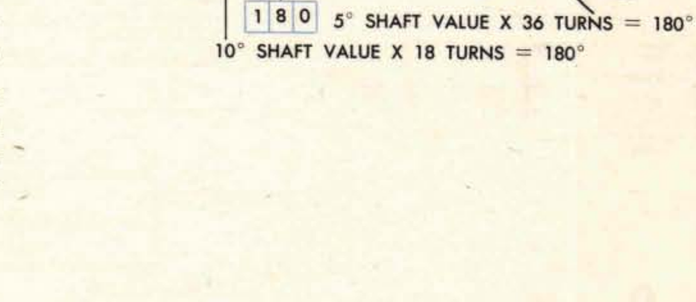
Here a handcrank and shaft line are used to position two large slotted vector gears in computing mechanisms.

The handcrank and the shaft have a shaft value or value per revolution of 10°. The shaft turns both vector gears through a 1 to 36 gear ratio. Thirty-six turns of the handcrank at 10° per revolution position the shaft line at 360° total value. The shaft value or value per revolution of both vector gears is also 360°.

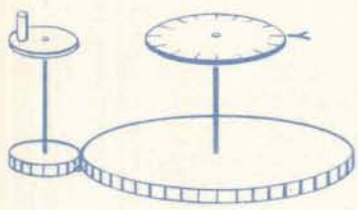
In solving a fire control equation mechanically it is sometimes necessary to have any given input turn one of these vector gears twice as far as the other. In this example, one vector gear will then turn *two* revolutions instead of one when the input shaft turns from 0° to 360° total value. If the vector gear turns two revolutions for 360° total value, the required value per gear revolution is 180°. To obtain this 180° value, a 2:1 gear mesh is introduced into the shaft line to multiply the shaft revolutions by two and so reduce the input shaft value to 5°. With this new gear ratio the 18 revolutions of the handcrank required to set in a value change of 180° will turn one vector gear one-half a revolution and the other vector gear one revolution.

By introducing gear meshes to change shaft value and so change the value per revolution of the mechanism input, any value may be multiplied by a constant. The constant is usually written *K*.



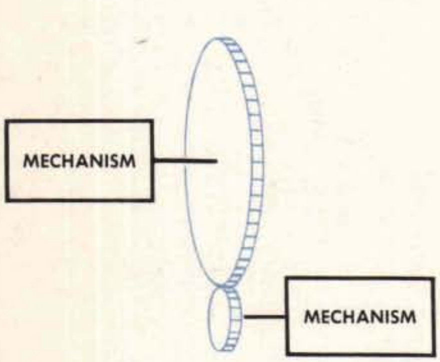


Using gears to change shaft values



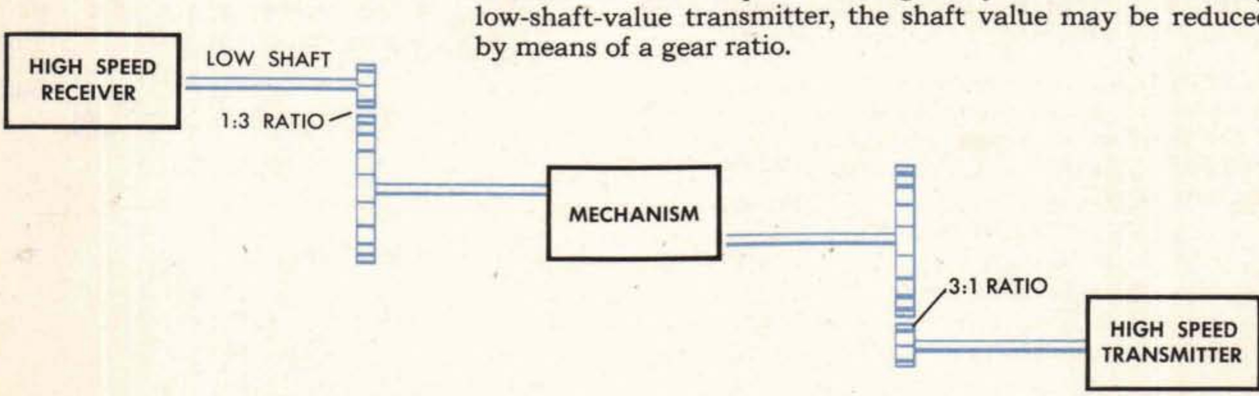
Gear ratios are often used for no other reason than to change the shaft values. If a shaft has a value of 500 yards per revolution, it is very often desirable to reduce this value to some other value, say 50 yards per revolution.

Suppose that a dial is to be positioned very accurately by means of a hand crank. Delicate motions of a hand crank are almost impossible under battle conditions. It is often desirable to use a gear ratio between the hand crank and the dial so that 10 or more revolutions of the hand crank will produce only one revolution of the dial.



Computing mechanisms invariably require different shaft values. One mechanism might be built, with the required accuracy, having an output of 5 revolutions equals 500 yards. To obtain the same accuracy with another computing device it might be necessary to make the shaft value 9 revolutions equals 500 yards. Rather than build all mechanisms to produce the same shaft values, which would make most mechanisms larger and produce a much bulkier computer, it is customary to use gear ratios to adjust the output of one mechanism to fit the input of the next.

Various electrical follow-up devices operate efficiently only at comparatively high speeds with low shaft values. When a signal is received by means of such a device, it is customary to reduce the speed and increase the shaft value of the signal received to the values of the mechanisms in the computer, by means of gear ratios. Similarily, when a high value signal is to be sent from the computer to the guns by means of a relatively low-shaft-value transmitter, the shaft value may be reduced by means of a gear ratio.



Using gears to reduce lost motion errors

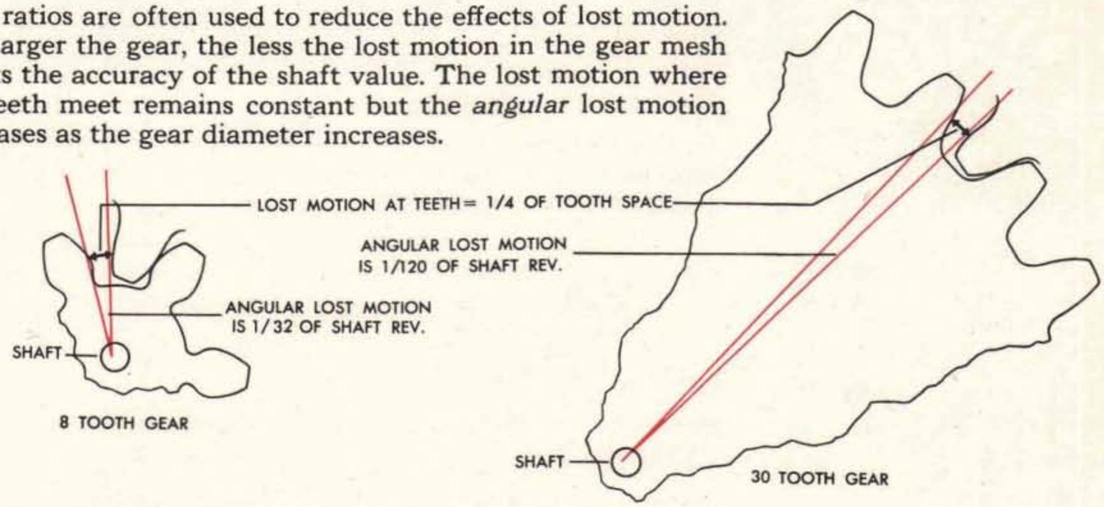
The total amount of value loss due to lost motion in a shaft line depends on:

1 The size of the gears used

2 The shaft value carried by the shafts in one revolution

Larger gears reduce angular lost motion

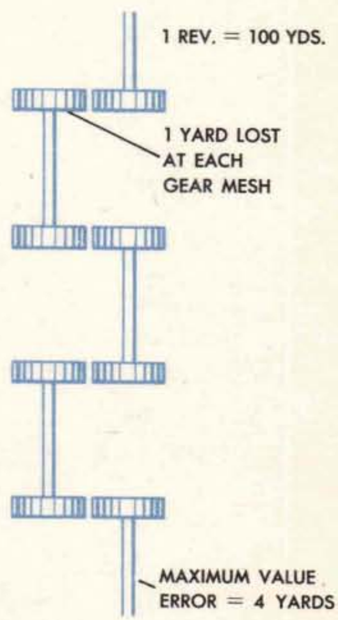
Gear ratios are often used to reduce the effects of lost motion. The larger the gear, the less the lost motion in the gear mesh affects the accuracy of the shaft value. The lost motion where the teeth meet remains constant but the *angular* lost motion decreases as the gear diameter increases.



Because large driving gears have less angular lost motion in transmitting a signal mechanically from one mechanism in the computer to another, it is often advantageous to reduce the shaft value with a gear ratio and step it up again at the point of delivery.

How gear size and shaft value affect lost motion error

Assume that a shaft line has four 1 : 1 gear ratios and the value per revolution of each shaft is 100 yards. If the gears used are all of such a size that the angular lost motion at each mesh is one yard, the greatest value error due to angular lost in the shaft line will be 4 yards.

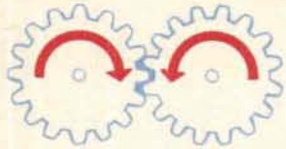


If the gears used were twice as large, the linear lost motion between the meshing teeth would remain about the same, but the *angular* lost motion would be half as great, thus cutting the value error in half, that is, to 2 yards.

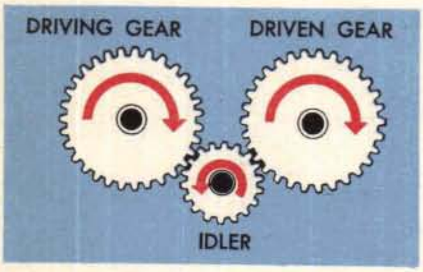
If the shaft value per revolution were only 50 yards instead of 100 yards, the maximum value error would also be cut in half.

It is important to understand that the maximum value error due to angular lost motion remains the same regardless of the number of shaft revolutions. As soon as the teeth on all the gears in a shaft line take up the lost motion by moving to their driving position, the maximum value error is reached and cannot increase during any additional turning in the same direction.

GEAR TRAINS

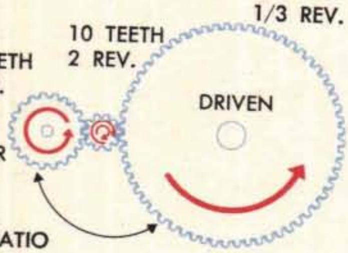


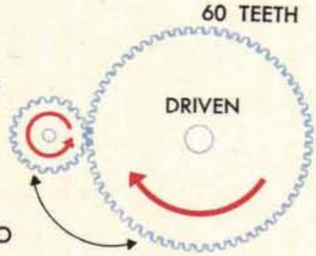
Any two mating spur gears turn in opposite directions.



If a shaft is required to turn another shaft in the *same* direction, an idler gear must be put between the driving gear and the driven gear. The idler will turn in the *opposite* direction to the driving gear, and will turn the driven gear in the *same* direction as the driving gear.

An idler between two gears does not affect the gear ratio, because each time the driving gear turns one tooth of the idler, the idler turns one tooth of the driven gear.





Here's an example:

Suppose a 20-tooth pinion is driving a 60-tooth gear through a 10-tooth idler.

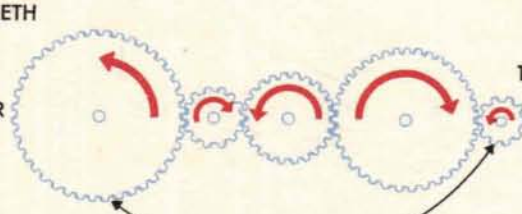
For each revolution of the driving pinion the idler will make 2 revolutions, because the idler has half as many teeth as the pinion.

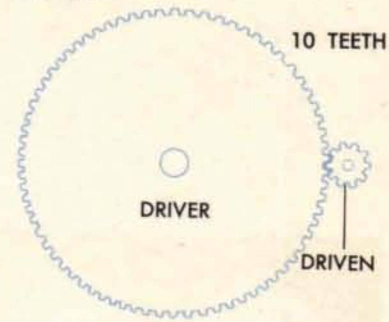
For each revolution of the idler, the driven gear will turn 1/6 revolution, because the gear has 6 times as many teeth.

So for each revolution of the pinion, the idler makes 2 revolutions and the driven gear makes $2 \times 1/6 = 1/3$ revolutions.

The ratio is 1: 3, which is the same as if the pinion had driven the gear directly.

Thus when several gears are meshed together in this way, the ratio between the driving gear at one end and the driven gear at the other end is always the same as if the driving gear were meshed directly with the driven gear.



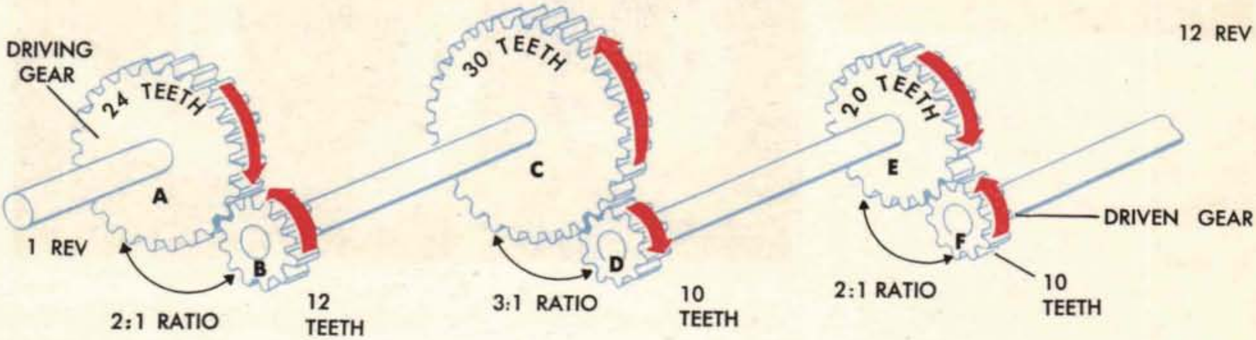


When a large increase in the number of revolutions is required, the increase can be made in several steps, using intermediate shafts, each of which carries two different size gears.

For example, suppose a 12 : 1 ratio is needed between two shafts.

To do this in one step would require the driving gear to be 12 times as big as its pinion, which would be very inconvenient and waste a lot of space.

It might be done this way:



Gears *A* and *B* have a 2 : 1 ratio. For each turn of the driver *A*, gear *B* makes 2 revolutions.

Since gears *B* and *C* are on the same shaft, gear *C* also turns twice for one turn of gear *A*.

Gears *C* and *D* have a 3 : 1 ratio. Gear *D* turns 3 revolutions for each turn of *C* or $(3 \times 2 =)$ 6 revolutions for each turn of *A*.

Gear *E* is on the same shaft as gear *D; E* also turns 6 times for one turn of *A*.

Since *E* and *F* have a 2 : 1 ratio, *F* turns twice for each turn of *E*, or $(2 \times 6 =)$ 12 times for each revolution of the driving gear *A*.

The ratio between *A* and *F* is, therefore, 12 : 1, and this ratio is achieved without the use of large gears.

To find the ratio of a train of this kind quickly, multiply together the ratios between each pair.
The ratio in this example is:

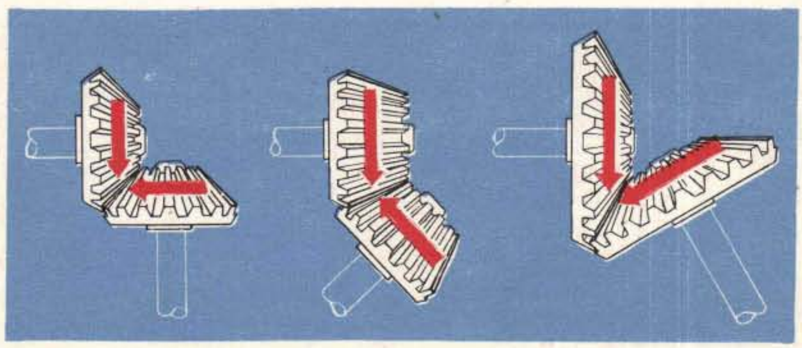
$$\frac{24}{12} \times \frac{30}{10} \times \frac{20}{10} = \frac{12}{1}$$

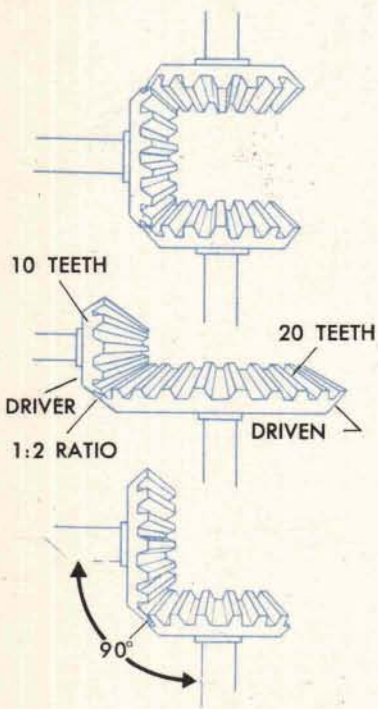
DIFFERENT TYPES of GEARS

So far only spur gears have been considered.

Spur gears will transmit motion only between parallel shafts. When shafts are not parallel *bevel gears* are usually used.

Bevel gears can transmit motion between shafts at almost any angle to one another because bevel gears can be designed to suit the angle between any two shafts.





MITER GEARS 1:1 RATIO

By using bevel gears several shafts at different angles can be driven by one driving shaft.

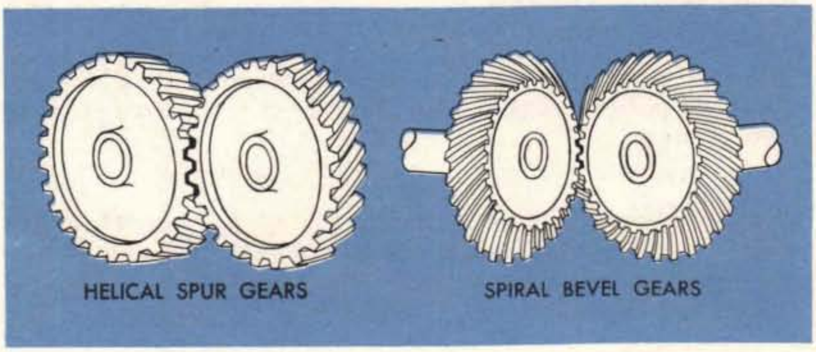
The gear ratios for bevels are found in the same way as for spur gears, by counting the teeth on each gear.

If a pair of bevel gears are of equal size and their shafts are at right angles, they are called MITER gears.

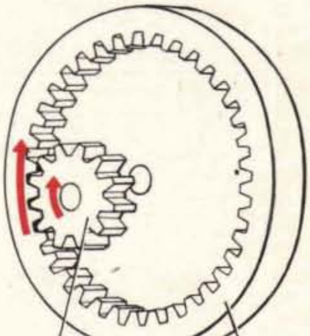
In SPIRAL GEARS, the teeth are cut slantwise across the face of the gear. One end of a tooth, therefore, lies ahead of the other. That is, each tooth has an "advanced end" and a "trailing end."

In straight tooth spur gears, the whole width of the face of the gear comes into contact at one time. But in spiral gears, contact between two teeth starts first at the advanced end of each tooth and moves progressively across the face of the gear until the trailing ends of the teeth are in contact.

Because of the slant cut of the teeth more than one tooth is in mesh at a time. This kind of meshing action keeps the gears smoothly in contact with one another, resulting in smoother and quieter operation.



INTERNAL GEARS are gears with their teeth cut on the inside of a ring and pointing inward toward the axis of rotation.



An internal gear must mesh with an external gear, whose center is offset from the center of the internal gear.

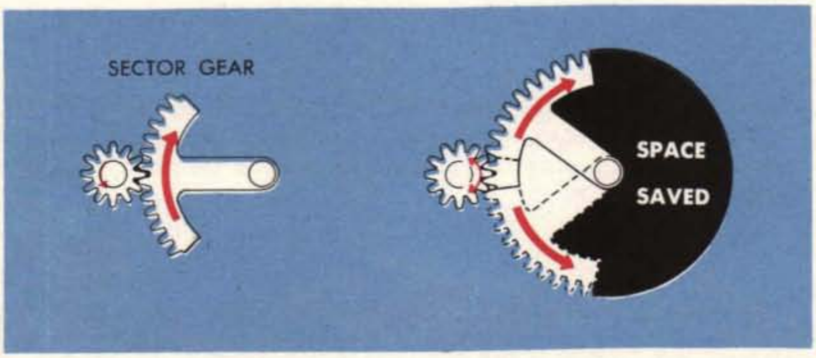
Either the external or the internal gear can be the driving gear. The gear ratio is the same as for external gears. It is:

$$\frac{\text{The number of teeth in the driving gear}}{\text{The number of teeth in the driven gear}}$$

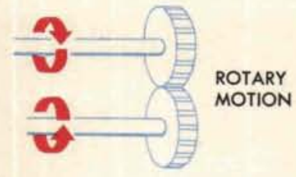
Sometimes only a part of a gear is needed, where the motion of the pinion is limited.

In a case like this a *sector gear* is used to save space.

A sector gear is simply part of a gear.



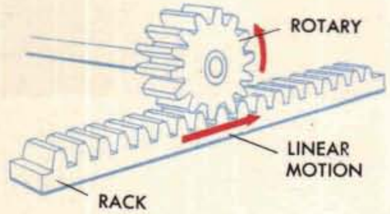
STRAIGHT and ROTARY motion



In fire control, values are transmitted by positions of shafts and parts of mechanisms. Some of these parts of mechanisms, such as racks, move in linear motion.

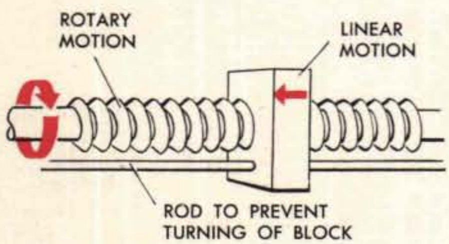
A rack is simply a straight bar with gear teeth cut on it.

When a gear positions another gear it is transmitting rotary motion.

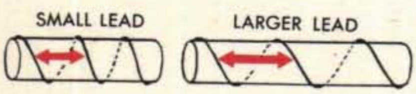


When a gear positions a rack it is converting rotary motion into linear motion. When the gear turns, the rack moves along its guide rails. The rack can also drive the gear. As the rack moves along, it turns the gear.

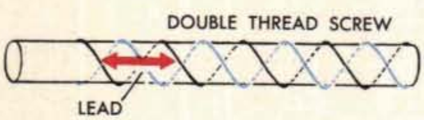
The rack transmits values by its position, just like shafts and gears. Its position is the *linear* distance it has moved from its zero position.



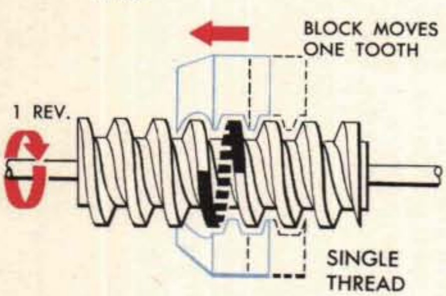
Another device which converts rotary motion to linear motion is the screw and traveling block, or nut. The block travels on the screw just as a nut moves along a bolt when the bolt is turned and the nut is held.



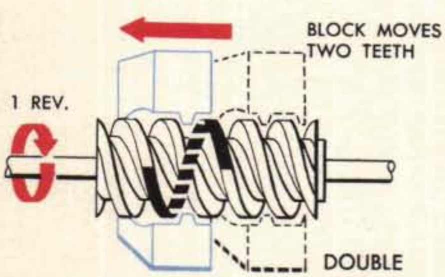
The distance the block travels for each turn of the screw depends on the "lead" of the screw thread. If a line is drawn along the screw parallel to the center line of the screw, the lead is the distance between the spirals of a thread, measured along this line.



Sometimes a screw has a second thread cut parallel to the first in order to get more contact surfaces between the screw and the follower. A screw with one thread is called a single-thread screw; a screw with two threads is called a double-thread screw.



FOR EACH TURN OF THE SCREW THE FOLLOWER BLOCK TRAVELS A DISTANCE EQUAL TO THE LEAD.

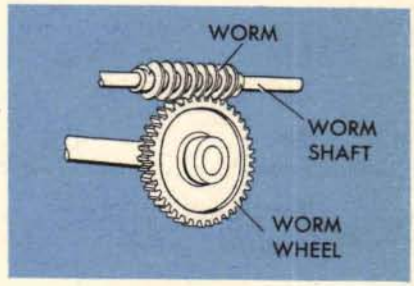


The distance the follower block travels for one turn of the screw is always equal to the lead, that is, the distance between corresponding points *on the same thread,* no matter how many threads there are.

In a *single-thread* screw the lead is the width of *one* tooth.

In a *double-thread* screw the lead is the width of *two* teeth.

The WORM and the WORM WHEEL

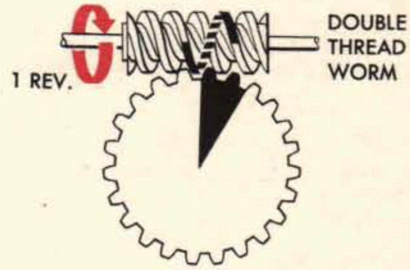


A worm is a screw with a thread of special shape.

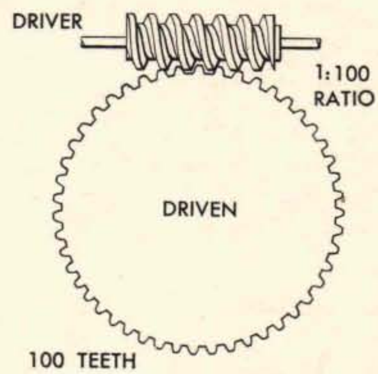
Instead of moving a block the worm drives a worm wheel.

A single-thread worm turns its worm wheel one tooth for each revolution of the worm.

The black sectors show how much the wheels will be turned by one revolution of the worms.



A double-thread worm turns its wheel two teeth for each turn of the worm.



Worms can also have three or four or more threads. The number of wheel teeth turned for each revolution of the worm is always the same as the number of threads on the worm.

Worms are often used where great reductions in amount of rotation are needed, because the ratio of rotation between the worm and its wheel is usually large.

Since each thread of the worm moves only one tooth of the wheel the gear ratio between worm and wheel is:

$$\frac{\text{The number of threads in the driving worm}}{\text{The number of teeth in the driven wheel.}}$$

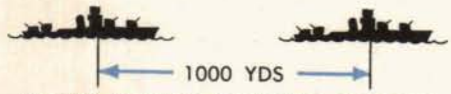
Here is a single-thread worm with a 100 tooth wheel. The worm must make 100 revolutions for one complete turn of the worm wheel.

The gear ratio is 1:100.

Sometimes the worm wheel drives the worm. This is possible only when the slope of the worm threads is greater than 5°.

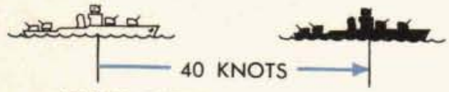
BASIC MATHEMATICS

Mastery of certain mathematical principles is a fundamental requirement for understanding fire control mechanisms. Many of these are well worth committing to memory:



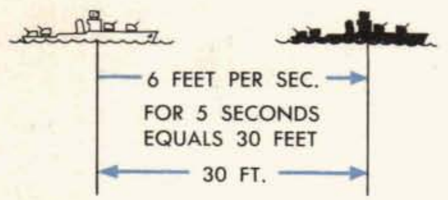
LINEAR MEASURE INDICATES DISTANCE

Linear measure is the *distance* between two fixed points measured in a straight line. In fire control, the units of measurement are usually yards and nautical miles.

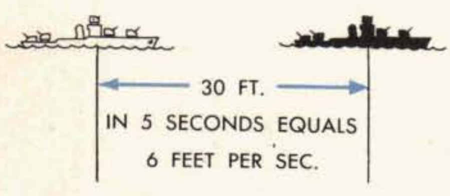


LINEAR RATES REPRESENT SPEED

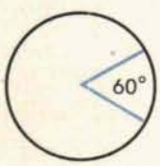
A *linear rate* is the *speed* of an object moving in a straight line. All linear rates tell the *distance* that an object will move in a given *time*. Linear rates are usually expressed in yards per second or in knots.



Multiplying a *linear rate* by the *time* that has elapsed during the movement of an object produces the *linear distance* traveled in that time. A ship traveling at a linear rate of 6 feet per second for a period of 5 seconds will move a distance of 30 feet.

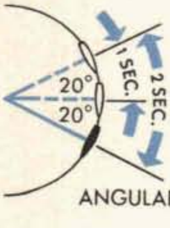


Dividing linear *distance* by the *time* required for an object to move that distance will produce the *linear rate*. A ship traveling 30 feet in 5 seconds moves at the rate of 6 feet per second.



ANGULAR MEASURE SHOWS THE SIZE OF AN ANGLE

Angular measure is the size of a given angle expressed in degrees, minutes, and seconds. Angles can also be expressed in *radians* as will be shown later.

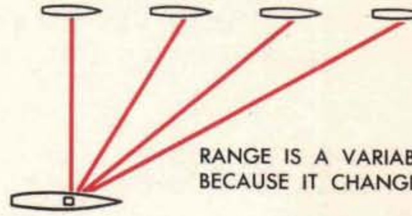


ANGULAR RATES SHOW THE SPEED WITH WHICH AN ANGLE VARIES

ANGULAR RATE = 20° PER SEC.

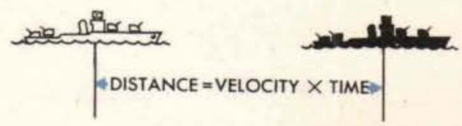
An *angular rate* is the speed with which an angle changes. Angular rates can be expressed in degrees per minute, or minutes per second, or *radians* per second.

A quantity that changes is called a *variable.* For example, the RANGE input to a computer is a variable because the range value is constantly changing as the position of the Target changes with relation to Own Ship.

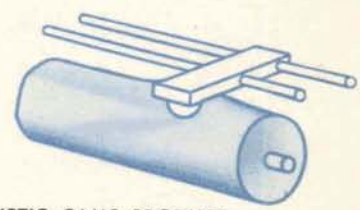


RANGE IS A VARIABLE BECAUSE IT CHANGES

A variable that derives its value from another variable is called a *function* of that variable. When the function increases or decreases uniformly as the variable increases, the function is called a *linear function.* If an object is moving at a constant velocity, the distance it travels is a linear function of the time of travel. Distance equals velocity times time.

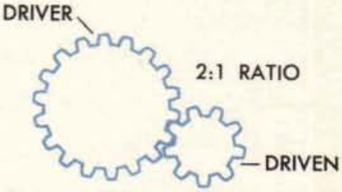


In fire control problems, an *empirical function* is one whose value in relation to a variable has been established by observation. Ballistic cams deliver empirical functions because the data cut into each cam is based on the observations of the flight of the projectile.



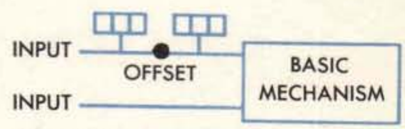
BALLISTIC CAMS PRODUCE EMPIRICAL FUNCTIONS

A *constant* is a quantity whose value does not change.



GEAR RATIOS PROVIDE A CONSTANT FOR MULTIPLICATION

A variable is often multiplied by a constant to produce an approximation of another variable. When a constant is *added to* or *subtracted from* a variable, it is called an *offset.*

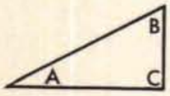


AN OFFSET IS A CONSTANT TO BE ADDED OR SUBTRACTED

The *reciprocal* of a number is 1 divided by that number. The reciprocal of 5 is 1/5. Multiplying by the *reciprocal* of a number is the same as *dividing* by that number. Division in mechanical computers is usually accomplished through multiplication by the reciprocal.

RECIPROCALS CAN BE COMPUTED BY A CAM

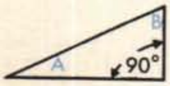
Right Triangles



ANGLE A + ANGLE B + ANGLE C = 180°

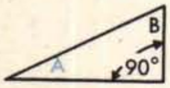
The sum of the angles in any plane triangle is always 180°.

A right triangle has one 90° angle; therefore 90° plus angle A plus angle $B = 180°$.



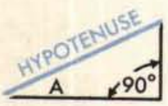
ANGLE A + ANGLE B = 90°

Angle A plus angle B will always equal 90° in any right triangle.

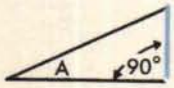


ANGLE A = 90° − ANGLE B

If angle A is known, angle B can be found because angle $B =$ 90° minus angle A.

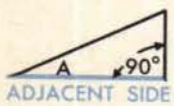


The side opposite the right angle is always the longest side and is called the *hypotenuse.*



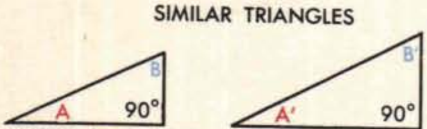
OPPOSITE SIDE

The side opposite angle A is called the *opposite side* to that angle.



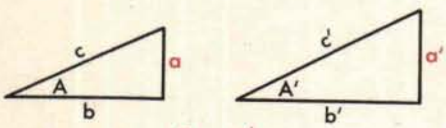
Angle A is formed by the hypotenuse and one *side* of the triangle. This side is called the *adjacent side* to angle A.

SIMILAR TRIANGLES



ANGLE A = ANGLE A'
ANGLE B = ANGLE B'

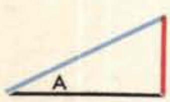
Right triangles can have the same *angles* but be of different *sizes.* Triangles of different sizes but having the same angles are called *similar triangles.* In two similar triangles the ratio between any two sides of one triangle is equal to the ratio between the corresponding two sides of the other triangle.



$$\frac{a}{c} = \frac{a'}{c'}$$

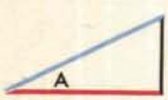
As long as angle A remains the same, the *ratio* of any two sides of the triangle will be the same, regardless of the *size* of that triangle. Six ratios can be obtained by using the three sides. These ratios are called natural trigonometrical functions.

Trig functions



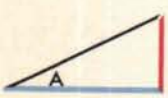
$$\frac{\text{OPPOSITE SIDE}}{\text{HYPOTENUSE}} = \sin A$$

1 The opposite side divided by the hypotenuse is called the *Sine of A.* It is written *sin A.*



$$\frac{\text{ADJACENT SIDE}}{\text{HYPOTENUSE}} = \cos A$$

2 The adjacent side divided by the hypotenuse is called the *Cosine of A.* It is written *cos A.*



$$\frac{\text{OPPOSITE SIDE}}{\text{ADJACENT SIDE}} = \tan A$$

3 The opposite side divided by the adjacent side is called the *Tangent of A.* It is written *tan A.*

4 The adjacent side divided by the opposite side is called the *Cotangent of A*. It is written *cot A*.

5 The hypotenuse divided by the adjacent side is called the *Secant of A*. It is written *sec A*.

6 The hypotenuse divided by the opposite side is called the *Cosecant of A*. It is written *csc A*.

These are the six Natural Trigonometric Functions. If the value of any one of these functions is known, the value of the angle in degrees can be found in a table of Trigonometric Functions.

The cotangent and cosecant are seldom used in the mechanical solution of a fire control problem. The other four functions should be carefully memorized.

The first three functions, Sine, Cosine, and Tangent, are the most used functions. Knowing the first three functions the other three can be found.

$$\csc A = \frac{\text{hypotenuse}}{\text{opposite side}} \text{ and } \sin A = \frac{\text{opposite side}}{\text{hypotenuse}}$$

If the terms in the sin A equation are inverted:

$$\frac{1}{\sin A} = \frac{\text{hypotenuse}}{\text{opposite side}}$$

Then: $\csc A = \dfrac{1}{\sin A} \quad \sec A = \dfrac{1}{\cos A} \quad \cot A = \dfrac{1}{\tan A}$

Measuring the sides of the right triangle

If one side of a right triangle and angle A are known, the other two sides may be found by using the trig functions of angle A.

Knowing that $\dfrac{\text{opposite side}}{\text{hypotenuse}} = \sin A$, to solve for the opposite side, multiply both sides of this equation by the *hypotenuse:*

$$\text{opposite side} = \text{hypotenuse} \times \sin A.$$

In the same way, the other equations can be changed to give:

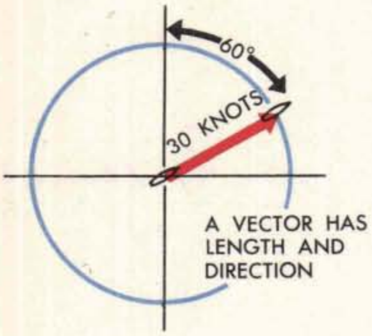
$$\text{opposite side} = \text{adjacent side} \times \tan A$$

$$\text{adjacent side} = \text{hypotenuse} \times \cos A$$

$$\text{adjacent side} = \frac{\text{opposite side}}{\tan A}$$

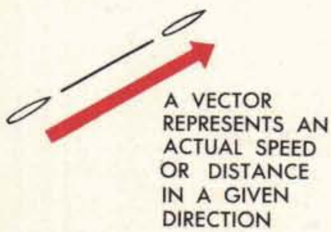
$$\text{hypotenuse} = \frac{\text{adjacent side}}{\cos A}$$

$$\text{hypotenuse} = \frac{\text{opposite side}}{\sin A}$$



VECTORS

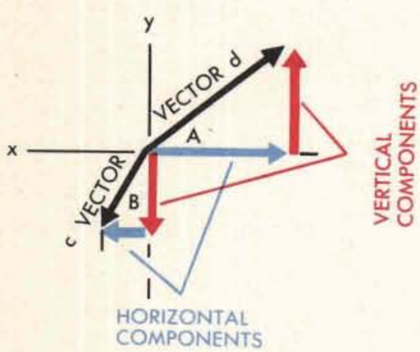
A *vector*, as used in a fire control problem, is a straight line with a definite *length* and *direction* which may represent either a *linear rate* or a *linear distance.*



To add or subtract vectors with *different* directions, it is necessary to break them up into *components,* with reference to a common axis, and add or subtract the corresponding components.

Suppose that two vectors with different directions are drawn from a common point. Their components from the point in a horizontal and vertical direction can be found by solving the two right triangles formed.

The y components are $d \sin A$ and $c \cos B$
The x components are $d \cos A$ and $c \sin B$



Solving an equation

An algebraic equation may be solved or simplified by adding the same value or subtracting the same value from both sides of the equation, or by multiplying or dividing both sides of the equation by the same value.

In the equation $ay = bx$, x can be found by dividing both sides of the equation by b.

$$\frac{ay}{b} = \frac{bx}{b} \text{ or, } x = \frac{ay}{b}$$

In the same equation, y may be found by dividing the original equation by a.

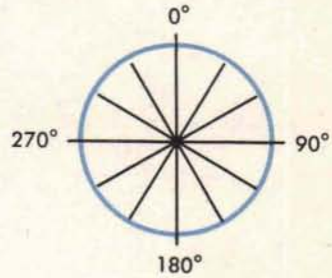
$$\frac{ay}{a} = \frac{bx}{a} \text{ or, } y = \frac{bx}{a}$$

If the equation read $y = \frac{bx}{a}$, the value of x could be found by multiplying both sides of the equation by $\frac{a}{b}$.

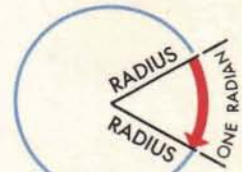
$$\frac{ay}{b} = \frac{abx}{ab} \text{ or, } x = \frac{ay}{b}$$

The values of a or b may be derived in the same manner.

RADIANS

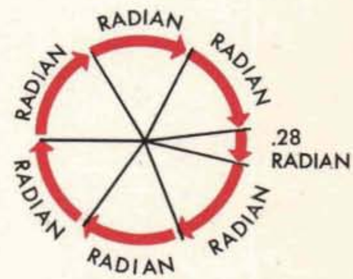


The usual way to measure an angle is in degrees and minutes. The circumference of a circle is divided into 360 equal parts, or degrees. Each degree is further divided into 60 minutes.



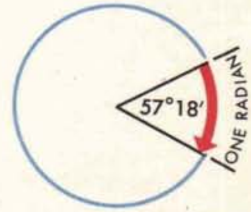
Another extremely useful system of measuring angles is called *radian measure.*

In radian measure, an arc equal in length to a radius of a circle is measured on the circumference of that circle. When two radii are drawn to the ends of this arc, the angle they measure is called a radian. A circle contains *6.28 radians.*



A circle contains 6.28 radians because the circumference of any circle equals 2π times the radius. As π equals 3.14 (approx.) then 2π equals 6.28. Since one radius measures one radian on the circumference there are always 2π or 6.28 radians in a circle.

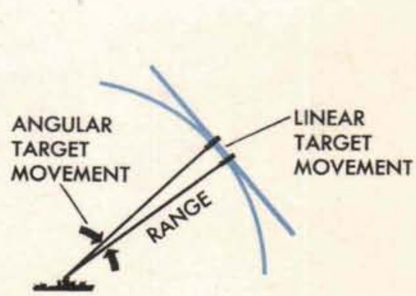
Angles expressed in radians can be translated to angles expressed in degrees if it is remembered that 2π radians equal 360°.



ONE RADIAN = 57°18′

$$\text{One radian} = \frac{360^\circ}{6.28} \text{ or } 57^\circ\ 18'$$

The chief importance of the radian measure in fire control is that the radian can be used to translate two linear measurements, such as target movement and range, into an angular measurement. If the target movement in a given period of time is known, and the range is known, the angular movement of the target can be expressed as a fraction of the range. Considering the range to be a radius, the fraction obtained will be the angular target movement in radians.



It should be borne in mind, however, that the radian is a *curved* unit, whereas the linear movement of a target is in a *straight* line. For the purposes of computation it is within the limits of accuracy to assume that the straight line and the curved arc of the radian are equal in length when the straight line measures a small angle.

BASIC SETTING INFORMATION

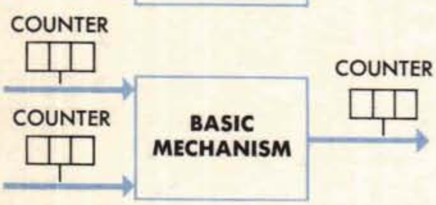
Each basic mechanism solves *a part* of the fire-control problem. It does not work alone, but is joined by shafts into a *network* of mechanisms. The *output* shaft from one mechanism is usually the *input* to another mechanism.

Naturally there must be coordination between all these parts. The problem of setting includes the setting of each individual mechanism and the joining of these mechanisms in their proper relationship.

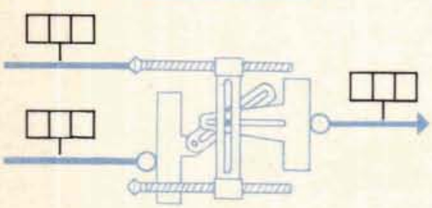
Each chapter in this pamphlet contains general setting instructions for the basic mechanisms covered in that chapter.

These setting notes in each chapter are not intended for making actual settings. They show only how *the parts of the various mechanisms are set*. Basic mechanisms used in more than one Ford Computer are covered in these notes. For this reason the setting procedures have been kept general. Specific setting instructions for each computer and its mechanisms are covered in each computer's setting notes.

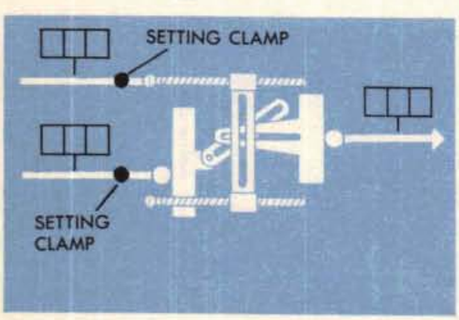
Every computer has the necessary dials and counters to show the positions of the mechanisms. However, every shaft in the computer *could* have its *own* dial or counter to show the value of the quantity on the shaft.



In these setting notes it will be *assumed* that there is a counter on the input and output shafts of each mechanism.



For instance, on a multiplier the shaft positioning the lead screw input will be shown with an attached counter, also the shaft which positions the input rack will have a counter, and the shaft positioned by the output rack will have a counter.



In all these mechanisms the setting clamp is placed between the imaginary counter and the input of the mechanism. The counter indicates the value on the shaft. Setting the mechanism to this counter automatically sets it to whatever value positions the shaft.

Here are a few things to remember in reading these setting instructions:

1 All setting clamps are loose before adjustment. They are tightened when the setting is completed.

2 Many mechanisms are set by positioning one input at zero, and then moving the other input while watching the output for zero or minimum motion. Take a multiplier for example: Any number multiplied by zero equals zero, so if one input to the multiplier is put at its zero position, movement of the other input should produce *no* movement of the output.

In general, this is the setting procedure:

a. One input line to the mechanism is put at its zero position.

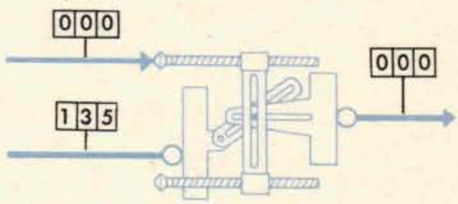
b. The corresponding input of the mechanism which is to be joined or "set" to the input line, is put at its estimated zero position.

c. The setting clamp is partly tightened—"slip-tightened."

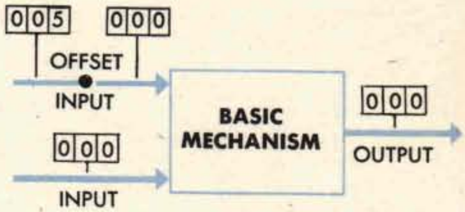
d. The other input of the mechanism is then moved.

e. If there is motion of the output, the setting is corrected through the setting clamp until the output motion is reduced to zero or to a minimum.

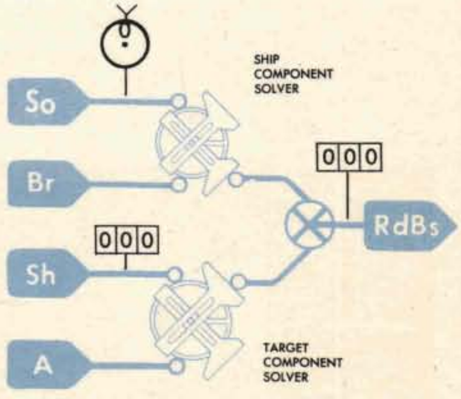
f. The other input usually can be set in the same way.



3 Usually, when an input to a mechanism is at its zero position, its counter is at zero. Sometimes this is not true, for example, when a constant offset is required. In this case, the zero position of the mechanism will be indicated on the counter by a reading equal to zero, plus the offset value. Each computer's setting notes give the offset values for the individual mechanisms.



4 For some of the mechanisms in the computers several input settings may be required to put one shaft in the zero position—for example, *RdBs* equals zero when both the *So* dial and the *Sh* counter read zero.



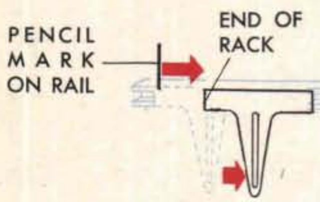
5 A computer's setting notes are more specific than these general setting notes, and should be used for all actual settings.

Here and there in the setting notes are instructions like "Observe the motion of the indicator," "Push the cam," or "Wedge the input." It will be a good idea to find out how to do these things now.

How to use the INDICATORS

Most mechanisms are set by observing the *motion of an output.* In these general setting notes *counters* are the only indicators used. However, there are several other devices which make good motion indicators.

1 A dial may be substituted for a counter.



2 A rack may be used as an indicator by marking both the rack and its rail. Then the distance the rack moves from the mark can be measured.

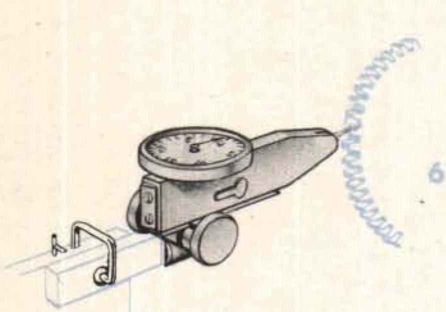
3 A gear may be marked with a pencil and read against a stationary mark made on the computer frame.

Here, too, the distance the gear moves from the mark can be measured.

4 The output gear on a follow-up makes an excellent indicator if the follow-up input is the value to be measured. When used to set for minimum motion, the follow-up output gear or shaft is marked with a pencil so that any motion can be detected and measured.

5 A dial indicator of the universal type illustrated provides an accurate means of measuring movement when setting to obtain minimum motion.

It is attached to a rack or gear in this way. Movement of the rack or gear is amplified many times in the indicator and moves a hand around a dial.

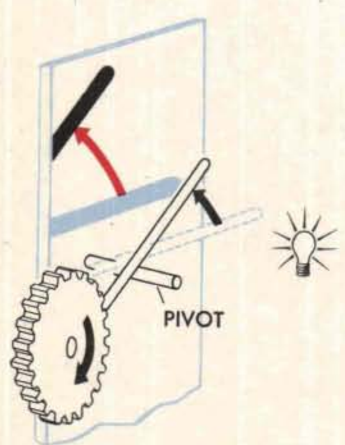


6 Another accurate way of amplifying small motions is to use a "shadow stick."

A shadow stick is a light lever which magnifies the motion of a gear or rack when a light casts the shadow of the lever on a surface behind it. The pivot may be a convenient shaft or surface in the mechanism.

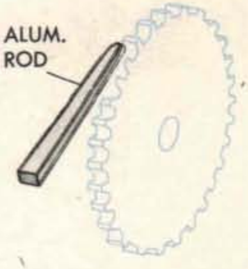
This is how it is used: Mark the position of the shadow before the rack or gear moves, and *after,* to see how far it has moved.

To get the best results the distance from the pivot to the rack or gear should be short and the light should be close to the stick.



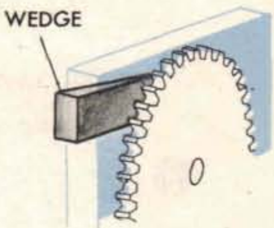
The factors governing the selection of the type of indicator to be used are *accessibility* and *sensitivity.* It is not necessary to use a sensitive dial indicator on a rough setting—it just makes the setting more difficult.

How to push a CAM or GEAR



The best way to slip a cam or gear which cannot be turned by hand is to put an aluminum rod against the base of one tooth and push firmly but gently in the proper direction to change its position. *Never use a hard metal pusher...* Steel rods and screw drivers should never be used for this purpose.

WEDGING an input



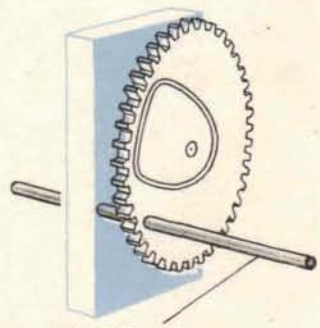
To hold an input shaft in one position, insert a bakelite or wooden wedge between the gear and the computer frame so that it keeps the gear and shaft from turning. To avoid damaging the shaft assemblies, a wedge should be inserted just firmly enough to hold the shaft line, but should not be hammered in.

When a setting has been completed, remember to remove all the wedges.

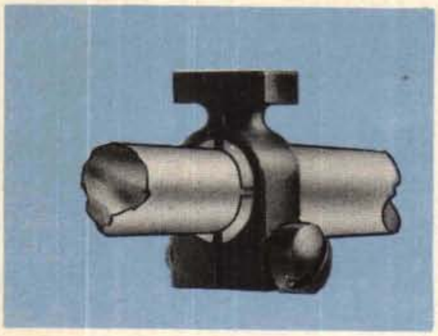
To ENERGIZE

When power is needed, the setting instructions say "Energize ...." This means to complete a circuit by connecting the proper leads to the power supply.

How to use a SETTING ROD



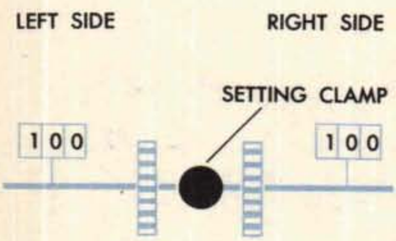
A setting rod is an accurately ground steel rod. There are usually two accurately sized holes provided in the parts to receive the setting rod... One hole is in the mechanism to be set and the other is in the computer frame. The Computer's setting notes give the values at which counters should be set when the setting rod is inserted through both holes.



CLAMPS

Clamps are mechanical "knots." They are used to tie inputs and mechanisms together, and to join the mechanisms of a computer into a network. Because clamps are *adjustable,* they can join these mechanisms in their proper relationship.

Setting clamps are placed in a computer so that they control the inputs to a mechanism or a series of mechanisms. Whereever possible, they are placed where they are easy to reach and easy to see. *Any clamp* in a computer, whether a setting clamp or an assembly clamp, can be used for setting. If any clamp becomes loose, it disturbs the network.

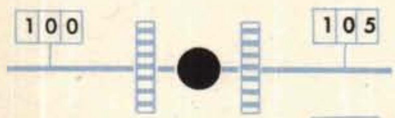


Here is a simple setting.

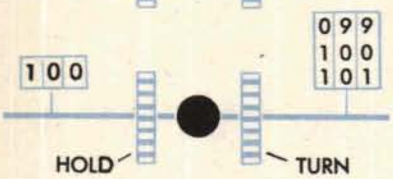
The clamp controls the relationship between the right and left sides. The counters indicate the value on each side of the clamp.

Most of the time the values have to be made equal. Here this is shown by a similar reading on both the counters.

When the counters are in agreement and the clamp has been tightened, the setting is complete.



Here the two sides of the clamp disagree. . . . Tightening the clamp now would make the right side in error by the amount of 5.



The error can be corrected by holding the left side and moving the right until the counter readings match.

Now tightening the clamp completes the setting.

Sometimes the sides should not be equal. A constant offset, *K*, can be added or subtracted by a clamp. Tightening the clamp when one side differs from the other by the constant *K* completes the setting. Here the constant is 20.

"Slipping through the clamp," means changing the relationship between two mechanisms controlled by the clamp, by holding one and turning the other.

"Slip-tighten the clamp," means to make the clamp tight enough to drive, but loose enough to allow "slipping through the clamp."