Restricted

MAPS, CHARTS and AERIAL PHOTOGRAPHS

STUDENT'S WORKBOOK

PREFLIGHT

First Edition

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RESTRICTED

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ARMY AIR FORCES FLYING TRAINING COMMAND

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MAPS, CHARTS, AND AERIAL PHOTOGRAPHS

The purpose of this course is to present to you information which will be of use during your entire military career. The subject of Maps, Charts, and Aerial Photographs is one which vitally concerns pilots as well as navigators and bombardiers. You will at once appreciate the importance of military personnel being where they are supposed to be when they are supposed to be there. Precise timing is very important, particularly in the combat zone. Often success or failure of a mission may depend upon the perfect coordination of all units participating. In order to make and put into execution the intricate plans necessary in aerial warfare, particularly the plans of flights, it is absolutely necessary to understand both the fundamentals and details concerning maps and charts. Because in the zone of operations many of the latest maps are in the form of aerial photographs, it is essential that the flyer understand the full meaning and interpretation of these vast sources of valuable information.

The information given in this course will serve as a nucleus around which the cadet can build a working knowledge of the subject, for during his work at primary, basic, and advanced schools he will obtain through training and experience other data which will be essential in successfully completing missions assigned to him.

PLAN OF COURSE

The course is planned so that the fundamentals of the construction and interpretation of maps are given first consideration. Later in the course more details are given regarding the construction and uses of specific types of maps and charts. The final subject discussed in the course, namely the use and interpretation of aerial photographs, is one which deserves emphasis for all those planning to be flyers.

For your convenience this workbook has been prepared to enable you to follow the instructor's lectures and at the same time organize your notes in an orderly and useful manner. The figures given in this workbook have been reproduced in order that you may have a more accurate record of the drawings given by the instructor than could be obtained by sketches made from any illustration that he might use. Frequently the exact angles in drawings are significant and if the drawings are inaccurate, the value of the drawing will be lost.

The outlines of the lectures are incorporated in the workbook in order that you may have a complete record of the main topics discussed during the lecture hours. By following the outline in taking notes you will have a well organized set of notes for reference.

The exercises in the workbook are to be completed outside of class time. The cadet should be reminded that only by doing this work independently will he obtain the full benefits from this course.

In order to be able to recognize land features from the air, it is necessary to be able to read maps accurately and quickly while aloft. The importance of interpreting maps correctly cannot be over-emphasized, for it is imperative that the correct identification of objectives and other features be made. It is therefore without any apology whatsoever that the cadet is required to learn certain of the more common conventional signs and symbols used on maps and aeronautical charts. The indication of signs and symbols on maps and charts is a matter of mathematical exactness and correctness, and the interpretation of signs and symbols by the flyer must be equally exact. Detailed information regarding conventional signs and symbols is an important part of this workbook.

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TESTS AND EXAMINATIONS

The schedule of tests and examinations will be announced by the instructor.

CONVENTIONAL SIGNS AND MILITARY SYMBOLS

The conventional signs and military symbols on pages 2 to 6, inclusive, will be studied outside the classroom. The trainee's attention is invited to importance of learning Conventional Signs and Military Symbols. It is necessary that the trainee have a full understanding of these signs and symbols and that he be able to identify them accurately and without hesitation.

CONVENTIONAL SIGNS AND MILITARY SYMBOLS

Roads
- Good motor
- Poor motor or private
- On small-scale maps
- *Routes usually traveled may be further classified by red overprinting as follows:*
- Hard impervious surfaces
- Other surface improvements

Good pack trail

Poor pack trail or footpath

Railroads
- Railroad of any kind, small scale
- Railroad single track, large-scale maps

Railroad crossing
grade--rr above--rr beneath

Tunnel
- railroad
- road

Railroad station of any kind

Telegraph and telephone lines — On ground or poles

Electric power transmission line

Buildings in general

Church

Hospital

Schoolhouse

Triangulation point or primary traverse station

Permanent bench mark (and elevation)

Cemetery

Mine or quarry of any kind (or open cut)

- Bridges
  - General symbol (capacity in tons indicated by figures)
    - road
    - railroad
  - Foot
  - Ponton
- Ferries
- Fords
  - General symbol (for vehicles)
  - Equestrian
- Dam
- Streams in general
- Intermittent streams
- Spring
- Wells and water tanks
- Marsh in general (interior salt marshes and coastal fresh marshes are to be indicated as such)
- Woodland (or as shown below)
- Woodland (or broad-leaved trees)
- Orchard
- Fences
  - Stone
  - Worm
  - Wire — barbed — smooth
  - Hedge
- Depression contours
- Fills
- Cuts

Area gassed, to be avoided

Automatic rifle

(Dotted when emplacement is not occupied)

Machine gun
(Arrow to point in principal direction of fire. When used alone it indicates Machine gun, water-cooled, cal. .30)
Machine-gun symbol under symbol of unit of any arm indicates machine-gun unit of that arm.

Caliber .50 (antitank) — .50 AT

Machine gun (single gun)
(arrows to indicate sectors of fire, shaded portion to show danger space when fire is placed in final protective line.)

Machine-gun section (two guns)

Gun

Gun battery

Howitzer or mortar

Open when emplacement is unoccupied, thus

37-mm gun — 37-mm
(AT or AA to be added where applicable.)

81-mm mortar — 81-mm

APPLICATION OF SPECIAL SYMBOLS

Light Machine-Gun Platoon, Troop A, 2d Cavalry — A 2

Machine-Gun Troop, Caliber .50, 2d Cavalry — 2 .50

Troop F, 2d Cavalry — F 2

Company A, 2d Engineers (combat) — A E 2

Battery F, 2d Field Artillery — F 2

One Squad, Company A, 4th Infantry — A 4

Light Machine-Gun Section, Company A, 2d Infantry — A 2

1st Platoon, Company B, 2d Infantry — 1 B 2

Machine-Gun Platoon, Caliber .50, Company H, 29th Infantry — 29 .50

Headquarters Company, 3d Infantry — Hq 3

Company D, 20th Infantry — D 20

Command Post, 3d Battalion, 4th Infantry — 3 4

Observation Post, 6th Infantry Regiment — III 6

SYMBOLS FOR AIR NAVIGATION MAPS AND CHARTS

Army, Navy, or Marine Corps field

Commercial or municipal field

Department of Commerce intermediate field

Marked auxiliary field

Airplane landing field, marked or emergency (where not shown in plan nor by symbol indicating characteristics)

Mooring mast

Night lighting facilities — LF

Seaplane base with ramp, beach, and handling facilities

Anchorage with refueling and usual harbor facilities

Protected anchorage with limited facilities

Airway light beacon
(arrows indicate course lights)

Auxiliary airway light beacon, flashing

Airport light beacon with code light (within airport symbol)

Airport light beacon without code light (within airport symbol)

Landmark light beacon with bearing projector (arrow indicates fixed beam pointing to airport)

Landmark light beacon without bearing projector

Radio station with call letters and frequency — or RS (WUF 1830) OR RS WLW 700

Radio direction-finder station with call letters and frequency (radio-compass station) — RC (NDW 3010)

Radio beacon with call letters — RBn (WRO)

Radio range beacon — RR Bn

Air routes, optional synbols — 120 Miles

Radio marker beacon — 344

Fan marker beacon — ARCOLA

Lines of equal magnetic variation — 10° E

Air Space Reservation (or Danger Area)

Caution Area

Railroads

- Single track, crosstie spacing 5 miles
- Two or more tracks, crosstie spacing 5 miles
- Electric, crosstie spacing 2½ miles
- Abandoned

Highway, prominent

Highway, less prominent

Road or trail, prominence uncertain

Oil well derrick

Obstruction (numerals indicate height above ground in feet) — 257

Prominent elevation (numerals indicate height in feet) — 862

Coast Guard station

Look-out tower

High explosive area

- Marked
- Unmarked

Cities and towns

- Less than 1000
- 1000 to 5000
- more than 5000, actual shape

Race track

Prominent transmission line

Radio range

Bearings are magnetic at the station

Gradient of elevations

0 to 1000	1000–2000	2000–3000	3000–5000	5000–7000	7000–9000	9000–Maximum
Green	Light green	Pale brown	Light brown	Medium brown	Deep brown	Dark brown

GENERAL CONSIDERATION OF MAPS AND CHARTS

I. INTRODUCTION

A. Now beginning an eighteen hour course in maps, charts, and aerial photographs.

B. Every soldier should acquire skill in reading and interpreting maps, charts, and aerial photographs early in his career. The success or failure of many military operations depends upon the accuracy of available maps and the use that is made of them.

C. Maps of some form are used in almost all military operations. Often the success of outstanding military leaders has been based on the skillful use of maps. One cannot hope to become a successful military leader unless he has acquired skill in using maps, charts, and aerial photographs of all types.

D. The speed of aircraft necessitates immediate and accurate interpretation of maps, charts, and aerial photographs by the aviator. Much of his combat flying will be over unfamiliar territory. Success in finding the target, accurate timing, ability to safely find the way home - in short, the success of the mission and the safe return depends primarily on the ability of the aviator to quickly and accurately interpret maps, charts, and aerial photographs.

E. Aerial navigation especially involves the use of maps and charts.

II. PURPOSE AND SCOPE OF THE COURSE

A. Purpose.

1. Two-fold

a. Serves as an introduction to aerial navigation

(1) The study of Navigation will be an essential part of the training of every flyer. In flying an airplane or sailing a ship, it is the basis for determining position and route. In moving from one place to another, however short the distance, navigation is involved.

(2) Four kinds of navigation are in use; usually two are used in combination. These are

(a) Pilotage---flying from starting point to destination by observation of prominent landmarks. It may be that these mountain peaks, crossroads, cities, bodies of water, etc., are previously known, or that they are identified from a map.

This method is naturally of little value over large water areas, at night (unless on a route well supplied with aerial beacons) and when the weather makes visibility poor.

(b) Dead reckoning (often abbreviated "DR")--calculating position and maintaining a desired course by the ground speed the ship is making and the time she has been in the air. A ship flying at 300 m.p.h., for example, should be 600 miles along her course in two hours. Allowance must be made for the influence of wind, of course. This method is much used over large water areas where there are no landmarks to allow pilotage, but cannot be depended upon alone for long flights because it is not sufficiently exact.

(c) Celestial navigation--determining location by observing the position of the heavenly bodies.

(d) Radio navigation--flying from one point to another by use of the radio range, radio direction finder, or radio bearings. The great advantage of this type of navigation is that no view of the ground is necessary, and instrument landings are possible. It is of little value in war time, however, because it is often necessary to shut off various radio devices lest they be used by the enemy.

b. Gives information on interpretation, use, and construction of maps, charts, and aerial photographs that should be part of the education of every military man.

B. Scope

1. Course will cover consideration of subject of military maps, charts, and aerial photographs.

2. Subjects are important for the following reasons:

a. Military maps are indispensable to commanding officers in the field in arriving at tactical decisions and in transmitting orders. Maps are also indispensable to subordinates that are charged with the duty of executing the orders.

b. Aerial activities must be coordinated with ground forces-the map is a common reference for both forces.

c. Supporting fire of many weapons is controlled by use of map data.

d. Charts are necessary in navigating:

(1) Over poorly mapped country
(2) Over water
(3) In conditions of poor visibility
(4) At night

e. Aerial photographs are used as map substitutes and in selection and development of bombardment targets.

III. DEFINITIONS

Before proceeding further we should define maps, charts, and aerial photographs. Other definitions will be given throughout the course as they are needed.

A. Map

A map is a graphic, conventionalized representation of a portion of the earth's surface, which is drawn to scale upon a plane.

Analysis of definition

When we say graphic, we mean that the information concerning the ground or terrain is conveyed by a picture or drawing instead of verbal description.
When we say conventionalized, we mean that the various natural and artificial objects, such as trees and houses, are represented by a system of standardized or conventional signs.

B. Chart

A chart is a type of map designed for the use of navigators. Heretofore a chart has been taken to mean a map of those portions of the earth's surface which are mostly covered by water. Recently the term chart has been used with reference to maps which are used for the purposes of aerial as well as marine navigation.

C. Aerial photograph

An aerial photograph is a picture, with either a vertical or an oblique viewpoint, taken from an aircraft.

IV. KINDS OF MAPS

A. Military maps (Scales to be considered in later lecture)

1. Strategic or small scale maps. These maps contain a great deal of information concerning communication lines, cities, airports, rivers, mountains, and other terrain features for an area of considerable size. Such maps are used by commanders in preparing plans for large scale operations over a wide area. Strategic maps do not contain much detailed information.

2. Tactical or medium scale map. Tactical maps do not cover a large area but they include considerable detail of the area mapped. Tactical maps are generally used by commanders of large units, such as a division or corps.

3. Terrain or large scale maps. This is a very detailed map and is used by commanders of small units involved in operations of local character. The terrain map supplies the most exact and complete detail of the limited area.

B. Other types

1. Many types of maps used for different purposes.

   a. Filling station road maps, used by tourists.

   b. Educational maps such as those published by the National Geographic Society.

   c. Engineering maps, used in planning and executing engineering projects, such as roads, canals, etc.

   d. Topographic maps, which show the details of the irregularity of the terrain.

   e. Cadastral maps, which place emphasis upon political and property boundaries.

2. Any of the above maps are used as military maps as the occasion demands.

V. CONVENTIONAL SIGNS AND MILITARY SYMBOLS

A. Importance

Cartographers (map makers) have devised a common set of signs which have definite meanings to map readers. Such signs are called "conventional signs" and are used in the designation of landmarks and other information which flyers find of great value in navigation. Some of these signs look enough like the objects they represent to be easily recognizable. Others require careful study and for this reason it is desirable to consider the subject of conventional signs and symbols briefly. Because of the speed of aircraft it is essential that aviators be thoroughly familiar with signs and symbols, the language of maps.

B. Types of Symbols and Colors Used
(Refer to map in Workbook)

Conventional signs and military symbols are divided into several classes, of which the following are the most important:

1. Water features. Printed in blue on maps and charts. These include streams, lakes, canals, swamps and all other bodies of water.

2. Cultural features. Usually printed in black on maps and charts.
Include such features as towns, cities, roads, railroads, and other works of man.

3. Relief features. Printed in brown on maps and charts. Include mountains, hills, valleys, and other inequalities of land surface.

4. Aeronautical data. Printed in red or blue on maps and charts. Include such data as location of airways, radio stations, radio ranges, airports, beacons, danger zones and other information of interest in air navigation.

5. Vegetation. Printed in green on maps.
Include wooded areas, orchards, and hedges.

6. Military symbols. Usually printed in black on maps and charts; however, in time of war symbols may be printed in red if in territory occupied by enemy and in blue if in territory occupied by allies or friendly nations.
Includes such data as positions of military posts, troop units, gun emplacements, arms of service, size of units, boundaries between units, and other data of military significance only.

C. General Characteristics

1. Size

a. In general, resemble objects which they represent.

b. Symbols vary in size with scale of map.

c. On small scale maps, symbols are reduced to their most elementary form and do not conform to scale. As scale is increased, symbols assume the shape and scaled size of the object represented.

2. Lettering. Generally, styles of lettering are used on maps as follows:

a. Vertical roman indicates civil divisions.

b. Slant roman indicates natural water features.

c. Vertical gothic indicates natural land features.

d. Slant gothic indicates works of man.

GENERAL CONSIDERATION OF MAPS AND CHARTS

1. What are the important differences, to flyers, between maps and charts?

2. Would the term "North Atlantic Pilot Chart" or "North Atlantic Pilot Map" be more correct? NORTH ATLANTIC PILOT CHART.

3. In the following cases, which type of navigation would be the most useful?

   a. Flight over 800 miles of ocean. CELESTIAL NAVIGATION.

   b. Flight in the U. S. at night, distance of 320 miles. RADIO.

   c. Flight from Seattle to Los Angeles, by day. PILOTAGE.

   d. Flight across the U. S. RADIO.

4. Ground speed, 210 m.p.h.; trip, 700 miles. Departure time is 10:00 A.M. When should you arrive at destination? ________. What method of navigation have you used? ________.

5. What is the difficulty with radio navigation in time of war?

   1. LIMITED IN RANGE
   2. MAY BE CUT OFF

6. List the types of features which the pilot would expect to find on the ground as indicated by the following colors on a map.

   a. Black WORKS OF MAN (MILITARY SYMBOLS)

   b. Brown RELIEF

   c. Green VEGETATION

   d. Red ENEMY TERRITORY

   e. Blue ALLIES "

7. Give four situations in which charts are necessary to navigation.

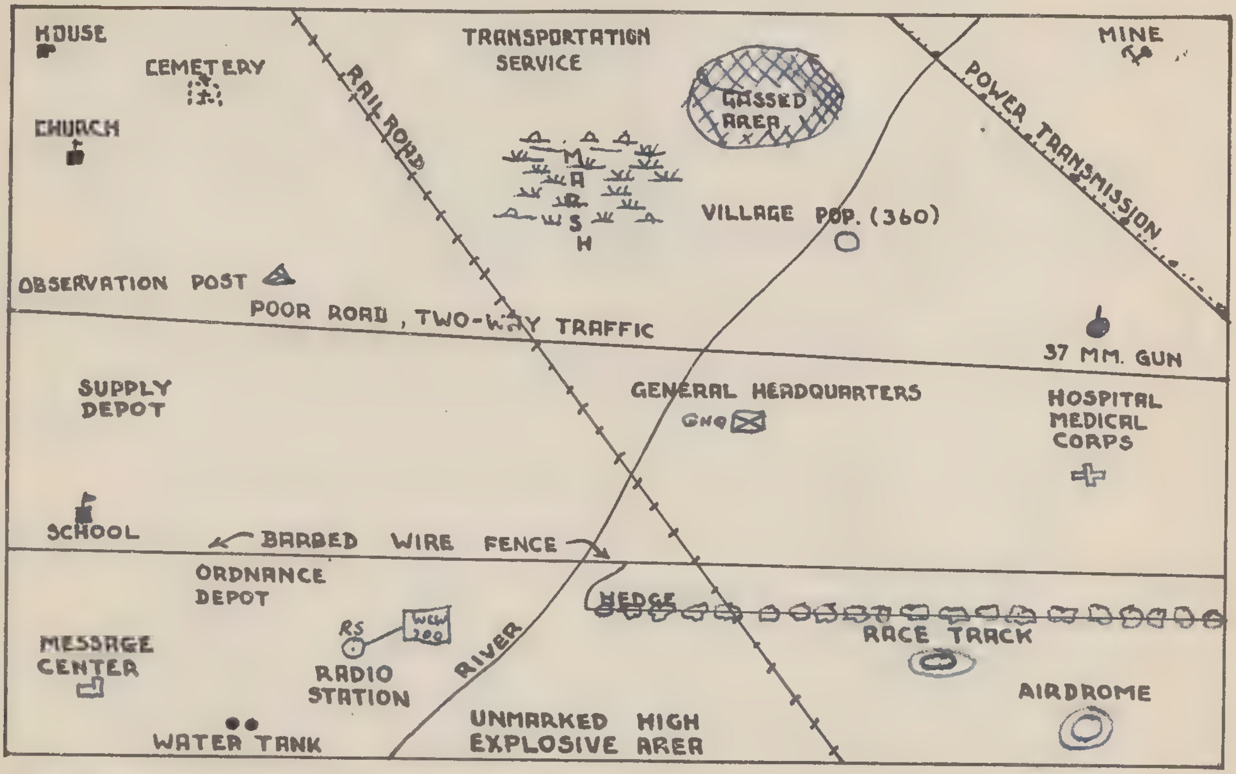
   a. OVER POORLY MAPPED COUNTRY

   b. OVER WATER

   c. POOR VISIBILITY

   d. AT NIGHT

8. Reconstruct the labeled area in the bottom space using appropriate conventional signs and symbols in place of words. (Refer to pages 2-6 for conventional signs and military symbols.)



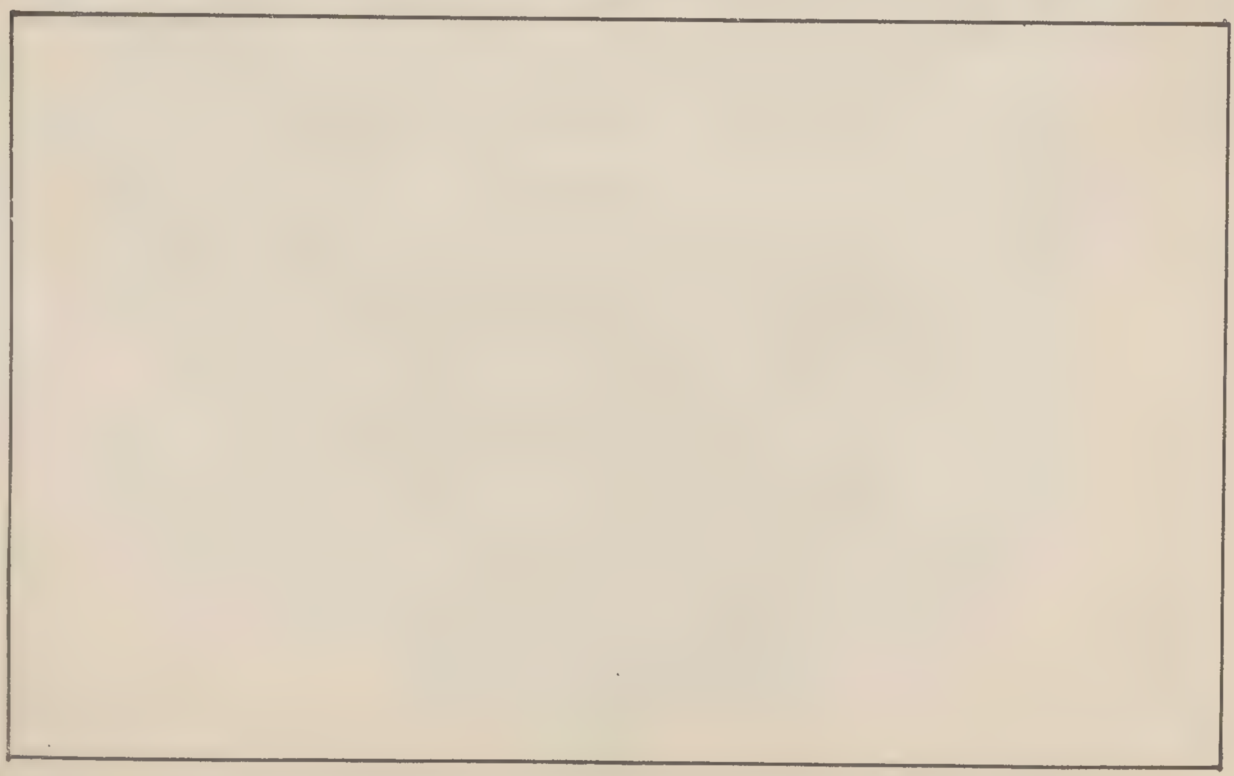
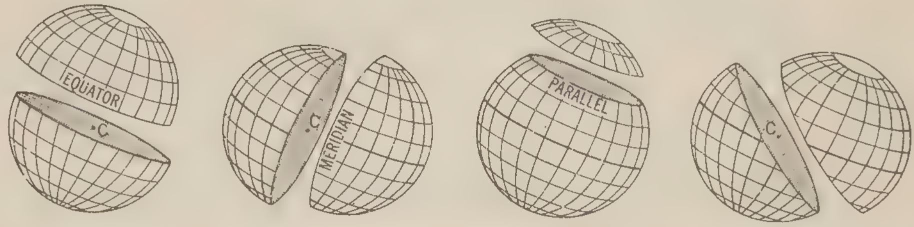


Fig. 1 GLOBE SHOWING MERIDIANS AND PARALLELS



The equator is a great circle.

Any meridian is a great circle.

C = center of the earth

A parallel is NOT a great circle.

Any plane passing through the center of the earth cuts the surface in a great circle.

Fig. 2 CIRCLES ON THE EARTH

Fig. 3 GREAT CIRCLE AND RHUMB LINE

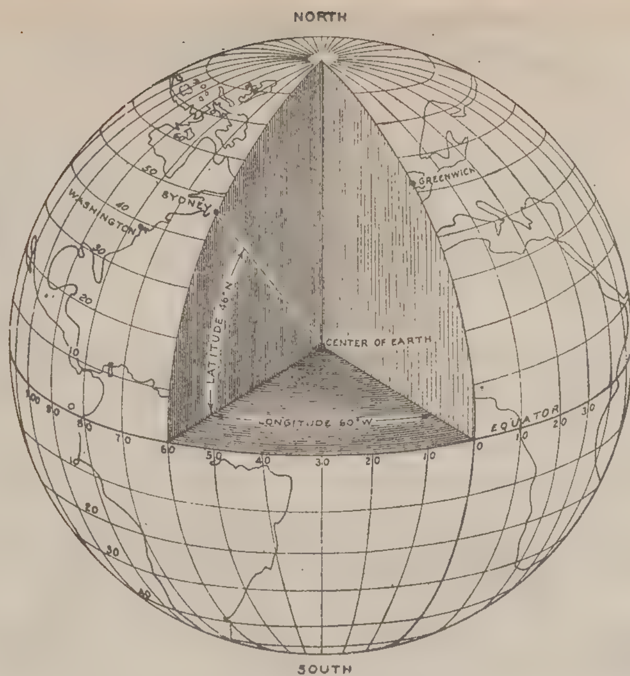


Fig. 4 MEASURING LATITUDE AND LONGITUDE

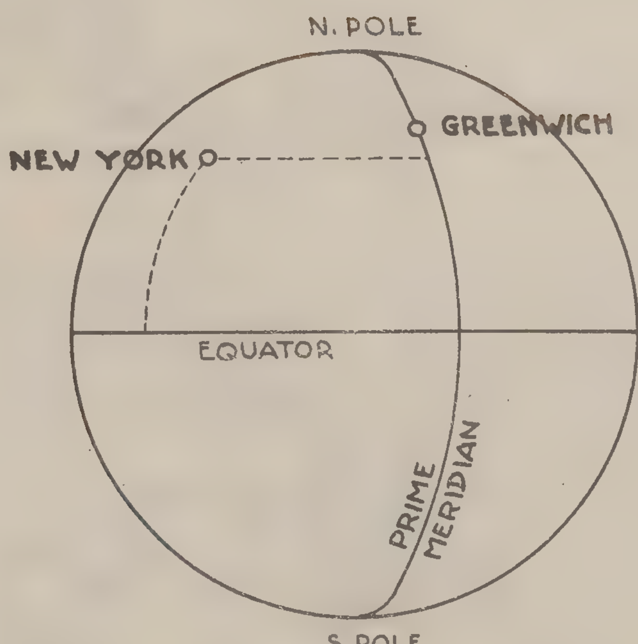


FIG. 5 LOCATION OF POINTS
USING GEOGRAPHIC COORDINATES

FIG. 6 MAP OF THE WORLD SHOWING THE RELATIONSHIP OF PARALLELS AND MERIDIANS

LATITUDE AND LONGITUDE

I. MAP MAKING (Refer to Fig. 1)

A. The fundamental problem which confronts the cartographer is one involving the process of transferring a portion or all of the surface of a sphere to a plane surface.

1. A globe atlas is the most accurate known type of representation of the shapes on the earth's surface.

2. It is not practical in most cases to transport and use a globe atlas for all purposes for which a map is needed.

3. A map on a sheet of paper, which may be folded or rolled, is generally regarded as being the most usable type of map.

4. As will be explained later in the course, the surface of a sphere cannot be removed and flattened into a plane surface without stretching or distortion.

5. All maps used at the present time, except globe atlases, are approximations of the surface of the earth.

B. In order to provide a permanent system of reference, meridians of longitude and parallels of latitude have been devised.

II. TERMINOLOGY

Before the discussion of latitude and longitude in detail, it is desirable to consider certain terms which are directly concerned with the subject.

A. <u>Sphere</u>

A sphere is a body bounded by a surface all points of which are equidistant from a point called the "center". For the purposes of navigation the earth is usually considered to be a sphere. Actually it is a spheroid whose polar diameter is 7,899.7 and whose equatorial diameter is 7,926.5 statute miles. Obviously, the earth's deviation from the sphere is slight.

B. <u>Geographic Poles</u> (Refer to Fig. 1)

It is one of the qualities of a sphere that any point on its surface is just like any other. The earth, however, has two points that are different from all others. These are the points at which the axis, around which the earth rotates, intersects the surface of the earth. These points are called the north and south geographic poles.

C. Equator

With the north and south poles as starting points, the earth is conceived to be divided into two equal parts, or hemispheres, by a plane perpendicular to the axis of the earth at its center. The circle formed by the intersection of this plane and the surface of the earth is the Equator.

D. Great Circle (Refer to Figs. 1 and 2)

A great circle is one formed by the intersection of the earth's surface by a plane passing through the center of the earth. The great circle equidistant from the two poles is called the Equator. A great circle can be made to pass through any two points on the earth's surface. The shorter arc of a great circle through two points represents the shortest distance between the two points. In flying long distances it is desirable to use the great circle route. This fact becomes important in choosing the type of projection to be used in plotting courses to be flown as will be explained in a later lecture.

E. Small Circle

A small circle is a circle on the earth's surface the plane of which does not pass through the center of the earth.
An example of a small circle would be any parallel of latitude other than the equator.

F. Meridians (Refer to Fig. 1)

Meridians are lines representing great circles the planes of which intersect both the north and south geographic poles.

G. Parallels (Refer to Fig. 1)

Small circles the planes of which are parallel to the equator are called "Parallels of Latitude".

H. Rhumb Lines (Refer to Fig. 3)

A rhumb line is one which crosses all meridians at the same angle. Any two points on the earth's surface may be connected by a rhumb line. The rhumb line drawn on a sphere is known as a loxodromic curve. According to the foregoing definition, the Equator and the parallels are rhumb lines, but the Equator being also a great circle is usually not considered as a rhumb line. The parallels are a special type of rhumb line since they intersect every meridian at 90°. All other rhumb lines are curves which approach but never reach the poles. The path of an airplane maintaining a constant course is a rhumb line.

I. Prime Meridian (Refer to Figs. 5 and 6)

To furnish a starting point from which meridians could be numbered, the meridian passing through Greenwich, England, was arbitrarily chosen as the zero meridian. This is called the "prime meridian".

J. Degree

If the earth's circumference is divided into 360 equal parts, each part will equal one degree, written 1°.

K. Minute

If a degree is divided into 60 equal parts, each part will equal one minute, written 1'.

L. Second

If a minute is divided into 60 equal parts, each part will equal one second, written 1".

III. GEOGRAPHIC COORDINATES

A. On globes, parallels of latitude form equally spaced lines extending east and west, while meridians of longitude form equally spaced lines extending north and south.

B. Parallels and meridians intersect each other at 90° angles and their points of intersection form a network of reference points from which unknown points may be located. This system of equally spaced crossed lines is called the "Earth Grid" and provides a system of reference whereby any point on the earth can be located and designated as being so many degrees, minutes, and seconds north or south of the Equator, and so many degrees, minutes, and seconds east or west of the prime meridian.

C. When the latitude and longitude of a point are given they are called the geographic coordinates of that point. In giving coordinates, latitude is always named first.

IV. LATITUDE AND LONGITUDE

A. Latitude (Refer to Fig. 5)

1. Definition

Latitude is the angular distance north and south of the Equator, as subtended at the center of the earth and measured from the Equator as a plane of origin.

2. Measurement

Latitude is measured in degrees, minutes, and seconds of arc and may have any value from 0° at the Equator to 90° north or south, which would indicate the north or south pole.

3. Distance

The smallest conventional unit of measurement of distance for latitude is one second. Longer distances are measured in terms of degrees and minutes. For example, parallels of latitude are usually indicated on a globe atlas every 15°.

4. Use

Parallels of latitude are used not only as points of refer-

4. Use

ence for map projections but also to determine distance north or south of the Equator.

B. Longitude (Refer to Fig. 5)

1. Definition

Longitude is the angular distance, as subtended at the center of the earth, between the plane of a meridian and the plane of the prime meridian at Greenwich, England, measured eastward or westward.

2. Measurement

Longitude is measured in degrees, minutes, and seconds of arc, and may have any value from 0° at Greenwich, England, just outside of London, to 180° east or west.

3. Distance

The smallest conventional unit of measurement of distance for longitude is one second. Longer distances are measured in terms of degrees and minutes. For example, meridians are usually inserted on a globe atlas every 15°.

4. Use

Meridians are used in navigation to determine the distance of a given point east or west of the prime meridian.

C. Measurement by latitude and longitude

1. Latitude and the nautical mile

a. The angular distance between the Equator and the north or south pole is 90° or 5400 minutes.

b. If the actual length of a minute of latitude is used as a unit of linear measurememt, there will be 5400 of these units as the distance between the Equator and one of the Geographic Poles. This unit of measurement is called the "nautical mile" and is 6080 feet in length. It is also equal to 1 minute of arc of any great circle.

c. This relationship between one nautical mile and one minute of latitude makes the former a very convenient unit for measurement in navigation and has led to its adoption as a standard unit of measurement in marine navigation and for work on the mercator chart.

d. Speed measured in nautical miles per hour is referred to as "knots", the per hour being understood, but not written out. One knot, therefore, is one nautical mile per hour. The term is used in navigation of seaplanes and military aircraft.

2. <u>Longitude and the nautical mile</u>

a. Meridians of longitude converge as they are traced from the Equator to the poles. Therefore, the linear distance between meridians decreases proportionately as they leave the Equator and approach the Poles, although the number of degrees or angular measurement remains the same. Thus, one minute of longitude equals one nautical mile only at the Equator.

b. Location of points between meridians on a chart is determined by one of two methods:

(1) <u>Graphic Calculation (Estimation)</u>

This method involves the judgment of the angular distance from one meridian to the given point, which gives an approximate location of the point.

(2) <u>Calculation</u>

This method involves the use of trigonometric functions in the determination of the exact location of the given point.

3. <u>Nautical and Statute miles</u>

a. The statute mile, which was chosen arbitrarily, equals 5280 feet, while the nautical mile equals 6080 feet. The nautical mile is longer than the statute mile, the ratio being 115 to 100

b. <u>Conversion</u>

(1) Statute miles are converted to nautical miles by the following formula:

$$\frac{\text{Statute miles}}{1.15} = \text{Nautical miles}$$

(2) Nautical miles are converted to statute miles by the following formula:

$$\text{Nautical miles} \times 1.15 = \text{Statute miles}$$

c. Illustrative problems

(1) Point x is at 90° E. Longitude. Point y is at 45° W. Longitude. Both are on the equator. What is the distance between these two points in statute miles?

<u>Solution</u>:

Add longitude to obtain difference

90° E. Longitude
+ 45° W. Longitude
135° Difference in Longitude

1' of arc of any great circle = 1 nautical mile, therefore, multiply 135° by 60 to obtain the number of nautical miles. (135 x 60 = 8100 nautical miles). Nautical miles x 1.15 gives statute miles, therefore, 8100 x 1.15 = 9135 statute miles.

(2) The geographic coordinates of two points are
A = 70° S. Latitude B = 7° S. Latitude
34° E. Longitude 34° E. Longitude
Express the distance between these two points as nautical miles and as statute miles.

Solution:

70° S. Latitude
$-\ 7^\circ$ S. Latitude
63° = Difference in latitude.

63 x 60 = 3780 nautical miles
3780 x 1.15 = 4347 statute miles

V. SUMMARY

LATITUDE AND LONGITUDE

1. What is the angular distance, in minutes, between the equator and the north pole? 5400'.

2. In flying directly toward the north or south pole, what is the relationship between nautical miles and minutes of latitude? 1' = 1 nautical mile.

3. At a position of 86°N. 170°E. what is the distance from the equator expressed in nautical miles? 86 x 60 = 2760 naut. mi.
In statute miles? 1.15 x 2760 = 3174.

4. Point A = 34°N. 118°W. Point B = 39°N. 118°W. Find the distance between these two points in nautical and statute miles.
39° - 34° = 5° = 300 nautical mi. 300 x 1.15 = 345.00 s. mi.

5. How many feet are there in one nautical mile? 6080.

6. How many statute miles are there in 1251 nautical miles? 1438.65 s. mi.

7. Express 681 statute miles in terms of nautical miles. 592.173.

8. Where does one minute of longitude equal one nautical mile? Equator.

9. Points A & B (both on the equator) are 1092.5 statute miles apart. How many nautical miles separate these two points? 949.6 naut. mi.
How many degrees of longitude separate these points? 15°18'.

10. Given two points with longitude readings of 15°W. and 72°E. Is the longitude interval determined by adding or subtracting? Adding.

11. Point A = 1173 statute miles east of Greenwich. Point B is 3480 nautical miles west of Greenwich. Both points are at 0° Latitude. What is the distance between these points in nautical miles? 4500.51. In statute miles? 5175. What are the coordinates of these two points? A=________. B=________.

1.15) 681.00 = 592.173

1173 x .87 = 1020.51; + 3480 = 4500.51

3480 x 1.15 = 4002.00; + 1173 = 5175

2760 x 1.15 = 3174.00

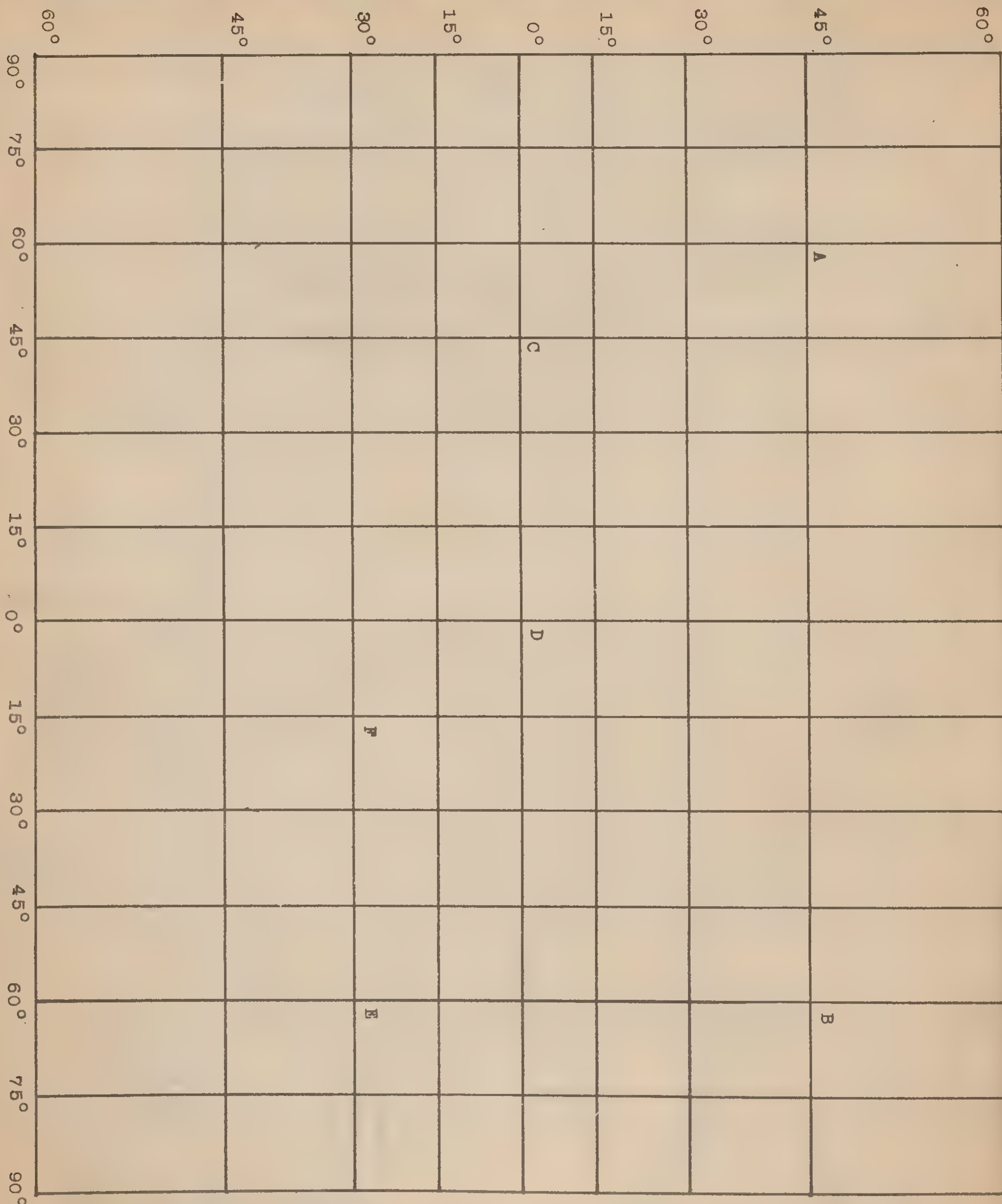
1251 x 1.15 = 1438.65

60) 949.60 = 15.827

1.15) 1092.000 = 949.5

75/115 = 15/23

3/10 x 60/1 = 18'



Give the geographical coordinates of the points listed below:

A 45° N LAT 60° W LONG B 60° N LAT. 60 E LONG C 0° LAT. 45° N. LONG

D 0° LAT. 0 LONG. E 30° S LAT. 60 E LONG F 30° S LAT. 15° E.

Give the statute miles and nautical miles between:

C and D: Statute miles__________; nautical miles__________

B and E: Statute miles__________; nautical miles__________

Fig. 7 COVERING FOR A GLOBE AS IT APPEARS ON A PLANE

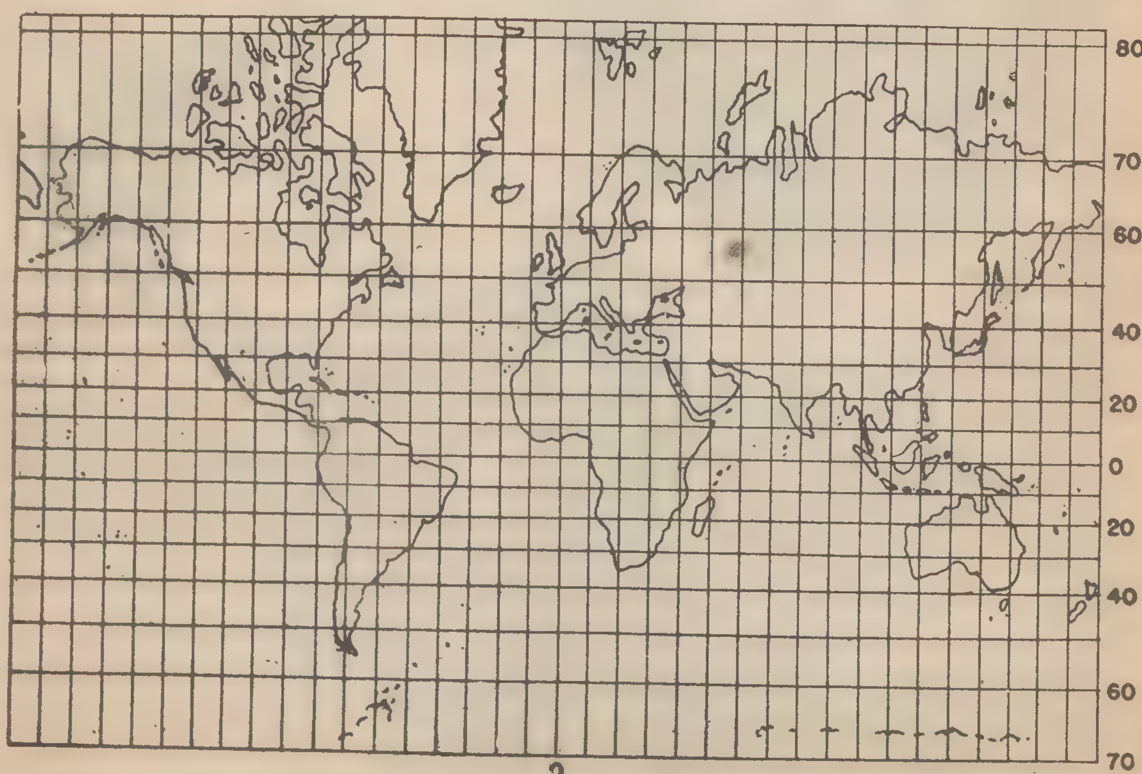


Fig. 8 WORLD ON A MERCATOR PROJECTION

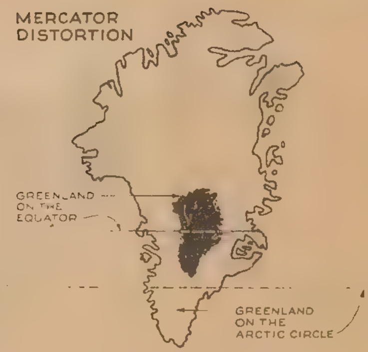


Fig. 10 GREENLAND AS IT APPEARS ON THE EQUATOR AND IN THE ARCTIC REGION ON A MERCATOR PROJECTION

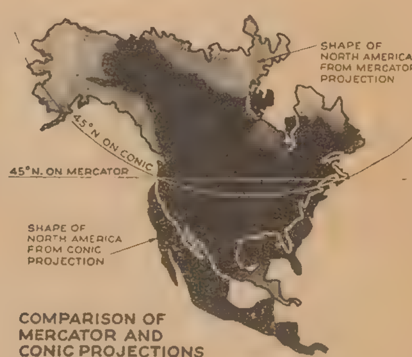


Fig. 11 NORTH AMERICAN CONTINENT ON MERCATOR AND CONIC PROJECTIONS

'ig. 9 GLOBE ENCLOSED IN A CYLINDER

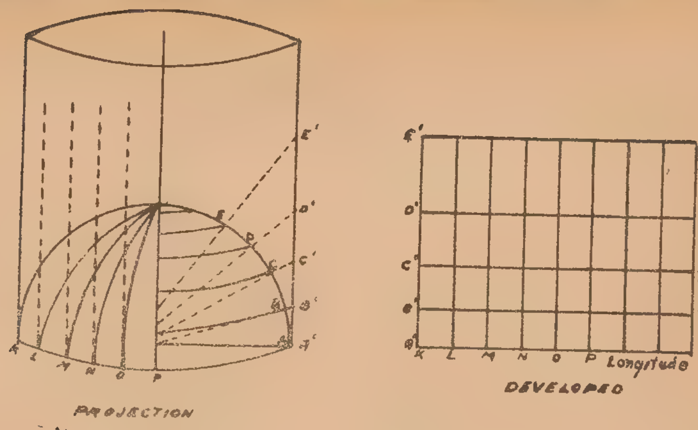


Fig. 12 THEORY OF MERCATOR PROJECTION

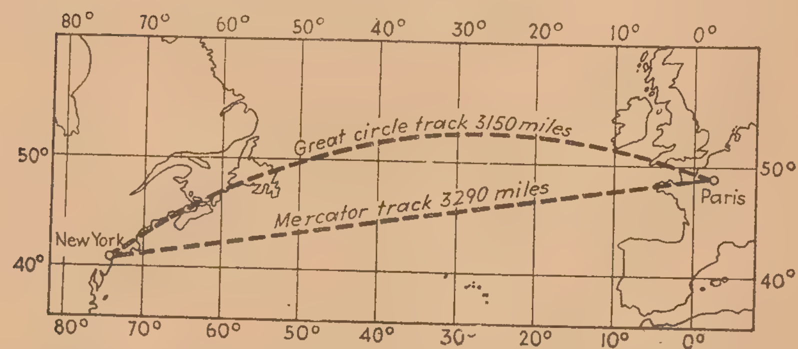


Fig. 13 GREAT CIRCLE AND RHUMB LINE ON MERCATOR CHART

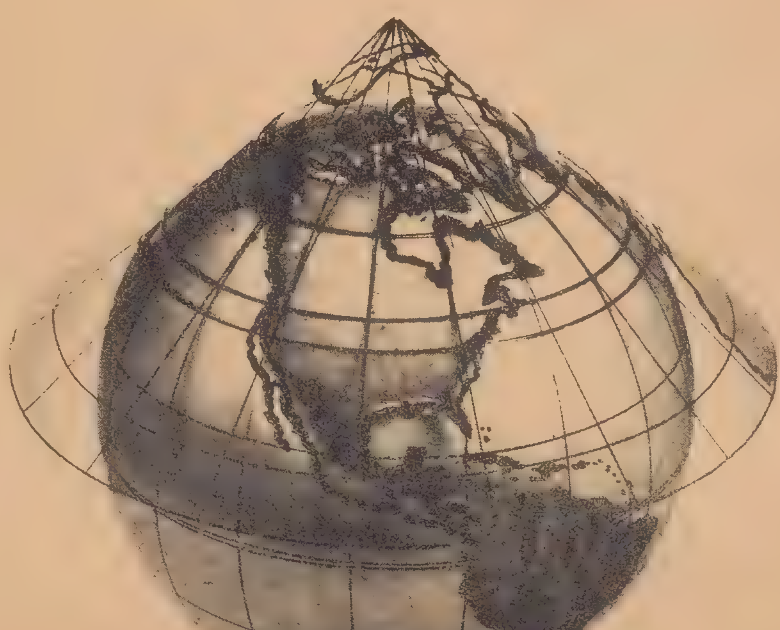


Fig. 14 CONE APPLIED ON A GLOBE

Good East - West chart.

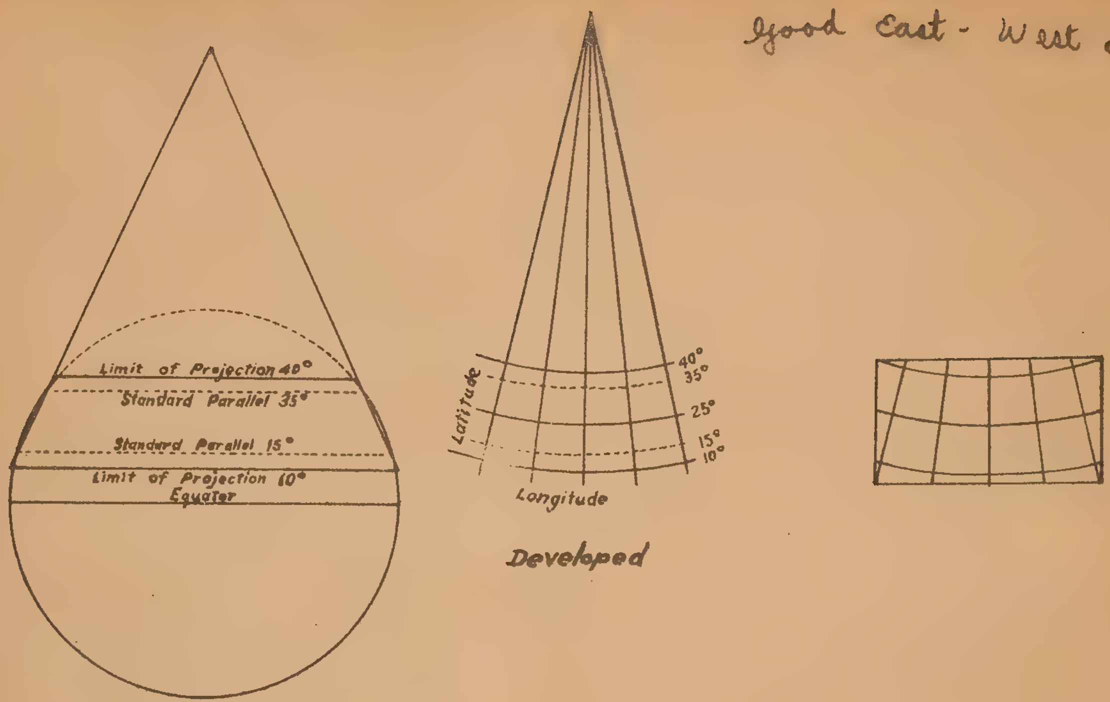


Fig. 15 THEORY OF LAMBERT PROJECTION

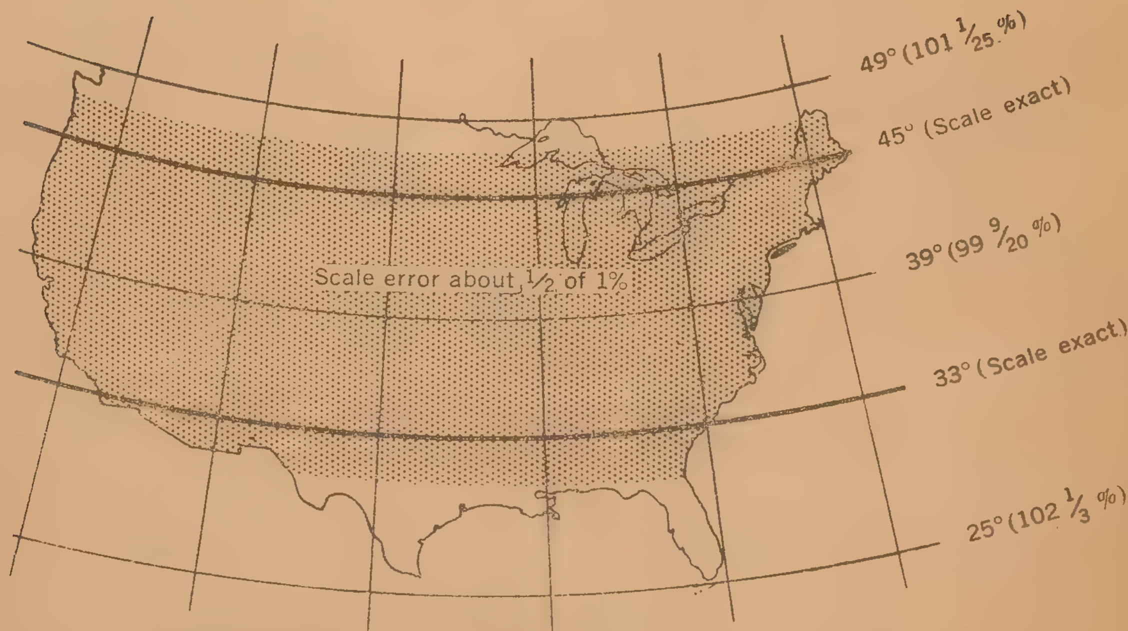


Fig. 16 UNITED STATES ON LAMBERT PROJECTION

MAP PROJECTIONS: MERCATOR AND LAMBERT PROJECTIONS

I. PROJECTIONS

A. General Considerations

1. Necessary to transfer reference system from the surface of a sphere to the plane surface on which the map is to be constructed.

.. Definition

A map projection is a systematic drawing of lines representing meridians of longitude, parallels of latitude, and the shape of the land and water bodies on a plane surface, either for the whole earth or some portion of it.

B. Distortion

Axiomatic that surface of a sphere cannot be unrolled or developed to lie flat on a plane surface without some stretching or distortion. (Refer to Fig. 7). A sphere is therefore called a "non-developable" surface.

e.g. Orange peel
Anyone who has tried to flatten out an orange peel has found that it was necessary to tear the edges or stretch it.

1. Properties of projections

There are certain properties that are obtainable in projections which are desirable. The following things should be observed therefore in making projections:

a. Areas should be kept in true proportion as on the globe.

b. Scale should be kept constant for measuring distances.

c. Shapes of physical features should not be altered.

d. Great circles should appear as straight lines.

e. Rhumb lines should appear as straight lines.

f. Ease in plotting.

Only one map possesses all of these desirable features. That is the globe itself, and in common usage the globe map is impracticable, hence the need for projections. It is necessary therefore, to consider what purpose the map is to serve, and to select the projection that affords the necessary properties. One projection alone cannot give every desirable feature.

2. Problems involved in distortion

a. Assumed that distortion will always be present. No map maker has designed a projection which will show the entire earth's surface accurately on a single map.

b. Necessary to determine amount of distortion to be permitted, considering the purpose for which the map is to be used.

c. Two fundamental properties subject to distortion:

(1) Size
(2) Shape
} The navigator may regard these as distance and direction

3. Equal-area projection

a. Preserves relation between areas on the map and areas on the ground.
e.g. A square inch on any portion of the map will cover the same proportionate ground area.

b. Divisions on the ground as represented on the map may have shapes changed but area will still bear same relationship.

c. Disadvantages of varying scale throughout projection. Because the areas are maintained in constant ratio, whenever one dimension of an area is diminished, the other dimension must be increased enough to maintain the ratio of the areas.

4. Conformal projection

a. Has the same scale in all directions at any point, but scale varies from point to point.

b. Small areas represented in their true shape; continents' shapes will not be preserved.

c. Angles at any point are represented by their proper value. Meridians and parallels intersect at right angles.

C. Functions of Map Projections

Because it is impossible to make a projection on a plane compare in all respects with the spherical surface of the earth, it is necessary to decide on one of three plans:

1. To keep areas on map directly comparable to areas on ground for entire map at expense of correct shape (equal-area projection).

2. To keep shape of smaller geographical features correct at expense of a changing scale all over map, knowing that large areas will not preserve their shape.

3. To compromise between these conditions so as to minimize errors both as to shape and area, or direction and distance respectively.

D. Types of Map Projections

Although there are many types of map projections, the four which are most commonly used are as follows:

1. Mercator
2. Lambert Conformal Conic
3. Gnomonic
4. Polyconic

II. MERCATOR PROJECTION

A. History

Given the Latin surname (Mercator) of its inventor, Gerhard Kramer, cartographer, born in Flanders in 1512. His system originally published in 1569, and 30 years later the present methods of construction and computation had been developed.

B. Definition

The Mercator projection is a conformal projection upon a cylinder tangent to the earth at the equator. (Refer to Figs. 9 and 12.)

C. Description (Refer to Fig. 8)

1. It is a conformal projection upon a cylinder tangent to the earth at the equator.

2. When cylinder is rolled out into a plane, the equator is a straight line.

3. Meridians are represented by straight lines perpendicular to the equator. These are equally spaced depending upon their actual distances at the equator.

4. Parallels of latitude represented by a system of lines parallel to the equator.

5. Spacing of parallels to keep the projection "conformal" is arranged so that the scale along meridians will be equal to the scale along the parallels at any point.

6. The spacing between the parallels is determined by computation, but tables are available to give all the requisite data.

7. Meridian exaggeration

At equator, there are 60 nautical miles between each degree of longitude; at poles, distance would be 0. On Mercator projection meridians are shown 60 nautical miles apart from equator to poles.

8. Latitude Exaggeration

At latitude 60°, the meridians are twice as far apart as they should be. To correct this, the scale of the parallel of latitude would also be doubled in order to make it conformable. Due to distortion, use is generally limited to areas between 60°N and 60°S Latitude.

9. Results of Exaggeration

a. Affects size of areas. (See Figs. 10, 11)

b. At 60° latitude, makes the scales equal to increase of area four-fold.

c. At 80° latitude, areas are increased to 36 times their actual size.

d. Gives erroneous idea as to relative sizes of continents because such areas as Greenland appear to be larger than South America, whereas South America is 9 times larger than Greenland.

e. Shapes of small areas will not be distorted; but shapes of large areas are distorted because of varying scale.

D. Uses

1. Mercator projection designed to be used in navigation. Long flights over oceans have increased the use of and importance to aviation of the Mercator charts.

2. Value of projection realized by world-wide use. Of 15,000 nautical charts published by various countries, not more than 1% are noticeably different from Mercator Charts.

3. Airway strip maps issued by the hydrographic office are on the Mercator Projection.

E. Advantages and Disadvantages

1. Advantages

a. Rhumb line is shown as a straight line. (Refer to Fig. 13).

b. Meridians are straight and parallel. Positions plotted easily.

c. Course line may be plotted directly or easily transferred without error.

d. All charts are similar, and if of same scale will join exactly.

e. Areas within any narrow latitude belt are represented by true shapes.

f. Projection is readily constructed.

2. Disadvantages

a. Distortion: physical features out of proportion, bad if latitudes above 60°.

b. Scale not constant, varies with latitude.

c. Great circles not straight lines. (Refer to Fig. 13).

III. LAMBERT CONFORMAL PROJECTION

A. History

1. Devised by Johann Lambert and first came to notice in 1772.

2. Little used until French chose it for their military maps.

3. Merits not fully appreciated until the beginning of World War I, when it was adopted by Allies.

B. Definition

A projection which is based on a right circular cone which has its apex on the axis of the earth produced and which cuts the earth on two parallels of latitude known as the upper and lower standard parallels.

C. Description (Refer to Figs. 14, 15).

1. Standard parallels are chosen to give minimum distortion for area to be mapped. (Refer to Fig. 16).

Between the standard parallels the earth is projected inward upon the cone, and thus the scale on the cone is somewhat smaller than the scales on the larger earth. Outside the parallels the earth's surface is projected outward, and the scale on the cone is slightly larger than that of the earth.

The standard parallels of true scale adopted for all aeronautical charts of the United States are latitude 33° and 45° N. For aeronautical charts of Alaska, the standard parallels are latitudes 55° and 65° N. (Actually any two parallels may be used as standard parallels.)

2. Not a true geometric projection; that is, the system of meridians and parallels is not transferred from thesphere to the secant cone by geometric methods.

3. Positions of meridians and parallels are determined by computation in order that the projection may be conformal. It is to be noted that the standard parallels are represented to exact scale.

4. Meridians are represented as straight lines converging to a common point beyond limits of map.

5. Parallels are concentric circles the center of which is at the point of intersection of the meridians. Interval between parallels is computed from formulas to make the projection conformal.

6. Meridians and parallels intersect at right angles on the projection as they do on the earth's surface. Angles formed by any two intersecting lines on the earth's surface are correctly represented on the projection.

D. Uses

1. Best suited for areas having a predominating east-west dimension.

2. For maps on which it is desirable that the great circle be practically a straight line.
   e.g. Great circle from Cape Hatteras to English Channel (3,200 nautical miles) departs only 15.6 nautical miles from a straight line. Error in this case less than 0.4%. This is an example of the extreme distance accurately afforded by this projection.

3. On maps on which distances must be measured accurately.

4. Department of Commerce airway maps both in strip and sheet form are on Lambert conformal conic projection using 33° and 45° as standard parallels. Scale errors are very slight, varying approximately .5% between these latitudes.

E. Advantages and Disadvantages

1. Advantages

   a. One scale suffices for entire map. The scale error of any single chart is so small that distance may be measured as if the scale of the chart were constant.

   b. Distortion through projection is very slight.

   c. A straight line approximates a great circle. Although this is only an approximation, for all practical purposes a straight line on a Lambert chart may be regarded as the shortest distance between two points.

   d. Its directions conform very closely to directions on the earth.

   e. It affords a simple and satisfactory solution for all problems of dead reckoning, not excepting the rhumb line.

   f. It is unsurpassed for all types of radio navigation.

   g. It is well suited to problems requiring the plotting of positions and for celestial navigation.

   h. It provides the best possible chart for pilotage.

i. Permits junction of adjacent charts in any direction without error (for all practical purposes).

2. Disadvantages

a. Plane flying a rhumb line will not fly over points through which line on map drawn from point of departure to destination on map would indicate.

b. Course line on chart makes different angle with every meridian.

c. Because of curvature of the parallels and the convergence of the meridians, positions are plotted less easily by latitude and longitude.

IV. SUMMARY

GRAPHIC CONSTRUCTION OF MERCATOR PROJECTION

1. General

The graphical construction of a mercator chart is based on the assumption that the earth is a true sphere, in which case the meridians are true circles. While this assumption is not true, the resulting error for a small area is negligible.

2. Problem

Required a small area mercator chart from latitude 40°N, to 43°N, and from longitude 75°W. to 78°W., on a scale of 1 inch to 1° of longitude.

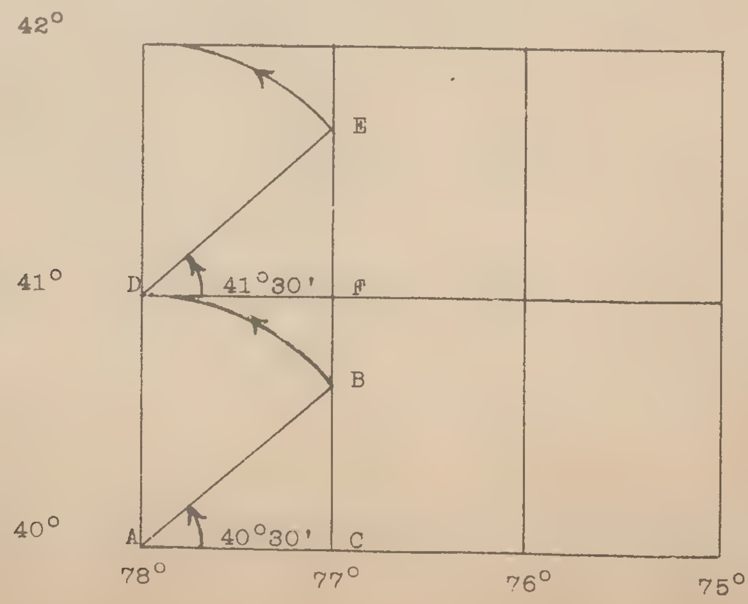
3. Solution

a. Draw a straight line 3 inches in length parallel to the lower edge of sheet. This will represent the base parallel of latitude 40° N. From the ends of this line and at 1 inch intervals along it carefully erect perpendicular lines, which from right to left will be the meridians 75° W., 76° W., 77° W., and 78° W.

b. Lay off a line A B so that the angle BAC equals the mean latitude between the parallel 40° and 41°, or 40° 30'.

c. Measuring upward along the meridians from the base parallel 40°, lay off the distance AD equal to AB, and through these points draw the latitude 41°.

d. In the same manner, determine the parallel 42° by laying off the line DE so that angle DEF equals 41° 30', and the parallel 43° by laying off the line so that the angle equals 42° 30'.



1. Procedure

If the chart for which the projection is to be made includes the Equator, the values to be measured off are given directly by the tables of meridional parts. If the Equator is not to be shown on the chart, then the parallels of latitude to be laid down should be referred to a principal parallel, preferably the lowest parallel to be drawn on the chart. The distance of any other parallel of latitude from the principal parallel is then the difference of the meridional parts for the two taken from the table and reduced to the scale of the chart.

2. Problem

Let it be required to construct a mercator chart between the parallels of latitude 32°00' N. and 35°00' N. and between longitudes 116° W. and 120° W., on a scale of 1° longitude equals 2 inches. Integral degrees of latitude and longitude are to be shown.

3. Solution

a. Draw a straight line 8 inches in length parallel to the lower edge of the sheet. This line will represent the principal parallel of latitude 32°00' N.

b. At intervals of 2 inches along the principal parallel erect perpendiculars. These lines from right to left will be the meridians 116° W., 117° W., 118° W., 119° W., and 120° W.

c. Since the scale of the chart is 1° of longitude equals 2 inches, the unit of measurement (one meridional part) will be 1/60 x 2 = 1/30 inch.

d. From the tables of meridional parts find for latitude 32° the value 2016 and for latitude 33° the value 2087. The difference is shown between the two numbers, namely 71, the number of meridional parts between the parallels 32° and 33°. Then the distance on the chart between these parallels will be 1/30 x 71 = 2.36 inches.

e. On two of the meridians already constructed lay off the distance 2.36 inches, and through the points thus obtained draw a straight line which will be parallel 33°00'.

f. Proceed in the same manner to lay down all of the parallels.

g. The whole degrees of latitude and longitude may be subdivided as minutely as required.

Lat. *L*	Meridional parts *M*		Length of 1° of Long.	Length of 1° of Lat.	Lat. *L*	Meridional parts *M*		Length of 1° of Long.	Length of 1° of Lat.
0°	0	60	60.1	59.7	40°	2608	78	46.1	59.9
1	60	59	60.1	59.7	41	2686	80	45.4	59.9
2	119	60	60.0	59.7	42	2766	81	44.7	59.9
3	179	60	60.0	59.7	43	2847	83	44.0	59.9
4	239	59	59.9	59.7	44	2930	83	43.3	60.0
5	298	60	59.8	59.7	45	3013	86	42.5	60.0
6	358	60	59.7	59.7	46	3099	87	41.8	60.0
7	418	60	59.6	59.7	47	3186	88	41.0	60.0
8	478	61	59.5	59.7	48	3274	90	40.3	60.0
9	539	60	59.3	59.7	49	3364	93	39.5	60.0
10	599	61	59.2	59.7	50	3457	94	38.7	60.0
11	660	61	59.0	59.7	51	3551	96	37.9	60.0
12	721	61	58.8	59.7	52	3647	98	37.1	60.0
13	782	61	58.5	59.7	53	3745	101	36.2	60.1
14	843	61	58.3	59.7	54	3846	103	35.4	60.1
15	904	62	58.0	59.7	55	3949	106	34.5	60.1
16	966	63	57.8	59.7	56	4055	108	33.7	60.1
17	1029	62	57.5	59.7	57	4163	111	32.8	60.1
18	1091	63	57.1	59.7	58	4274	115	31.9	60.1
19	1154	63	56.8	59.7	59	4389	118	31.0	60.1
20	1217	64	56.5	59.7	60	4507	122	30.1	60.1
21	1281	64	56.1	59.7	61	4629	125	29.2	60.1
22	1345	65	55.7	59.7	62	4754	130	28.3	60.1
23	1410	65	55.3	59.8	63	4884	134	27.3	60.1
24	1475	65	54.9	59.8	64	5018	140	26.4	60.2
25	1540	66	54.5	59.8	65	5158	144	25.5	60.2
26	1606	67	54.0	59.8	66	5302	150	24.5	60.2
27	1673	67	53.6	59.8	67	5452	157	23.5	60.2
28	1740	68	53.1	59.8	68	5609	164	22.6	60.2
29	1808	69	52.6	59.8	69	5773	171	21.6	60.2
30	1877	69	52.1	59.8	70	5944	180	20.6	60.2
31	1946	70	51.5	59.8	71	6124	189	19.6	60.2
32	2016	71	51.0	59.8	72	6313	199	18.6	60.2
33	2087	71	50.4	59.8	73	6512	211	17.6	60.2
34	2158	73	49.9	59.9	74	6723	225	15.6	60.2
35	2231	73	49.3	59.9	75	6948	239	15.6	60.2
36	2304	75	48.7	59.9	76	7187	257	14.6	60.2
37	2379	75	48.0	59.9	77	7444	278	13.6	60.2
38	2454	76	47.4	59.9	78	7722	301	12.5	60.2
39	2530	78	46.7	59.9	79	8023	329	11.5	60.3
40	2608		46.1	59.9	80	8352		10.5	60.3

TABLE OF MERIDIONAL PARTS

MAP PROJECTIONS (MERCATOR AND LAMBERT)

1. Under what conditions would a pilot prefer to fly a rhumb line rather than a great circle route?
   1. If he has to navigate for himself
   2. Poor visibility

2. What type of projection would you choose if you wish a rhumb line to appear as a straight line? Mercator.

3. If you were flying from Washington, D.C. to Los Angeles, which type of projection would you probably use? LAMBERT CONFORMAL Why? GOOD FOR ALL TYPES OF NAVIGATION - CONSTANT SCALE GREAT CIRCLE = APP. ST. LINE.

4. In flying over oceans, what type of projection is usually used? MERCATOR.

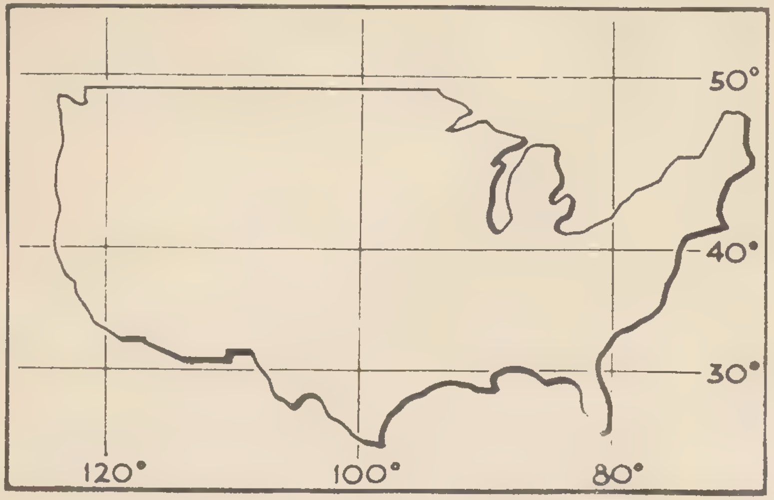
5. On what type of projection are geographic coordinates (latitude and longitude) most easily plotted? MERCATOR.

6. On Lambert projections do great circles appear as absolutely straight lines? No, ONLY APPROX..

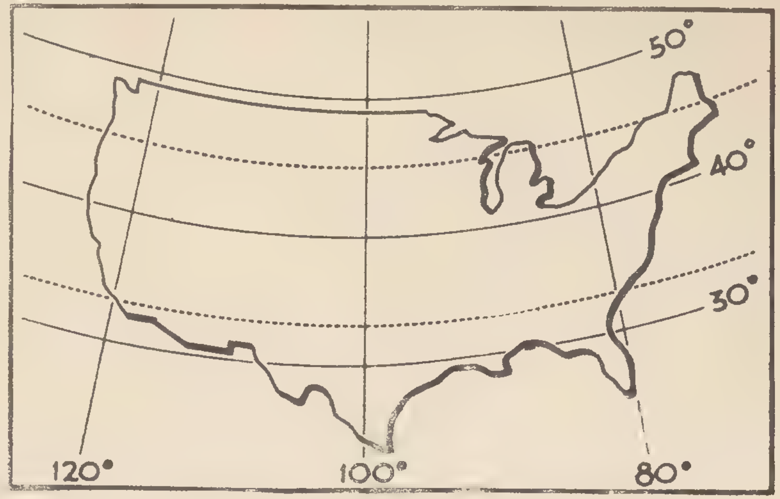
7. Explain principle involved in constructing Lambert projections.
   Earth is projected inward upon a cone which cuts the earth a two selected parallels and outward above the standard parallels.

8. Using the Mercator projection, construct a map covering the area between 30°00' and 33°00' north latitude and 105°00' and 108°00' west longitude. Use a scale of 1 inch to 1° of arc at the Equator. This projection is to be constructed graphically. Show by a dashed line how a rhumb line would appear between 30°00' N. Lat. - 108°00' W. Long. and 32°00' N. Lat. - 105°00' W. Long. Put projection on following page.

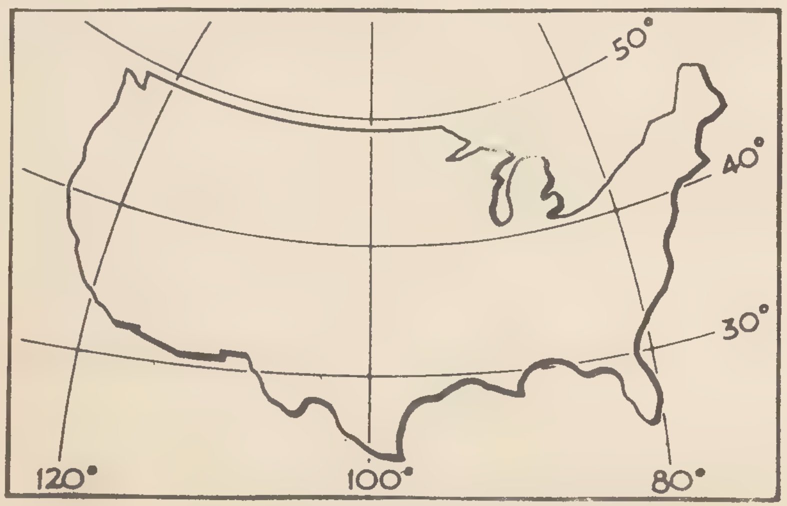
9. Using meridional parts table, construct a Mercator projection covering the area between 40°00' and 43°00' north latitude, and 105°00' and 108°00' west longitude. Use a scale of 1 inch to 1° of arc at the equator. Put projection on following page.



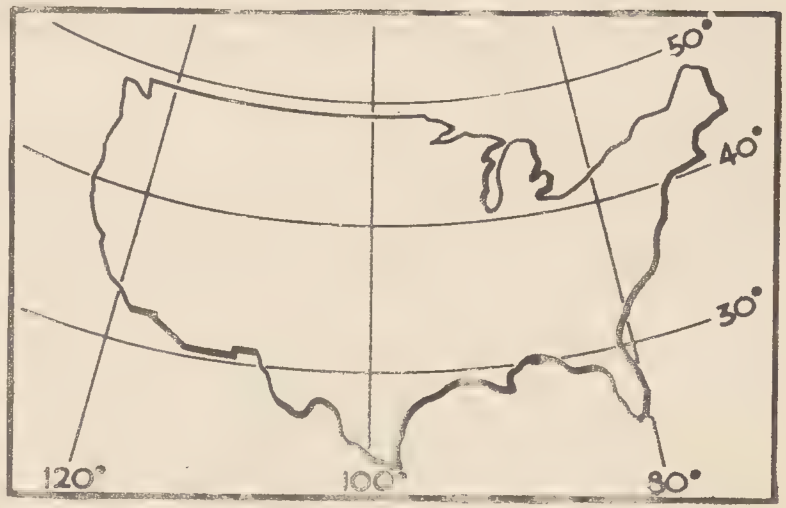
U. S. on Mercator Projection



U. S. on Lambert Projection



U. S. on Polyconic Projection



U. S. on Gnomonic Projection

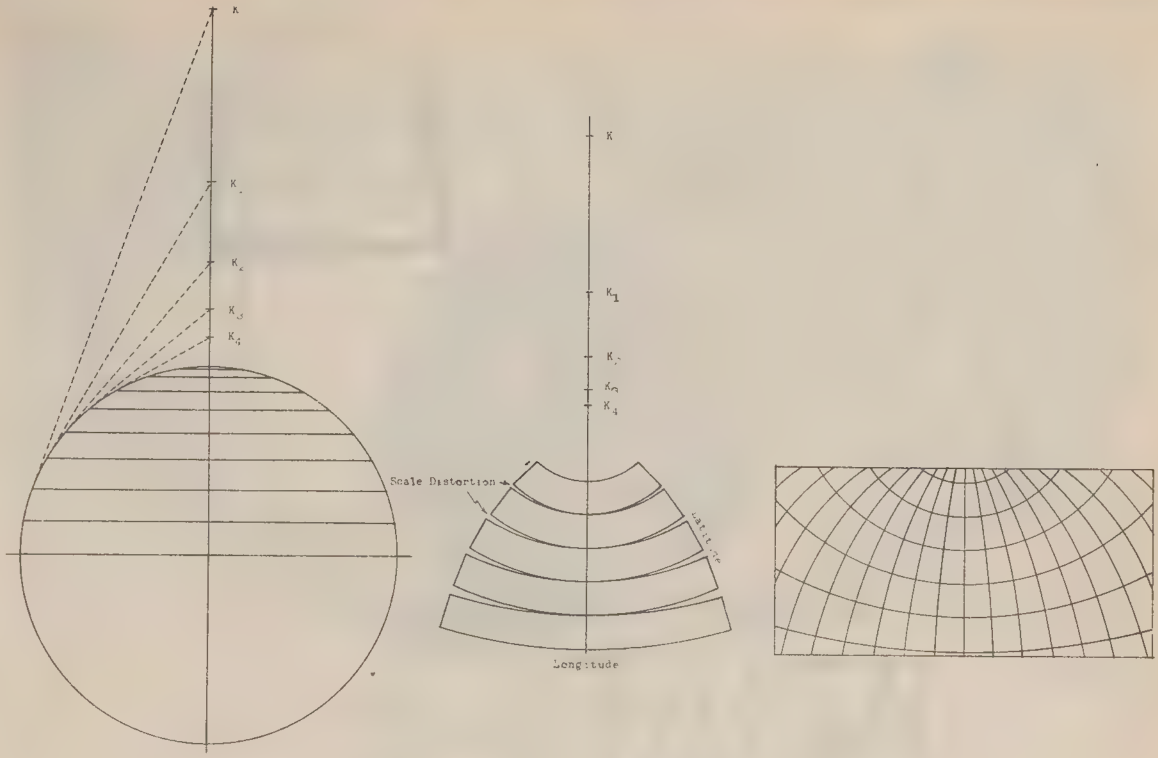


Fig. 17 THEORY OF POLYCONIC PROJECTION

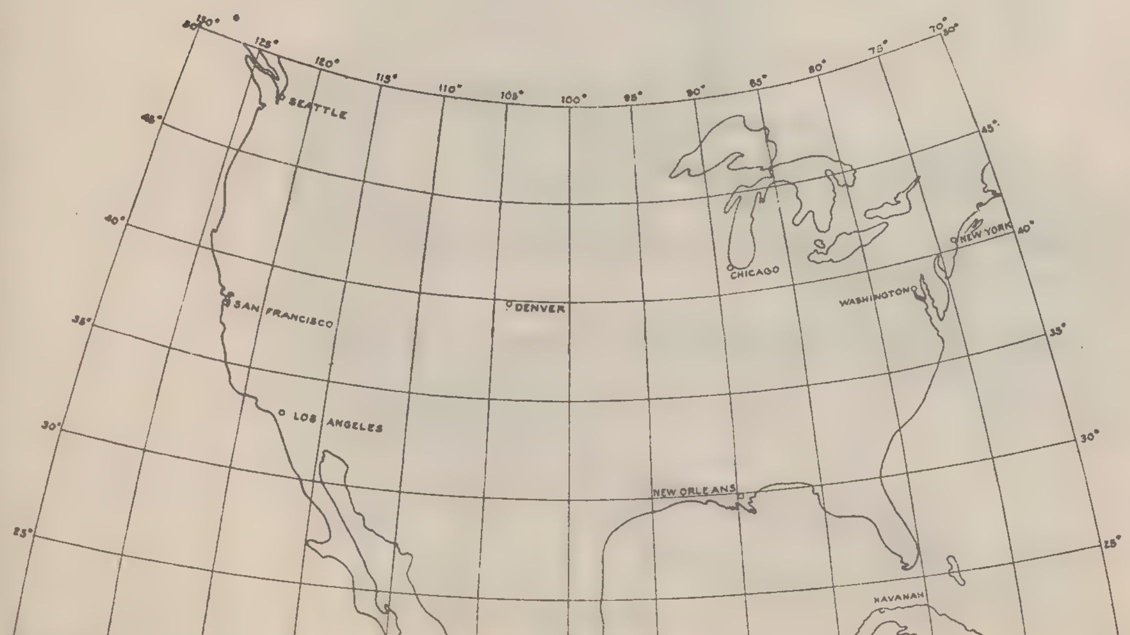


Fig. 18 UNITED STATES ON POLYCONIC PROJECTION

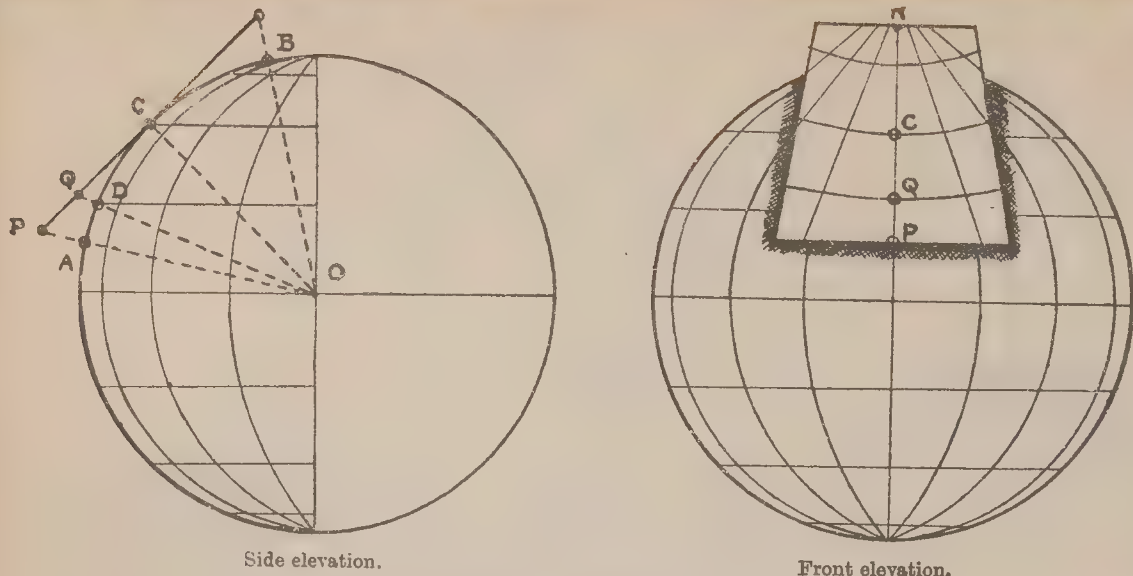


Fig. 19 THEORY OF GNOMONIC PROJECTION

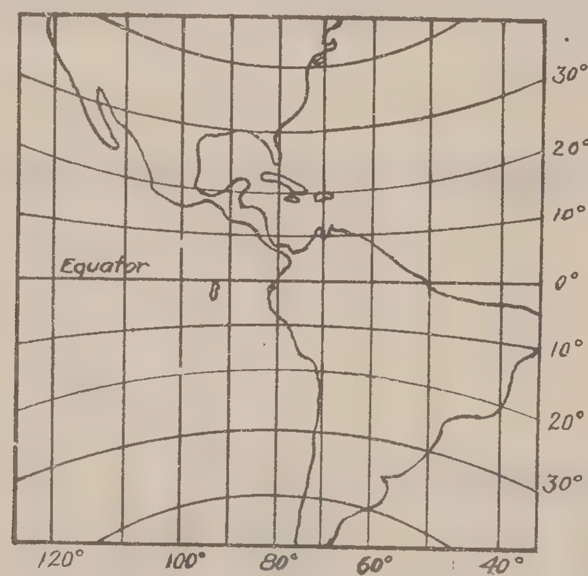


Fig. 20 GNOMONIC PROJECTION TANGENT AT THE EQUATOR

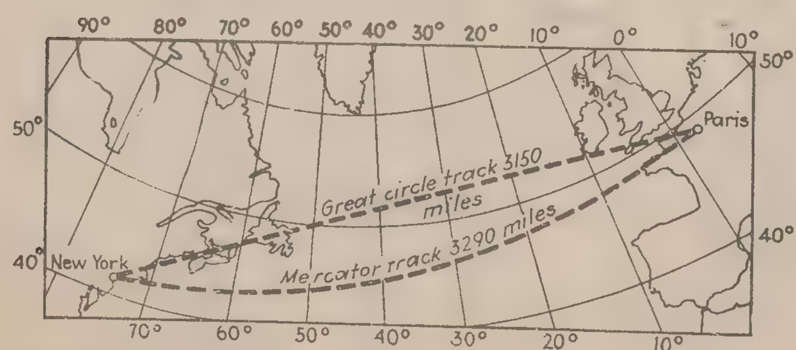


Fig. 21 GREAT CIRCLE AND RHUMB LINE ON A GNOMONIC CHART

Fig. 22 PROJECTION OF A POLAR CHART

Fig. 23 POLAR CHART

POLYCONIC AND GNOMONIC PROJECTIONS

I. POLYCONIC PROJECTION (Refer to Fig. 17)

Good north - South chart.

A. History

1. Devised by Ferdinand Hassler, first Superintendent of U.S. Coast and Geodetic Survey.

2. Popular because it is easy to construct and because a general table has been computed for constructing a projection for any part of the earth.

B. Definition

A polyconic projection is a development of the earth's surface upon a series of cones each one tangent to and having a common axis with the earth.

C. Description (Refer to Fig. 17)

1. Theoretically, the cone acts as an intermediary between the spheroid and the plane; the details on the spheroid are projected on the cone and then the cone is unrolled into a plane.

2. Practically, the transfer is made directly from the spheroid to the plane, the formulas for the transfer being based on the use of a series of cones with their elements tangent to the spheroid.

3. Central meridian is assumed upon which the intersections of the parallels are truly spaced.

4. Each parallel is then separately developed upon a cone tangent to the earth at that parallel.

5. On developed chart, central meridian will appear as a straight line, but all other meridians will appear as curves, the curvature increasing with longitudinal distance from the central meridian.

6. Parallels will appear as arcs of non-concentric circles. The centers lie in extension of the central meridian.

7. Intersections between the meridians and parallels are not at right angles except at the central meridian.

8. A straight line on the chart approximates a great circle.

D. Uses

1. Seldom used for precise navigation except when navigation over terrain not mapped on Mercator or Lambert projections. Even then a plotting chart is used, employing the polyconic map as a reference.

2. Chief use is in Ground Force military maps.

3. Maps based on Polyconic projection are sometimes the only one available when navigating over land areas outside the United States, hence the need for familiarity with its construction.

4. Most maps on polyconic projections are used for areas extending predominantly north-south although they may be constructed to extend east-west.

E. Advantages and Disadvantages

1. Advantages

a. Distortion is slight in the vicinity of the central meridian.

b. Constant scale is used although this scale is not exact for all sections of the chart.

2. Disadvantages

a. An airplane flying a rhumb line course will not pass over the points through which the course line passes on the map.

b. A course line on the chart makes a different angle with every meridian. Courses must therefore be measured at the mid-meridian, a measurement which is difficult because meridians are curved and, furthermore, the parallels do not cut them at right angles.

c. For same reason, positions may not be readily plotted on the chart, nor may the coordinates of a physical feature on the map be easily determined.

d. Because of distortion, the projection is restricted in its use to maps of wide latitude and narrow longitude.

II. GNOMONIC PROJECTIONS

A. Definition

A gnomonic projection is a perspective projection upon a plane tangent to a sphere with the point from which the projecting lines are drawn situated at the center of the sphere. (Refer to Fig. 19).

Hemisphere cannot be shown on this projection because at 90° the projecting lines are parallel to the plane of projection.

B. Description (Refer to Fig. 22).

1. The point from which the projecting lines originate is the center of the sphere, and as the planes of all great circles likewise pass through the center of a sphere, great circles will be projected on the tangent plane as straight lines. Therein lies the chief value of the projection. (Refer to Fig. 21).

2. Points near center of projection are projected in approximately their correct positions, but toward edges of projection, areas and shapes are distorted.

3. Neither distance nor direction can be measured directly on gnomonic projection, except when it covers relatively small area.

4. Meridians, being great circles, are projected as straight lines which converge to a point somewhere on the earth's axis, except when the projection plane is tangent at the Equator, in which case the meridians appear as parallel, non-equidistant straight lines. (Refer to Fig.

5. Since planes of the parallels do not pass thr ter of the earth, they will be projected as curved e The same statement is true of any other small c f the sphere.

6. Angles of meridians and parallels do not intersect at right angles except where the parallels intersect the central meridian (meridian through point of tangency).

Exception to this is a special type of gnomonic projection, the polar, wherein the projection plane is tangent to the earth at the pole. In this case all parallels and meridians intersect at right angles. The parallels are projected as concentric lines with common center at point of convergency of the meridians. (Refer to Fig. 23).

7. Shortest distance between two points on earth's surface is great circle arc between the two. A line on the sphere joining the two will be a straight line in projection.

C. Uses

1. Gnomonic charts are not used for general navigation purposes with exception of navigation in polar areas where distortion of Mercator projection renders it objectionable.

2. Greatest application in planning air routes.

   a. In higher latitudes considerable distance may be saved by flying a series of rhumb line chords approximating the great circle arc between two distant points, especially when their difference of latitude is small.

b. Polar projection type shows an area which is otherwise difficult to chart.

D. Advantages and Disadvantages

Used to find shortest distance between two points

1. Advantages

a. Great circles are projected on the tangent plane as straight lines.

b. Polar projection type shows an area which is otherwise difficult to chart.

2. Disadvantages

a. Areas, shapes, and distances become greatly distorted near the boundary of the map.

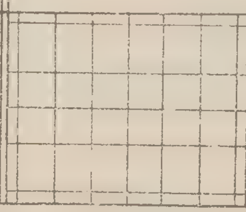
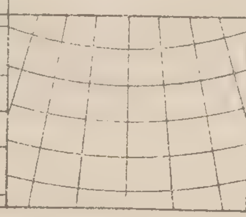
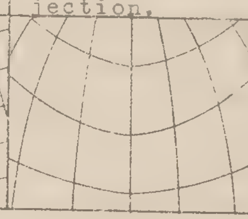
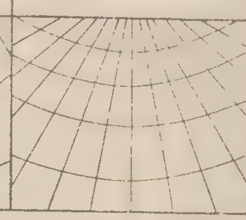
b. Scale of distance is complicated and difficult to use.

c. Courses are difficult to measure.

d. Not suitable for use as a general navigation work chart because the flight path of an aircraft on a constant course would appear as a curve.

III. SUMMARY OF ALL TYPES OF PROJECTIONS

SUMMARY OF PROJECTIONS

	MERCATOR	LAMBERT	POLYCONIC	GNOMONIC
PLAN OF CONSTRUCTION	Sphere and cylinder.	Sphere and cone.	Sphere and series of cones.	Sphere and plane.
RELATIONSHIP OF MERIDIANS	Parallel, straight and equidistant. Right angles with parallel.	Converging and straight. Right angles with parallels.	Central meridian straight, all others curved.	Converging and straight.
RELATIONSHIP OF PARALLELS	Parallel and straight. Non-equidistant.	Equidistant, concentric circles. Right angles with meridians.	Portions of non-parallel curves.	Curved; non-equidistant.
GREAT CIRCLES	Curved line.	Approximates a straight line.	Approximates a straight line.	Straight line.
RHUMB LINE	Straight.	Curved.	Curved.	Curved.
SHAPES	Shapes true for small area. Continents distorted.	Only slight distortion.	Shape distorted except near central meridian.	Shape true only near center of map.
AREAS	Areas greatly distorted in high latitudes.	Only slight distortion.	Area distorted except near central meridian.	Area true only near center of map.
USES	Precise aerial and marine navigation.	Aeronautical charts. Areas elongated east-west.	Used by U.S. Army Engineers. Only available maps sometimes on this projection.	Aeronautical planning charts. Polar Charts.
TYPICAL DIAGRAM				

1. What type of projection would you prefer in determining the shortest possible route between London, England and Capetown, South Africa? __________

2. What type of projection would you prefer in determining the shortest route between San Francisco and Berlin? __________

3. In actually flying from Natal, Brazil to Dakar, Senegal, what type of projection would you use? __________

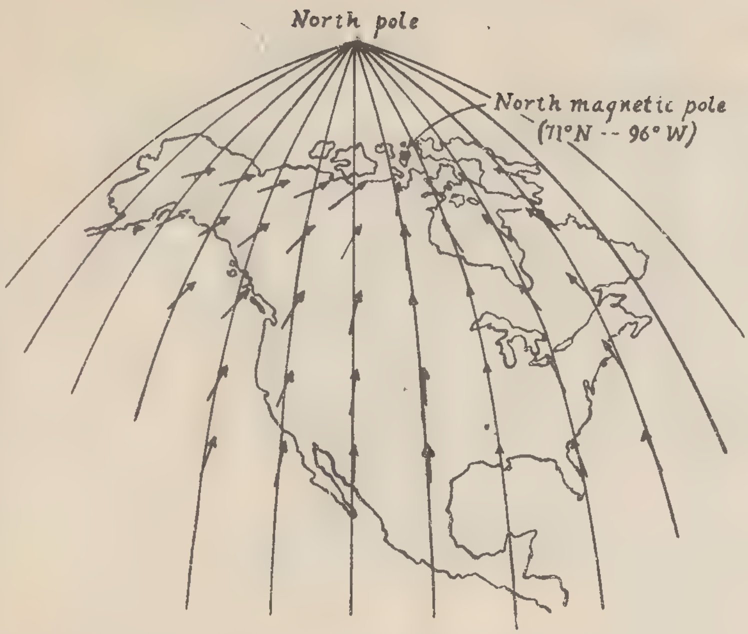


Fig. 24 THE MAGNETIC POLE AND MAGNETIC VARIATION

Fig. 25
MAGNETIC COMPASS

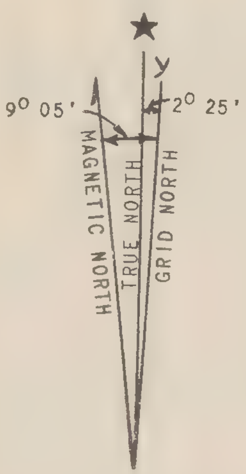


Fig 26 CONVENTIONAL METHOD OF INDICATING MAGNETIC, TRUE AND GRID NORTH LINES. ANGLES VARY BETWEEN THEM.

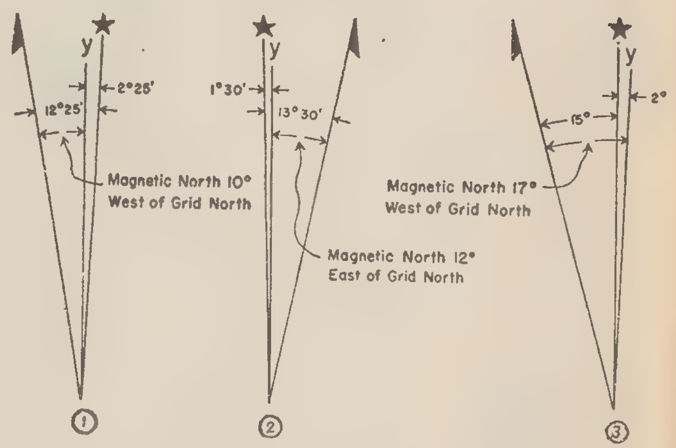


Fig. 27 EXAMPLES OF DIFFERENCE IN DIRECTION BETWEEN GRID AND MAGNETIC NORTH

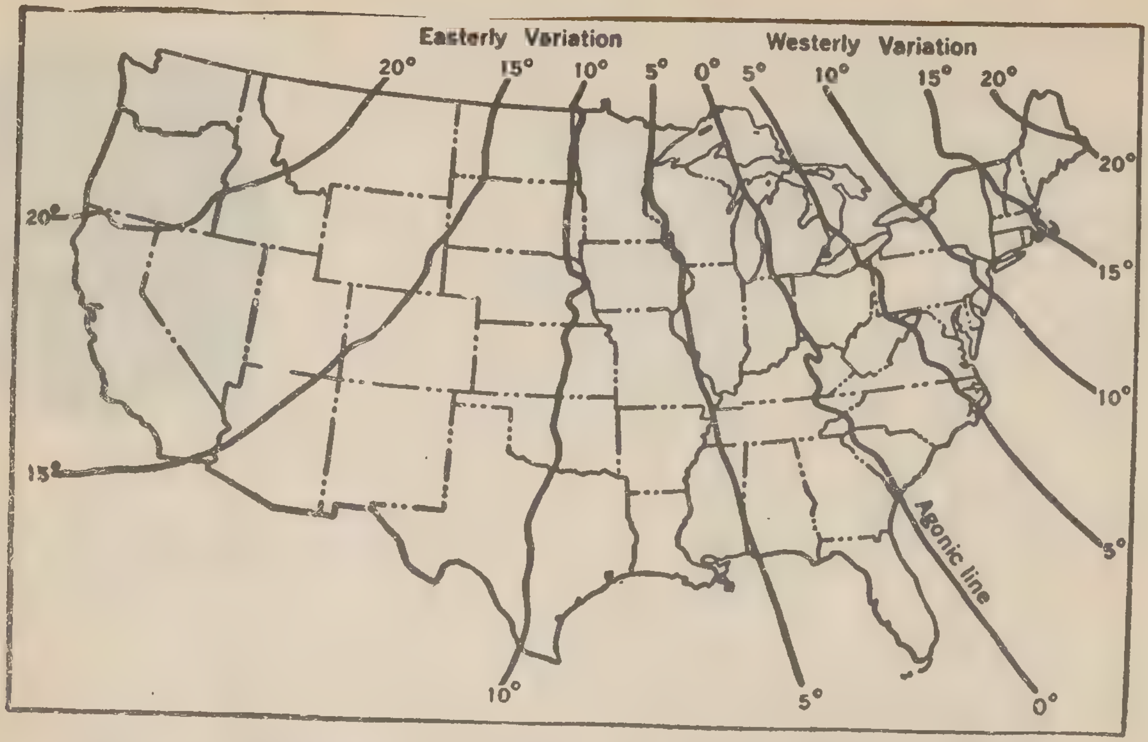


Fig. 28 MAGNETIC VARIATION IN UNITED STATES, 1935

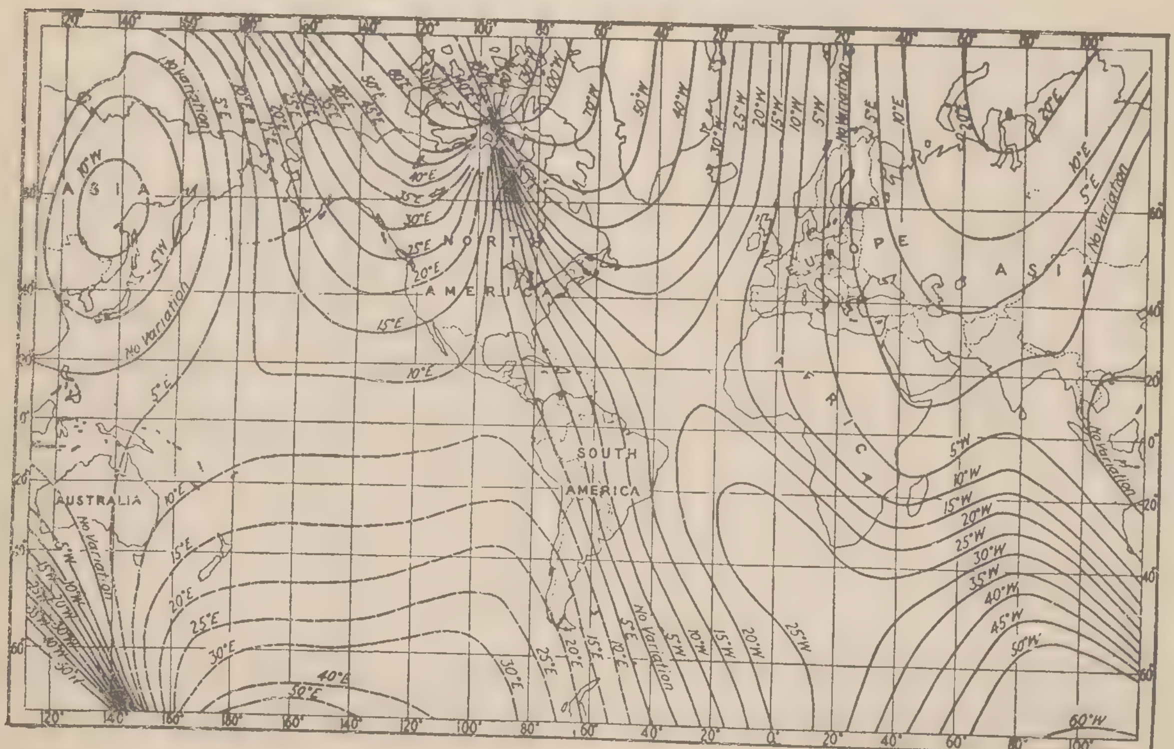


Fig. 29 LINES OF EQUAL MAGNETIC VARIATION.

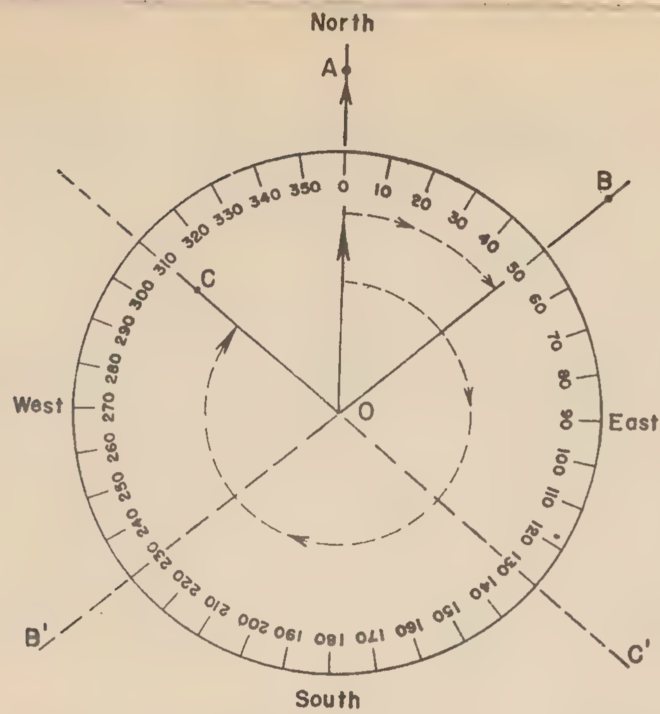


Fig. 30 CIRCLE SHOWING BEARINGS IN DEGREES

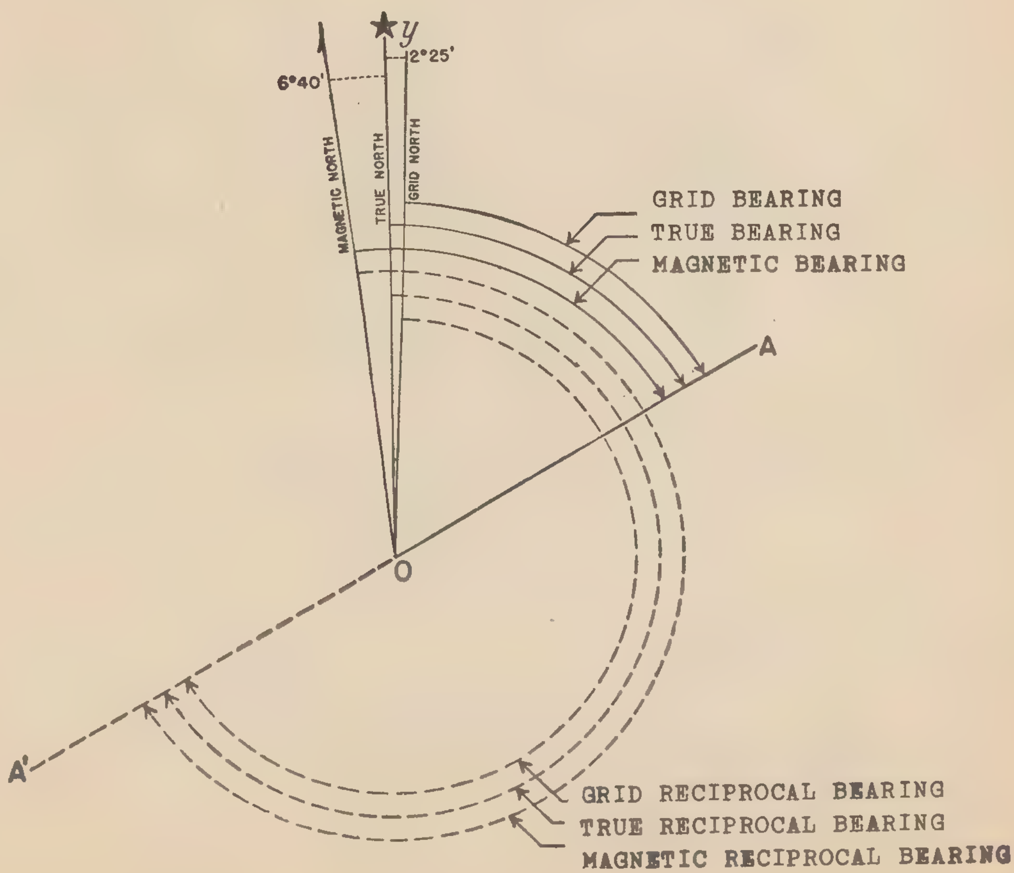


FIG. 31. EXAMPLE OF RELATIONSHIP BETWEEN THREE BASE DIRECTIONS ON A MAP, SHOWING CORRESPONDING BEARINGS AND RECIPROCAL BEARINGS OF LINE OA.

DIRECTIONS, BEARINGS, AND COURSES

I. DIRECTIONS

A. Need for Direction

1. To locate objects both direction and distance are needed. For example, an object can be located by telling in what direction and how far away it is from a given point.

2. Most persons are familiar with the established geographic terms north, south, east, and west. These are directions that are indicated by the common military compass.

3. Direction, like distance, is a measurement. In order to measure anything, we must have an origin, or place from which to measure, and a unit with which to measure.

B. Unit of Angular Measure

1. General

   a. Angles may be measured in degrees, minutes, and seconds.

2. Angles

   a. Degree measurements (Refer to Fig. 30).

   If the circumference of a circle is divided into 360 equal parts by lines drawn from the center to the circumference, the angle at the center between any two adjacent lines is one degree. If one degree is divided into 60 equal parts by lines drawn from the center to the circumference, the angle at the center between any two adjacent lines is one minute. If one minute is likewise divided, a one-sixtieth part of the angle is called one second.

   Thus--
   60" (seconds) = 1' (minute)
   60' (minutes) = 1^{o} (degree)
   360^{o}(degrees) = 1 circle or circumference
   Angles are written $4^{o}2'45"$

C. Base Direction

For military purposes direction is always expressed as an angle between the given direction and some base line. For this purpose three base directions have been established, namely, true north, magnetic north, and grid north.

1. True North

   a. Direction to the actual geographic north pole.

b. On a map true north is shown by a line with a star at the end pointing to true north.

c. True north is used in surveying or other work where great accuracy is desired.

d. For military purposes true north is used only as a base from which variation can be computed.

e. Meridians or longitude lines represent true north and south direction.

2. Magnetic north (Refer to Figs. 24, 25)

a. Magnetism

(1) It was discovered early that a certain ore called 'lodestone' had the peculiar property of always pointing in the same direction when freely suspended in space. It was further discovered that this was due to a magnetic influence and that the earth itself was a huge magnet.

(a) The earth, being a magnet, has a north magnetic pole and a south magnetic pole. A compass is simply a magnetized needle which is suspended to allow it to rotate freely on a horizontal plane. To avoid confusion it is customary to refer to that end of the compass needle which points to the earth's magnetic north pole as the "north seeking" end of the needle; the other end is the "south seeking" end.

(b) Unfortunately the geographical poles and the magnetic poles do not coincide. Thus, the compass needle does not usually point toward true north. This discrepancy in direction is known as magnetic variation (or magnetic declination). (Refer to Fig. 28)

b. Direction of the north magnetic pole

(1) Location of north magnetic pole: N. Lat. 71°, W. Long. 96°.

(2) Location of south magnetic pole: S. Lat. 72°-73°, E. Long. 156°.

c. It is indicated by N (north seeking) end of all compass needles.

d. Shown on a map by a line with a half arrowhead pointing in direction of north magnetic pole.

e. This direction usually used in field work because it is so easily found by means of a compass.

3. Grid north

Grid north is an arbitrary direction established for the purpose of orienting the military grid system on maps.

D. Variation

1. Definition

Variation is the angular difference in direction between true north and magnetic north, or between true north and grid north; therefore, there are two variations, magnetic and grid.

a. Magnetic variation (Refer to Figs. 28, 29)

Magnetic variation is the angular difference between the directions of true north and magnetic north. In some localities, the compass needle points east of true north; in these localities the variation is said to be east. Similarly, in some other localities the compass needle points west of true north; in these localities the variation is said to be west. In some instances, true north and magnetic north are the same and the variation is zero. Magnetic variation changes annually. On military maps the magnetic variation and annual change are shown in the margin.

(1) Imaginary lines connecting points of equal variation are called 'isogonic' lines.

(2) The dividing line between areas of opposite variation, the line of 0° variation, is known as the 'agonic' line.

b. Grid variation (Refer to Fig. 26)

(1) Fixed difference between true north and grid north.

(2) This variation is always the same on any given map,

(3) Grid variation reaches a maximum of 3° either east or west of true north depending on the locality.

(4) On military maps grid variation is shown on the same diagram as the magnetic variation.

c. Deviation

The angle that the earth's magnetic lines of force are deflected from their normal course because of the magnetic influence of local bodies, is called 'deviation'. High tension wires, iron ore deposits, some metal parts of an airplane, or other such objects or deposits cause such magnetic deflection.

2. Use

a. Figure 27 illustrates three positions of grid, magnetic, and true north. There are other possible positions. In ordinary map reading, the difference in direction between grid north and magnetic north is usually desired. In Figure 27, (1) the difference between magnetic and grid variation is seen by inspection to be 10°0' (12°25' - 2°25'). In (2) it is 12°0' (13°30' - 1°30'). In (3) it is 17° (15°0' + 2°0'). In any other positions magnetic variation is determined in the same manner.

b. In aerial navigation the difference in direction between true north and magnetic north is usually desired. In areas having westerly variation, a true course can be converted into a magnetic course by adding the westerly variation. Similarly, to convert true course to magnetic course while in areas having an easterly variation, such easterly variation should be subtracted.

(1) Many pilots have found it helpful to remember the rhymes 'East is least, west is best' or 'East is minus, west is plus'.

(2) The pilot will be confronted constantly with the problem of variation and therefore must have a complete understanding of the subject. Most of the conversions will be from true to magnetic north because only magnetic readings can be made directly from the compass in a plane. (Refer to Fig. 25) because maps and charts are oriented true north, and because magnetic north is read on the compass in a plane it is necessary to make many conversions which involve magnetic variation.

II. BEARINGS (Refer to Fig. 31)

A. Kinds of Bearings

In aerial navigation, the standard method for determining direction is the bearing. Bearings are angular measurements on an arc of 360° in clockwise direction from true or magnetic north. There are two kinds of bearings for any given line or direction:

Stress

True bearing
Magnetic bearing

1. True Bearing

The true bearing of any given line is the angle measured clockwise from true north to the given direction. All bearings are true bearings unless otherwise stated.

2. Magnetic Bearing

The magnetic bearing of any given line is the angle measured clockwise from magnetic north to the given line.

B. Reciprocal Bearings

The reciprocal bearing of a line is its forward bearing plus 180°. If the sum of the forward bearing plus 180° is greater than 360°, subtract 180° from the forward bearing to get the reciprocal bearing.

III. COURSES

A. In aerial navigation work, the course is the direction over the surface of the earth, expressed as an angle with respect to true north, that an aircraft is intended to be flown.

B. There are three kinds of courses:

True course
Magnetic course
Compass course

1. True course is the direction, with respect to true north, that an aircraft is intended to be flown. It is the course laid out on the map or chart. Course is always true course unless otherwise designated.

2. Magnetic course is the true course with magnetic variation applied.

3. Compass course is the magnetic course with deviation applied.

IV. BEARINGS AND COURSES COMPARED

Bearing, as used in aerial navigation, expresses direction of one point from another as an angle measured clockwise from north. Course is direction over surface of the earth that an aircraft is intended to be flown. If plotted on a Mercator Chart, bearing and course are almost identical for short distances, but for long distances are not identical.

V. SUMMARY

DIRECTIONS, BEARINGS, AND COURSES

1. What two facts are of importance in locating one point on the map in respect to another? (1) DISTANCE (2) DIRECTION.

2. What is the relationship between grid north and true north?
   T... -GEOGRAPHIC, GRID NORTH - PARALLEL TO MERIDIAN - NOT TRUE DIRECT.

3. When is the direction of true north the same as that of magnetic north? ON THE AGONIC LINE

4. What is the angle between grid north and magnetic north, assuming grid variation to be 1°57' east and magnetic variation to be 9°45' west? 11°42'.
   1°57'
   10 2'
   11°42

5. Of what importance is deviation to a pilot?
   MUST CORRECT FOR DEVIATION TO FLY COMPASS COURSE.

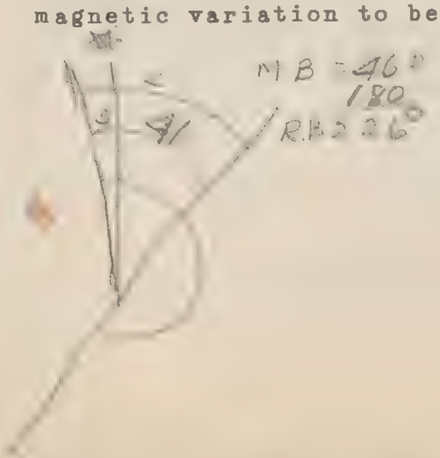
6. On military maps:

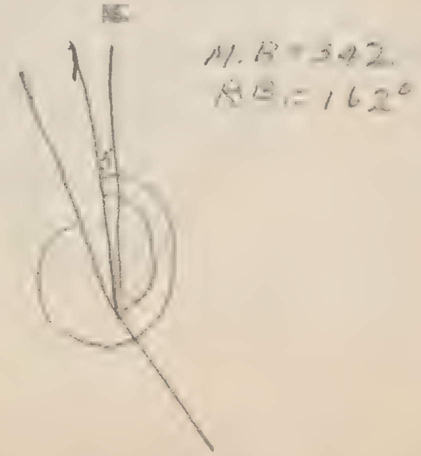
   A straight line ending in half an arrow-head indicates MAGNETIC north.
   A straight line ending at a star indicates TRUE north.
   A straight line ending at a letter 'y' indicates GRID north.

7. In converting true courses to magnetic courses, are easterly variations added or subtracted? SUBTRACTED. Why?
   TO CORRECT FOR MAGNETIC VARIATION

8. Distinguish between an isogonic line and an agonic line.
   ISOGONIC LINES CONNECT POINTS OF EQUAL VARIATION
   AGONIC LINE POINTS TRUE NORTH

9. A plane flies along a magnetic bearing of 46°. Illustrate by a well-labeled figure the reciprocal magnetic bearing of the course. The magnetic bearing of another course is 342°. Illustrate the reciprocal bearing of this course which will be the direction in which the plane would return along the same course. Assume the magnetic variation to be 5° west.





$R.F. = \frac{1}{62,500}$

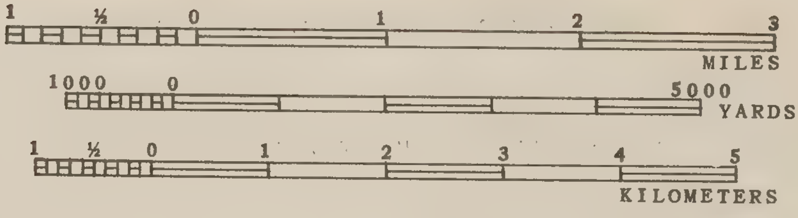


Fig. 32 USUAL SCALES ON MILITARY MAPS

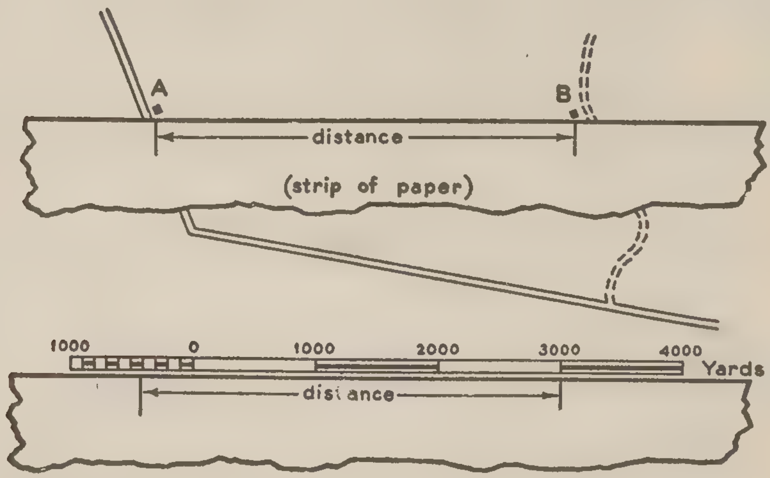


Fig. 33 MEASURING DISTANCE ON A MAP BY USE OF GRAPHIC SCALE

1: 63,360 = 1 in. 1 mi.

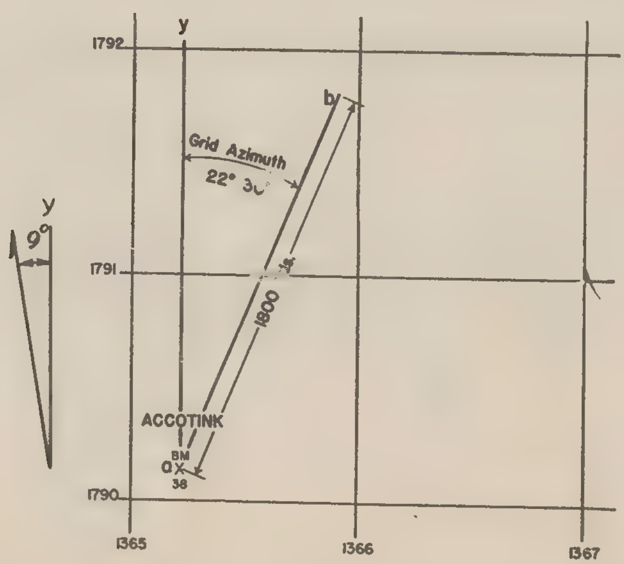


Fig. 34 POLAR COORDINATES

Grid north never varies more than 3° from true north.

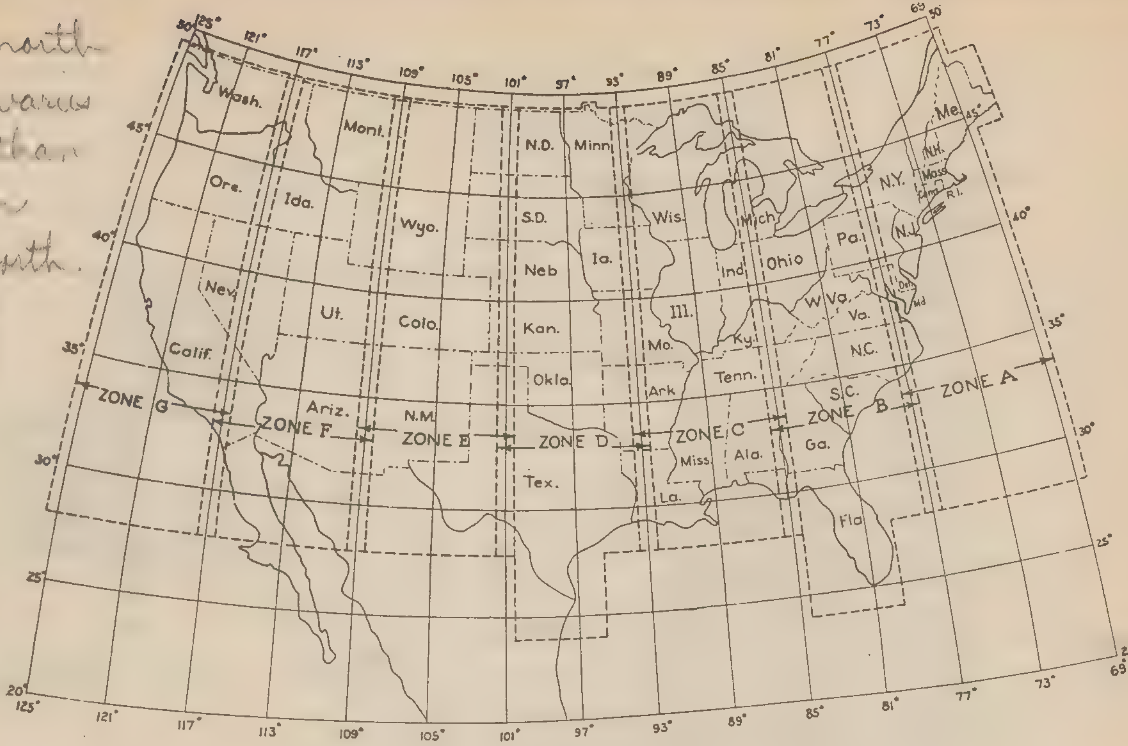


Fig. 35 GRID ZONES OF THE UNITED STATES

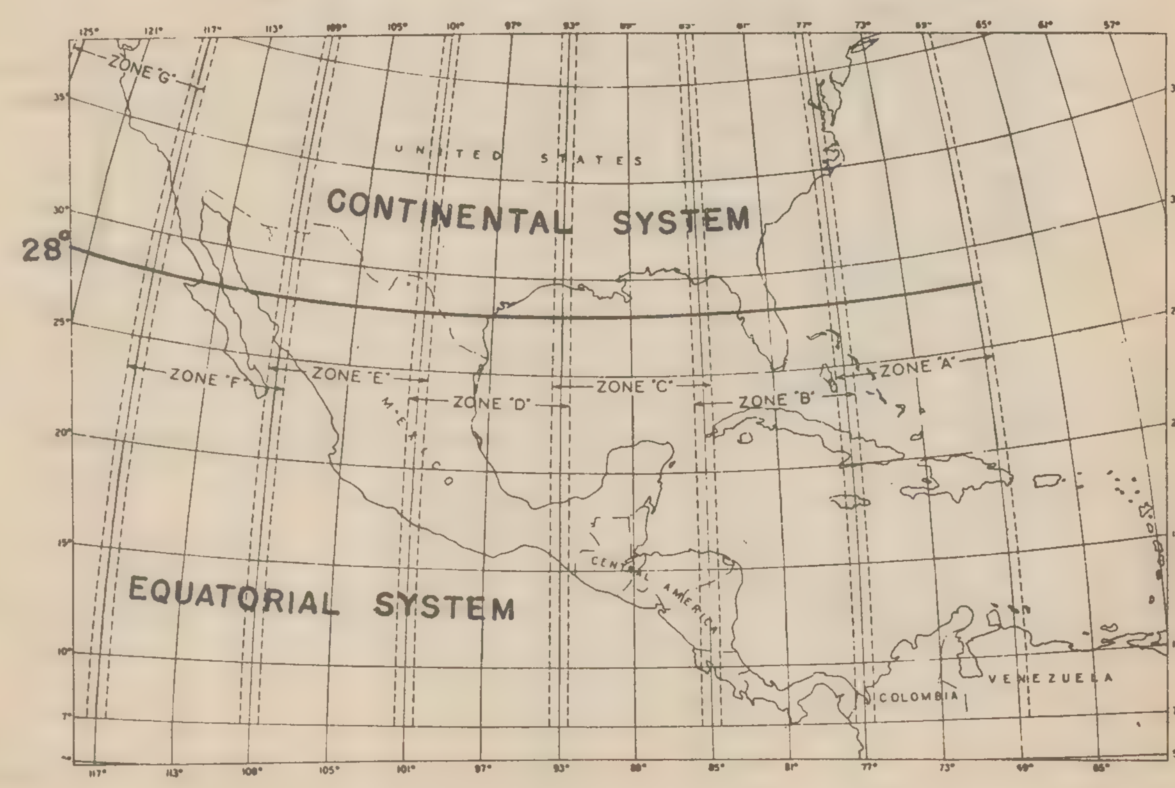


Fig. 36 EQUATORIAL GRID SYSTEM

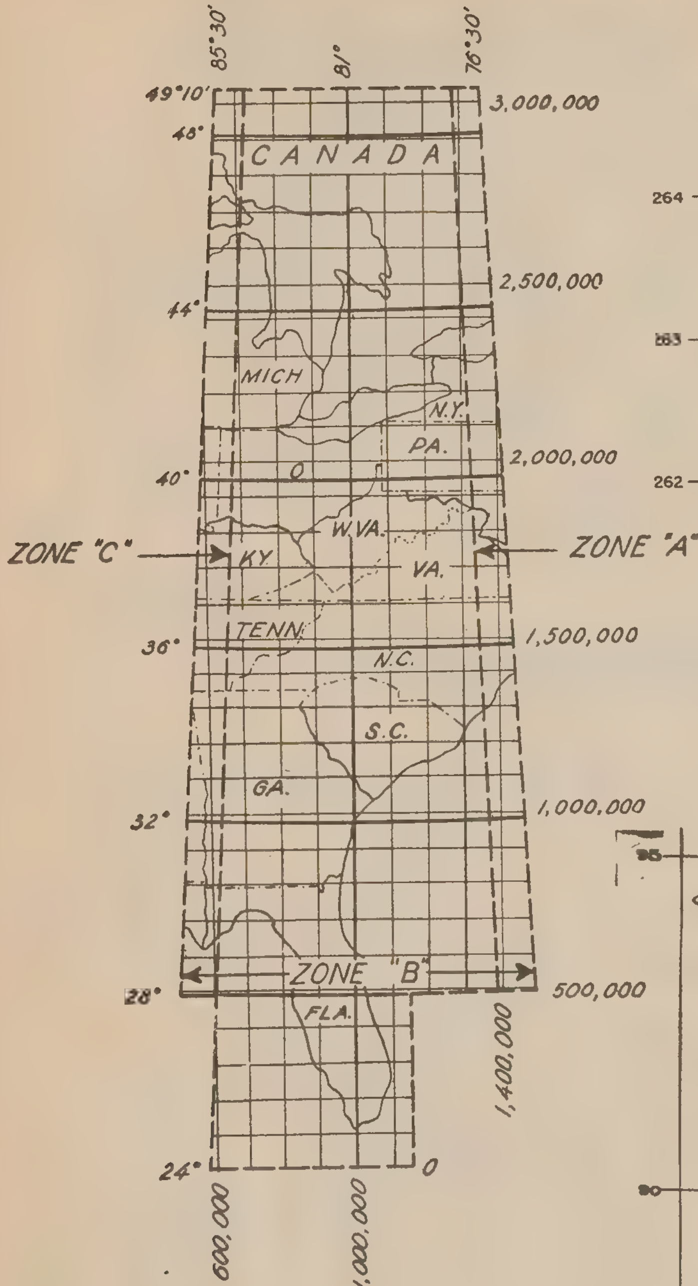


Fig. 37 GRID
ZONE B

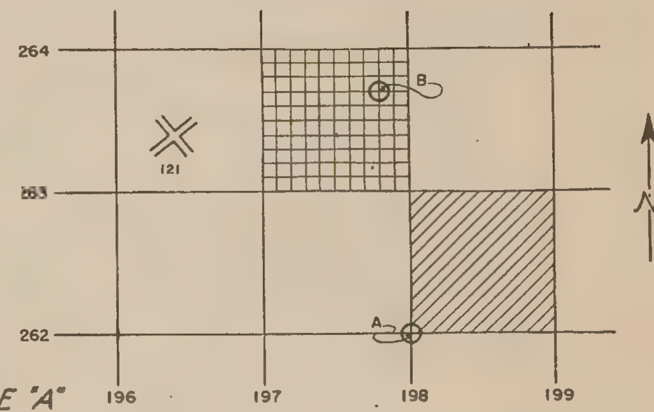


Fig. 38 GRID COORDINATES

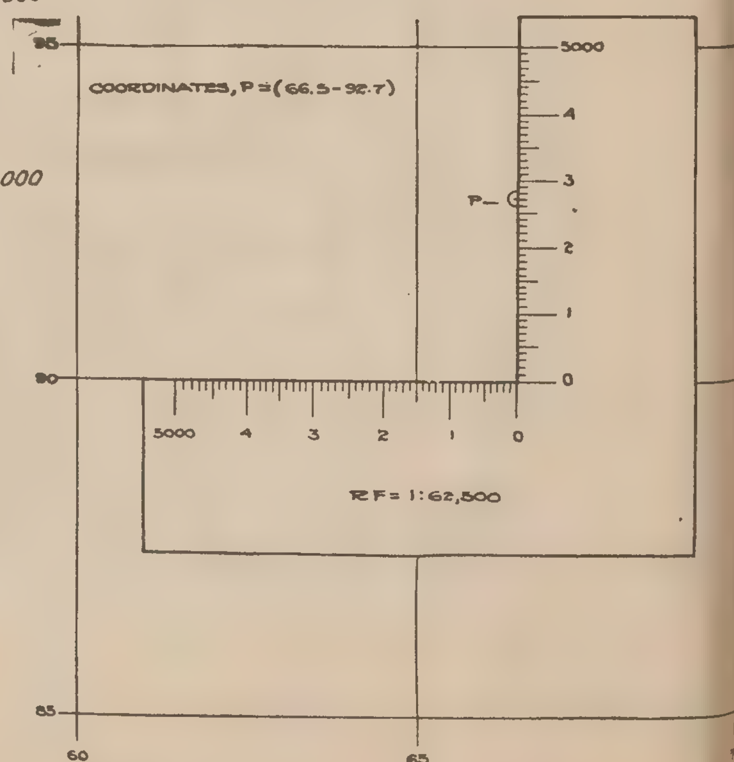


Fig. 39 COORDINATE SCALE

DISTANCES AND COORDINATES

I. DISTANCE

A. Need for Determining Distance

1. One of the first considerations in reading a map or chart is distance.

2. Distance on a map is judged by the use of a "scale".

B. Map Measurements

1. Scales

a. Definition

The scale is the numerical relationship between measurements on the map and actual distances on the ground.

b. Types

The scale of a map is expressed in one of the following ways:

Words and figures
Representative fraction
Graphic

(1) Words and figures

In this type of scale the actual equivalents are given in words and figures.

Example: 3 inches equal 1 mile. This means that a distance of 3 inches on the map is equal to a distance of 1 mile on the ground.

(2) Representative fraction (Refer to Fig. 32)

(a) Relationship between distance on map and on ground is shown as a representative fraction, which is usually abbreviated RF. The RF is shown thus:

$$1{:}62{,}500 \text{ or } \frac{1}{62{,}500} .$$

(b) RF expresses ratio between a given distance on map and the corresponding distance on the ground. In other words, in the above RF, 1 unit of measurement on the map equals 62,500 of the same units on the ground.

(c) The greater the denominator, the smaller the scale. For example, a 1:20,000 map is a large scale map, and a 1:1,000,000 map is a small scale map.

(3) Graphic scales (Refer to Fig. 33)

(a) The figure resembling a small ruler printed on a map is also called a scale.

(b) Scale is divided into parts, and each division is marked not with its actual length, but with the distance it represents on the ground.

(c) Most military maps show a scale in miles and one in yards. Some show a scale in kilometers to be used in countries where the metric system is employed.

(d) Eachgraphic scaleconsists of a primary scale and an extension to the left of the zero. The extension consists of one primary unit subdivided into appropriate fractions.

c. Classification of maps according to scale

It should be noted that a large scale map represents a small territory whereas a small scale map represents a large territory.

(1) Small scale -- 1:1,000,000 to 1:7,000,000

(2) Intermediate scale -- 1:200,000 to 1:500,000

(3) Medium scale -- 1:50,000 to 1:125,000

(4) Large scale -- 1:50,000 and larger

2. Distance determination

a. General

Once the scale is known, the matter of determining distance on a map becomes simple. Even though the scale is given in words and figures or as RF, a graphic scale is usually necessary. The graphic scale is the most accurate and the most common means of determining distance on a map. Following are some of the methods of employing the graphic scale:

(1) To find the distance between two points! (Refer to Fig. 33)

(a) Lay the straight edge of a piece of paper along line connecting the two points on the map. Mark the distance on the paper.

(b) Take the marked paper and lay off the distance on the graphic scale. From the scale determine the ground distance required.

(2) To find the distance along an irregular line on the map

(a) To measure an irregular line divide the line into a series of straight segments. After the sum of the segments has been determined by measuring and adding the segments along the edge of a sheet of paper, the total distanceis laid off on the scale and the ground distance determined.

(b) Another method for measuring distances along irregular lines is to use a piece of thread or string. Usually one end of the thread is knottedand is used as a starting point. The thread is easily bent along curves of a line being measured. After this measurement has been made, the thread is then laid off on the scale andthe ground distance determined as outlined above.

3. Conversion formulas

(a) Metric system

In most European countries the meter is the standard unit of measurement. The metric system is a decimal system in which a meter is equal to 39.37 inches or 3.281 feet; a kilometer or 1000 meters, is therefore equal to 3281 feet.

(1) To obtain distance in statute miles from a known number of kilometers divide by 1.61.

$$\text{Distance in statute miles} = \frac{\text{Kilometers}}{1.61}$$

(2) To obtain distance in nautical miles from a known number of kilometers divide by 1.85.

$$\text{Distance in nautical miles} = \frac{\text{Kilometers}}{1.85}$$

(3) To obtain distance in kilometers from a known number of nautical miles multiply by 1.85.

$$\text{Distance in kilometers} = \text{nautical miles} \times 1.85$$

(4) To obtain distance in kilometers from a known number of statute miles, multiply by 1.61.

$$\text{Distance in kilometers} = \text{Statute miles} \times 1.61$$

4. Conversion of distance to time

a. To determine the time required to travel from one point to another the following formula will be useful:

$$\frac{\text{distance}}{\text{rate}} = \text{time.}$$

The required distance is determined by procedure as previously outlined. The rate of travel must be known. Thus:

$$\frac{\text{1500 miles}}{\text{300 m.p.h.}} = \text{5 hours.}$$

II. LOCATION BY COORDINATES

A. General Considerations

1. Necessity for reference points

a. Often necessary in military operations to designate points on the ground or terrain features in short, convenient, unmistakable terms.

b. Military maps often show names and numbers of important locally known features, but it is not possible to name or number all points on a map. For this reason, a simple method for quickly and accurately identifying points on a map is absolutely essential.

2. Systems

a. To solve the above problem the use of what are called "coordinates" has been adopted. There are several types of coordinate systems, but the polar and military grid are the two types most used.

B. Polar Coordinates

1. Definition

The polar coordinate system is one in which a point is located by giving its distance and direction from another known and given point.

2. Use (Refer to Fig. 34)

a. Commonly used in designating points with a compass in the field and in designating positions on maps not equipped with the military grid.

b. In Fig. 34, point b is located 1800 yards on a grid bearing of $22^\circ 30'$ from B.M. 38.

C. Military Grid

1. General Considerations

a. Description of Grid System (Refer to Figs. 35, 36, 37).

A nation-wide grid system has been devised, by which the location and the identification numbers of the grid lines for the entire United States is prescribed. Briefly, the United States has been divided into 7 grid zones, designated, from east to west, as Zone A, Zone B, etc. Each zone is nine degrees of longitude in width and extends all the way across the country (Gulf to Canada) in height. The width allows for a one-degree overlap of adjacent zones. The center vertical grid of each zone is placed on the central meridian of the zone, and, therefore, is on a true north-south axis. The numbering of the grids of each zone is based upon the intersection of this central y-grid with an x-grid tangent to the 40°30' parallel of latitude. The y-grid (vertical) at this point was given the arbitrary number - 1,000,000 and the x-grid (horizontal) the arbitrary number of 2,000,000 and the other grids of the zone are are numbered to conform. In order to simplify the numbering of coordinates, it is customary to refer to them in terms of number of thousands of yards instead of in terms of number of millions of yards, thus the coordinates of the intersection of the central y-grid and x-grid would be read as 1,000 and 2,000 instead of 1,000,000 and 2,000,000.

b. Scales

(1) On larger scale maps, lines are 1,000 yards apart.

(2) On medium and smaller scale maps, lines are 5,000 yards apart. (Refer to Ludlow, Mass. Quadrangle)

2. Location by Grid Coordinates

a. See Fig. 38; also refer to Ludlow Quadrangle.

b. Points are designated by coordinates by reference to the intersection of the north-south (vertical) grid lines with the east-west (horizontal) grid lines. Thus in Fig. 38, location of point A is indicated by the intersection of the 198 grid line and the 262 grid line. The coordinates of point A are therefore (198-262).

c. The rule followed in reading coordinates is to "read right up".

d. It is often necessary to designate points which do not fall at the intersection of grid lines. For example, find point B in the figure above in terms of coordinates.

If it is assumed that each grid square is subdivided into 10 equal parts, then point B is 8 parts east and 7 parts north of the intersection of grid lines 197 and 263. The coordinates of B can therefore be written 197.8-263.7.

e. Often points can be determined by estimation. For example, the coordinates of crossroad 121 are about 196.4-263.4. Since on all commonly used large scale maps, the grid squares measure 1000 yards on a side, a reading to tenths (one decimal place) gives a location to the nearest 100 yards. When grid numbers have more than two digits, it is customary to drop all except the last two. Thus, crossroad 121 may be designated as being at (96.4-63.4). When a point is easily identified, it is necessary to give only the coordinate square. Thus, crossroad 121 may be designated as being CR 121 (96-63).

3. Coordinate scale

a. General (Refer to Fig. 39; also Wall Display)

To facilitate the division of each grid square into ten equal parts, a coordinate scale is used. A grid card or scale, as shown in the figure below, permits coordinates being found easily and quickly. Scales may be of cardboard, metal, or celluloid. For larger scale maps, the coordinate scale is divided into 10 units of 100 yards each. For smaller scale maps, having grids 5000 yards apart, the coordinate scale is first divided into 5 equal parts of 1000 yards each. Each part is then subdivided into 10 equal parts of 100 yards each.

b. Reading coordinates of a given point (Refer to Fig. 39)

Required: Find point P as illustrated on grid.

Solution: First identify the grid square in which the point is located. In this case (65-90). Now place the coordinate scale with its east-west edge along 90 grid line. Keeping this edge on grid line 90, slide the scale until its north-south scale runs through point P. The Y coordinate is read on the horizontal scale at the point of intersection of grid lines 65 and 90. The X coordinate is read onthe perpendicular scale at point P. These readings are then written (66.5-92.7) This reading is to the nearest 100 yards.

c. Plotting a point with given coordinates

This process is the reverse of that described in the paragraph above.

III. SUMMARY

DISTANCES, COORDINATES

1. On a map, how could the word and figure scale "one inch equals 1 mile" be expressed as a representative fraction? (There are 5,280 feet in one mile.) 1: 63360

2. Using a scale of one inch equals 2 miles, determine the length of the stream, below, between points A and B. Distance 12 mi. miles.

3. Using the sketch in question 2 and the scale as stated, compute the time which would be required to fly directly between points A and B in a plane traveling 275 miles an hour. 1.6 minutes.

4. On a military grid map, the coordinates of a point A are 36.75-84.20 and those of point B are 38.40-86.70. What is the distance between these points in yards? ______________.

5. What type of projection is usually used in construction of military grid system? Polyconic.

6. What is the rule for reading coordinates on a military grid map.

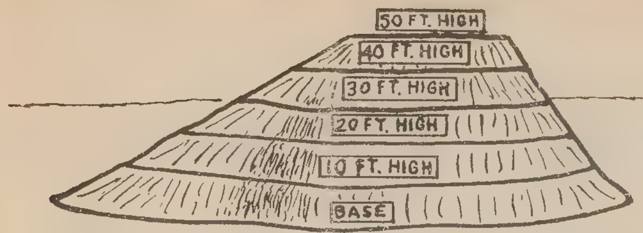
   READ RIGHT [illegible]

7. What is meant by the scale 1:5,000,000?

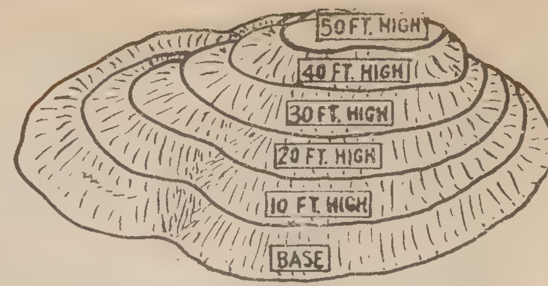
   1 part on map = 5,000,000 parts on [illegible]

8. Is a map with a scale of 1:20,000 considered as being a larger or smaller scale map than one having a scale of 1:62,500?

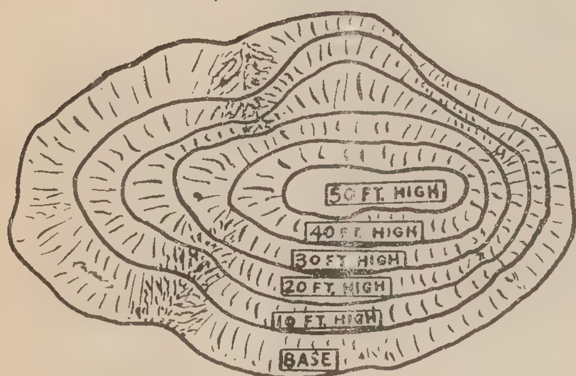
   Larger.



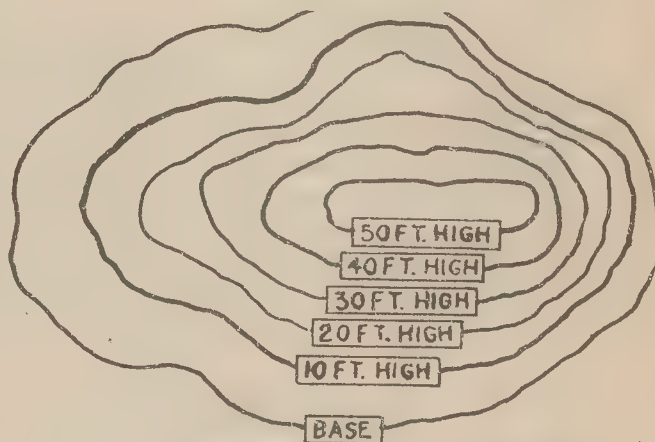
SIDE VIEW OF HILL



OBLIQUE VIEW OF HILL



TOP VIEW OF HILL



HILL SHOWN BY CONTOURS

Fig. 40 CONTOURED HILL

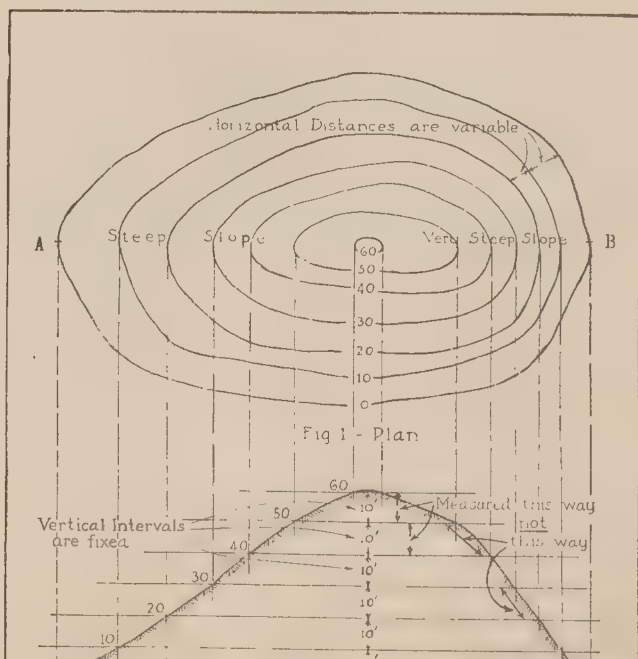


Fig. 41 PLAN AND PROFILE OF A HILL

Fig. 42 PERSPECTIVE SKETCH

Fig. 43 CONTOUR MAP

Fig. 44 HACHURE MAP

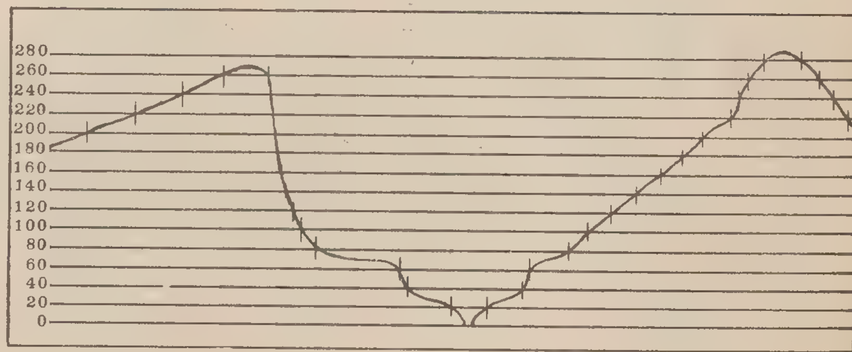


Fig. 45 PROFILE ALONG TOP EDGE OF CONTOUR MAP, Fig. 24

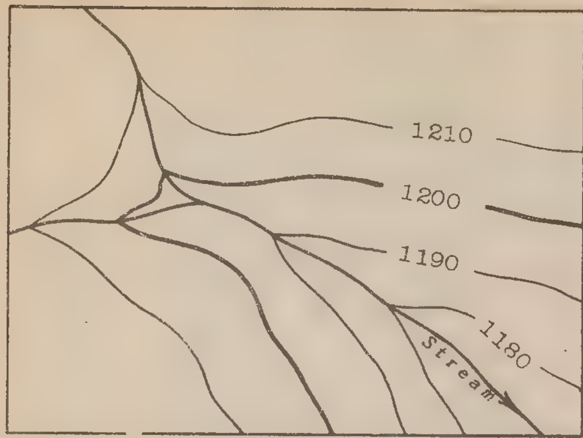


FIG. 46 VALLEYS AND STREAMS

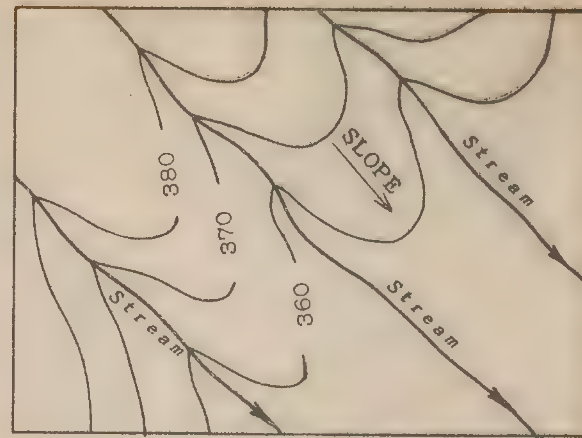


FIG. 47 RIDGES OR SPURS

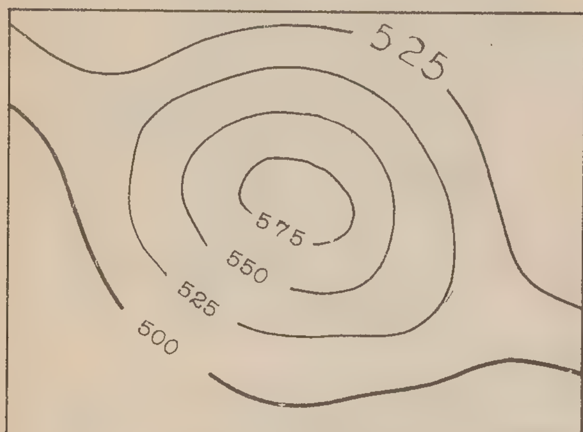


FIG. 48 HILL

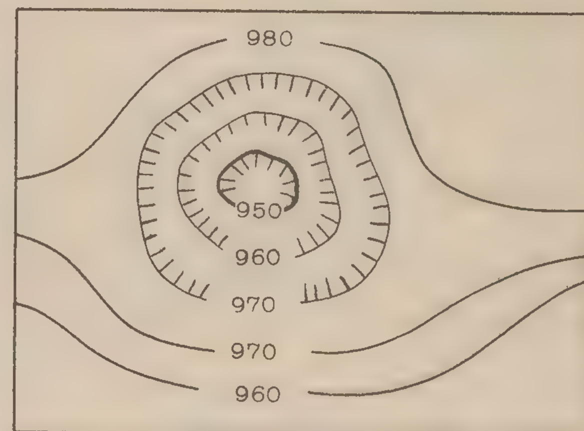


FIG. 49 DEPRESSION

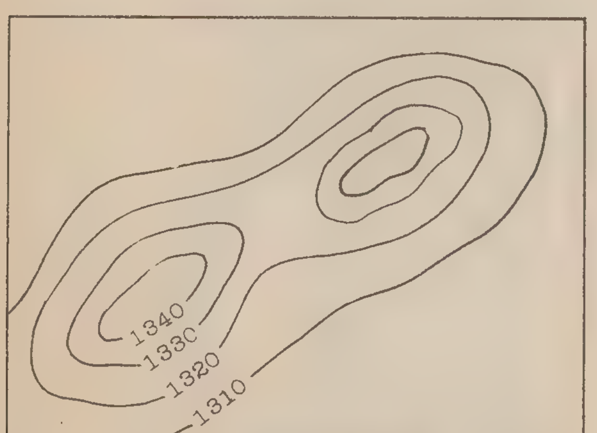


FIG. 50 SADDLE

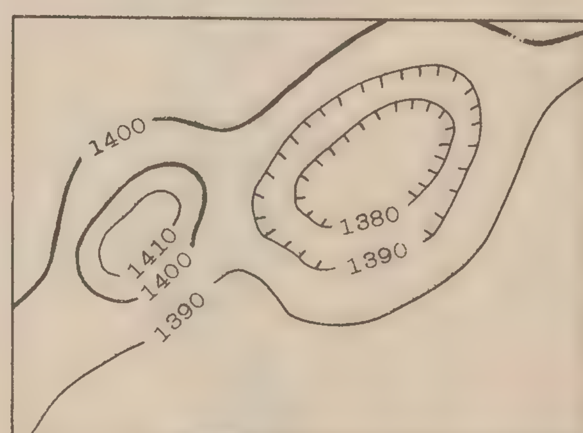


FIG. 51 HILL AND DEPRESSION

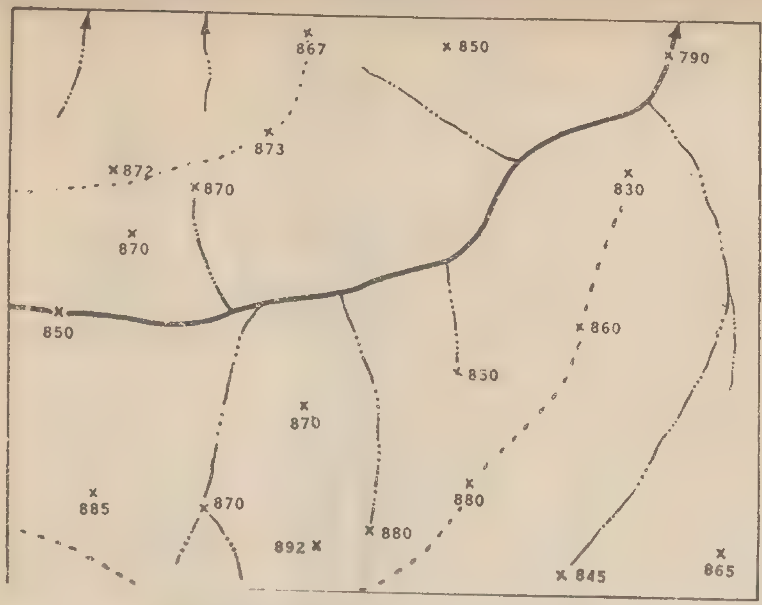


Fig. 52 BASIC SKETCH BEFORE CONTOURING

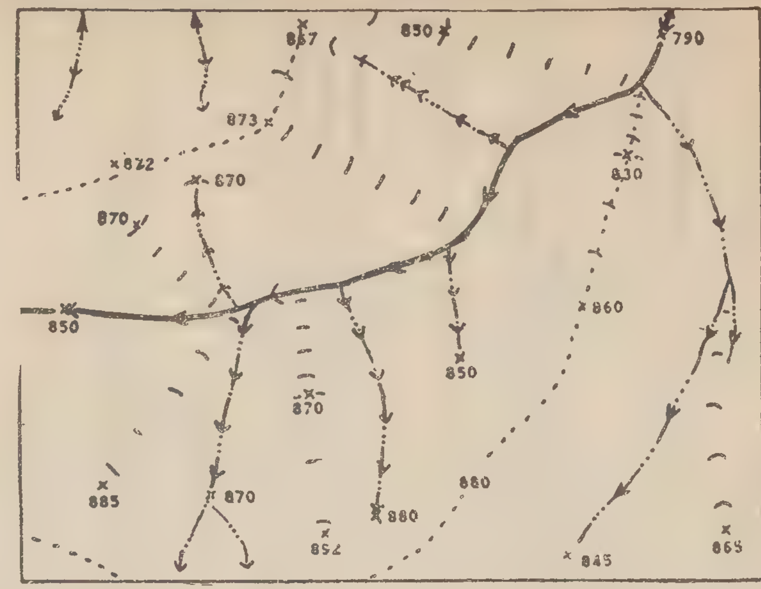


Fig. 53 METHOD OF SPACING CONTOURS

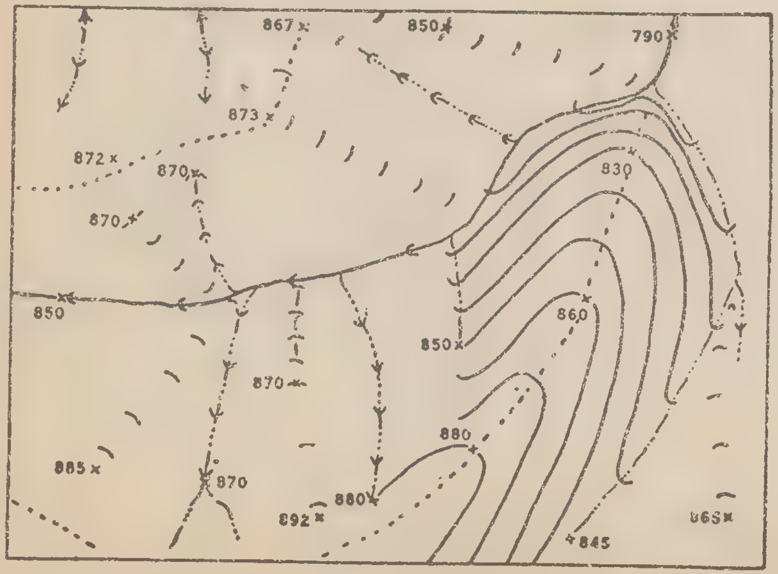


Fig. 54 DRAWING THE CONTOURS

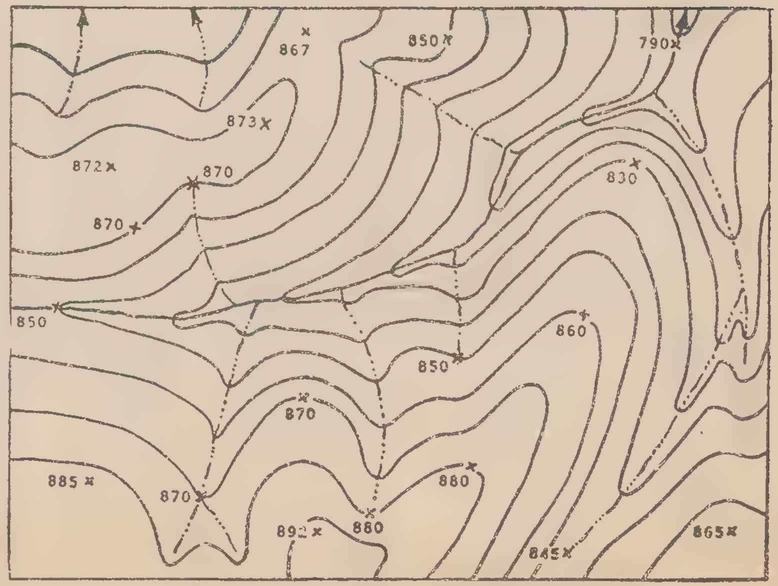


Fig. 55 COMPLETED CONTOUR SKETCH

I. GENERAL

A. Ground Form and Elevation

1. Thus far, the map has been regarded only as a representation on a flat surface, and only features in a horizontal position have been considered.

2. In order to be of practical value to military service, a map must indicate the appearance and shape of actual ground forms within the area covered by the map.

3. The representation of three dimensional features on a flat surface is known as relief.

4. In connection with relief the subject of elevation becomes important. Elevation is the vertical distance of any specific point on the earth's surface above a selected reference plane, which for most maps is mean sea level.

B. Means of Representing Relief and Elevation

1. Because a map is a flat surface, some form of conventional sign must be used to represent relief and elevation.

2. Methods of showing relief and elevation:

a. Hachures

b. Hill and valley shading

c. Color tinting

d. Precise figures

e. Contours (most commonly used)

II. ELEVATION AND RELIEF

A. Hachures

1. Definition

Hachuring is a method of representation of different slopes by means of shading strokes drawn in the direction in which water would flow on the ground at the point represented on map.

2. Characteristics (Refer to Fig. 44).

a. Steepness of slope is indicated by length, weight, and spacing of the hachure lines, i.e., level spaces being left blank.

b. Heights are marked only at points the exact elevations of which are known.

3. Uses

a. Hachured maps are used extensively in Europe, but not in this country except in special instances. Relief on the Strategic Map of the United States (Scale 1:500,000) is shown by hachures.

b. Advantages

(1) They give a pictorial representation of the relief.

(2) Because they are generalized, they are more easily made than contour maps because actual elevation measurements are not required.

c. Disadvantages

(1) Time consumed in making not commensurate with inaccurate results obtained.

(2) On steep slopes, the hachures are so heavy that they preclude the representation of other detail that may be of greater importance than relief.

B. Hill and Valley Shading

1. Shows relief features by means of shading.

2. Seldom used because of skill required in constructing maps and inaccuracy with which details are shown.

C. Color Tinting (Refer to Regional Aeronautical Chart)

1. Involves the use of various colors, usually tints or shades of green and brown for general designation of altitudes. Several thousands of feet may be indicated by certain colors depending on the color scheme which is adopted.

2. Uses

Used frequently on physical maps which show relief features. Also used on aeronautical charts.

a. Advantages

(1) Gives a general idea as to the range of altitudes in an area.

(2) Range of altitudes determined quickly.

b. Disadvantages

(1) Altitudes of specific points not determinable.

(2) Care must be taken in order not to confuse various colors.

D. Precise Figures

1. Frequently, altitudes of outstanding or prominent mountain peaks and obstructions are printed on maps and charts.

2. Altitudes of cities, airports, crossroads, or other points are given on some maps and charts.

E. Contours

1. Definition

A contour is a line on a map which represents an imaginary line on the ground all points of which are at the same elevation.

2. Characteristics (Refer to Ludlow Quadrangle)

a. Contours shown in brown on topographic maps

Typical contours can be seen on topographic map (Ludlow Quadrangle).

b. Contours constitute a medium by which ground forms can be easily visualized

For example, note the shape of Bagg Hill in northwestern part of map (N. Lat. 42°14'30", W. Long. 72°28'30"). The direction of elongation of these hills can be determined by a study of the contour arrangement.

c. Contours have a characteristic wavy appearance

This is caused by irregularities resulting from drainage. Most contours exhibit this characteristic; specific examples can be seen in the southeastern quadrangle of the Ludlow sheet.

d. Numbering of Contours

Elevations of contours above the reference plane are shown by numbers, usually in terms of feet. In some instances, all contours are numbered; however, usually only heavy contours are numbered. Examples of the numbering of contours may be seen on Minechoag Mountain in the center of the map. Note that only contours having values of fifties and hundreds are numbered. Note that there are many separate numbers in black. These are specific elevations, not contours. Such specific elvations are printed in brown on many contour maps.

e. Contour interval

(1) The contour interval is the vertical scale of the map and is usually stated on the bottom of the map. (Note to Instructors. Put especial emphasis on "contour interval". Show cadets where to find it on the map and stress importance. Trying to read a contour map without knowing the contour interval is like trying to measure distance without knowing the scale.) On map of Ludlow Quadrangle, the contour interval is 10 feet, as indicated below the graphic scale. This means that all contours in normal sequence will represent changes in elevation of 10 feet with respect to contours adjacent to them. Some exceptions will be made to this last statement in cases of hills and depressions where closed contours are involved.

(2) The contour interval chosen depends upon the character of the topography (irregularities of the earth's surface), the amount of relief, the scale of the map, and the purpose for which the map is to be used.

(a) If the relief is great, the contour interval chosen will be large. If the relief is small, the contour interval will be small. Thus, the common contour intervals with their corresponding heavy lines are as follows:

Contour interval (in feet)	Heavy lines
1	5 and multiples thereof
2	10 " " "
5	25 " " "
10	50 " " "
20	100 " " "
25	100 " " "
50	250 " " "
100	500 " " "
250	1250 " " "
500	2500 " " "

In general, the contour interval remains the same for the entire map, although in very mountainous areas there are exceptions to this rule.

(b) Example

In plains areas where relief is slight, an interval of 5 feet might be chosen; whereas, in rugged, mountainous areas, the interval might be 250 feet. Although contours would be approximately the same distances apart on maps of the two areas, the amount of relief represented would be decidedly different.

(c) A small scale map usually will have a large contour interval - a large scale map a smaller contour interval.

(d) A map made for the purpose of planning drainage changes will have a smaller interval than a map made for military maneuvers.

f. Contour lines are closed curves

Although all contour lines are closed curves, they do not all close within the boundaries of the map. Find the hill, just south of Ludlow City, along the western border of Ludlow Quadrangle and note that some of the contours are closed lines, whereas others may be traced off the map without closing. The 350 and 360 foot contours close but the others leave the map.

g. Contours never cross

The contours on the east side of Chicopee River, just south of Red Bridge in the southwestern part of the central eastern quadrangle (North lat. 42°10'30", West long. 72°24'30") are very close together and indicate a steep slope, but they do not cross.

h. Close spacing of contours

The close spacing of contours indicates a rapid change in elevation and is characteristic of bluffs or steep slopes.

Excellent examples of rapid changes in elevation may be seen to the left of the valley near the center of Fig. 43, and along the east side of Chicopee River in locality noted above.

On contour maps steep slopes may be represented by contour lines so closely spaced that individual lines are not identifiable. On some maps, for convenience in printing and interpretation, contour lines end before they merge on the steep slopes, and start again where the slope lessens. (See Ludlow Quadrangle in the general area of latitude 42°8', longitude 72°24'.)

i. Distant spacing of contours

The distant spacing of contours indicates a gradual slope. In case of very distantly spaced contours, a relatively flat area is indicated.

This is demonstrated in the northeast quadrangle of the Ludlow Sheet - the Washington School area. Also in the valley in the center of Fig. 43, and on the peninsula in the foreground of the same figure.

j. Regular contours

Unless contours are marked by hachures, they are regular contours. If marked by hachures, they are depression contours, and hachures extend toward center of depression.

Examples of both types of contours are illustrated in the southern part of the western quadrangle of the Ludlow sheet.

k. Regular closed contours

A regular closed contour has an elevation one interval higher than the lower adjacent contour.

(1) Any regular contours within a regular contour have successively higher values, increasing one contour interval with each contour.

(2) Examples

Notice the closed contours on the hill illustrated in Fig. 43. Each of the regular contours increases in elevation at the rate of one contour interval per line, or in this case 25 feet for each contour. This characteristic is shown again in Fig. 50. The hill is indicated by 2 closed 10-foot contours. In Fig. 51 note that the first closed regular contour has the value of 1400, or one interval higher than the lower adjacent contour.

There are many excellent examples of closed contours in the Ludlow Sheet.

l. Depression contours

A depression contour takes for its elevation the value of the adjacent contour with the lower elevation, or one interval lower than the higher adjacent contour.

(1) Any depression contours within a depression contour have successively lower values, decreasing one contour interval with each contour.

(2) Examples

In Figs. 49 and 51, two illustrations demonstrate the arrangement of depression contours. In the illustration labeled "depression" note that the first depression contour is closed and has the value of the lower adjacent contour, namely 970, and each successive contour within the 970 is decreased in value of one interval, which on the map is 10 feet. Likewise, in Fig. 51, the illustration labeled "Hill and Depression", the first depression contour between the 2 regular contours has as its elevation 1390 feet, or the value of the lower adjacent contour. The inner depression contour is 1380 feet, or one interval lower than the first depression contour.

m. Contours crossing streams

Contours extend upstream to cross. Contours characteristically form inverted V's when they cross streams.

For examples regarding manner in which contours cross streams, see Figs. 43 and 46, and any stream on the map of Ludlow Quadrangle. In the case of every stream, the contour lines bend upstream to cross, and it is therefore possible in this way to determine the direction of flow of any stream crossed by contours.

n. Ridges or spurs

The inter-stream areas are commonly known as ridges, or spurs, and are usually represented by the downswing of contours, as opposed to the up-swing of contours along streams. Such ridges or spurs are demonstrated in Fig. 47.

o. Configuration of contours at junction of stream

At the point of confluence of streams, usually a Y will be formed with the leg of the 6 pointing downstream. because contours swing upstream to cross, and down on spurs to cross, the result is that when contours cross streams immediately above their junction, an M will be formed by the contours.

A good example of such a configuration of the contours may be observed on the east-central side of the map in Fig. 43.

p. Saddles

The term saddle is commonly used for low areas between two hills or for topographically low areas which have been caused by dissection incident to stream action.

An example of a saddle may be seen in Fig. 50, and on the map of Ludlow Quadrangle at Minechoag Mountain in the central part of the map.

3. Logical contouring (Refer to Figs. 52, 53, 54 and 55)

a. Methods

(1) A topographer may actually survey the location of the contours on the ground. This laborious and expensive method is justified only when the greatest accuracy obtainable is desired.

(2) A topographer may survey enough contours to define ground forms and interpolate between them by eye.

(3) A topographer may run out only stream lines and ridge lines, getting "critical elevations". The contours may then be sketched by interpolating between the elevations. This is the most common method of contouring. The sketching should be done in the field whenever possible, but may be done in the laboratory.

b. Example (Refer to Figs. 52, 53, 54, and 55)

The critical points whose elevations have been marked on the basic sketch, Fig. 52, were selected at the major changes of slope, so it follows that the slope between any two adjacent critical points will be approximately uniform. Therefore, the contours should be uniformly spaced. Small marks in pencil, known as ticks, are accordingly plotted between adjacent critical points, their number depending on the known difference of elevation. Thus on Fig. 53 there have been indicated the ticks between the stream courses and the known elevations, for example, six between the 810 elevation near the stream and the 873 ridge point, and five between the 800 elevation, near the stream, and the 850 ridge point. The next step is to connect up the tick points with the contour line, beginning with the lowest elevation and working uphill. Their trace conforms to the ridge and to the stream lines. This last step should be performed in the field so that the topographer can view the area being contoured, and be able to adjust, by estimation, the actual trace and the spacing of the contours to conform to the minor changes of slope and direction. Figure 54 indicates the method of drawing in the contours to conform to the basic terrain structure. Figure 55 shows the completed contoured sketch. As a final step, it adds to clarity to accentuate the 800 and the 850-foot contours.

4. Interpretation of contour maps

a. Drill on interpretation of contour maps (Refer to Fig. 43 and to Ludlow Sheet). Place emphasis on interpreting elevations of contour lines in Figs. 49, 50, and 51.

F. Slopes

1. Definition

a. Slope is the inclination of the land surface relative to a horizontal plane and is a junction of two factors-horizontal distance and vertical distance.

2. How determined

The vertical distance between two points can be determined on a contour map by reading the contours and interpolating between contours when the points do not fall directly on the contour line. Horizontal distance may be scaled directly from the map.

3. How expressed

a. Slope is usually expressed in terms of percent (one unit of vertical distance in 100 units of horizontal distance) but may be given in units, degrees, or gradient.

G. Profiles (Refer to Figs. 43 and 45)

1. Definition

a. A profile is a constructed cross-section of an area along an established line. Any horizontal and vertical scale may be chosen but usually the horizontal scale is the same as the map and the vertical scale is exaggerated for ease in construction and clarity in interpretation.

2. Importance and use

a. Profiles are distinct aids in visualizing topography.

b. Profiles are useful in determining visible and invisible areas from any given operation point.

III. SUMMARY

CONTOUR THE MAP BELOW USING A CONTOUR INTERVAL OF 20 FEET. CONTOUR LINES, THE VALUES OF WHICH ARE MULTIPLES OF 100, SHOULD BE HEAVIER THAT OTHERS AND SHOULD BE NUMBERED.

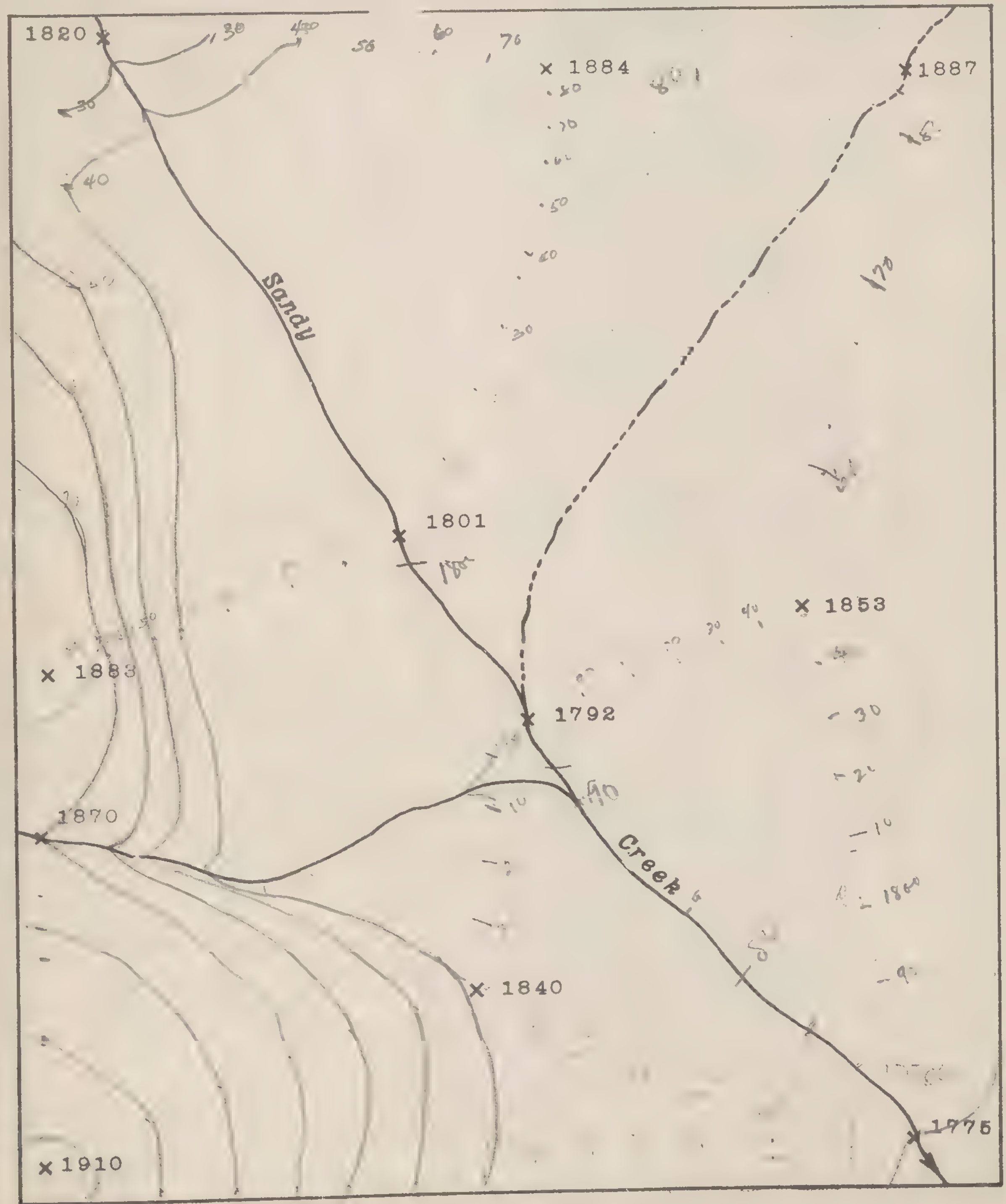


FIG. 56 CONTOUR MAP.

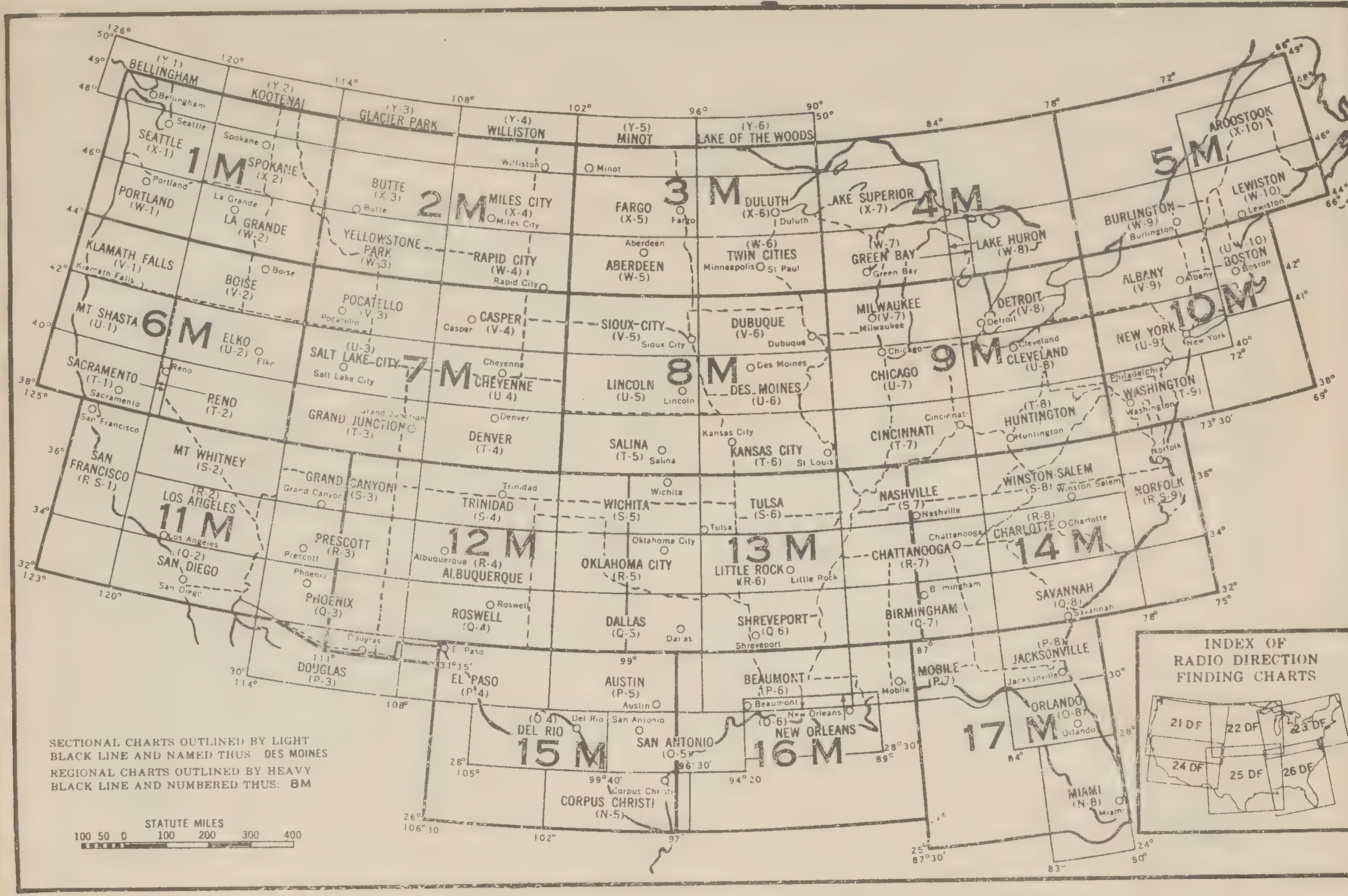


Fig. 57 AERONAUTICAL CHARTS OF THE UNITED STATES
Published by the U. S. Coast and Geodetic Survey

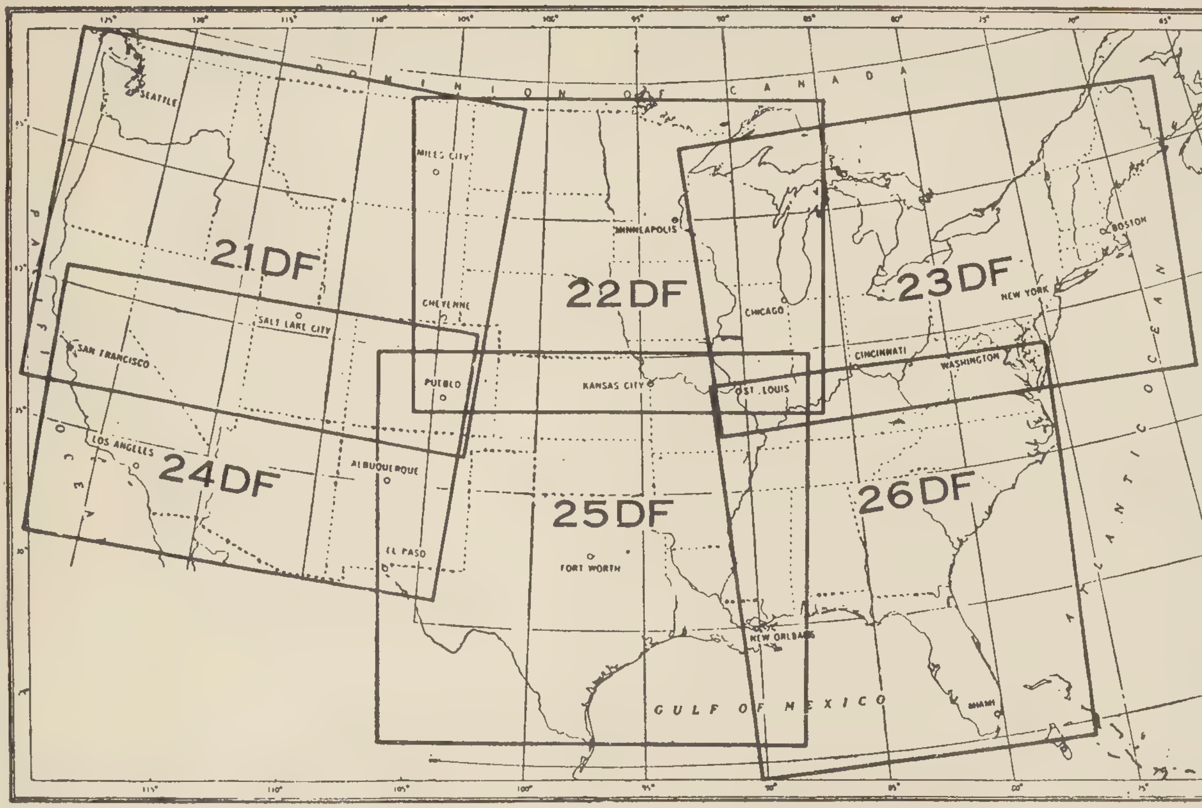


Fig. 58 INDEX OF AERONAUTICAL CHARTS FOR RADIO DIRECTION FINDING

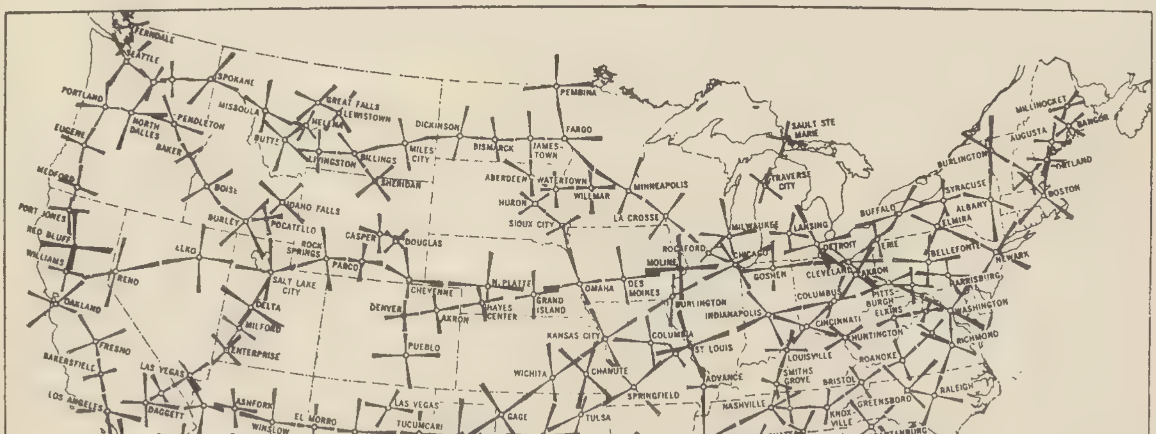


Fig. 59 RADIO RANGE SYSTEM OF CIVIL AERONAUTICS ADMINISTRATION

87 Sectional charts of U.S.

CHARTS

I. DEFINITION

A chart is a type of map designed for the use of navigators.

a. Formerly, a chart was taken to mean a map of those portions of the earth's surface which are mostly covered by water.

b. Recently, the term chart has been used with reference to maps, which are used for the purposes of aerial as well as marine navigation.

II. KINDS OF AERONAUTICAL CHARTS

A. Sectional Charts (Refer to Fig. 57)

1. Entire U. S. covered by 87 sectional charts.

2. Scale of charts is 1:500,000 or 1 inch equals approximately 8 miles.

3. Lambert conformal projections used.
Lambert projection is chosen because meridians are represented by straight lines converging toward a common point outside the boundary of the chart, and the parallels by curved lines which are sections of concentric circles whose center is at the supposed point of intersection of the meridians. Meridians and parallels intersect at right angles, and the angles formed by any two lines on the earth's surface are correctly represented.

The scale of error of any single chart is so small that distances may be measured directly by means of the graphic scales printed in the borders. On a chart of the country as a whole, the maximum (total) scale error for nearly 90 per cent of the area of the United States is within ½ of 1 per cent, which is an error negligible in practice.

4. Provide aeronautical data required in aerial navigation over a limited area.

5. Entirely suitable for all forms of air navigation, but are intended primarily for use in pilotage.

6. Much data concerning landmarks printed on these charts.

7. Most commonly used charts in aviation.

B. Regional Charts (Refer to Fig. 57)

1. Entire U. S. covered by 17 regional charts.

2. Scale of charts is 1:1,000,000, or 1 inch equals approximately 16 miles.

3. Lambert conformal projections used for same reason given in A-3 above.

4. Provide aeronautical data required in aerial navigation over a wide area.

5. Designed particularly for air navigation as contrasted with pilotage. They were made necessary by faster planes flying greater distances.

6. Most of landmark data appearing on sectional charts eliminated because, for purpose of these charts, clarity is more important than completeness of detail.

C. Radio Direction Finding Charts (Refer to Fig. 58)

1. Entire U. S. covered by 6 charts. Use magnetic con-for-Rose

2. Scale of charts is 1:2,000,000 or 1 inch equals approximately 32 miles.

3. Lambert conformal projections used for same reason given in A-3 above.

4. Used to facilitate the plotting of radio bearings.

5. To facilitate the plotting of radio bearings, there is printed around each radio range station a special compass rose oriented to magnetic north.

6. Areas of dangerous land elevations shown.

D. Aeronautical Planning Charts

1. Aeronautical Planning Chart of U. S. #3060A

a. Entire U. S. covered by one chart.

b. Scale of charts is 1:5,000,000 or 1 inch equals approximately 80 miles.

c. Lambert conformal projections used for same reason given in A-3 above. Standard parallels of true scale at latitude 33° and 45°.

d. Affords a high degree of accuracy in the measurement of distances between widely separated points and may also be used for the plotting of radio bearings.

e. About 40 of the principal broadcasting stations and 250 of the most important airports are shown in red, facilitating radio compass navigation, and the plotting of routes.

f. Plotting of routes simplified by overprint showing the limits of each sectional chart, thus making it possible for the pilot to see at once which sectional charts will be required for a projected flight.

g. A straight line on this chart is a close approximation to the path of a great circle, and for all practical purposes may be regarded as the shortest route between two points. It is especially suitable for measurement of distances, courses, and bearings.

h. The 87 sectional charts of the U. S. are shown.

2. Aeronautical Planning Chart #3060B

a. Same construction as for chart #3060A.

b. Same uses as for #3060A.

c. Chart #3060B is printed in color using gradient of elevations.

E. Great Circle Chart of U. S. #3074.

1. Entire U. S. covered by one chart.

2. Scale of chart is 1:5,094,000 at the point of tangency, or 1 inch equals approximately 80 miles. This scale, however, becomes considerably greater away from the point of tangency.

3. Gnomonic projection used. Scale is not constant.

4. Chart is not suitable for measurement of navigation courses, bearings, or distances, but any straight line on this projection represents a precise great circle track. The chart is therefore very useful for an exact determination of the great circle route over long distances.

5. Airports, shown on Aeronautical Planning Charts, are also shown on Great Circle Chart, although radio stations are omitted.

F. Magnetic or Isogonic Chart of U. S.

1. Entire U. S. covered by one chart.

2. Scale of chart is 1:7,500,000, or 1 inch equals approximately 115 miles.

3. Lines of equal magnetic variation at 1° intervals are shown on this chart.

4. There is no uniformity in the type of base map or projection used for magnetic charts because there is only a small variation over a wide area and, as a result, a very precise base map is not necessary.

G. Night Flying Charts

1. Special edition of Regional Charts with night flying chart printed on reverse side.

2. All detail lost to view incident to darkness is eliminated from these charts, and only those features of interest in night flying are shown.

3. Following data shown on charts: Major drainage, principal cities, radio aids to navigation, obstructions and beacon lights and airports at which all night operation of lighting facilities is assured.

4. Scale of chart is 1:1,000,000 at latitude 40°.

5. Mercator projections used.

H. Universal Plotting Chart

1. Partiallyconstructed blank Mercator chart for small areas. Has fixed latitude and distance scale, a compass rose, a longitude scale, and other useful data.

2. Scale of chart is 1 inch equals 16 nautical miles.

3. One chart may be used for any latitude and longitude and covers an area of 175 to 260 nautical miles.

4. The chart must be developed to accomodate the area involved.

I. World Outline Charts

1. Entire world to be covered by World Outline Charts; all charts not yet published, however.

2. Scale of series 1:5,000,000.

3. Lambert conformal conic projection used.

4. Chart size: 30" x 45".

J. World Long Range Air Navigation Charts

1. Entire world covered by this chart series; however, all charts are not yet published.

2. Scale of series 1:3,000,000.

3. Mercator projection used between 60° N. Latitude and 60° S. latitude. Lambert Conformal conic projection used between 60° and 80°. Stereograpnic projection used for polar caps north of 80° and south of 80°.

4. Chart size: 30" x 40".

5. Charts are printed with outstanding radio stations, marine and navigation lights, isogonic lines and compass roses, but do not include airports or anchorages.

K. Hydrographic Office Sectional Area Charts

1. West Indies, Mexico, Central America covered by this chart series.

2. Scale of series 1:1,000,000.

3. Mercator projection used.

4. Chart size: 35" x 50".

L. World Aeronautical Charts

1. Entire world covered by this series; however, all charts are not yet published.

2. Scale of series 1:1,000,000.

3. Lambert conformal conic projection used.

4. Chart size 22" x 29".

M. Africa Aeronautical Charts

1. Continent of Africa covered by chart series.

2. Scale of series 1:2,000,000.

3. Modified polyconic projection used.

4. Chart size 25" x 34".

N. European Aeronautical Charts

1. All of western Europe covered by chart series although not all charts have been published.

2. Scale of series 1:500,000.

3. Modified polyconic projection used.

4. Chart size 28" x 40".

5. Elevations are shown by a system of purple layering.

O. Pilot Charts

1. Small scale charts of the upper air, showing prevailing winds (average), the percentage of foggy days, and other data of interest to aviator.

P. Flight Charts

1. Courses of flights may be plotted directly on one of the charts listed above. Commonly sectional, regional, or universal plotting charts are used as bases.

III. REVISION OF CHARTS

A. Maps usually regarded as requiring relatively few changes. Charts are entirely different.

B. The thousands of miles of airways (about 25, 000 miles) are equipped with beacon lights, radio ranges, and other related features which may be changed quickly and this, therefore, obviously necessitates the revision of charts at relatively frequent intervals.

IV. INTERPRETATION OF AERONAUTICAL CHARTS

A. Colors

Shades of green and brown indicate elevations of relief.

0-1000	Green
1000-2000	Light green
2000-3000	Pale brown
3000-5000	Light brown
5000-7000	Medium brown
7000-9000	Deep brown
9000-up	Dark brown

B. Waterways

Streams, oceans, lakes, or seas indicated by blue.

C. Cultural features

Towns, cities, roads, railroads, and any other works of man are usually indicated in black.

1. Towns

Less than 1,000 indicated by black circle. 1000-5000 indicated by yellow square outlined by purple. Actual shapes of larger cities drawn to scale and outlined in purple.

2. Highways

Prominent highways indicated by heavy purple lines. Secondary highways indicated by lighter purple lines. Poor roads indicated by broken purple lines.

3. Railroads

Single track with single cross-ties. Cross-ties 5 miles apart.
Double track with double cross-ties.

4. Race-Tracks

Indicated by oval appearance. Form good landmarks.

5. Transmission Lines

Easily identified from the air and therefore serve as aids in the location of positions.
Indicated on map in red by "T's" (Poles) with lines (wire) between them.

D. Relief

Mountains, hills, valleys, and other inequalities shown either by colors or direct labels.

V. SUMMARY

CHARTS

1. How do charts differ from other forms of maps?

2. Complete the following table:

Type of Chart	Area Covered	Scale	Projection Used	Chief Use
Sectional	1/87 of U S	1:500,000	Lambert conformal	Pilotage
Regional	1/17 of U [illegible]	1:[illegible]	"	aerial nav long distances
Radio D F	1/6	1:2,000,000	"	Radio nav
Aero. Planning of U. S.	1	1:5,000,000	"	Planning long [illegible] accurate radio Bearing
Great Circle of U. S.	1	1:5,000,000	[illegible]	[illegible]
Isogonic of U. S.	1	1:750 000	any.	magnetic variation
Night Flying	1/17	1:1000.000	Mercator	night flying
Universal Plotting				
World Outline				
World Long Range Air Navigation				
H. O. Sectional Area				
World Aeronautical				
Africa Aeronautical				
European Aeronautical				
Pilot				
Flight				

3. What color tint on an aeronautical chart represents an altitude of 8000 feet?

4. On an aeronautical chart how would a town with a population of 2300 be represented?

5. Indicate the symbol for a single-track and a double-track railway on an aeronautical chart?

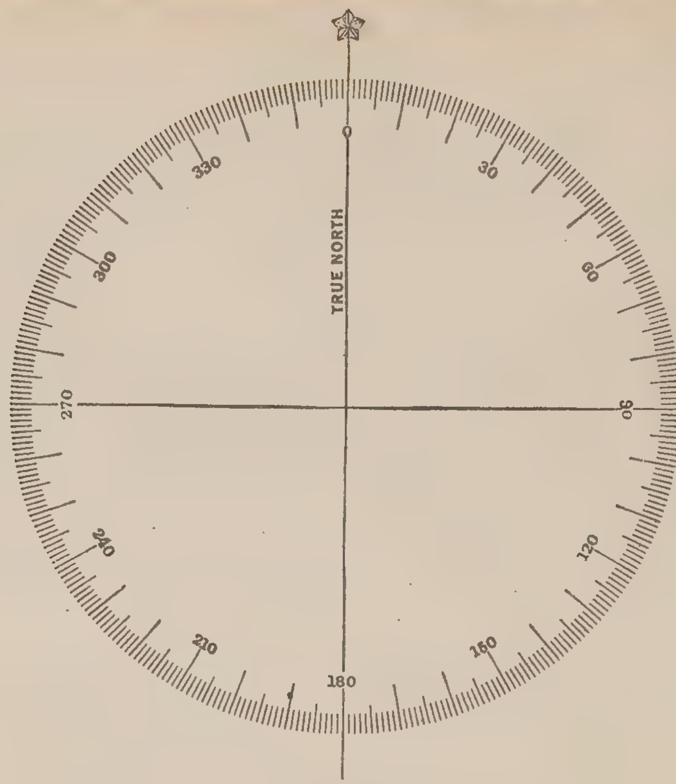


Fig. 60 TRUE COMPASS ROSE

Fig. 61 MAGNETIC COMPASS ROSE

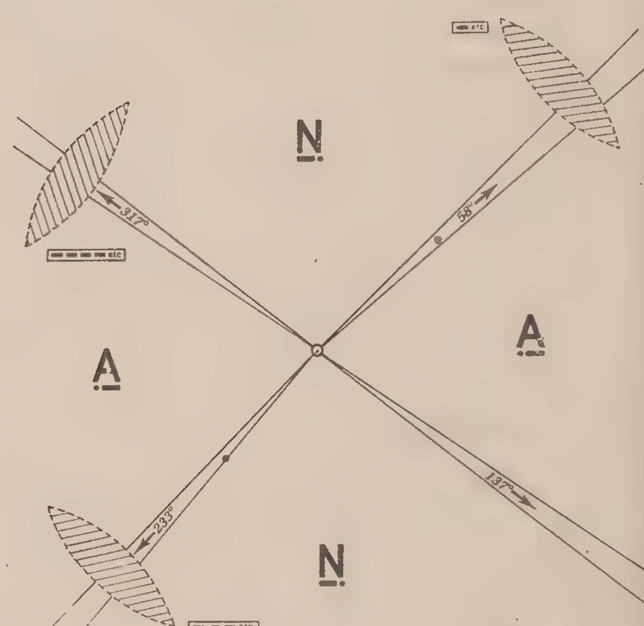


Fig. 62 RADIO RANGE AND FAN MARKERS

INTERPRETATION OF AERONAUTICAL CHARTS

AERONAUTICAL INFORMATION

A. Features shown in red

Airports
Beacon lights
Radio ranges
Radio identification signals

B. Kind of Airport

Whether army, commercial, municipal

C. Elevations of Airports

Shown in slanting numerals

D. LF adjacent to airport indicates that field is equipped with lighting facilities for landing at night

E. Beacons

1. Rotating beacons

   a. Arrows, if present, indicate that course lights are present at that station on the ground.

   b. Adjacent to beacon symbol are placed number of beacon and corresponding code signal which is flashed by the course lights for identification at night.

   c. Number of intermediate beacon or field is obtained by dropping final digit of mileage from origin of airway on which it is located.

   d. If airport is equipped with beacon light, proper beacon symbol is placed inside of airport symbol on chart.

   e. Landmark beacon, privately owned beacon, or commercially operated beacon makes 2 revolutions per minute instead of 6, as in the case of airway beacon.

F. Airspace Reservation

1. Designated by executive order.

2. Cannot be flown over at any altitude. Examples are White House and Capitol in Washington.

G. Danger Zones

1. Designated by Army and Navy, and should not be flown over at altitudes below 5,000 feet. Included are such areas as bombing ranges.

H. High Explosive Areas

1. Must be flown over only at altitudes such as to permit landing outside the area in case of complete power failure.

I. Marked Areas

1. Same symbol used on ground as on map for marking area.

J. Radio Data

1. Radio Stations

a. Call letters of station and frequency always indicated on chart.

b. Indications also made if the station is used in connection with radio direction finding (radio compass).

c. Magnetic courses to stations shown.

d. Weather broadcast schedules shown for many stations.

2. Radio Range (Refer to Figs. 59 and 62)

a. The beam alone is a highway as definite as a road on ground---and an even better guide because it broadcasts to tell one where it is. The government-operated radio range stations transmit radio beams in end-to-end succession along the nation's airways. Each range has 4 transmitting towers, which are located around the station, forming a five-spot design which can frequently be identified near airports.

b. Two towers transmit Morse code .— (dit-dah) for A; the other two transmit —. (dah-dit) for N. Like circular waves from pebbles in a pool, the radiating signals soon run into each other. Transmission is automatic, and so synchronized that the staccato dot-dashes and dash-dots mesh to form a steady buzz or constant tone. This is the "on course" signal and is not confused with either of the other two signals.

c. On the beam the A and N signal intensities are so nearly equal that the ear detects no difference. Along each side, however, in a narrow "twilight" zone, the pilot hears the steady "on course" plus a definite overtone of A or N. That is what he follows. By doing so, he "keeps well to the right of the road instead of wandering down the middle".

d. Periodically interspersed with each 12 A or N signals, the station call letters will be given. Thirty seconds are required for the transmission of the A or N signals and approximately 15 seconds for the transmission of the station call letters. Each complete cycle of signals therefore requires 45 seconds.

e. Over each radio station there is a cone of silence, at which point neither the A nor N signal will be received. Coincident with the cone and literally shooting up inside of it, an ultra-high frequency "Z marker" impulse lights a light on the instrument panel of the plane. Thus, the beam gives audible and visible check and double check of precise arrival over the station. This is desirable in night flying because it indicates that the plane is directly over the station.

f. Radio beams are transmitted for several hundreds of miles, but after extending for a distance of approximately 250 miles become too wide for practical use. At a distance of 100 miles from the station the beam has a width of about 5 miles. It is therefore desirable after planes have travelled this distance or less to follow another beam.

g. A and N sides of beams are marked on charts. A signals usually indicate east or west quadrants whereas N signals indicate north or south quadrants.

h. Radio Marker Beacons

Located at critical points along the radio range courses. Low power transmitters which emit a distinctive signal on the same frequency as that of the range on which they are located, and serve to inform the pilot of his progress along the route. Equipped for two-way voice communication and are prepared to furnish weather reports or other emergency information. In case the airplane is not equipped with a transmitter, if the pilot circles the marker beacon the operator will come on the air with the weather for that particular airway. The pilot indicates that he has received the information by a series of short blasts of his engine and proceeds on his way.

i. Fan Marker Beacons (Refer to Fig. 62)

Ultra-high frequency stations, 75 megacycles (75,000 kilocycles) and have no facilities for voice communication. One to four fan markers may be located around any given range station , usually at distances of about 20 miles. Markers around a given radio range station are identified by a succession of single dashes, or by groups of two, three, or four dashes. Single dash identification is always assigned to a course directed true north from a station, or to the first course in a clockwise direction therefrom; the groups of two, three, or four dashes are assigned respectively to the second, third, and fourth courses of the station, proceeding clockwise from true north. Used for purposes of location.

K. Isogonic Lines

1. Used for determining magnetic variation.

L. True Compass Rose (Refer to Fig. 60)

1. Oriented true north.

2. Can be used in absence of protractor for approximate measurements of courses and bearings. On some charts, corrections made for magnetic variation.

3. Because of convergence of meridians in Lambert projection, inaccuracy introduced if a compass rose is used for measurement of direction at a point more than 1° or 2° of longitude away.

M. Magnetic Compass Rose (Refer to Fig. 61)

1. Two sets of readings. One on inner and one on outer circle. Frequently reciprocal bearings are plotted, thus necessitating the two circles.

2. Readings are magnetic.

3. Usually used in connection with radio direction finding procedure.

N. Airways

1. "Garbo" system used.

2. G-A-R-B-O refers to Green, Amber, Red, Blue, and Off airways.

3. G-A-R-B-O also indicates the order of precedence of airways. When airways cross, the one first mentioned takes precedence over any which follow as indicated in 2 above. The aircraft in the airway which takes precedence does not have to change elevation whereas the aircraft in other airways must change altitude.

4. Direction of Airways

Green airways trend east-west (main transcontinental routes)
Amber airways trend north-south (main transcontinental routes)
Red airways trend east-west (shorter or subsidiary routes)
Blue airways trend north-south (shorter or subsidiary routes)
Off airways in directions other than main airways.

5. Altitudes

Northbound fly at altitudes measured in odd thousands of feet.

Eastbound fly at altitudes measured in odd thousands of feet.
Southbound fly at altitudes measured in even thousands of feet.
Westbound fly at altitudes measured in even thousands of feet.
Off airways: $0^\circ - 179^\circ$: odd + 500 feet
$180^\circ - 359^\circ$: even + 500 feet

INTERPRETATION OF AERONAUTICAL CHARTS

1. Assume that you are making a flight from Kelly Field to the Houston Airport. Use San Antonio Sectional Chart in answering questions.
   a. What is the magnetic bearing from Kelly to Houston? __________

   b. What is the airline distance? ________________ statute miles.
   c. What is the average magnetic variation along the course? ____________________________________
   d. What is the elevation of Kelly Field? ____________________ Of Houston Airport? ______________________________
   e. If direct course were flown, how many railroads would be crossed? ________________________________
   f. List in order the 'check points' (distinctive features, 20-40 miles apart, used in checking position along course) which could be used in making a 'contact' flight (one in which landmarks are used for reference rather than instruments) of the course outlined above.

   g. What kind of projection is used on this chart? ______________ .
   h. In flying this course, would you be flying a great circle route? ________________. A rhumb line route?______________________.
   i. If the Amber, Red, and Green airways were used, what would the distance be? ______________________________ statute miles.
   j. What are the identification letters of the San Antonio Radio Range Station? __________________ .

2. Determine as precisely as you can the difference in latitude and longitude between the San Antonio Radio Range Station and Houston Airport. Difference in latitude: ________________ . Difference in longitude: __________________ .

3. What is the significance to a pilot of the two dashes at Losoya fan marker on the intersection of the Amber and Red Airways south of San Antonio?

4. According to the color tinting on the San Antonio Sectional Chart, what is the highest possible elevation in the area covered by the chart? _____________ feet.

5. Why do pilots need true compass roses on sectional charts?

6. What is the approximate population of Yoakum, Texas, (In Red Airway number 32)? ____________________ .

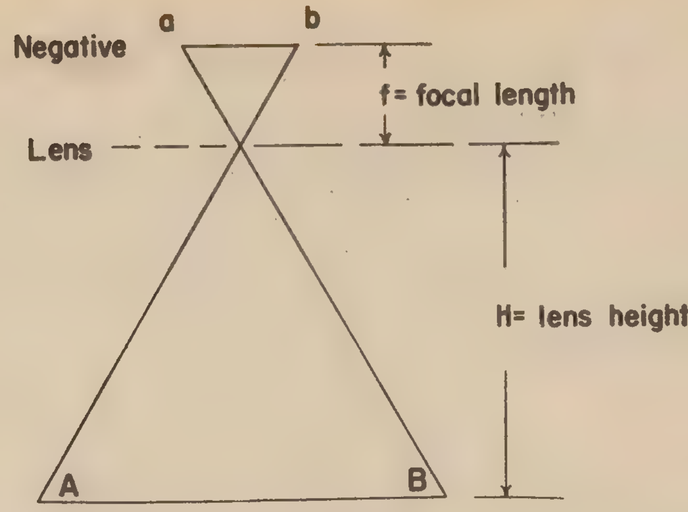


Fig. 63 COMPARISON OF FOCAL LENGTH AND CAMERA HEIGHT

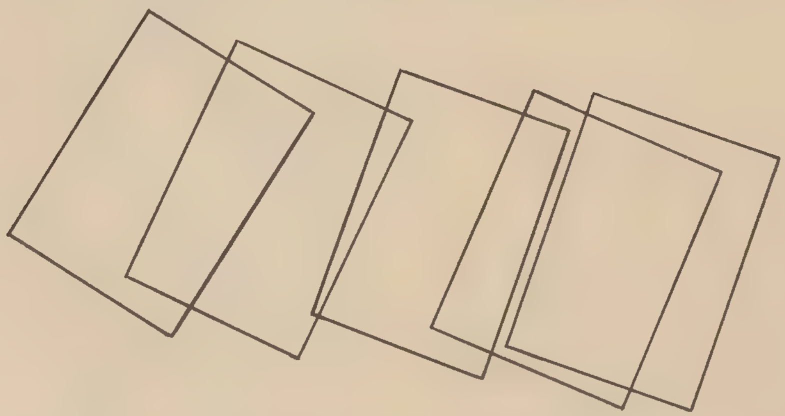


DIAGRAM OF PHOTO ARRANGEMENT

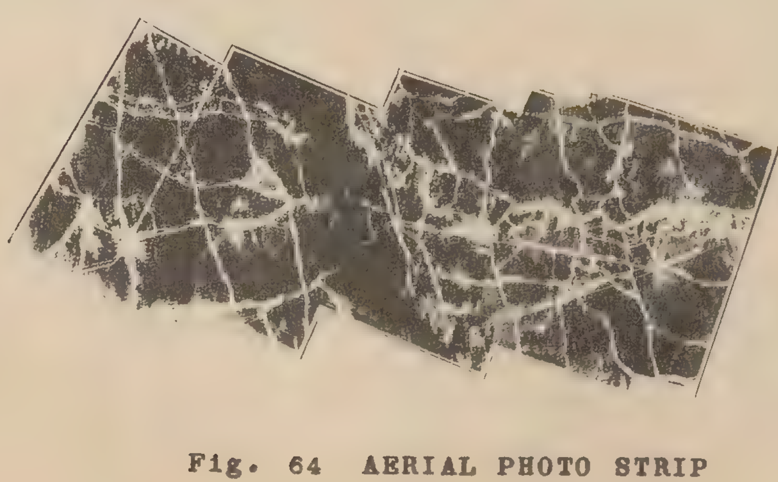


Fig. 64 AERIAL PHOTO STRIP

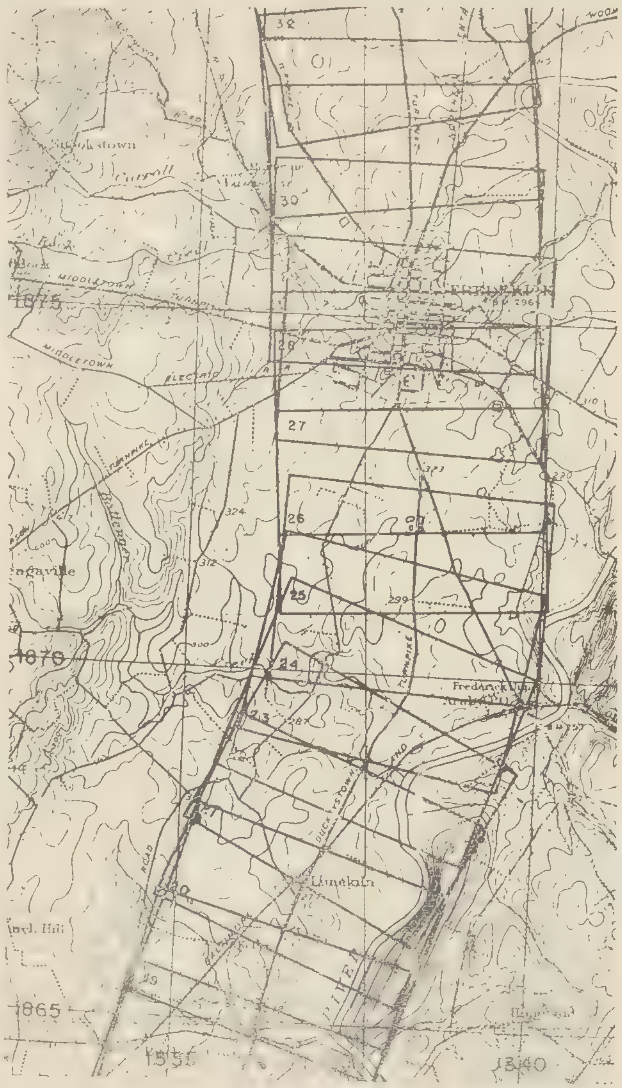


Fig. 65 AERIAL PHOTO STRIP PLOTTED ON MAP

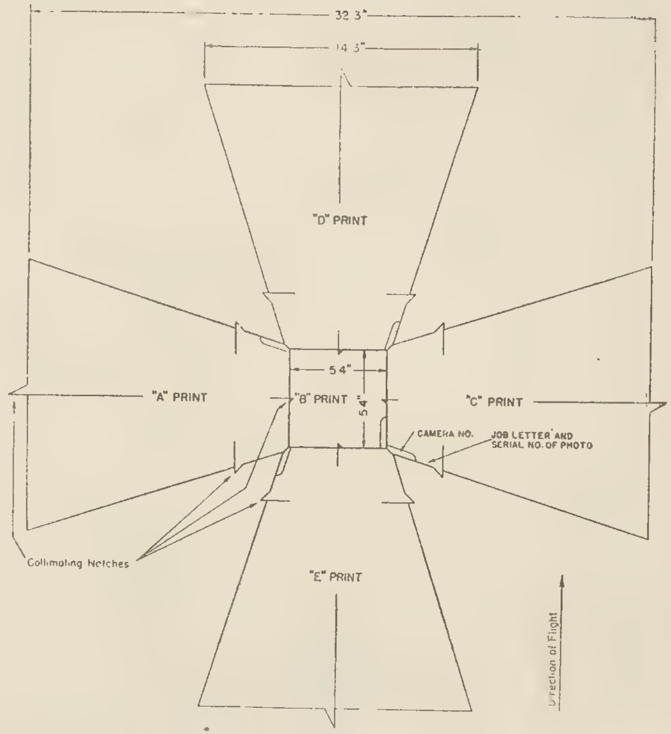


Fig. 66 DIAGRAM OF PHOTOGRAPH MADE WITH FIVE-LENS CAMERA

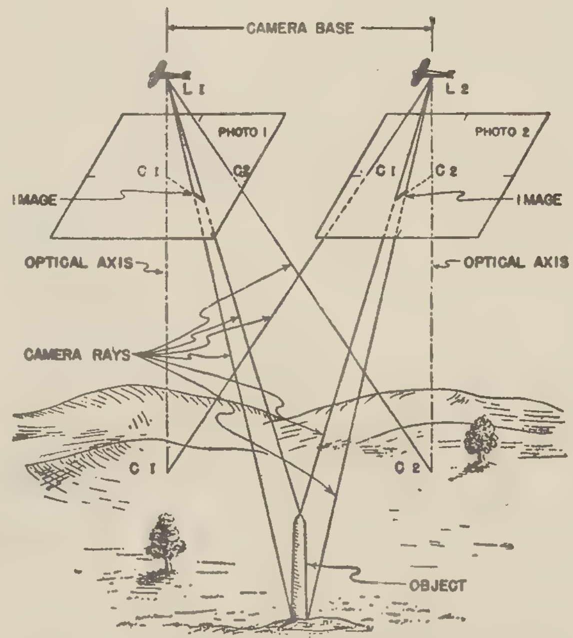


Fig. 67 POSITIONS IN TAKING STEREO-PAIR PHOTOGRAPHS

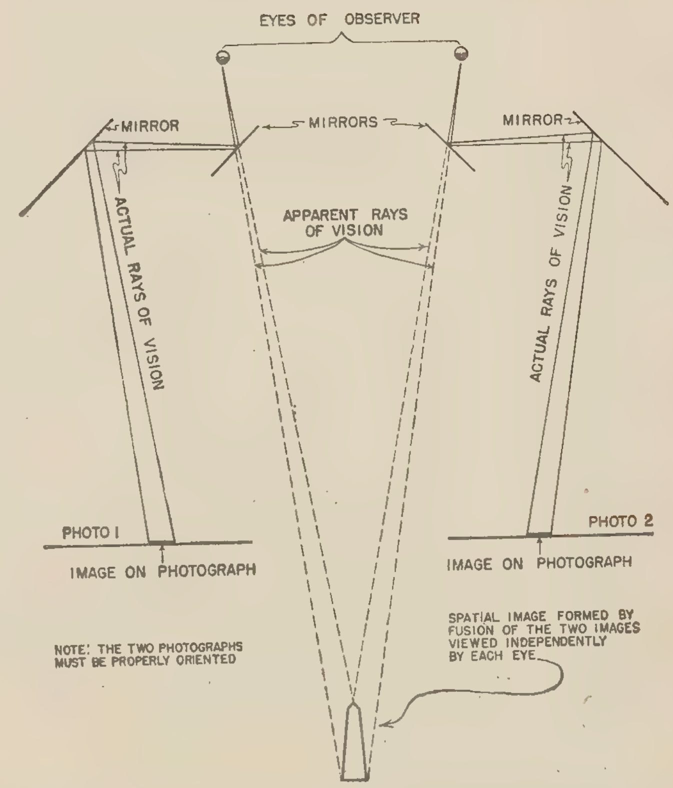


Fig. 68 METHOD IN STEREO PERCEPTION

Fig. 69 PHOTO GRID SYSTEM OF U.S.

INTRODUCTION TO STUDY OF AERIAL PHOTOGRAPHS

I. MILITARY HISTORY OF AERIAL PHOTOGRAPHY

A. Before World War I

1. Civil War: at least one photograph taken from a balloon.
2. Franco-Prussian War (1870-1871): photographs taken from balloons.

B. During World War I

1. Widely used by U. S.; schools were established in 1918 in U. S. and France.
2. Germans also developed Aerial Photo-interpretation.

C. Since 1939

1. Great Britain and Germany have concentrated on aerial photography and interpretation.
2. U. S. now emphasizing aerial photo interpretation.
3. Air Intelligence School at Harrisburg, Penn., chief school for this training.

II. IMPORTANCE OF AERIAL PHOTOGRAPHS

For military purposes, aerial photographs are frequently substituted for topographic maps. The type of map which engineers would construct as a result of months of field work, would in most zones of combat be neither available nor practicable. Aerial photographs have a number of advantages over the conventional topographic map.

A. They possess in pictorial form a wealth of detail which no map can equal.

B. They can be prepared in a short time by flying an area, taking pictures, developing, printing, and making a mosaic.

C. Because they can be prepared in a few hours, they are up to date, and in a combat zone, where conditions change rapidly, they show vital information which is not on any other type of map.

D. They can be made of any area, even those inaccessible to ground mapping parties.

E. In combat areas, where high flying speeds are necessary, aerial photographs are an essential supplement to the observation of features and their relative positions.

F. They are essential to camouflage experts, who from scrutiny of aerial photographs can detect hidden installations and objectives which cannot be observed by any other method.

G. By flying at high altitudes it is possible to cover a large area in a photograph and then by a process of enlarging the relatively small original it is possible to obtain a map with a usable size and scale.

H. Prerequisite to successful bombing missions. Needed in the planning of missions, determining types and priority of targets, by bomber crews in locating objectives, and in determining results of bombing.

I. Aerial photographs serve as a source of military intelligence. Over 80% of intelligence information comes from this source. Other information comes from radio interception, questioning of prisoners, neutral observers, enemy newspapers, and spies.

III. TYPES

A. Basic Types

1. Vertical (Refer to Aerial Photograph Supplement)

a. Taken from bottom of plane with axis of camera perpendicular to the earth.

b. Best form of aerial photograph for construction of maps because center of picture is accurate even though the edges are slightly distorted.

c. Type of photograph used in making mosaics.

d. Camera is operated automatically so that there is a 60% overlap of pictures which is necessary for accurate work.

2. Oblique

a. Taken with axis of camera deliberately tipped from the perpendicular position.

(1) High Oblique--includes horizon. (Has nothing to do with altitude of plane or camera) (Plates 14, 15, in Aerial Photograph Supplement)

(2) Low Oblique--does not include horizon. (Plates 16, 17, in Aerial Photograph Supplement)

b. In combat zones it is desirable to get pictures of as wide an area as possible in one flight, and under such conditions the three-fold arrangement of cameras from the bottom of the observation plane is adopted.

c. The chief advantage of oblique photographs is that because of the tilting of the camera a larger area can be covered.

d. The chief disadvantage of oblique photographs is that a constant scale cannot be used for the entire map because objects in the background will appear small because of their distance, whereas in the foreground, because of the proximity to the camera, objects will appear relatively larger.

. Special Arrangements of Aerial Photographs

1. Reconnaissance Strip (Refer to Figs. 64 and 65 and Plate 38 in Aerial Photograph Supplement)

   a. Definition

      A series of overlapping photographs made from an aircraft flying a selected course.

   b. Preparation of strip

      Strip fitted together by trimming off edges to eliminate distorted portion. This process removes 15% to 20% of photograph. Photographs overlap each other 60%.

2. Mosaic (Refer to Plate 4, Aerial Photograph Supplement)

   a. Definition

      Made by joining photographs taken at different camera positions.

   b. Individual photographs overlap 60% longitudinally and 30% laterally.

3. Composite (Refer to Fig. 66)

   a. Definition

      Made with camera having one principal lens and two or more adjacent oblique lenses.

   b. Resulting photographs are transformed in printing so as to permit assembly as verticals with the same scale. Result is one large photograph of a large expanse of terrain.

   c. Special T-3A camera used by Air Corps has one central chamber and 4 peripheral chambers, the 4 lateral chambers inclined at an angle.

   d. Transforming printer changes obliques to plane of vertical and result of exposure at 20,000 feet is picture of an area 20 x 20 miles.

4. Photomap

   a. Definition

      A single photograph, a composite, or a mosaic, which is reproduced usually by lithography after the addition of marginal data, scales, and other desired data.

   b. Photomaps may be reproduced in various colors; however, usually they are reproduced in brown, green, or black. Brown prints make very satisfactory field maps because it is possible to make corrections and notes on them. The dull finish of the lithoprints permits writing on them.

   c. They are used both in connection with and in lieu of other maps.

   d. They are made quickly and can be reproduced in great quantities at very low cost.

   e. Photomaps are particularly desirable because the method of reproduction used permits reproduction without change in scale or loss of detail. Photomaps differ from other maps in that objects are shown in true form instead of conventional signs and symbols.

5. Pinpoint

   a. Definition

      A pinpoint is a photograph taken for the purpose of studying a particular object which is centered in the photograph.

   b. When taken from high altitudes, large areas are covered, because of the small scale.

6. Stereo-pair (Refer to Figs. 67 and 68)

   a. Two consecutive and adjacent vertical pinpoints taken from same altitude, but from two different camera positions, with overlap of 60% to 75%.

   b. Primarily for study by intelligence officer.

   c. Used in study of relief or any object on which the 3 dimensional effect would be of benefit.

IV. MARGINAL DATA

A. Purpose

An aid in reading and using photograph.

B. Location

On photograph near lower margin.

C. Style

1. Varies within U. S. Army and in RAF.

2. In some instances representative fraction is given; whereas, in other instances the focal length of camera and altitude are given.

3. Localities are actually lettered on some photographs while on others military grid coordinates are given and still others utilize photo grid coordinates.

D. Interpretation of Marginal Data (Refer to Plates 3,4,5,6,7,9, 17, 36, in Aerial Photograph Supplement)

1. Arrow approximately 1/2 inch in length in lower left corner of photo points north. Arrows not present on all photographs.

2. Name of locality or nearest locality may be given.

3. Serial number is given for purpose of filing. Photographs are filed under type under which they are classified such as vertical, oblique, mosaic. Photographs are numbered consecutively under each of the various types.

4. Approximate grid coordinates of center of photograph. Some organizations use military grid coordinates; others use photo grid coordinates. The photo grid system of the United States consists of 905 one-degree quadrangles each of which is further divided into 16 fifteen minute quadrangle. The one-degree quadrangles are numbered consecutively, from north to south, across the nation forming north-south strips. These strips are in successive order across the nation from west to east. The fifteen-minute quadrangles are arranged in the same manner, but are designated by letters ranging from A to P. (Refer to Fig. 69)

5. Date. Usually given in following form: 12-25-42.

6. Hour. Practice varies in the recording of the time on photographs in that some use the 24 hour clock and others refer to hour as being A.M. or P.M. In any event, the exact time when the photograph was made is given.

7. Scale or focal length of camera and altitude are given or the RF (representative fraction) will be given.

8. Squadron or organization flying the mission is designated by numerals.

9. M B in the marginal data refers to "minus blue" filter used in photography to eliminate the effect of haze caused by water vapor.

V. ORIENTATION OF PHOTOGRAPHS

A. By comparison with other maps already made.

B. By checking on well defined landmarks on the ground.

C. By use of shadows:

1. Hours 1000 to 1400 are the ones utilized in taking most of the photographs.

2. From hours 1000 to 1200 the shadows will be slightly west of north in the northern hemisphere and west of south in the southern hemisphere; between hours 1200 and 1400 the shadows will be slightly east of north or south, according to the hemisphere. If taken before 1000 or after 1400 hour, the shadows will fall west or east of north or south correspondingly greater distances.

VI. SCALE (Refer to Fig. 63)

A. Scale is computed in the following way:

$$\frac{\text{focal length}}{\text{lens height}} = \frac{\text{distance on photograph}}{\text{distance on ground}} = \text{RF}$$

Example:

A 12-inch focal length at 3000 feet equals $\frac{\text{12 inches}}{\text{3000 feet}}$ or

$\frac{\text{1 foot}}{\text{3000 feet}}$ or RF of $\frac{1}{3000}$ which may also be written 1:3000.

VII. SUMMARY

INTRODUCTION TO THE STUDY OF AERIAL PHOTOGRAPHS

1. Why are aerial photographs of particular importance to pilots?

2. What are the advantages of vertical photographs as opposed to obliques?

3. What are the advantages of obliques as opposed to verticals?

4. Are obliques or verticals of most value in determining exact locations of objects?

5. Why are vertical photographs taken with a large (60%) overlap?

6. What is a 'reconnaissance strip'? Under what conditions are reconnaissance strips taken?

7. What is the advantage of mosaics as compared to pin points?

8. How are photomaps distinguished from other maps?

9. What is the difference between photographic prints and photomaps?

10. Why are many photomaps printed in brown?

11. How do photo grid coordinates differ from the military grid coordinates?

12. How may shadows be used in orienting a photograph?

13. (a) Compute the scale of Plate 74, Aerial Photograph Supplement.
    (b) What is the length (in feet) of the longest Jap ship? Do not include the wake of the ship in the calculation.

USE AND INTERPRETATION OF AERIAL PHOTOGRAPHS

I. HOW TO HOLD AERIAL PHOTOGRAPHS

A. Rule 1: Always hold a vertical photograph so that the shadows are toward the observer. This simulates lighting conditions existing at the time the photograph was taken. If held otherwise high ground appears to be low ground and low ground appears to be high. Note the shadow of the bridge in Plate 8, Aerial Photograph Supplement. Orient the picture so that the shadow of the bridge is away from you – then reorient the picture so that the shadow falls toward you and note how much better the details of the bridge are observed.

B. Rule 2: Always hold an oblique photograph in normal position (as camera viewed it).

II. CALCULATION OF SIZE OF BUILDINGS OR OTHER OBJECTS

A. Dimensions

1. Length and width

   If the dimensions of any object on the photo is known, the length and width of other objects shown can be calculated.

2. Height

   If the height of any object on the photograph is known, the height of other objects may be calculated by comparing the length of the shadows.

3. Example

   In Plate 23, Aerial Photograph Supplement, if the size of any of the planes, buildings, or cars is known, the sizes of others may be calculated by comparison. If the height of the water tower near the center of the picture is known, or can be closely estimated, the height of other objects may be determined by comparison of the shadows.

III. INTERPRETATION OF AERIAL PHOTOGRAPHS

A. Difficulty of Interpretation

1. Requires skill and practice.

2. Frequently dissimilar objects, such as roads, railroads, and canals which normally appear differently on maps may look alike on aerial photographs, thus causing confusion to the inexperienced observer.

3. Difficult to distinguish the character of some objects on vertical views because of absence of perspective.

B. Purposes of Interpretation

1. As a map

Photographs are detailed representations of the terrain as it appears at a particular time. Many areas of the world are inadequately mapped. Photographs serve as maps or give up-to-date information that can be applied to existing maps. Accurate mapping may be done by aerial photography if sufficient time is available. (Refer to Plate 4, Aerial Photograph Supplement)

2. In planning bombardment missions

Bombing attacks are generally planned by aid of aerial photography. Objectives are selected and located on aerial photographs. (Refer to Plate 64, in Aerial Photograph Supplement)

3. In damage assessment

Damage caused by aerial bombardment is estimated from aerial photographs taken during and after the attack. (Refer to Plate 64, Aerial Photograph Supplement)

4. Engineering planning

In planning engineering operations that will be required in territory held by the enemy, but over which an advance is planned, study of aerial photographs is essential.

5. In landing operations

Aerial photographs of beaches and the adjacent terrain made prior to a landing are of great value. (Refer to Plate 38, Aerial Photograph Supplement)

6. Detection of camouflage

This subject will be discussed in the seventeenth hour.

IV. PRINCIPLES OF IDENTIFICATION

A. Shape

In oblique photographs objects appear as we are accustomed to seeing them. In vertical photographs objects appear in only two dimensions and are difficult to identify. (Refer to plates 3, 4, Aerial Photograph Supplement)

B. Relative Size

Relative size of objects aids in interpretation of photographs. A truck on a road, a box-car, a residential house, or other familiar objects aid in estimating size of unfamiliar objects.

C. Tone

1. Definition

Tone is the shade of gray by which an object is represented. The tone is due to the amount of light reflected. The more light that is reflected, the whiter the object appears on the photograph.

2. Explanation

a. A smooth surface is a good reflector of light and appears white when the camera is in a position to catch the reflected rays of the sun. If light is not reflected to the camera, a smooth surface will appear dark. Smooth water will be dark on some photographs and light on others.

b. The majority of natural surfaces reflect light in all directions and appear intermediate in tone.

c. Any change in the texture of a portion of an object is evident on an aerial photograph through a resulting difference in tone when compared to other portions. Thus the trampling of grass in a field by walking across it alters the reflection of light and registers a difference in tone on a photograph. (Note how easily paths and trails may be seen on Plates 2, 7, 26, 33, Aerial Photograph Supplement)

D. Shadow

1. Importance

The interpretation of shadow is of exceptional importance on aerial photographs.

a. Shape. The shape of an object is often easier to obtain from the shadow it casts than by either the image or tone. This is because vertical dimensions shown by shadow may be more characteristic than the horizontal dimensions and tone may blend into the surrounding landscape.

b. Shadow may be the index to valuable military information, such as approximate height of towers and buildings, the number of spans and type of bridge, the depth of cuts, the height of vertical cliffs, the. The photograph must be held so that the shadows fall toward the observer.

c. Examples (Refer to Aerial Photograph Supplement) Note how easily the water towers may be seen and identified by studying the shadows on Plate 4 (6.0-G.0), Plate 5 (left side of photo); Plate 29, (4.1-C.2); note how information may be obtained concerning the bridges on Plate 7 (7.9-D.6) and Plate 8 by studying the shadows.

V. EFFECTS OF SEASONS

Seasonal changes produce corresponding characteristic changes in the physical appearance of terrain on aerial photographs.

A. Summer

1. In summer deciduous forests show great matted expanses of treetops, hiding the detail of the terrain. The line of demarkation between forests and open areas is sharply defined.

2. Appearance of grass and farm land changes with the seasons.

B. Winter

1. Vegetation. Deciduous forests shed the leaves and light penetrates to reveal roads, trails, drainage, and relief, with good effect.

2. Line of demarkation between forest and open areas not so clearly shown.

3. Snow

a. Snow may completely blanket an area and cover the detail.

b. Snow reflects little light as compared to chalk or sand.

c. Details that show up in the snow.

(1) Tracks.

(2) Discolorations such as blasts caused by gunfire.

(3) Shadows of objects like planes show up well.

(4) Fences and barbed wire entanglements usually show up in snow as band of gray.

VI. TOPOGRAPHICAL FEATURES

A. Relief

Single vertical photographs afford only a few clues in regard to relief. Such clues are streams and ponds which indicate low ground. High ground casts shadows on slopes and low areas but these shadows may be very misleading unless care is used in interpretation. Direct evidence of relief may be obtained by stereo examination of overlapping pairs of photos. (Refer to Aerial Photograph Supplement, Plates 26 and 27.)

B. Natural and Man-made Features

1. Natural features appear as irregular lines without precision of form.

2. Man-made features can be distinguished usually by the straight lines, geometric forms, and unnatural regularity. (Refer to Aerial Photograph Supplement, Plates 9, 18, 26.)

3. Villages and towns are easily distinguished and appear about the same as they do on maps.

4. Trails and paths appear as irregular white bands, lightness and width indicating degree of use. (Refer to Aerial Photograph Supplement, Plates 10, 26, 77.)

5. Trenches are readily distinguished by their traversed or zigzag trace revealed by shadows of the trench walls or by spoils. Shadows indicate depth. Shallow, dummy, or incomplete trenches cast little shadow.

6. Organized shell holes will generally be in pairs, constructed in well drained ground, and be connected by underground passages. Such shell holes are not difficult to distinguish from ordinary shell holes.

7. Other military features may ordinarily be recognized by their characteristic shape and arrangement.

C. Vegetation

1. Coniferous forests show up much the same in both winter and summer. Deciduous forests show up as dark masses in the summer that shut out all detail below. In the winter some detail of the ground below may be seen through the trees.

2. Nurseries are sometimes taken for ammunition dumps as they usually appear as a series of rectangular beds surrounded by paths.

3. Brush appears similar to light woods but may be distinguished by sparseness and lack of height.

4. Orchards may be distinguished by the regularity and arrangement of the trees. (Refer to Aerial Photograph Supplement, Plate 32.)

5. Farm crops difficult to distinguish on small scale photographs.

6. Pasture land shows up as medium tone with considerable yellow that gives mottled appearance on photograph. Variations in tone will indicate relief by showing up drainage and moisture. Such fields may be used as landing fields. (Refer to Aerial Photograph Supplement, Plate 5.)

D. Water

1. Bodies of water

Show up as darker or lighter than surrounding land depending on amount of reflection.

2. Streams

a. Presence shows up by dark or light irregular lines. (Refer to Aerial Photograph Supplement, Plates 9, 56.)

b. In arid or semi-arid climates streams show up by the linesof vegetation along them.

c. Mud flats along streams ordinarily look darker than water and may have light spots due to pools of water.

3. Factors affecting light reflection on water

a. Still water is normally dark but if sunlight is directly reflected the water may show up as light or blurred.

b. Wind on water gives a lighter effect and the ripples ordinarily show up.

c. Muddy water is lighter than clear water under ordinary conditions. This is very noticeable in estuaries and may give evidence as to whether tide is coming in or going out.

d. Oil on water gives a lighter tone than usual.

E. Buildings

1. Show up as indistinct roof images but can generally be definitely distinguished by shadows.

VII. SUMMARY

USE AND INTERPRETATION OF AERIAL PHOTOGRAPHS

1. Why is it important to hold vertical aerial photographs with the shadows toward the observer?

2. On Plate 28 (Aerial Photograph Supplement) locate the B-17. The wing spread of a B-17 is 103 feet and 10 inches. Using this scale determine the greatest length of the pool at 3.1-F.O.

3. The Bremen is 898 feet long and has a beam 102 feet. The Europa is 890 feet long and has a beam of 102 feet. With this information calculate the RF scale on Plate 62.

4. Plan a bombing attack on the area shown in Plate 65. What specific points would you select as primary objectives?

5. Why will a road or trail often show a lighter tone on an aerial photograph than a field of yellow grass?

6. Quiet bodies of water usually appear inky black on aerial photographs, but sometimes water is lighter and may be almost white. Explain why water shows up in different tones.

7. Orient Plate 8 (Aerial Photograph Supplement) with the shadows away from you. (a) Does the railroad west of the bridge appear to run in a cut or on a fill? (b) Now orient the photograph with the shadows toward you and check your conclusion.

8. Draw a rectangle about 4 inches long and 3 1/2 inches high to represent the area shown in Plate 38. Sketch in the streams and tributaries.

INTERPRETATION OF AERIAL PHOTOGRAPHS

ANALYSIS OF PHOTOGRAPHS

This hour will be spent in analyzing various photographs in the Aerial Photograph Supplement with especial emphasis on the recognition and interpretation of features discussed in the fourteenth and fifteenth hours.

A. Photographs of General Interest

1. Plate 2, Pin Point

   a. This is a high altitude photograph with the main objective centered in the picture. Scale would be correct for the central part of the picture but the scale would be distorted at the outer edges.

2. Plate 4, Mosaic

   a. Marginal data - analysis

   V indicates the picture is a vertical view. The photograph is really a mosaic and the V should be replaced by M. 70 indicates that it is the seventieth vertical picture filed for coordinates 467K. 467K are photo grid coordinates and indicate the location of the center of the photograph. 53 is a number assigned to the organization that took the picture. 9-4-42 indicates the date on which the picture was made. 1545 indicates the hour at which the picture was made. 12-10,000 indicates that the picture was made with a 12-inch lens at 10,000 feet. This gives a RF of 1:10,000 or 10, 000 inches on the ground equals one inch on the photo. Note that the word 'restricted' appears on the photograph because the area involved is a military objective and therefore photographs of the area are classified as restricted and for official use only.

   b. Orientation

   The picture may be oriented by the shadow cast by the water tower (6.0-G.1). The picture was taken at 1545 and the shadow points east of north.

   c. Mosaic

   This picture is obviously a mosaic made up of the central part of several separate pictures to give a uniform scale and minimum distortion. Note the difference in intensity of cloud shadow where two prints have been joined in the upper right hand corner. The sharp break in the shadow at 8.2-D.0 and the difference in tone in the lower left corner are also evidences of separate photographs having been joined.

d. Highways and building area

The exact location of all roads, trails, and highways, and the size, shape, and distribution of buildings may be easily determined from the photograph.

e. Automobiles

Note the appearance of cars parked along the roads and in the parking lots in various parts of the picture.

f. Cultivated fields

In the lower left corner of the photograph, several plowed fields are discernible.

3. Plate 3, Oblique

a. Marginal data

The data may be interpreted in the same way that it was in plate 1. Note that the O stands for Oblique.

b. Cloud and cloud shadows

In the upper right portion of the picture is a misty cloud that casts a dark shadow on the ground.

c. Building area

It should be noted that the obliques give a better conception of perspectives than do vertical pictures. This is true of buildings as well as many of the other cultural features and even of topographic features.

d. Drainage

The main stream of the area may be seen in the left central portion of the photograph and in addition several of the tributaries may be seen in the lower left part of the picture.

e. Perspective

Note that this photograph represents a single exposure by the camera. In the background objects become smaller than those in the foreground. This is true, for example, of the buildings which appear to be quite different in size in the foreground and background. This means that the scale on the photograph would vary over the picture, whereas on a mosaic such as shown in Plate 4, a uniform scale may be used. On Plate 4, all buildings over the entire field are the same scale on the photograph. This demonstrates the uniformity of scales for vertical views, and the characteristic of perspective for oblique view.

4. Plate 33, Vertical

a. Label

Note the north arrow which precedes the label line on the bottom of the photograph. This is a vertical view, apparently the 541st vertical picture of an area, the center of which has coordinates 444J. The numeral 1 after the J indicates that it was taken by the First Photo Section, U.S. Army (located at Brooks Field). The picture was taken on November 5, 1936, at noon with a 12-inch cone from an elevation of 7,000 feet.

b. Race Tracks

You have been told earlier in this course that race tracks are easily seen from the air and form unmistakable features. On this photograph two race tracks may be seen, one near the lower margin in the center and the other near the central part of the photograph. Note that even though the old track has been abandoned it is still distinguishable. Note also that there is a white circle which indicates that a landing field is present.

c. Fences

Along central right margin note the position of fences as indicated by relatively straight lines along which no vegetation appears.

d. Trails

Along central left margin notice dim lines indicating positions of roads or trails.

e. Waterways

The position of the main waterway may be seen extending from the central upper margin on the map across the west central portion to the bottom. Note that water appears dark on the photograph.

5. Plate 18, Vertical

a. Drainage

This photograph demonstrates the appearance of streams and their tributaries, typifying the branching pattern which may be found on many aerial photographs. Notice that the areas between the streams are flat, and that roads are found, not along the streams, but on the uplands. (Refer to Plate 17, an oblique showing divides and deep valleys.)

b. Cultural features

Notice the scarcity of the cultural features on this photograph. They consist of roads, one group of houses, and a few fences, which you will be able to find as a result of changes in vegatation along the fence lines. This vegetation change results from differences in amount of grazing on the sides of fences.

6. Plate 32, Oblique

a. Label

This is an oblique picture, the second exposure made in the series, of an area the center of which has the grid coordinates 470-0. The picture was taken on August 20, 1942, at hour 1840, or 6:40 p.m., from an altitude of 3,000 feet. A 12-inch cone was used in taking the picture.

b. Perspective

Because this is an oblique photograph, perspective is again well demonstrated. In the background, the sections of land appear much smaller than in the foreground as a result of the change in the distance. Notice also that the highway which begins in the central portion of the bottom margin and extends to the right, exhibits the characteristic of perspective in that the road appears to be narrower to the right.

c. Orange groves

One outstanding characteristic of the photograph is the presence of regularly spaced trees which are in reality orange groves. This demonstrates the ease with which orchards may be detected from aerial photographs. Note along the road, approximately 1-1/2 inches above the lower left corner, that palm trees line both sides of the road. The fact that these are palm trees is easily detected from this view; however, it would be difficult to make this observation had the picture been a vertical view instead of an oblique picture.

d. Irrigation ditches

Extending from left to right across the photograph are several irrigation ditches which are lined by thick vegetation. Note the sinuous or winding character of these ditches.

e. Cultivated fields

Those fields which are in cultivation are easily deteced because of the absence of woody vegetation on them.

f. Airport

An examination of the airport area reveals the presence of runways, wind indicator, sheds to protect planes, the air depot and other buildings connected with the airport. One plane may be seen on the field, and another may be seen partially obscured by the improvised hangar.

g. Orientation

Notice that there is no north line indicated on the photograph. It is possible, however, by observing the directions of the shadows and by knowing the time of day when the photograph was taken to orient the picture exactly. For example, observe the shadows of the trees in the lower left part of the photograph. It is obvious that the shadows are long. This would be caused by the taking of the pictures either early in the morning or late in the afternoon. As we know that the picture was taken at 1840, it is obvious that the shadows would be to the east or slightly north of east. The main highway, which extends across the lower left corner of the photograph, apparently extends north-south with the north end toward the bottom of the picture.

7. Plate 10, Mosaic

a. Label

This is a vertical view of an area which has as its center grid coordinates 304E. The photograph was made by the First Photo Section, U.S. Army, at one P.M. on February 22, 1929. The picture was made with a 12-inch focal length from an altitude of 5,600 feet.

b. Matching of pictures in mosaic

This picture is obviously a mosaic or a composite which is made up of several photographs which have been matched and later photographed as a unit. The lines along which the pictures were matched can be found easily. Two of them are very prominent and extend from the top to the bottom of the photograph. It seems as if only portions of three pictures were used in making this mosaic. As a result, it was not possible to match the pictures exactly because of distortion along the edges. In order to have obtained perfect matching, from one photograph to another, only the central portions of each photograph should have been used. It is customary to use only the central 40% of the photographs, as has been explained previously. Distortion usually shows up as offsets in streams, roads, fences or other lines which appear on more than one photograph of the mosaic.

c. Highways

The main highways are black on the photograph, because they are paved roads and are covered with asphalt. The unpaved roads appear lighter in color, as may be noticed in the hospital area.

d. Drainage

Along the entire lower portion of the photograph may be seen several streams which appear to be braided or interlaced. The smaller tributaries of the main stream begin toward the left of the picture and enter the larger tributaries as they flow to the right, indicating that the main stream flows from left to right. The main stream appears to grow larger toward the right of the picture because of its width on the photograph. This is another indication that the stream is flowing to the right and not to the left.

e. Orientation

Because the picture was taken at 1:00 P.M., the shadows formed by tall objects would appear to the north of the objects themselves. Thus, by examining the shadows of the tanks which are found in the left central portion of the photograph it is possible to orient the picture approximately.

f. Vegetation

It is significant that no part of the area involved in this photograph is under cultivation. It is equally interesting to note that, even though the region is not cultivated, there still seems to be little vegetation present, even along the streams. This would indicate that the photograph was taken in an area which has an arid climate because it is normal in humid climates for the banks of the streams to be heavily wooded, even though the streams may be intermittent.

B. Photographs to Illustrate Special Features

1. Plate 19, Night Photo

   a. Night pictures are possible at reasonably low altitudes.

   b. The lighting is obtained by dropping magnesium flash bombs.

   c. The night photos have the element of surprise, and thus often obtain valuable information that might be hidden in the daytime.

2. Heavy Industry Photographs

   a. Plate 13, Railroad yard and terminal facilities

(1) Can be identified by the shape of the buildings and the maze of tracks.

(2) The round house turntable may be easily identified at 3.6--C.9 and would be a primary target. If the turntable were put out of commission, it would seriously cripple these yards.

(3) Note the number of freight cars present as an indication of the activity of the yard.

3. Aircraft and Airdromes

a. Plate 34, Templehof Airdrome, Berlin.

(1) Note evidences of bomb damage in the vicinity of this airdrome.

(2) Note the 'T' shaped blast shelters. These have been built to simulate a small house project.

4. Marine Interpretation

a. Plate 70, Harbor of La Havre, France.

(1) Note the bombs bursting on the ships. This picture gives an opportunity for interpretation of installations and identification of ships.

5. Damage Appraisals

a. Plate 64

(1) This picture is a good illustration of the value of aerial photographs in selecting a bombing target and in appraising the damage after the attack.

b. Plate 61. Damaged Heinkel Factory in Germany.

(1) This is a good picture to illustrate damage assessments from bombing. Each building must be considered separately. From a study of this photograph, a skilled interpreter can make a very accurate estimate of the amount of damage to the plant.

II. SUMMARY

INTERPRETATION OF AERIAL PHOTOGRAPHS

1. On Plate 4, Aerial Photograph Supplement, the RF is 1/10,000. Plate 2 is a pin point of the same area but the focal length of the camera and the height are not given. Measure between two established points on Plate 4 and the same two points on Plate 2 and calculate the RF of Plate 2.

2. Plate 4. What is the airline distance between the center of the water tower (6.0-G.0) and the center of the street intersection on the northwest corner of the main parade ground (2.5-D.7).

3. Plate 4. How may the hospital area (vicinity of 1.5-E.5 and 1.5-G.0) be distinguished from the other building areas?

4. Plate 4. Using the time of day at which the picture was taken, and the direction of shadows cast by buildings and the water tower (6.0-G.0), determine the bearing of a point on the main road at (5.0-D.3) measured from another point along the main road at (0.5-D.3).

5. How many radio towers are there at the station, in the area of 0.5-E.0 on Plate 4?

INTERPRETATION OF AERIAL PHOTOGRAPHS AND CAMOUFLAGE

INTRODUCTION

A. Definition of Camouflage

1. Any and every means of hiding or disguising a military installation from the enemy and misleading and confusing him as to its true character.

B. History

1. Camouflage made necessary by the development of the airplane and the desire to conceal military installations from the eyes of the observer and the camera.

C. Purpose

1. Conceal new installations and delay recognition by photograph interpreter.

2. Confuse the pilot and bombardier by:

    a. Delaying recognition of the target.

    b. Preventing precision bombing.

D. Success of Camouflage

1. Easier to deceive the human eye than the camera lens, thus easier to confuse the observer than the photograph interpreter.

2. Pilots often find it difficult to locate their own highly camouflaged bases when returning from a mission and have to be guided in by radio.

3. The photograph interpreter, with magnifying lens and stereoscope, can spot camouflage with comparative ease.

METHODS OF CAMOUFLAGE

A. Concealment

1. Completely concealing an object by constructing overhead cover or lateral screening.

2. Examples

    a. Concealing aircraft

        (1) Under trees

        (2) In tents covered by foliage

        (3) Under elaborate structures of netting

b. Burial

(1) Fuel stores

(2) Personnel shelters

B. <u>Blending</u>

1. The process of making an object indistinguishable from its surroundings by breaking up its form and shadow. This method is particularly valuable where the terrain pattern is intricate.

a. Example - blending an airfield with pattern of surrounding terrain by painting:

(1) Roads; avenues of trees.

(2) Canals (on one field the Germans painted a lake).

(3) Hedges, fences, furrows.

(4) Regular pattern of subdividing farm fields.

(5) Each installation at airfield may have its own disguise.

C. <u>Decoy</u> (a German specialization)

1. Methods

a. Making an object appear to be something else. For example, constructing an airplane hangar so that it looks like a barn.

b. Using dummies to mislead the enemy as to troop dispositions and to draw his attention away from actual positions.

c. Examples

(1) Near a real airfield, set up a decoy field complete with runways, car tracks, dispersed areas, dummy aircraft, field markers, etc.

(2) For night bombing set up rows of lights away from real field; these lights are switched off after the enemy sees them.

(3) Set up mock airfield and treat runways with material so that it will give faint glow.

D. <u>Fundamental Requirements</u>

1. Proper choice of position, taking into account the mission, easy access without making telltale tracks during installation or importation of supplies, ease of concealment, etc.

2. Good camouflage discipline, including:

   a. Discipline of personnel in preventing paths, trails, cutting trees, or leaving foreign objects exposed.

   b. Maintenance of camouflage material and keeping it up to date.

3. Proper erection of camouflage material

4. Proper choice of camouflage material

II. EXAMINATION OF AERIAL PHOTOGRAPHS ILLUSTRATING CAMOUFLAGE

A. <u>Examples (Aerial Photograph Supplement)</u>

1. Plate 75, Camouflage technique

   a. The collar button is easily seen in Fig. 1. In Fig. 2, the button is over near the edge of the rug and is more difficult to locate. In Fig. 3, the button is near the center of the rug but is difficult to locate. This is an illustration of camouflage by blending.

2. Plate 76, Camouflage illustration

   The four tanks are easily seen in Fig. 40. They are dispersed and partially blended in with the sand in Fig. 41, and fairly well concealed in Fig. 42.

3. Plate 82, Bremen

   a. This picture illustrates deceptive painting of permanent installations. Note arrows pointing to best examples.

4. Plate 80, Hamburg

   a. This picture illustrates camouflage installation duplicating an actual installation and the covering up of a lake to make it look like several city blocks. This is to confuse the bombardier and cause him to bomb the dummy installation.

5. Plate 81, Tank farm at Brest, France.

   a. Note the partially concealed tanks. If they were all treated in this way they would be difficult to identify.

6. Plate 43, German refinery

   a. Note the covering of the canal and the attempt to make the refinery buildings look like ordinary city blocks.

7. Plate 77, Poor camouflage discipline

   a. An example of well camouflaged field guns but poor camouflage discipline. By following the tracks across field the location of the guns is easily found.

IV. SUMMARY OF DISCUSSION ON AERIAL PHOTOGRAPHS

V. REVIEW

INTERPRETATION OF AERIAL PHOTOGRAPHS AND CAMOUFLAGE

1. What is camouflage?

2. Why is camouflage much more important in this war than in World War I?

3. Are aerial photographs or human observers more effective in discovering camouflage?

4. What is meant by camouflage discipline? Why is it necessary?

5. What is more easily detectable from an aerial view, an object or its shadow?

6. Under which of the following conditions would a motor vehicle be most likely to be overlooked: 1. On a surfaced road; 2. In a field with low scattered bushes; 3. On plowed ground; 4. On a grass covered field?

7. An airfield runway is painted to blend with the surrounding grassy plain. Would the runway be detectable on an aerial photograph? Why?