STANDARD NOTES

FOR

PHOTOGRAPHIC SURVEY.

AMENDMENT LIST

No.	Date	Amended by	No	Date	Amended by

OPS. PUB 1

ADASTRA AIRWAYS PTY. LTD.

STANDARD NOTES

FOR

PHOTOGRAPHIC SURVEY

CONFIDENTIAL

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SECTION 1.

AVIATION PHYSIOLOGY FOR AIRCREW

INDEX.

1. Introduction.

Man is a terrestrial animal; in other words his body is designed to live and work near the ground within a narrow range of temperatures and air pressures. The body has a large safety factor and will continue to perform reasonably well under conditions which are beyond the normal range.

However we must realize the limitations of the body. If we recognize them and make use of special techniques and special flying equipment we can normally fly safely and comfortably.

11. The Effects of Altitude.

When man leaves the ground and ascends into the atmosphere, the pressure of the surrounding air decreases and this has various effects on his body. They may be summarised as follows:

(a) Pressure differences in the ear. (From ground level up.)
(b) Oxygen lack or Anoxia. (Mainly above 10,000 feet.)
(c) Expansion of gases in body cavities. (Mainly above 20,000 feet.)
(d) Decompression sickness or "Bends". Usually above 30,000 feet.)
(e) Increasing Cold with Altitude.

111 The Need for Clearing the Ears.

The middle ear is an AIRFILLED space on the inner side of the eardrum. It is connected to the back of the nose by the Eustachian tube which is normally closed.

As one climbs, the external air pressure falls below that in the middle ear. After a small pressure difference develops, the excess is blown off through the Eustachian tube, causing the bubbling or clicking sound one notices at a few hundred feet. If one continues to climb the excess pressure is repeatedly blown off through the Eustachian tube which thus acts as an AUTOMATIC SAFETY VALVE.

On descent the pressure outside becomes the greater and this pressure difference tends to seal the Eustachian tube more tightly, and thus there is no automatic safety valve during descent. If no voluntary action is taken to equalize the pressure the drum is forced inwards causing a sensation of fullness in the ear, deafness, ringing and pain. The eardrum may rupture. Minor degrees of injury may result in deafness and ringing for hours or days after flying. Repeated minor degrees of injury may eventually lead to permanent damage.

The Eustachian tube may be made open by:-
Swallowing, yawning, pushing the lower jaw forward, or (most effectively) pinching the nose and breathing out hard into the nasal cavity with the mouth closed.

If the pressure difference is allowed to become excessive without clearing the ears, no amount of voluntary effort will open the tubes; reascent is then the only way of re-establishing ear ventilation. Each ear has a separate Eustachion tube and both must be cleared on descent. When you have a Cold in the head it may be difficult or impossible to open the tube.
The sinuses are airfilled cavities in the bones of the head separately connected with the nose by the orifices which are normally open, but which maybe obstructed by a cold in the head or by inflammation of the sinuses Pressure difference in an obstructed sinus causes pain, usually in the forehead.

111. The Need for clearing the Ears Contd.

but sometimes in the teeth. Pinching the nose and blowing, as described above may relieve it.

(a) Clear your ears frequently during descent.
(b) Inform members of the crew when you are going to lose height and wake up members of the crew or passengers who are asleep.
(c) Do not go flying if you have a cold and cannot clear your ears.
(d) If you suffer pain, deafness, or ringing in the ears, or sinus pain after flying, see your Medical Officer at the earliest opportunity. It is fairly simple to relieve the trouble if treatment is sought within half an hour of descent, much more difficult if later.

1V. Oxygen Lack or Anoxia.

A continuous supply of oxygen is vital to life. The purpose of breathing is to provide this supply. Air is one fifth oxygen by volume and this propor- is constant at least to 73,000 feet. In the lungs atmospheric pressure forces oxygen into the blood stream by which it is transported to the various parts of the body. Sea level atmospheric pressure is needed for the blood to be fully saturated with oxygen as it passes through the lungs.

As the atmosphere pressure decreases with altitude, the blood is less than fully saturated and consequently the body is starved of oxygen. This condition, called ANOXIA, causes loss of mental and physical efficiency, loss of consciousness, and, if it is sufficiently severe, death.

The effects of Anoxia depend on altitude and duration of exposure. Below 8,000 feet your night vision is affected, and use of oxygen from the ground is advisable when good night vision is important. The most important result on long flights above 8,000 feet but below 15,000 feet is fatigue. For this reason it is very worthwhile to use oxygen in the range 8,000 feet to 10,000 feet if the time above 8,000 feet is to exceed 3 hours. Oxygen need not be used continuously at this level, but should be used for at least half the time.

Anoxia affects particularly the brain. Up to 15,000 feet, headaches and an indifferent mental attitude are common effects. Between 15,000 feet and 18,000 feet the tendency to make mental errors is more pronounced and you may be unable to solve navigational and other problems. Your capacity for physical work is also reduced.

Around 20,000 feet fits of laughing or crying may occur, or there may be a feeling of unusual well-being. Some people get sleepy. Precise hand movements are impossible after 15 minutes or so, and uncontrollable twitchings often occur. Above 20,000 feet unconsciousness comes after a variable period and death may follow prolonged exposure. At 25,000 feet you pass out in less than 10 minutes, and over 30,000 feet in less than 2 minutes. At these heights death is very likely if you are without oxygen for 30 minutes.

The effects of cold are intensified by lack of oxygen, and exposure to cold increases your oxygen requirements. Most cases of frostbite occurring among aircrew during the recent war were associated with failure of the oxygen supply or failure to use it properly. Liability to airsickness is increased with Anoxia. If you feel airsick at oxygen requiring heights the first thing to do is check your oxygen supply. Exertion increases your oxygen require- ments many times, and consequently makes the effects of Anoxia more severe.

Recovery from the effects of anoxia is usually rapid on descent level or on breathing oxygen. There may be a momentary feeling of dizziness. Headache is common after prolonged Anoxia, but this usually disappears after a good sleep.

1V. Oxygen Lack or Anoxia Contd.

Physical fitness raises your ability to stand up to Anoxia; the following factors lower it:- exertion, cold, fear, excitement, presence of carbon monoxide, alcoholic drinks, bleeding.

Anoxia can be prevented by breathing oxygen or air enriched with oxygen at external atmospheric pressure. Efficient equipment using this method provides protections up to 38,000 feet, above which height the atmospheric pressure is insufficient adequately to oxygenate the blood even when 100% oxygen is breathed. Above 38,000 feet the degree of anoxia increases very rapidly with altitude.

38,000 feet with 100% oxygen = 10,000 feet breathing air.

43,000 feet with 100% oxygen = 22,500 feet breathing air.

It is therefore dangerous to fly over 38,000 feet with standard equipment.

Breathing oxygen under a small positive pressure raises your ceiling to 44,000feet. Above this altitude a pressure suit or pressure cabin is needed.

One of the early effects of anoxia is to paralyse your powers of judgment so that you do not realize your inefficiency. The only safe rule therefore is to disregard your personal feelings and use oxygen according to the indicated altitude.

The following rules are advised. Oxygen is to be used on all flights:

(a) From 10,000 feet in any circumstances.
(b) From 8,000 feet when is likely that the flight will last more than three hours above 8,000 feet.
(c) From 5,000 feet for night flying.
(d) From the ground in aircraft with rate of climb greater than 2,000 feet per per minute when it is intended to fly above 10,000 feet.

V. The Demand Oxygen System.

The A-12 demand regulator is automatic. When the user inhales, the demand valve opens, and the regulator supplies a mixture of air and oxygen whose proportions are correctly controlled by an aneroid for any altitude up to 38,000 feet. At sea level the mixture is practically pure air, over 30,000 feet it is pure oxygen. When he exhales, the demand valve automatically stops the flow of oxygen.

Automix Control.

(a) With the control at Automix ON or NORMAL OXYGEN the regulator automatically mixes the proper proportions of air and oxygen for all altitudes. The luminous spot on the automix handle lines up with the luminous spot on the Regulator. With the control to Automix OFF or 100% OXYGEN no air can enter the regulator and the user breathes pure oxygen. The luminous spot on the automix handle is hidden. In either position of the automix, the regulator is a demand regulator supplying oxygen only when the user inhales.

(b) The automix will normally be used in the ON or NORMAL OXYGEN POSITIONAT ALL TIMES, except when pure oxygen is needed, that is :-

(i) on the ground before take-off, during ascent, and during an entire flight as protection against bends (on medical advice only).
(ii) as part of treatment for shock, loss of blood, or as protection from carbon monoxide or poison gas

(iii) When the user feels he is getting anoxic.

(iv) Whenever the emergency is turned on at altitudes below 30,000 feet.

(v) In pre-take-off check for leaky diaphragm.

EMERGENCY VALVE.

The emergency valve, operated by a red knob, is designed for emergency use only. It by-passes the demand valve, and when turned on, provides a continuous flow of pure oxygen to the mask. Oxygen which is not used escapes through the outlet vents in the mask. The emergency valve is normally sealed in the OFF position with breakable wire. Turning on the emergency valve is extremely wasteful. It depletes the oxygen supply very rapidly, using up one hour's supply every three minutes. It should not be used except: -

(a) To revive an unconscious member of the crew;
(b) When a bad mask leak develops in flight:
(c) When the demand regulator becomes unserviceable in flight, as indicated by flow indicator's failure to work, or on user's feeling of anoxia persisting after turning automix OFF;

FLOW INDICATOR.

The type A-3 flow indicator blinks open and shut with each breathing Cycle. When the emergency valve is turned on the flow indicator does not blink.

MASKS.

Fit. Good fit is vitally important. Leaks can so reduce the mask suction That it will not trip the demand valve. For full details of fitting and attaching mask to flying helmet, refer to leaflet supplied with each mask. To test for good fit of the mask either of the two methods detailed below may be used:

(i) Suction test. Hold your thumb over the quick disconnect fitting and inhale normally (i.e. gently). If only slight resistance to inhalation is felt or air can be felt flowing in past the nose, a leak is indicated. This is only a rough test.

(ii) Sniff test. Connect your mask to the regulator and turn the automix to OFF or 100% oxygen (to prevent air entering the mask via the regulator). Dip a swab of cotton wool into any strong volatile oil (oil of peppermint, eucalyptus oil, methyl salicylate, flyspray, liniment etc.) and hold it close to your face. If you can detect the smell, a leak is indicated.

DEMAND SYSTEM CHECK LISTS.

PREFLIGHT.

1. MASK.	(a) Ensure you mask is clean, fits properly, and is ready for instant use. (b) Check mask and mask tube for tears, holes, kinks or other damage. Ensure all clamps are in place. (c) Check for leaks by suction test.
2. SUPPLY TUBE.	Check regulator for tears, holes and kinks. Ensure all clamps are in place

DEMAND SYSTEM CHECK LISTS CONTD.

3. MASK TO REGULATOR UNION.	(a) Ensure rubber gasket is in place. (b) Ensure male connection of quick disconnect is not bent or warped, that it fits snugly into female connector. (c) A 12 lb. Pull should be needed to separate the two. To correct a loose fit pry open the prongs on the male fitting with a screwdriver or knife blade.
4. REGULATOR.	(a) Check emergency valve wired OFF. (b) With automix OFF or 100% OXYGEN, place end of regulator tube to mouth and blow gently. Once the diaphragm has risen, continued resistance to blowing indicates freedom from leaks. (c) Junction of regulator tube to regulator - ensure knurled collar is tight. (d) Flow Indicator. Automix OFF or 100% OXYGEN. Check indicator blinks normally with breathing. (e) RESET AUTOMIX ON OR NORMAL OXYGEN.
5. CLOTHES GRIP.	Clip regulator tube on to clothing close enough to face to permit free head movement without kinking or pulling the mask hose.

IN FLIGHT

1. MASK.	When you put on or replace mask, check the fit by pinching mask tube and inhaling gently.
2. MASK TUBE:	Do not twist or kink corrugated mask tube (except as in 1).
3. ICE:	Moisture may freeze in mask at high altitudes. Remove ice by bending or squeezing frozen parts.
4. FLOW INDICATOR:	Frequently check flow indicator is blinking with each breath.
5. OXYGEN CONSUMPTION:	Check pressure gauge from time to time to determine remaining duration.
REGULATOR:	AUTOMIX ON, NORMAL OXYGEN.

DEMAND SYSTEM CHECK LISTS. CONTD.

7. I/C CHECK: At regular and frequent intervals (every 5 to 10 minutes) captain calls each member on intercom. If no satisfactory answer is received another crew member is sent to investigate

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AFTER FLIGHT.

1. SERVICEABILITY: If aircraft system has shown evidence of failure in flight, declare aircraft U/S by appropriate entry.

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2. MASK: Wipe mask dry and stow in dry place, do not leave in aircraft.

V1. General precautions regarding Anoxia.

I/C CHECK:

To ensure that no member of the crew can suffer from anoxia unnoticed, with consequent danger to the crew's efficiency and the crew member's life the captain of aircraft flying over 15,000 feet, will at regular intervals (every 5 to 10 minutes) call each member of the crew separately on the intercom. If no satisfactory reply is received, another member of the crew should be dispatched to investigate. This simple precaution will almost eliminate the possibility of deaths from anoxia.

Moving about the aircraft:

From the discussion on anoxia and it's effects it must be apparent how foolhardy it would be to change stations in the aircraft when at high altitudes without a portable oxygen system. As the provision of such systems is not envisaged, it must be stated that a member is not to leave his position in the aircraft when at high altitudes unless an emergency arises.

Even in such cases it cannot be expected that a member without oxygen can move about for more than a few minutes before collapsing. Therefore if the matter cannot be rectified in that time, a descent to lower altitudes is the only alternative.

If a crew member is to leave his station in emergency, he should take up to a dozen deep breaths of 100% oxygen immediately prior to moving, and the hold his breath for as long as possible while his mask is off.

The folly of moving about the aircraft without oxygen when at high altitudes cannot be stressed too strongly.

Care of your mask:

The fit of your mask is the most important fit of your life. You can get along with misfit clothing, but a leaky mask can endanger your life and ruin the success of your flight. With a perfectly fitting mask your safe ceiling is 38,000 feet – if there is a 5% leak in the mask, this ceiling is reduced to 35,000 feet. To prevent leaks the mask must fit high on the bony part of the nose. It can be fitted properly only when worn with a flying helmet. Make your choice with the aid of a mirror. Adjust the nose wire where fitted to the shape of your nose. Try the mask harness in the alternate stud positions on the helmet. For detailed instructions of fitting, see the leaflet supplied with each mask. Change the strap adjustments only to take up the slack due to natural stretch

Wipe your mask from time to time with a clean cloth wrung out in warm soapy water and rinse well with plain water. Shake and blow the excess water out of the mask and tube. Take care not to wet the microphone. Do not remove the valves.

Care of your mask. Contd.

Do not dry the mask near any source of heat, or leave it in the aircraft or where it may be exposed to sunlight or high temperatures. Keep it in a bag or original or in it's original box where it will stay clean and dry. If you detect a hole or split or signs of perishing in the mask or corrugated tubing, have the defective part replaced as soon as possible and certainly before any further high altitude flying.

Your mask is on personal issue. Treat it as personal clothing and do not lend it Except in extreme emergency.

Failure of supply.

Should symptoms of anoxia be noticed, turn regulator to Automix OFF or 100% OXYGEN. If no immediate improvement is noticed, lose height as quickly as possible to below 15,000 feet and investigate the cause of the trouble.

Reviving an unconscious man.

Should a member be found unconscious, the rescuer will:

(a) First ensure his own safety by checking his own supply. Failure to do this exposes the would be rescuer to great risk of becoming himself a victim of anoxia.

(b) Call the captain and advise him of the situation.

(c) Check the unconscious man's mask, supply tube, connection, and regular pressure. Correct any fault.

(d) Set regulator to emergency.

(e) Give artificial respiration if the unconscious man is not breathing.

(f) Reset the regulator when he has regained conscious.

Oil and Grease.

Extreme care must be taken to see that oxygen installations are kept free of oil and Grease, since oil and grease in contact with oxygen under pressure may cause fire or an Explosion. Oil and grease should never be used to lubricate valves.

Carbon Monoxide.

Carbon monoxide in the cabin or cockpit of an aircraft has the same effect on the occupants as anoxia. Carbon monoxide is contained in the exhaust gases and acts by combining with and making useless the oxygen carrying part of the blood.

A small amount of carbon monoxide can do much damage: 0.04% in the cockpit air causes anoxin equivalent to exposure to 23,000 feet. Concentrations of this order may sometimes be brought about by worn or improperly fitted heat exchangers, or holes in the exhaust manifolds. Symptoms of carbon monoxide poisoning are similar to those of medium altitude anoxia: headaches dizziness, weakness, nausea.

If you smell exhaust fumes in the cockpit or suspect carbon monoxide, put on your mask and set the automix to OFF and 100% oxygen. Return to base immediately, U/S the aircraft and see the Medical Officer as soon as possible.

A FEW FACTS ABOUT OXYGEN.

Oxygen will not cure a hangover.
Excessive oxygen is not harmful, merely wasteful.
Oxygen is not inflammable, or explosive. It supports combustion and may make an existing fire burn more fiercely.
Oxygen has no smell, and the faint "rubbery" smell sometimes noticed come from dust in rubber tubing.
Anoxia does not give a warning by causing panting - this usually only occurs with exertion.

SECTION 2.

EQUIPMENT.

1. Cameras.

Introduction.

(a) The photo survey crew today may be assigned to a task using any one of the following types of camera.

Williamson Eagle 1X
" O.S.C.
Wild RC5
" RC7

(b) The operation of the particular camera will be thoroughly explained before any job, and in addition the relevant instructions manuals which accompany each contain the descriptions and information necessary to maintain them.

(c) These notes are intended to amplify the manuals particularly with regard to camera operation and defects likely to occur during flight, and methods of rectifying them whilst in the field.

(d) Additionally a considerable amount of survey work is rejected because of factors under the control of the camera operator. These factors and the elimination of errors due to them will be listed.

Williamson Eagle 1X.

This camera has been the mainstay of air survey operations in Australia for the past 6 or 7 years, and the Company's units have done extensive work. Because of this long sustained effort these finely adjusted instruments now require very careful handling and the exercise of vigilance during their operation. Familiarity with these notes and the appropriate manual is essential if the cameras are to continue giving reliable service.

1. Magazines.

Errors due to faulty magazine loading, handling and operation will be minimized by following these precautions:

(a) When loading ensure the spools are firmly and properly engaging the dogs on the spools discs.
(b) Keep the magazines free from foreign matter such as small pieces of paper, film etc. and dust or dirt.
(c) Always set the counter to zero after loading.
(d) The protective cover must be kept in place at all times (except of course during photography loading and unloading). This prevents fogging of the film and protects either the cork surface of the pressure plate or the film.
(e) Loaded magazines are to be carried with the locking screw to the top, to prevent the spools slipping off their discs.
(f) Check weekly the tension on the friction drivers, (see page 51 of the Instruction Manual).

2. Camera Check List

(To be carried out before starting photography)
(a) Thoroughly clean with a soft cloth, the register glass, filter and optical flat.
(b) Set the required aperture number and shutter speed.
(c) Check the shutter operation visibly.
(d) After mounting the magazine on the camera, fire two exposures by hand.
(e) Using the control box run over a film trail of 15 exposures (blanks).
During this run: - check timing of control box with stop watch.
Ensure film is winding over (Red and white disc revolving).
Ensure the counters are working.
(f) Connect Pilot's warning light.
(g) Remove camera hatch cover.
Then immediately prior to photo run:
(h) Set drift and time interval

2. Camera Check List Contd.

(i) Level the camera.

And during the run:

Keep a constant check on camera levels and make sure camera fires and film winds over at each required interval.

3. Mechanical Failure of the Camera.

This may be due to a variety of causes and a trouble shooting list is appended. If failure occurs during a photo run, the first indication will be that the red-white disc in the magazine does not revolve as the red light on the control box goes out.

An alert camera operator can save the run by immediately firing the camera and rewinding the magazine by hand, and then carrying out a similar procedure during the remainder of the run, using the stopwatch to fire the camera at the correct time intervals. (e.g. with a time interval of 36 seconds – stop the watch at 34 seconds; rest it to zero = 35 seconds; restart the watch and fire the camera = 36 seconds and so on).

Certain defects could be remedied in the air. However unless the repair is simple it is considered more advisable to complete the sortie firing and rewinding by hand. The trouble can then be located and the necessary adjustments made under more suitable conditions on the ground.

4. Fitting New Lens Cone to Camera.

(Ref Page 59 & Fig.22 of Instruction Manual)

1. Ensure the contact surfaces are clean.

2. Do not force the camera body over the cone. If it is not a push-fit there must be an obstruction.

3. When a replacement cone is fitted the shutter firing plunger (SDA 17) must be adjusted . Fully extend the screw in the top of the plunger and then gradually adjust clockwise until the shutter action is satisfactory, the body being refitted over the cone for each adjustment.

4. The correct shutter speed is obtained by adjusting the screw SDA 16 until there is no movement of the inertia wheel on maximum speed setting.

   The inertia wheel is actuated only on the 200, 150, and 100 setting.

Wild RC5A.

This camera has proved itself a very reliable unit. Except for a few isolated instances, abortive sorties or work rejected because of camera defects has been due to faulty handling of the unit.

Trouble-free operation can be assured, if the directions in the manual are adhered to, and the following check lists are carried out: -

A. Magazines.

1. Before attempting to load a magazine with unexposed film the operator should have sufficient practice in the open with a dummy film to learn a set loading procedure. This will save a lot of time especially if loading and unloading is done in the air, and will also prevent errors.

2. Check the escape holes in the pressure plate. They must be clean. Blockage causes soft spots on the film.

Magazines Contd.

3. Ensure that the dogs on the spool holding pins are positively engaged in the spool slots. (The springs in the system are strong enough to hold the spools even though the dogs are not in place. When this occurs the film is not centered correctly and will tear).

4. Keep the magazine from foreign matter and dust and dirt.

5. The dark slide must be kept in place at all times except during photography when it is replaced by the dummy slide. This prevents film fogging.

6. Reset the counters after loading.

B. Camera Check List.

1. Before operation ensure the aircraft power supply is not low. Although there may be sufficient current to operate the camera, a low supply will give poor illumination to the recording instruments and consequent illegibility on the print.

2. Cleaning: Always use a soft cloth or lens tissue.
   (a) Remove the lower cover from the lens cone.
   (b) Clean the filter and bottom surface of the lens.
   (c) Check shutter speed, i.e. correct set of springs in place.
   (d) Replace lower cover
   (e) Clean top surface of lens.
   (f) Clean eye piece and base of sight .
   (g) Clean instrument panel lenses.

3. Check Aperture (F. number)
4. Check forward overlap setting (normally 60%)
5. Check focal distance lever (wide angle or normal angle)
6. Remove the instrument panel and check the clock and altimeter.
7. Fuses: See that the two fuses (visible on top of camera body) are intact and firmly seated.
8. Mount the magazine, ensuring that the white marks are aligned.
9. Remove dark slide, insert dummy slide.
10. Connect power lead and vacuum line.
11. Switch to "ON" – Check power to camera (white indicating discs will revolve)
12. Switch to "SERIES" and fire a trail of 20 blank exposures.
13. While the trail is being fired adjust the vacuum gauge. (see page 15 of Instruction book)
14. Remove camera hatch cover and check operation of overlap regulator.

Prior to photo run:

15. Set drift.
16. Level Camera.
17. Set the overlap regulator.

During the Run:

18. Keep constant check on: -
   (i) Overlap regulator
   (ii) Camera Levels
   (iii) Black and white rotating discs on the magazine.
   (iv) Green exposure light.
   (v) Exposure counters.

Wild RC7.

This unit is owned by Victorian Lands Dept. and is used by Adastra only when flying a Job for that department. When necessary, a full training in the operation of the Camera, is given in Victoria.

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EAGLE IX CAMERA TROUBLE SHOOTING.

UNIT	FAULT	CAUSE	REMEDY	MANUAL REF.
Optical	1. Shutter fails to operate	Drive dog sheared	Return drive mechanism to	PAGE.
	2. When new lens fitted to body, hand winder jams	Shutter plunger out of adjustment	Readjust	59
	3. Heavy or light exposures	a. Mal-functioning of shutter blades b. Speed arm U/S c. Drive not working freely (usually distorted) d. Inertia wheel functioning incorrectly e. Inertia wheel spring broken	a. Return shutter drive to base b. Check for freedom c. Replace if possible, if not return unit to base d. Check according to manual e. Fit new spring	 59 59 57,58 59
	4. Shutter opens and closes slowly	a. Drive shaft tight on bearings b. Dirt between shutter blades	a. May need lubrication, or if bent replace b. Return optical unit to base	59,60
Camera Body	1. Motor fails to turn	a. Motor U/S b. Relay contacts U/S c. Delay switch U/S d. Wiring connections U/S	a. Replace b. Reface the contacts c. Check switch and repair d. Check and repair	19 62 41 63
	2. Motor turns but fails to operate camera	Motor clutch U/S	Replace clutch	20
	3. Camera fails to fire	a. Solenoid assembly b. Release levers out of adjustment c. Defective wiring	a. Check and adjust b. Check and adjust c. Inspect and rectify	39 36 63

UNIT	FAULT	CAUSE	REMEDY	MANUAL REF. PAGE.
Magazine	1. Incorrect spacing of exposures	Friction drives require adjustment	Adjust with friction testers	51
	2. Film fails to wind over	a. Taper pin in vertical shaft sheared b. Gear GB11 jammed due to broken tooth. (This gear responsible for dwell to allow pressure plate to rise)	a. Fit new pin b. Replace gear	49 50
	3. Soft spots on film	Pressure plate malfunctioning	Check a. Pressure spring b. Taper pins on shaft c. Gear timing	52 to 55
	4. Light, or light bars on film	a. Protective cover not properly fitted b. Pressure plate not locked down when magazine off camera c. Condensation due to defective heating d. Camera not wholly sealed, allowing light to enter	a. Check for warping etc. b. See No. 3 c. Check heating installation d. Check fit of all camera doors and for missing screws etc.	52-55 "
	5. Red white disc not turning (or not turning fully).	a. Out of film b. Film not winding over c. Bearing tight	a. Check counter and reload b. See No. 2 c. Check bearing for lubrication and recheck friction tension.	51
	6. Counter U/S	a. Cam not turning b. Trip lever not connecting c. U/S internally	a. Replace pin or screw b. Adjust c. Return magazine to base	51 51

THE TEN COMMANDMENTS – FOR CAMERA OPERATORS

1. Double Check your drift setting. Remember that the rear of the camera (where the drift indicator is positioned) points to the RIGHT when the drift is PORT and vice versa.

2. During photography constantly check your optical flat for foreign matter.

3. Keep the glass surfaces of your camera spotless. This applies particularly to the register glass.

4. Trail lengths are important. Watch your exposure counters and give the navigator constant advice on the amount of film left unexposed in he magazine once it has passed half way.

5. Store your film in a cool spot and do not leave loaded magazines in the aircraft.

6. Do not attempt to level camera or change drift setting during the exposure cycle. This could cause a blurred print.

7. Ensure the camera is firmly fixed in its mount and will not vibrate out of position.

8. If a film is to be cut, use a sharp instrument to give clean edges. Tearing a film leaves jagged edges which could lead to a longitudinal split along the film during processing.

9. Check the tension of the friction drivers once per week when the camera is in use. At regular intervals give your camera and associate equipment a thorough servicing following the instructions from the manuals.

10. Check the shutter section visually whenever a new magazine is fitted to the camera.

11 CAMERA CONTROL BOX

This unit, also known as the intervalometer, is used in association with the Eagle IX Camera. Its main function is to actuate the firing and rewind mechanisms of the camera at regular pre-determined intervals. The following is a brief description of its controls and various functions.

1. Main Switch.

When this switch is turned to the ON position, the camera makes an immediate exposure, the film is wound over and the cycle repeated after the time interval set on the control. This is explained in 2 below. The unit will continue actuating the camera mechanism at this constant interval until the switch is turned to OFF.

2. Time Interval Control.

This can be set to any position from 4 to 58 seconds. (The necessary time interval is received from the navigator and its determination will be explained in the lectures on photo theory.) If, as sometimes occurs, a time interval greater than 58 seconds is required the operator must fire the camera by hand using a stop watch for the timing.

3. Single Exposure Button.

A simple push button switch for single exposures is incorporated in the centre of the time interval control knob.

4. Red Warning Light.

This light comes on 3-4 seconds before the camera fires and thus alerts the operator to check that the camera is level as the exposure is made, and that it is operating correctly.

5. Pilot's Warning Light.

Situated on the instrument panel coupled with the operator's warning light and serves the same purpose with regard to the attitude of the aircraft at the time of exposure.

6. Green Light.

Immediately following an exposure, the film is wound over and the take of spool revolves. This operates a micro-switch connected to the green light on the control box which flickers on and off. Thus the operator is given a second indication of the correct functioning of the magazine.

7. Black and White Tell-Tale Disc.

As soon as the main switch is turned on, this small disc revolves continuously indicating that the control box is operating.

8. Exposure Counter.

The counter runs from zero to 115 marked at intervals of 5.

9. Counter Reset Button.

The counter is used most effectively if it is reset to zero before each run. Thus the number of exposures in the run is apparent as soon as the end of the run is reached. Used in this way the control box also provides a good check on the magazine counter.

10. Three Electrical Connections.

One from the aircraft power supply, one to the camera, and one to the pilot's warning light.

Repair and Maintenance.

It is considered preferable to carry spare control boxes rather than attempt to repair an unserviceable one in the field (except for, say, replacement of blown bulbs.) However a box which has been in store for some time may fail, due to a film which forms on the two pairs of contacts (visible once the cover is removed.) They should be cleaned using a fine blade such as a thin feeler gauge.

Pre-Flight Check List.

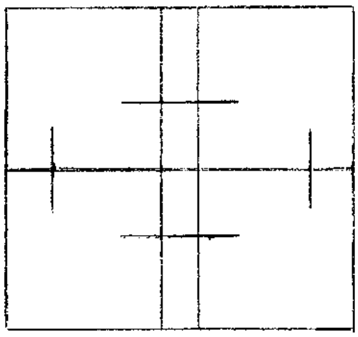
1. Plug in the three electrical connections.
2. Switch ON
3. Camera must fire immediately and rewind, check this including shutter operation visually
4. Is Black and White disc revolving?
5. Watch for Red warning light to come on 3 to 4 seconds before camera operation.
6. With a stop watch check the timing of the unit with the control set for several different time intervals.
7. Check exposure counter.
8. Check pilot's warning light.
9. When loaded magazine in place, check operation of green light.

111. THE ALDIS SIGHT

The Aldis sight is the instrument most used by the navigator in photo survey work. With it he determines the drift of the aircraft and the necessary time interval between exposures of the camera; he also uses it to direct the aircraft up to the start point for each photo-run and to track along the predetermined flight line.

The sight can be likened to a telescope pointing vertically downward through the floor of the aircraft. A lens system in the sight presents at the upper end or eye-piece, a view of the ground directly below the aircraft.

On one lens is superimposed a graticule of fine black lines which overlays the picture of the ground. This graticule has the appearance shown below. However its size is not fixed and will differ accordingly to the focal length of the camera, with which the sight is being used. The various purposes of the graticule will be explained in a later lecture.



Now the sight can be rotated in azimuth, the graticule rotating with it. Around the upper end of the sight is a circular collar which is fixed in the fore-aft line of the aircraft. On the collar is engraved a scale, in degrees Port or Starboard. A pointer attached to the sight moves over the scale as the sight is rotated.

The Prism.

Attached to the bottom of the sight is a mirrored prism. By rotating a control on the body of the sight, the navigator is able to move the prism backwards out of the field of view, or forward to give a picture of the ground ahead of the aircraft; this may be anywhere from directly ahead to as far as the horizon.

Mounting in the Aircraft.

The sight is not rigidly mounted but can be moved in the fore and aft line and athwartships (sidewards). However locking screws are incorporated and the sight can thus be positively fixed in any desired position.

When in operation the sight must always be in the true vertical. But the attitude of the aircraft can vary (depending mainly on its altitude and load). Thus before using the instrument, the navigator will adjust the levelling devices, locking it in the true vertical. Spirit levels are attached to achieve this.

The Determination of Drift.

The drift of the aircraft is found by rotating the sight until objects visible on the ground are passing through the field of view on tracks parallel to the centre lines of the graticule. The drift in degrees Port or Starboard is then indicated by the position of the pointer over the scale.

The prism affords a positive check on the drift found by this method. When the prism is turned forward the centre lines of the graticule appear over the image of the ground ahead of the aircraft. If the drift set on the sight is correct and assuming the wind velocity remains constant the aircraft must then pass directly over any object which appeared on the prism between the centre lines.

Aligning The Sight.

To give accurate results the centre lines on the graticule must be lined up parallel with the fore and aft axis of the aircraft.

This is done as follows:

1. The aircraft is positioned on a level piece of ground.

2. The sight is locked in position using the spirit level to ensure it is vertical in the athwartships Plane.

3. A centre point is found by measurement at the nose section of the aircraft.

4. The point on the ground vertically below this point is marked using a plumb-bob.

5. A cord line is stretched taut between this point and the centre of the tail section.

6. The sight is rotated until the centre lines of the graticule are parallel with the image of the cord.

7. With the sight steady in this position the drift indicating pointer is now adjusted to read zero.

IV Personal Equipment.

It is the member's own responsibility to acquire the flying clothing and equipment necessary to his job. Experience has shown that the distraction and discomfort of unsuitable personal gear seriously reduces aircrew efficiency therefore give some thought to its selection and subsequently treat it carefully. The dividends will be obvious.

This list is a suggested basic requirement:

(a) Overalls. 2 pairs tailored to measure. Make sure they are a loose fit as quite often bulky clothing will be worn under them. Launder them regularly.

(b) Flying boots and woolen socks. The boots should also be a reasonably loose fit. Tightness, by restricting the circulation defeats their purpose.

(c) Warm underwear and a heavy roll neck jumper. These are essential as a lot of flying is done at 25,000 feet where the temperature is always below freezing point and in winter often as low as -35°C.

(d) Helmet and intercom gear. A comfortable well fitting helmet is imperative.

(e) Oxygen mask. This important piece of equipment is fully discussed in the section on Aviation Physiology.

(f) Brief Case.

(g) Navigation instruments:

- Straight Edge
- Douglas Protractor
- Dividers
- Navigational Computer
- Stop Watch

These essential and expensive instruments will give years of service if carefully treated. When not in use keep them in their protective covers and in the brief case.

SECTION 3.

INTRODUCTION TO AIR NAVIGATION.

(N.B. For students who wish to progress beyond first principles in this subject, the following text books are recommended:
AP 1234 – Air Navigation
BENNETT – Complete Air Navigator)

1. Form of the Earth.

(a) For all practical navigation purposes the earth is considered to be a sphere. (In actual fact it is slightly flattened at the poles but the flattening is small enough to be disregarded.)

The earth revolves about an axis whose extremities are called the North and South Poles. The direction of rotation is from West to East. These four directions N.S.E.W. are known as the cardinal points.

(b) Lines drawn on the earth's surface.
Throughout navigation reference is made to and use is made of certain lines imagined to be dawn on the earth's surface. The most important of these are the following:

(i) Great Circle. A great circle is a circle on the surface of a sphere, lying in a plane which passes through the centre of the sphere.
The shortest distance between any two points on the earth's surface is the lesser arc of the great circle joining them.

(ii) Small Circle. Any circle on the earth's surface whose plane does not pass through the centre of the earth is a small circle.

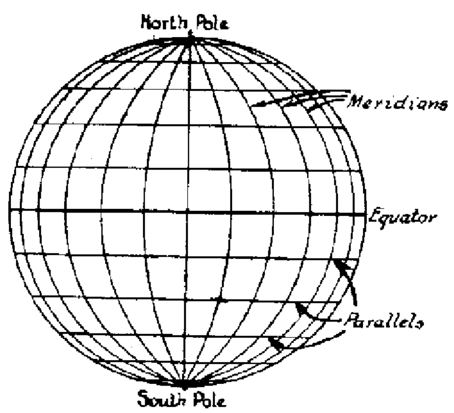
(iii) Equator. The Equator is the great circle which divides the earth into the North and South hemispheres. Its plane is at right angles to the axis of the earth.

(iv) Meridians of Longitude. These are semi-great circles joining the poles and cutting the equator at right angles. Each meridian has an anti-meridian and together they form a great circle.
The meridians lie in the true N-S direction.

(v) Parallels of Latitude. These are small circles lying in planes parallel to the equator.
The parallels of latitude indicate E-W direction.

(vi) Rhumb line. A regularly curved line cutting all meridians at the same angle. The equator and the meridians are the only examples of rhumb lines which are also great circles. Thus, except when two places are situated on the equator or the same meridian, the distance measured along the rhumb line joining them is not the shortest distance between them.
However the rhumb line is particularly useful in navigation as direction along it remains (vii)

(vii) graticule. A graticule is a network of fine lines. The meridians and parallels form regular graticule over the earth's surface.



The equator, meridians and parallels.

Form of the Earth Contd.

(c) Recording Position. The conventional method of recording position on the earth's surface is by reference to the parallels of latitude and the meridians of longitude. Every point of the Earth's surface lies at the intersection of one particular parallel and one particular meridian.

The parallels are numbered in degrees from 0 to 90 North and South of the equator. Thus 0° = the equator and 90° N = the North pole etc.

The meridians are numbered from 0 to 180 East and West from the Prime Meridian to the one passing through the observatory at Greenwich, London and known as the Greenwich meridian. Thus 180E and 180W coincide as the anti-meridian of Greenwich.

By convention the group of figures expressing latitude is always written first and is following by the figure expressing longitude. Figures below ten are preceded by the digit 0. The letter N or S is placed after the latitude group to indicate North or South of the equator; similarly the direction of the longitude is indicated by the letter E or W.

For example: A point in New Guinea is six degrees 28 minutes South of the equator and 142 degrees 57 minutes East of the Greenwich meridian. Its position is recorded as: 0628 S 14257 E.

(d) Direction on the Earth.

(i) In order to fly in a given direction an airman must be able to refer to a datum line or fixed direction whose whereabouts he knows. The most convenient datum is the meridian through his own position, since it is the North – South line. By convention direction is measured clockwise from north to the nearest degree i.e. from 000 to 360. It is always expressed as a three figure group. Thus east which is 90° from N is written 090 and west 270 etc.

(ii) True direction. Direction measured from a meridian is known as true direction. This is a constant unchanging reference and forms the basis of all charts and hence all plotting.

At present however no satisfactory method exists of directly and continuously presenting this true direction to the airman. Recourse is usually made to magnetic direction and true direction is derived from it.

(iii) Magnetic direction. The earth's magnetism radiates lines of force which are strong enough to influence a freely suspended magnetic needle. These lines of force are roughly parallel to the meridians and thus a freely suspended needle will assume a general N-S direction; the actual direction in which it points is called magnetic north.

The angular difference between True N and Magnetic N changes from place to place over the earth's surface and is called variation. This variation is a known factor and is displayed on aeronautical charts, thus enabling the airman to convert magnetic direction to true direction.

(iv) Variation. Is measured in degrees and is labelled E or W depending on whether the N seeking of the freely suspended magnetic needle lies to the E or W of True North at any given point

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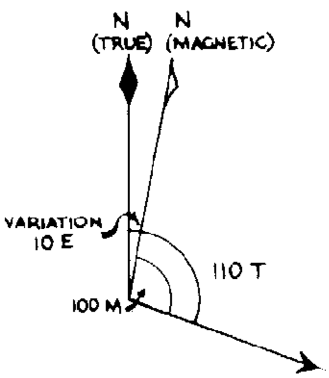
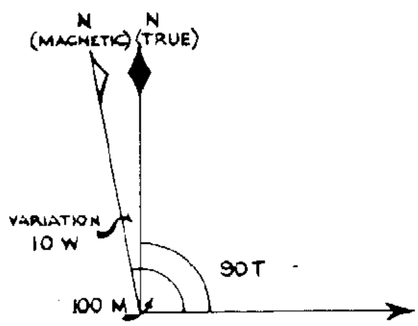




(iv) Variation Contd.

A useful rule for conversions between magnetic and true directions is:

Variation East Magnetic Least
Variation West Magnetic Best

(v) Isogonals. By means of surveys the variation at numerous points on the earth's surface is determined. Lines are then drawn joining places having the same variation; these lines are called isogonals. They are printed on all plotting charts and are labelled with the amount of the variation and its direction.

Thus at any particular point or for any section of a flight the variation is read from the chart and magnetic directions converted to true or vice versa.

(vi) Compass Directions. When a freely suspended magnetic needle is placed in an aircraft (e.g. the needle of a compass) it is subject to magnetic fields other than the earth's.

These fields are created by magnetised metals, electrical circuits etc. in the aircraft itself. Consequently the North seeking needle deviates from the magnetic North and indicates a direction known as Compass North.

(vii) Deviation. The angular difference between magnetic direction and compass direction is known as deviation. It is measured in degrees and named E or W according to whether the N seeking end of the compass needle lies to the East or West of Magnetic North.

Deviation is not a constant value for a particular compass but changes with the heading of the aircraft. Thus in order to convert compass direction to magnetic direction the airman must know the deviation of the compass in use on all the aircraft's headings.

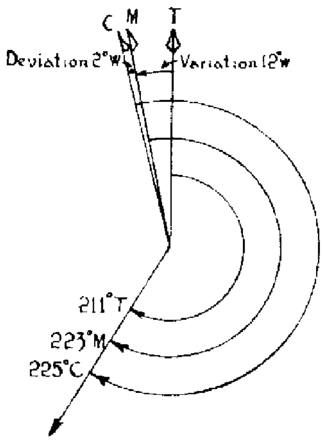
This is found by "swinging" the aircraft, usually on the ground and comparing the aircraft's compass directions on a number of predetermined headings with the directions shown by an external compass. The latter, of course, must be free from magnetic influences other than the earth's field. The results of the swing are tabulated on a card known as a deviation card and this is placed near the compass to which it applies.

A useful rule for the application of deviation is:

Deviation East Compass Least
Deviation West Compass Best

(Deviation is often given an algebraic sign (+) or (-) indicating how it is to be applied to the compass direction to give magnetic direction. Thus deviation E is (+) and deviation W is (-)).

(viii) Plotting Directions. From the above we see it is possible to express a direction with regard to a particular compass needle as true direction, provided deviation with regard to a particular compass needle as true direction, provided deviation and variation are known. To avoid complications arising from changing values of variation and deviation during flight plotting is invariably carried out in true directions.



Three Expressions for Direction.

(viii) Plotting Directions Contd.

Three Expressions for Direction.

Compass Direction . . . . . . 225°
Deviation . . . . – 2W

Magnetic Direction . . . . . . 223°
Variation . . . . –12W

True Direction . . . . . . 211°

(e) Measurement of Distance.

(i) Nautical Mile. The standard unit of measurement in navigating is the nautical mile. This is defined as the length of the arc of a great circle which subtends an angle of one minute at the centre of the earth.

The important thing to remember is that the nautical mile is part of a great circle. An aeronautical chart therefore presents a distance scale along its meridians (which are great circles) but not along the parallels of latitude.

Now a degree contains 60 minutes. Thus the distance between any two adjoining parallels (e.g. 32°S and 33°S) must be sixty nautical miles (60 NM) when measured along a meridian or in a true N-S direction. This distance remains constant regardless of latitude or position on the earth's surface.

The length of a nautical mile is taken to be 6080 feet.

(ii) Statue Mile. (5280 ft). This is a purely arbitrary unit of measurement and is rarely used in navigation. However in survey flying use is often made of maps drawn to a scale such as 1 mile to 1 inch, 2 miles to 1 inch etc.; the mile in these cases being the statue mile.

Examples of maps using these scales are military maps, country and parish maps town plans etc.

(iii) Knot. This is a unit of the measurement of speed and is equal to 1NM per hour. The air speed indicators of British and U.S. aircraft are nowadays graduated in knots.

(e) Bearings.

(h) The direction of one point from another is called its bearing. Like all directions, bearings may be expressed as true magnetic or compass although for convenience they are normally expressed as true.

(ii) Positions are often recorded or reported as a bearing and distance from a known point such as a town or airfield. An aircraft approaching Sydney from the vicinity of Katoomba may report its position as 265 SY. 60 NM.

The position of a radio beacon in relation to its aerodrome may be recorded as 189 airfield 4.2 NM.

2. Terminology and the Triangle of Velocities.

(a) Terminology.

(i) Heading: The direction in which an aircraft is pointing is called its heading. It is the angle measured clockwise from north to the fore and aft axis of the aircraft. Because there are three north datums, heading may be expressed in three ways:

True heading (Hdg T.) measured from true N
Magnetic heading (Hdg M.) measured from magnetic N
Compass heading (Hdg C.) measured from compass N.

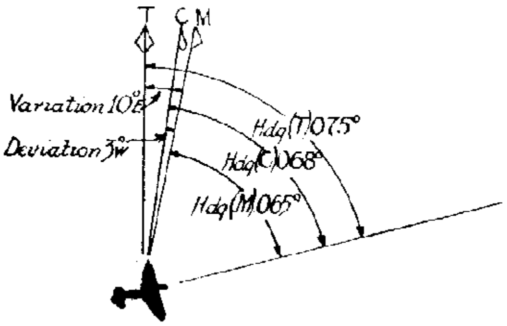


FIG. 15. Heading.

In fig. 1 an aircraft is flying on a heading of 068° according to its compass. Because the deviation of the compass on that particular heading is 3°W, the magnetic heading of the aircraft is 065°. The corresponding true heading is 075°, since local variation is 10°E.

(ii) Track: The direction of the path of an aircraft over the ground is called its track. If an aircraft flies directly upwind or downwind or in conditions of no wind its path over the ground lies in the same direction as its heading. In all other cases wind will cause the aircraft to move over the ground in a direction other than that which is in line with its fore and aft axis, and to an observer on the ground it will appear to move crabwise rather than straight ahead. In such cases the aircraft's heading and track are not the same.

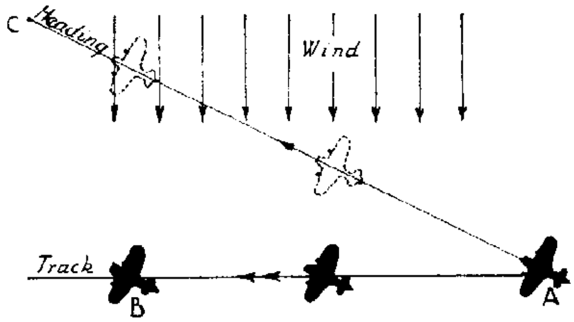


FIG. 16. Heading and Track.

In fig. 2 an aircraft at A is flying in the direction C. As it flies, maintaining a constant heading, a northerly wind carries the aircraft from the path it would have followed in the absence of wind, i.e. AC. It passes some time later over B. AB then represents the track of the aircraft and the aircraft is said to have tracked from A to B.

(iii) Air Speed: The air speed of an aircraft is its speed through the air mass in which it is flying. It is independent of wind and remains the same whether in conditions of no wind or with a head wind or with a tail wind, (The measurement of air speed is discussed in a later section).

(iv) Ground Speed: The ground speed of an aircraft is the speed at which it moves across the surface of the earth. It is measured normally in either of two ways.
(a) By measuring the distance between two positions on the ground over which the aircraft is observed to pass in a known time. This method is the most accurate and commonly used.
(b) By calculating the effect of wind on the progress of the aircraft.

(v) Wind velocity: Velocity is defined as rate of change of position in a give direction. It is therefore composed of both speed and direction.

Wind velocity is expressed as two groups of figures, separated by an oblique stroke. The first group denotes the direction from which the wind is blowing (and always expressed as three figures), the second denotes the wind speed in knots.

e.g. A Southerly wind of 30 knots – 180/30
A North-easterly wind of 15 knots – 045/15

(c) Drift and its Application.

(j) The angle between the heading and track of an aircraft is called drift. Drift is due to the effect of the wind and is the lateral movement imparted to an aircraft by the wind. An aircraft flying in conditions of no wind experiences no drift, nor does it drift if the heading of the aircraft is directly upwind or downwind; in such cases heading and track coincide and there is no drift. Under all other conditions the track and heading differ by a certain amount referred to as the drift.

(ii) Drift is normally measured by direct observation of the ground using an instrument which compares the passage of objects on the ground with the fore and aft axis of the aircraft.

For survey work the aldis sight is used. This was described in Section A, Equipment.

Drift is expressed in degrees Port (P) or Starboard (S) of the aircraft's heading. Thus an aircraft with Port drift drifts to Port and its track lies to port of its heading.

(iii) Application: In the greater part of survey flying the aircraft must be flown along predetermined tracks. Therefore, it is essential that the navigator has an exact knowledge of the aircraft's drift and is able to apply it correctly to determine the required heading.

A simple rule to give the necessary heading (the required track being known) is as follows:

Port drift	Plus to track
Starboard "	Subtract from track

e.g.	Drift	6P	Required Track 090	Heading 096
	"	2S	" " 270	" 268
	"	12S	" " 003	" 351

(c) The Triangle of Velocities.

The triangle of velocities is used to solve navigational problems in which the following six factors are involved:

Heading …..	Hdg.	
Track …..	Tr.	
True Air Speed	…..	TAS.
Ground Speed	…..	G/S
Wind Direction)		
Wind Speed)	Wind Velocity	W/V

(i) Vectors: Since a velocity is a speed in a given direction it may be represented graphically by a straight line drawn to scale and in the given direction with reference to a datum, usually North. Such a line is called a vector.

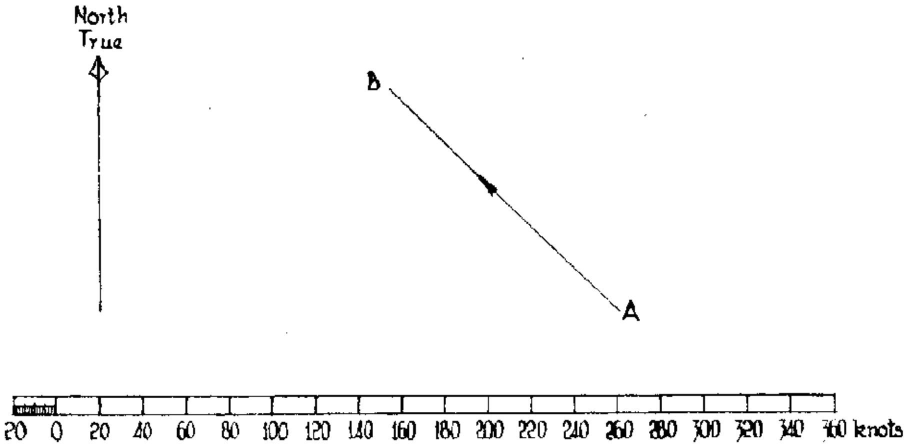


FIG. 22. A Vector.

The figure illustrates the vector of an aircraft which has a velocity of 150 k. in a direction of 315 T.

(ii) The vector parallelogram: A body may be subject to more than one velocity at the same time. In such a case the body has a resultant velocity due to the component velocities.

An example of this is an aircraft subject to two component velocities, a. its own velocity or air speed and heading, b. the wind velocity. The resultant velocity is the direction and speed of the aircraft over the ground, or its track and ground speed.

This resultant velocity can be determined by the construction of a vector diagram in the form of a parallelogram whose sides are the component velocities.

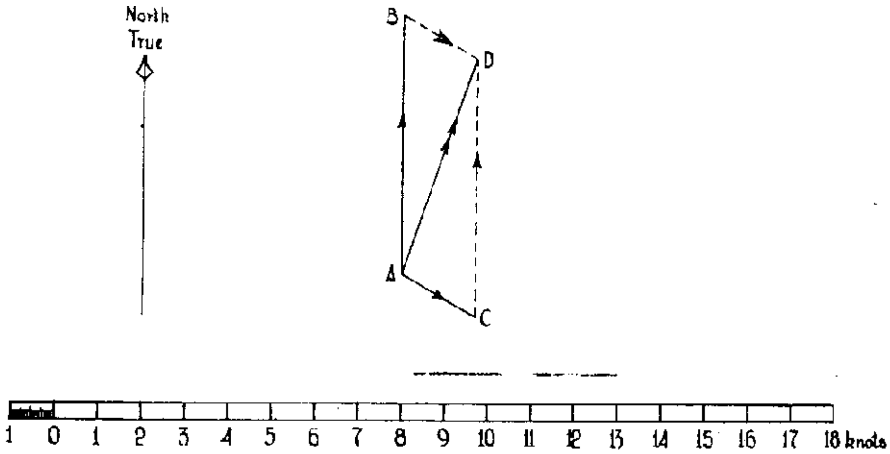


FIG. 23. The Vector Parallelogram.

In the diagram AB represents the heading and air speed of an aircraft and AC represents the wind velocity. The resultant velocity is the diagonal AD which represents the aircraft's track and ground speed.

Now the triangles ABD and ACD are identical ∴ it is unnecessary to construct a parallelogram when the resultant velocity of two component velocities is required; it is obtained more readily by the construction of a vector triangle. This is known as the triangle of velocities.

(iii) Use of the Triangle of Velocities in Navigation.

The triangle of velocities has been considered because if offers a solution to many of the problems of navigation. An aircraft is always subject to two component velocities, its own and that of the wind; these component velocities combine to produce a resultant velocity, i.e., the direction and speed of the aircraft over the ground. Knowing the component velocities of an aircraft, i.e., true heading and true air speed, and wind velocity, the vector triangle may be used to find the aircraft's resultant velocity, i.e., its track and ground speed.

(iii) Use of the Triangle of Velocities in Navigation (Contd.)

Conversely, if by some means the resultant velocity has been measured, it may be used in conjunction with either of the other velocities to determine the third.

(iv) The Arrow Convention.

Certain conventions are observed in labelling the vector triangle. The aircraft's own velocity, i.e., its true heading and true air speed, is indicated by a vector bearing one arrow pointing in the direction of flight. The wind vector bears three arrow indicating the direction in which the wind is blowing. The resultant vector of the aircraft's motion over the ground. i.e., the track and ground speed vector, is indicated by two arrows in the direction of flight.

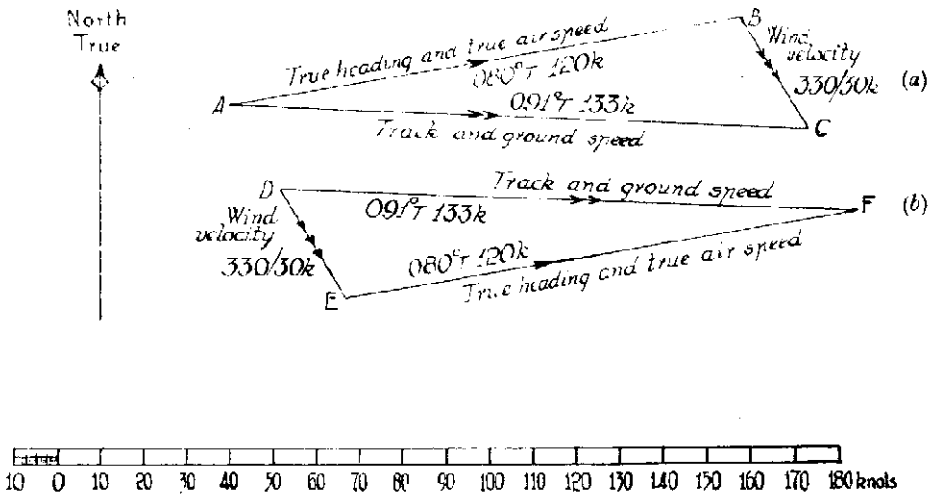


FIG. 25. The Vector Triangle.

In fig. 5 (a), ABC is a typical vector triangle. AB is the vector of the aircraft's true heading and true air speed and therefore bears one arrow pointing in the direction of heading, i.e., 060°T. BC is the wind vector and is labelled with three arrows pointing in the direction in which the wind is blowing, in this case from 330°T. The length of both vectors is determined by a scale line provided. AC is the resultant vector of track and ground speed and bears two arrows pointing in the direction of track. Its direction and length are measured to be 091°T and 133k. respectively.

(v) Rules for Plotting.

In plotting the vector triangle there are a number of points to note. True directions are always used for all vectors. A constant and uniform scale must be employed or results will be distorted. True heading and true air speed are inseparable, i.e., true air speed is measured only along true heading; track and ground speed are similarly linked as are wind direction and wind speed.

(vi) Types of Problems.

The triangle of velocity consists of six parts, each of its three vectors representing both a speed and a direction. A knowledge of any four of theses parts enables the navigator to solve the remaining two. There are fifteen different combinations of the two unknown parts. However many never arise in practice, and for our purposes in this introduction only the two most important will be discussed.

(vi) Types of Problems (Contd).

(a) To find the heading and Ground Speed: (the required track, the T.A.S. of the aircraft and the W/V must be known).

Example:

A navigator in an aircraft whose true air speed is 150 k. wishes to make good a track of 060°T, Wind velocity is 140/20K. What heading must he fly and what will his ground speed be?

Solution: (Fig. 6)

(i) Draw a line AX of indefinite length in a direction 060°T to represent required track.

(ii) From A lay off AB, the wind vector.

(iii) With centre B and radius true air speed, describe an arc to cut AX at C; the direction of BC, 068°T, is the heading required to make good a track of 060°T, AC represents ground speed, which is measured to be 144 k.

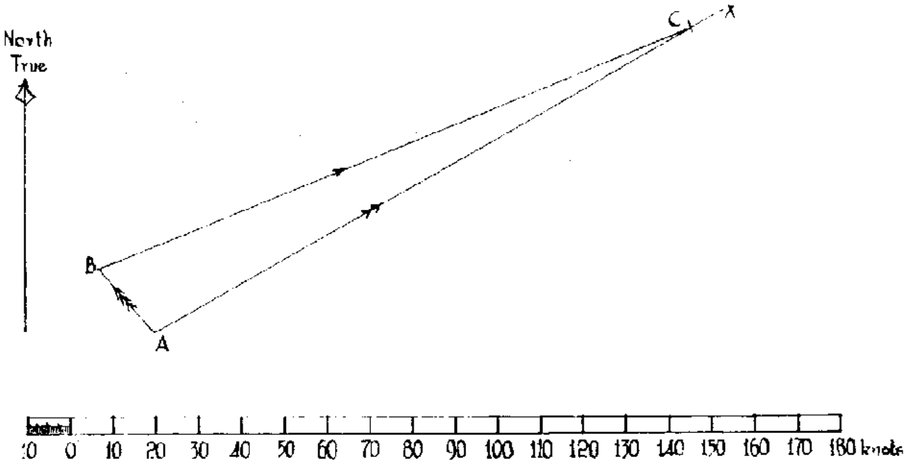


FIG. 29. Finding Heading and Ground Speed.

(b) To find the Wind Velocity: knowing the hdg., T.A.S., Tr. And G/S.

Example:

The ground speed of an aircraft is known to be 100 k. on a track of 255°T. Its rue air speed is 120 k. on a heading of 245°T. What is the wind velocity?

Solution: (Fig. 7)

(i) Plot AB, the heading and air speed vector.

(ii) From A lay off AC, the track and ground speed vector.

(iii) Join BC and measure its direction and length; wind velocity is found to be 207/28 k.

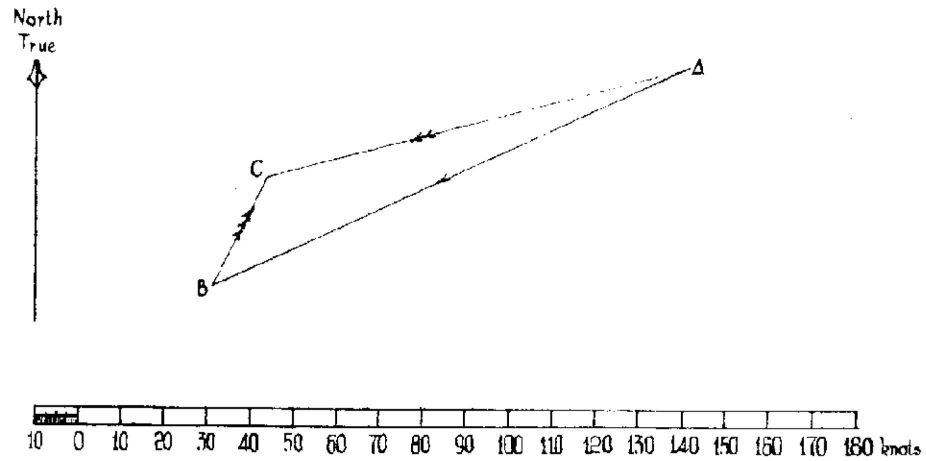


FIG. 27. Finding Wind Velocity.

(b) To find the W/V by the multiple drift method.

(This is a special case in which two or more triangles are used in conjunction. The theory is explained in he AP 1234).

Following is the most practical system of determining the W/V by this method:

(i) The aircraft flying at a known and steady TAS and on a known heading a drift is taken and recorded.

(ii) The aircraft is then turned 60 degrees to starboard of this heading and flown for three minutes during which time a second drift is taken.

(iii) At the end of the three minutes the aircraft is turned to port, 120° and a third drift taken.

(iv) After three minutes on this heading the aircraft is turned sixty degrees starboard thus resuming the original heading.

(v) This is known as flying a dog leg.

The turns could be the reverse of those illustrated, i.e. the original turn could be to port etc. and the result would be the same.

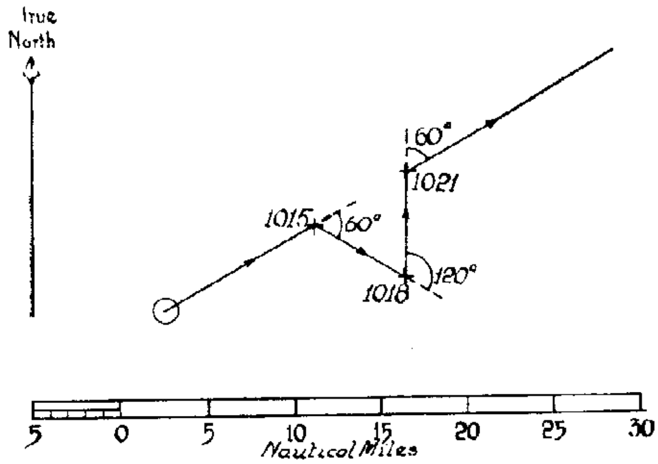


FIG. 10. The Dog-leg.

(vi) The wind velocity is now determined by plotting three triangles of velocity as shown below:

(The example illustrated is evidently not the result of flying a dog leg. However it demonstrates the theory – that the W/V can be found when drifts are taken on a number of different headings).

Example:

An aircraft of true air speed 120 k. observes a drift of 4°P. while on a heading of 220°T. Altering heading to 310°T., drift is measured to be 13°P. A third heading of 090°T. is flown and on drift is measured to be 13 ½ °S.

A circle of radius true air speed, 120 k. to scale, is described about any point 0. From 0 radii OA. 0B and 0C, are drawn in directions reciprocal to the headings flown. i.e. 040°T., 130°T. and 270°T. These vectors represent three headings of one hour's duration from points on the circumference of the air speed circle; the vectors meet at 0 which is, in effect, a common air position. By applying the relevant drifts, to the three headings, track vectors AX, BY and CZ are plotted. Since by construction the three headings flown have a common air position 0, the tracks must meet at a point because there can be but one wind vector. The tracks intersect at a point D. 0D is then the wind velocity for one hour; it is measured to be 017/27k.

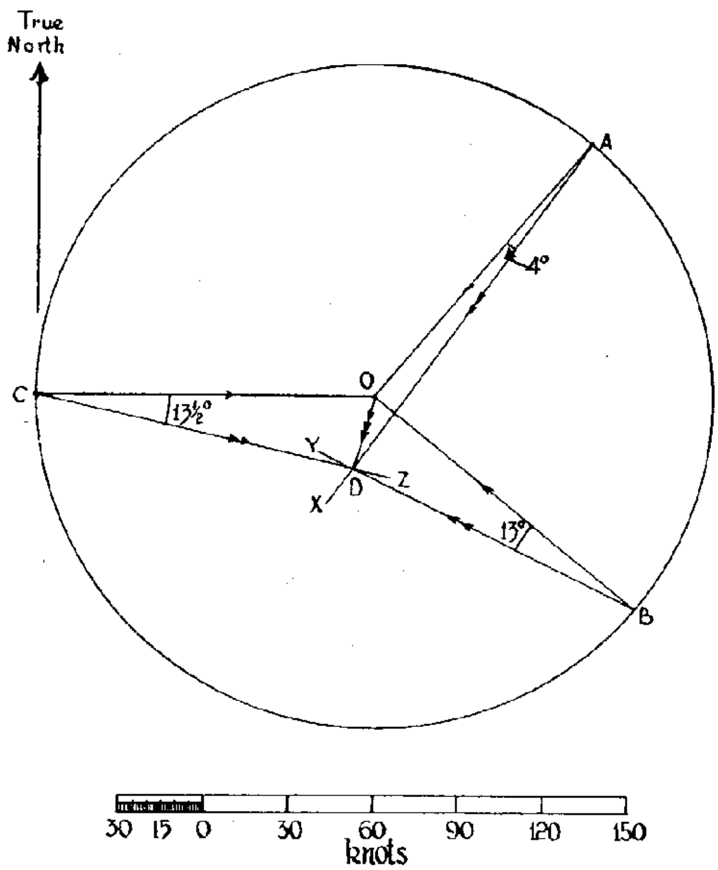


FIG. 9. The Multiple Drift Wind Velocity.

The Cocked Hat.

In practice measurement of drift may not be absolutely accurate and the plotted tracks may not meet at a point. Their intersection forms a small triangle, known as a cocked hat, the centre of which is taken to be the end of the wind vector, or wind point. Generally speaking, the size of the cocked hat is a measure of the reliability of the wind velocity so measured and date giving a large cocked hat should be re-observed.

Use in Survey Flying.

The majority of survey flying is along E to W and W to E tracks, and an exact knowledge of the W/V is not essential. The drift can be found on one track and checked on the reciprocal. However in such cases as a road survey, numerous different headings must be flown and if the W/V over the survey area is known the drift for each separate run can be computed and valuable time saved.

Therefore it is good practice in these operations to determine the W/V before starting the actual survey. The most convenient method of doing this is by multiple drifts.

Use of the Computor.

In practice problems involving the triangles of velocity are readily solved using a mechanical computer which eliminates plotting and is therefore much faster.

The computer and its use is explained later in the section on instruments.

3. Maps – Charts, Map Reading.

Introduction: The only way of reproducing a true undistorted picture of the Earth's surface is to do so on the surface of some object similar in shape to the Earth itself – that is on a sphere or part of a sphere. For obvious reasons this is not practical (except perhaps in the case of the familiar school room globe, the scale of which is too small for navigational purposes).

Therefore in practice the Earth's surface is represented on plane sheets in the form of maps plans and charts. However no flat map can represent a portion of the Earth's spherical surface in exact detail and some characteristics will be shown inaccurately.

Projections: A projection is a method of representing the Earth's surface on a plane or flat surface. There are various systems of projection but we need not concern ourselves here with these systems or the mathematics involved. Our discussion will be limited firstly to the desirable features of a projection and secondly to the uses and properties of the two projections most widely used in air navigation.

Desirable properties of a projection:

a. Representation of a rhumb line as a straight line.
b. Representation of a great circle as a straight line.
c. A constant scale for measurement of distance anywhere on the projection.
d. A simple and easy method of plotting positions.
e. True representation of shapes and areas as they are on Earth (this is known as Orthomorphism).

a. Representation of Rhumb Lines as straight lines:

This is a particularly useful feature. Except for very long distance flights an aircraft flies along a rhumb line track. This is so because, by definition, direction along a rhumb line remains constant, which greatly simplifies navigation and the steering of the aircraft.

Hence on a projection on which rhumb lines appear as straight lines, the rhumb line track between any two points is easily measured.

b. Representation of great circles as straight lines:

This is desirable for long distance flights when the difference in distance between the rhumb line and great circle tracks between two points may be considerable. In this case the aircraft will fly the great circle route and a projection showing the great circles as straight lines will be used to determine the distance and the route to be followed (normally a number of short rhumb lines approximating the one great circle).

Such a projection has a second useful property. Radio waves follow great circle paths and radio bearings are therefore easily plotted on it.

c. Constant Scale:

This is obviously desirable but on many projections does not occur due to the compromises which must be made when carrying out the projection.

(Scale: This scale of a map is the radio between a given length on the map and the actual distance this length represents on the Earth's surface. Scale may be indicated in any of three ways:

(i) By a statement in words e.g. 1 inch to 1 mile, four miles to the inch etc.
(ii) By a fraction e.g. 1: 1,000,000 (This is called the natural scale)
(iii) By a graduated scale line.)

d. An easy method of plotting positions:

In other words a straight forward and simple presentation of the parallels of latitude and the meridians of longitude.

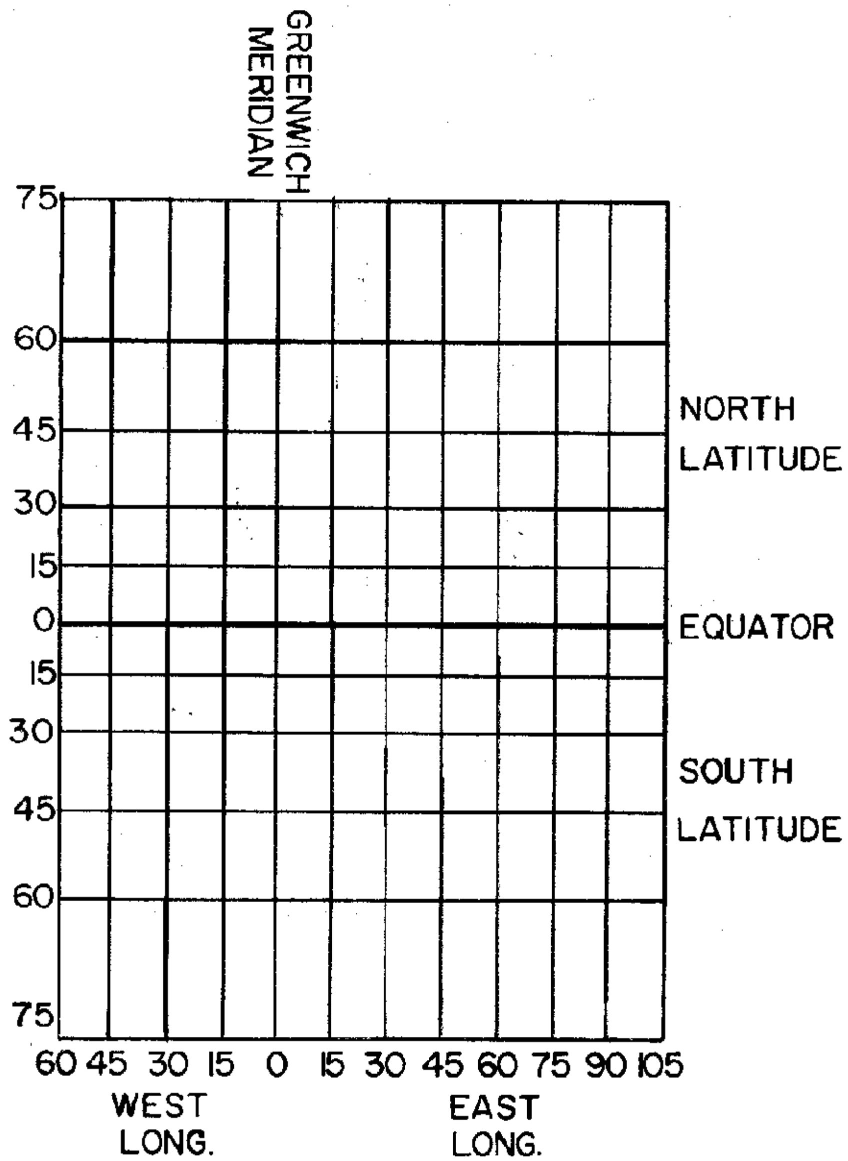
e. Orthomorphism:

This is highly desirable. An orthomorphic chart is free from angular distortion and hence direction is represented correctly and remains constant over the chart.

Mercator's Projection.

This is the most used of all projections in navigation. More than any other it possesses the characteristics desirable in a projection. It is orthomorphic, its rhumb lines are straight lines, positions are simply plotted and although the scale is not constant, distance is measured relatively simply on a uniformly increasing scale.

The principle disadvantages of Mercator's projection are that distortion of area increases with latitude and that great circles (except meridians and the equator) do not appear as straight lines.



MERCATOR PROJECTION.

From the above diagram it is seen that the meridians of longitude appear as parallel straight lines (Remember that on the sphere they converge to meet at the poles) Hence on the Mercator the poles cannot be projected. In fact the practicable limits of the chart are 75 S and 75 N.

It will also be seen that the distance between succeeding parallels of latitude increases from the equator towards the poles. This increase is in proportion to the opening out of the meridians and results in the projection being orthomorphic.

Measurement of direction: The direction of a rhumb line is measured by the angle it forms with any meridian.

Measurement of distance: As the scale over the chart is not constant, care must be taken when measuring distances on it However the latitude scale increases at a uniform rate and if this latitude scale approximately at the middle of the track is used, the measured distance will be correct.

Summary of Features of the Mercator.

Recognition of graticule: Parallels are straight parallel lines, the distance between them gradually increasing with increase of latitude. Meridians are straight parallel lines evenly spaced.

Properties:

(i) Scale varies but if the scale for the middle latitude of the distance required is used, then it is correct. Therefore when measuring a distance on a Mercator chart the scale must be used of the same latitude approximately as the middle of the distance.

(ii) It is orthomorphic. This valuable property accounts for its wide usage, together with the fact that:

(iii) A straight line represents a rhumb line

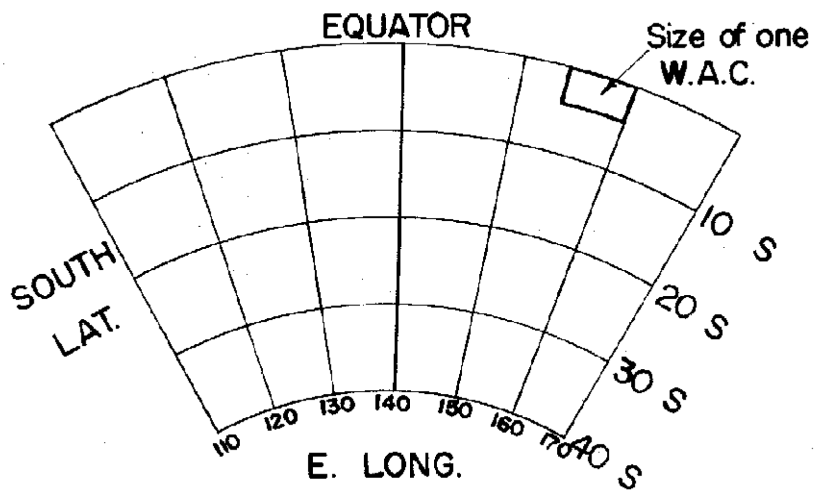
(iv) Area is amplified enormously towards the poles.

Lamberts Conformal Projection.

The great advantage of this project is that there is little distortion of shape and area, and it is therefore particularly adapted to charts for map reading purposes. Hence it is now used almost exclusively as a topographical series, that is for maps showing all the various ground details visible and useful to the airman.

The graticule differs from Mercator's in that the meridians are straight lines converging towards the nearer pole and the parallels are areas of concentric circle, spaced not quite evenly along the central meridian.

In its most used form the chart appears under the title of "World Aeronautical Chart", Scale 1: 1,000,000 (W.A.C.) It is intended that eventually every land mass on the earth will be covered by chars of this series.



LAMBERT'S CONFORMAL PROJECTION

Measurement of distance: For practical purposes the scale over the chart can be considered constant. Therefore distance along a track can be measured using any portion of the latitude scale for that particular chart.

Measurement of direction: Since the meridians are not parallel, a straight line does not represent a rhumb line. However the difference is slight and if measured at a central meridian, a straight line joining two points may be considered a true rhumb line.

In addition, great circles on the Lambert approximate a straight line and hence radio bearings may be plotted direct as straight lines.

Use of the Two Projections.

We may summarise the use of these two types of charts by saying that for precision work the Mercator is used, that the airman uses the Lamberts chiefly as an aid in identifying visible ground features, while plotting on a Mercator.

Map Reading

In normal point to point navigation, map reading, in spite of the introduction of advanced techniques and aids, still retains an important place.

In survey flying on the other hand, the airman uses it constantly and successful work is so often dependant on his map reading ability that he must develop the art to its highest pitch.

Map reading ability varies extensively according to the natural aptitude of the individual and the amount of effort put into practicing it.

The act of map reading consists of:

(a) Visualising without thought the ground features represented by the signs sown on the map. This calls for a thorough knowledge of conventional signs and the ability to translate them mentally into a picture of the features for which they stand.

(b) Knowing the relative values of the features represented on the map. This requirement calls for a combination of experience and common sense and varies with the nature of the terrain over which the flight is made.

(c) The ability to weld individual features into a composite picture of the ground below. This calls for ability to estimate the directions and distances of features relative to each other both on the map and on the ground.

Conventional Signs.

The first series of conventional signs with which the survey navigator must become familiar, is the one appearing on the normal topographical map, the World Aeronautical Chart partly described above. The continent of Australia and the nearly islands, including New Guinea, are covered by approximately 50 sheets in this series. (A small number of the series covering remote areas has not yet been issued and in these areas, recourse is made to the older 1: 1,000,000 charts based on Mercator's projection).

Each chart covers 4°of Latitude and 6° of Longitude and adjoins its neighbours so as to give a continuous coverage. On the reverse of each chart is an extensive legend detailing the symbols, and their colour, for every feature which occurs on the map.

These topographical maps are used in cross country flying, in flying from the operational base to the survey area, and frequently to locate the boundaries of the area. In some cases they are also used for the actual survey flying e.g. the first run and the key runs (of which more will be said in later sections).

However in most cases it will be found that the scale of these topographical maps is too small to give the accuracy required in survey work and so whenever they exist use is made of maps drawn to a larger scale. They may be Military, Lands Department, or other type plans drawn to varying scales.

Although certain symbols will be found to be common to two or more types of maps, the airman must become familiar with the signs for each, and for this purpose a legend is normally appended to each chart.

Indication of Height.

The height of the ground over which the aircraft has to fly is of vital importance to the airman because of safety factors. The survey navigator must also know the height of the ground in his operating area as this will often determine both the flying height and the distance between flight lines.

Information as to the height of the ground is indicated on the map in one or more of the following ways:

(i) By contour lines
(ii) By spot heights
(iii) By layer tinting
(iv) By hachuring

(i) Contour Lines: These are lines joining places of equal height above mean sea level. The interval of height at which contours are drawn depends on the scale of the map and thus varies greatly.

The height level of each contour is stated at some point or points along its length and the intervals of height between contours is normally given in the legend for the chart.

Steeply rising ground is indicated by closely spaced contours and conversely, widely spaced contours indicate flat or gently sloping ground.

(ii) Spot heights: Contour lines give a ready picture of the variations in height of the terrain. However they do not show the height of the highest point in each series of contours. This difficulty is overcome by stating in figures the height of the highest spot in the locality against a black dot denoting its position.

Those spot heights are also shown next to various other features such as townships, railway stations, homesteads etc., (and of course are always included in the information associated with aerodromes).

(iii) Layer Tinting: Topographical maps also make use of a system of height indication called layer tinting. The contours already described are emphasised by tinting the area between each pair of adjacent contours. The shades of colour chosen become deeper with increase of height and thus the map shows at a glance the areas of hilly or mountainous terrain.

(iv) Hachuring: Hachures are short tapered lines drawn on a map radiating from peaks and high ground. They appear on topographical maps only in unsurveyed areas, although they are used frequently on plotting charts where the ground detail is reduced to a minimum.

Relative Values of Features.

Knowing the amount of detail to be expected of maps of different scales and given a knowledge of the conventional signs by which the detail is indicated the map reader is in a position to appreciate the relative values of the features seen on the ground. The beginner is sometimes confused by the amount of detail shown. He must learn to distinguish the more significant features and discard the irrelevant background. The following is a list of the useable features in order of importance to the map reader.

(a) Railway Lines: These are easily distinguished from the air and afford one of the best means of ascertaining position or checking ground speed.

(b) Coastlines: When operating near the coast these also provide first class checking points.

(c) Towns: Except when in the vicinity of the large capital cities, towns are easily identified and are good check points. Permanent features such as the number and direction of railways, roads and rivers entering the town should be carefully noted to avoid error.

(d) Water Features: Large rivers, lakes, canals and reservoirs are the main water features and are normally quite prominent. However seasonal conditions especially in the Northern and Central parts of Australia must be taken into consideration. In times of flood or drought water features may differ considerably from the shape or position shown for them on the map.

(e) Mountains and Ranges: As an aircraft's height above the ground increases, the terrain below appears to flatten out. Hence mountains vary in their value as landmarks. This is especially so in the central regions of Australia where the ranges are rarely high and often poorly mapped due to inadequate surveys.

(f) Roads: In populated areas roads provide poor landmarks because of their profusion. In addition secondary roads which may not be mapped can cause confusion as they generally stand out more clearly than the black surfaces of first class roads. However in outback unsettled areas, roads are often valuable check points.

(g) Aerodromes and Airstrips: Due to the number of stations in Australia which nowadays have their own landing strips these features are often of doubtful value as the majority does not appear on he topographical series.

(h) Homesteads, Water holes, Tanks Fences: Although these features appear in great numbers on he Australian maps, they are of small value due to their multiplicity and the fact that new ones constantly appear after the drawing of the map.

Some Rules for Map Reading.

1. Always align the map so that the plotted track on the map lies in the same direction as the path the aircraft is making over the ground. (Remember that in conditions of a high beam wind, the heading of the aircraft will be considerably different to its track).

This is known as correct orientation. When the map is correctly oriented the direction in which a feature lies or the relationship of one feature to another is more readily perceived.

2. Look from the map to the terrain rather than vice versa. That is to say objects on the map should be searched for on the ground rather than that the country should be fitted to the map. The reason for this is that many objects on the ground may not be represented on the map but everything marked on a reliable map must be on the ground.

3. Wherever possible do not rely on any one feature in itself, but combine it with another nearby feature. This will resolve any ambiguity and provide a more definite fix.

4. Anticipate features before they show up. This is best done by selecting prominent features along the track beforehand and tabulating the estimated times of arrival at these points. Once a ground speed is established it is a simple matter to revise these E.T.A.s if necessary.

5. Do not jump to conclusions. After identifying a feature, ensure its accuracy by either combining it with a second feature or checking its position by D.R.

6. Compare as many pinpoints as possible with the D.R. position. A big difference indicates either an incorrect pinpoint or alerts the airman to a wind change.

4. Compasses.

Introduction: It was mentioned earlier that the Earth acts as a huge, if somewhat weak, magnet and radiates lines of magnetic force. These line of force emanate from the magnetic poles and cover the Earth's surface, lying approximately in a N-S direction. It must be understood that the magnetic poles do not co-incide with the true poles and in fact are a thousand miles or more from them. (The positions of the magnetic poles also slowly change from year to year however after many years of observation, the rate of change is now known).

The Magnetic Compass.

The magnetic compass is an instrument used to indicate direction in a horizontal plane. Its primary function is to show the heading of the aircraft in respect to magnetic north. To do this the compass makes use of the fact that a freely suspended magnet aligns itself with the Earth's lines of force, thereby indicating the direction of the magnetic poles.

The compass consists of a group of small magnets rigidly attached to a light wire framework, which is suspended from a pivot resting on a jewelled cap. The framework includes a N=S wire marked with an arrowhead to show N, and a series of damping wires to reduce oscillation. The whole system rotates inside a bowl filled with a clear liquid, usually pure alcohol.

The bowl is sealed by a glass cover, and incorporates refinements such as expansion chambers to compensate for alterations in the volume of the liquid, and a complex suspension system to prevent aircraft vibrations affecting the compass reading.

Fitted to the top of the compass is a grid ring, secured so that it may rotate freely but cannot be lifted off. The grid ring is graduated in steps of 2° from 000 to 360, the cardinal points being lettered. Two wires, known as grid wires, are stretched across the grid ring parallel to the N-S diameter of the ring. The degrees scale and the wires are protected by a second glass cover and a clamping device is provided to lock the grid ring in any desired position.

The compass is secured in the aircraft n such a position that a visible lubber mark, fitted inside the bowl, indicates the fore and aft line of the aircraft.

To determine the compass heading of the aircraft, the grid ring is rotated until the grid wires are parallel with the N-S wire of he magnet system and the heading is then read off against the lubber line.

To fly a required compass heading, the grid ring is rotated until the necessary heading is against the lubber line and the grid ring locked in that position. The aircraft is then turned until the N-S wire is lined up parallel to the grid wires.

Of course in both these operations care must be taken to ensure that the N seeking end of the magnet system and N as marked on the grid ring coincide and are not 180° out.

Objections to the Magnetic Compass.

In its finally developed form this type of compass is a reliable and reasonably efficient instrument. However, it suffers from a number of defects which make it unsuited for the precision flying required in aerial survey. These are as follows;

(a) Excessive Deviation Effects: Deviation is the error introduced into the compass by magnetic influences inside the aircraft itself. These magnetic influences are largely the result of electrical

Objections to the Magnetic Compass Cont.

circuits in the vicinity of the compass. The simple magnetic compass must be installed in the crew compartment and is thereby subjected to a variety of these circuits.

(b) Turning Errors: When an aircraft in flight executes a normal turn, it banks so that one wing is lower than the other. This tilts the magnetic system of the compass out of the horizontal plan and brings it under the influence of a force known as the "vertical component of the Earth's magnetic field". As a result the directional properties of the compass are upset and large apparent deviations appear during the turn, making the compass completely unreliable at such times. Then with the turn completed and the aircraft in a straight and level attitude again it will be some minutes before the magnetic system has settled down sufficiently to give an accurate indication of heading.

(Because of this defect the compass is normally disregarded during and immediately after a turn and use is made of the Directional Gyro. This instrument is described below).

(c) Errors in Reading the Compass: As the grid ring is graduated in 2° intervals, precise readings of the heading are difficult to make. In addition, unless the compass is placed directly in front of the pilot, an error due to parallax is also introduced.

(d) Effects of Turbulence: Turbulent conditions tend to upset the compass by imparting extraneous movement to the magnet system and the compass liquid.

Mainly because of these reasons the simple magnetic compass has been replaced in modern aircraft by the more advanced gyro-magnetic types. These instruments are also particularly well suited to the requirements of aerial survey.

Before describing the Gyro-magnetic type compasses it will be necessary to discuss briefly the Directional Gyro which is an integral part of these units.

The Directional Gyro.

A gyroscope is fundamentally a spinning wheel supported inside a suitable framework. If the speed of rotation of the wheel is sufficiently high, it acquires a property known as "rigidity in space". This means simply that when spinning in a certain direction the wheel will maintain that direction regardless of movement or changes in direction of the framework.

Use is made of this property to provide the airman with a directional reference in the form of an instrument known as the directional gyro or D.G. The D.G. is not a compass in that it has no north-seeking property, and has therefore to be lined up with the magnetic compass or some other datum. However, it possesses the great advantages that it does not suffer from magnetic disturbances or turning errors.

On the other hand it has one serious disadvantage. It will not maintain its direction indefinitely but slowly drifts away from the heading on which it has been set. This wander is brought about by mechanical imperfections in the instrument and an apparent drift due to the Earth's rotation.

For many years, in spite of the limitations of both, the D.G. used in conjunction with the simple magnetic compass was the best means available to maintain a heading or turn on to a desired heading.

Gyro-magnetic Type Compasses.

The ordinary magnetic compass is badly affected during turns as had already been explained and the pilot normally uses his D.G. when he knows the magnetic compass is giving inaccurate readings. The D.G. however, cannot be used for long periods of time because of the precessional effects described above.

In recent years compass development has been concentrated on

(a) the production of distant reading compasses, the idea being to place the direction seeking instrument in a position clear of disturbing magnetic influences within the aircraft, and
(b) the combination of the directional property of the Earths magnetic field with the useful qualities of the D.G.

This has been achieved and the resulting compasses are instruments of great accuracy and dependability. There are three systems in use. (In all three the master, or detector, unit is situated as far as possible from disturbing magnetic influences in the aircraft, e.g. in the wing tips, or rear of fuselage).

(a) Gyro-magnetic System.

In this system the basic unit is a bar magnet situated in the master unit and pivoted on a vertical axis. Heading indications from the magnet are transmitted at regular small intervals to a gyroscope which is housed immediately above the magnet. The reading of this gyroscope is transmitted electrically to repeater units in the cockpit.

(b) Gyro-fluxgate System.

A flux valve is a magnetic element which measures the strength of a magnetic field. Three fluxvalves arranged in the shape of an equilateral triangle will also measure the direction of the field.

In the gyro-fluxgate system, fluxvalves measuring the Earth's field are mounted on a gyro. The system is thus always kept horizontal and accurately indicates the aircraft's heading at all times even during turns. Signals from this master unit are amplified and transmitted to a master indicator and repeater units if required.

(c) Gyrosyn System.

This s the latest development and combines the advantages of the first two systems. Its master or detector unit is a flux valve fitted in a small hemispherically shaped bowl which is filled with oil and sealed. This unit is not stabilised but signals from it are relayed via an amplifier to a directional gyro. Thus it somewhat resembles the gyro-magnetic system in operation.

Besides the master unit, the D.G. unit, and an amplifier, the compass includes a master indicator and, if required, a number of repeaters.

A simple control is included on the D.G. unit to synchronise it in direction with the detector unit. A device known as the annunciator provides through a small window a continuous visual signal of an alternating dot and cross as long as the two units remain synchronised.

The master indicator is graduated in 1° intervals and gives very accurate readings of the aircraft heading. Also on the master indicator is a particularly useful control known as the Variation Setting Control or V.S.C. With this device the local magnetic variation can be set and the compass will then indicate true heading. (Compass deviation on the gyrosyn can be corrected such that the residual deviation should not exceed ½ ° on any heading).

The advantage of the gyrosyn type compass can be summarised as follows:

(i) The siting of the detector unit away from disturbing magnetic effects means that residual compass deviation is negligible.

(ii) The compass does not suffer from turning error and thus indicates the aircraft accurately during turns. This is particularly important to the operating survey crew who often must depend on the compass to arrive over a certain point on a given heading.

(iii) The presentation of the heading on the master indicator is very clear and enables headings to be maintained to an order of ½ °.

(iv) The provision of a V.S.C. enables true headings to be flown, a great advantage in survey flying.

(v) Turbulent conditions do not affect the accuracy of the compass.

Correction of Deviation.

Naturally enough, before any compass can be of service to the airman, he must know the amount and sign of its deviation on all heading. This deviation is determined in a procedure known as “Swinging the Compass”. The compass swing also aims at reducing the deviation to minimal amounts.

Briefly the compass swing is carried out as follows:

The aircraft is taken to a level area away from foreign magnetic influences, such as hangars, motor vehicles etc., and then successively positioned on the cardinal headings, usually in the order N, E, S and W.

In each of these positions the reading of the aircraft compass is checked against an accurate external compass, which is equipped with a sighting device enabling it to be lined up with therefore and aft axis of the aircraft. The difference in the readings indicates the deviation of the aircraft compass on each particular heading.

It is during this part of the swing that the deviation is reduced to the smallest possible amount. This is achieved by using correcting devices which vary from small magnets fitted under the simple magnetic compass, to resistances in the electrical circuits of the gyro-magnetic types.

After this “Correcting Swing” the aircraft is “check swung” i.e. it is positioned on the eight headings NE, E, SE etc. round to N and again the external compass (often called landing compass) is used to determine the residual deviations. Sometimes for greater accuracy the check swing is done on 12 headings each 30° apart. The results of the check swing are tabulated on a card which is then placed in the aircraft next to the compass to which it refers. From this card the airman is able to convert any desired heading from magnetic to compass, or vice-versa.

The subject of compass deviation and its correction is extensive and our description of it has given but the briefest of outlines. The student is advised to assist wherever possible at an actual compass swing; this will give a ready insight into the practical procedures used. Following this, if so desired, any standard navigational text book will explain the theoretical principles involved.

INSTRUMENTS

(a) The Air Speed Indicator (A.S.I.)

The A.S.I. is fitted to an aircraft to show the airman the speed at which his aircraft is travelling through the air. It does not of course indicate the speed at which the aircraft is passing over the ground, as that depends also on the speed of the air relative to the ground.

The instrument consists of a pitot or pressure head, a static head, tubes connecting these heads to a sealed case on the front of which is the indicating dial graduated in knots, and inside the case a flexible capsule which is mechanically linked to a pointer on the dial.

The pitot head is placed outside the aircraft in a position away from slipstream disturbances, and is a protruding open ended tube lying in the horizontal p lane and parallel to the fore and aft axis of the aircraft when it is in normal flying attitude. Tubing from the pitot head leads directly into the flexible capsule.

The static head (or vent) is usually placed on the fuselage in a position where tests have shown that the pressure (or static pressure) is as close to the surrounding atmospheric pressure as possible; in other words where it is unaffected by slipstream disturbances. The static head is connected to the inside of the scaled case.

Thus we see that when the aircraft is at rest the pressure inside the flexible capsule is equal to the pressure in the sealed case but when the aircraft is in flight the pressure in the pitot head is increased and this is transmitted to the inside of the capsule, which expands. This expansion is communicated to the pointer which moves over the dial indicating the increase in speed. It will be realised that the expansion of the capsule only occurs because the pressure inside the casing remains at still air pressure since it is connected to the static pressure vent. The expansion of the capsule is also directly proportional to the pressure in the pitot head, the higher the speed the greater the expansion and vice versa.

The A.S.I. is subject to a number of errors and rarely, if ever, indicates True Air Speed. These errors are as follows:

(1) Position Error. This is due to either the pitot head or static vent being in a position where the airflow is disturbed by some other part of the aircraft and thereby giving a false indication of the pressure at either point.

(11) Instrument Error is caused by small constructional defects in the mechanical parts of the indicator.

(Position error and instrument error are determined by calibration for each particular instrument and applied as a single correction to the indicated reading).

(111) Density Error. At low levels where the air density is high, a low speed setting up a particular pressure at the pitot head will cause the capsule to expand as such as will a greater speed at a high altitude setting up the same pressure in the less dense air. Therefore the A.S.I. underreads at height and a correction must be added to the indicated reading to obtain the True Air Speed. This correction is found using the navigational computor and is described later in this section.

The following terms are in common use in connection with air speed indicators:

Indicated Air Speed (I.A.S.) – The reading shown on the A.S.I.

Rectified Air Speed (R.A.S.) – The indicated air speed corrected for instrument and position errors.

True Air Speed (T.A.S.) – The rectified air speed corrected for height and temperature.

Instruments. Contd.

(b) The Altimeter.

The Altimeter is simply a pressure gauge, the dial of which is graduated in units of altitude instead of units of pressure. It is used to measure the height of the aircraft above a predetermined datum plane, normally sea level.

Before considering the construction of the altimeter we must note a few simple facts about the Earth's atmosphere. The pressure at any point in the atmosphere is due to the weight of the column of air above that point and is therefore related to the altitude. In other words as we ascend higher, the amount of air above us becomes less and hence the pressure it exerts becomes less.

A nominal relationship between pressure and altitude has been internationally agreed upon. This relationship has been based on the assumption that the surface pressure is 1013.2 millibars, that the surface temperature remains at 15°C and decreases with altitude at a constant rate of 1.98°C per thousand feet. This is known as the International Standard Atmosphere and nowadays all altimeters are calibrated in accordance with it.

However such an arbitrary set of conditions would rarely occur and the pressure (or altitude) indicated by an altimeter invariably needs adjustment for the departure from the standard atmosphere.

Construction.

The basic unit in the altimeter is an aneroid cell which expands or contracts with changes in the atmospheric pressure. This aneroid cell is a thin circular corrugated capsule from which the air has been evacuated. It is supported on the base plate of the altimeter and prevented from collapsing by a leaf spring.

When the instrument is taken to a higher altitude the decrease in pressure allows the cell to expand; this expansion is transmitted by a mechanical linkage to a pointer which moves over the dial and shows the decrease in pressure as an increase in height. The reverse effect occurs with a decrease in altitude. The whole mechanism is enclosed in an airtight casing which is connected to the aircraft's static pressure vent.

Errors.

(1) Pressure Error: This is due to the difference between the prevailing pressure and that assumed by the standard atmosphere. The instrument is provided with a so-called barometric sub-scale by means of which this difference can be corrected. The sub-scale can be set to any desired barometric pressure and indicates the "altimeter setting" by a group of figures showing through a small window at the bottom of the dial. These figures denote the setting in millibars (or mbs).

(11) Temperature Error: Once again this is due to the existing temperature of the atmosphere up to the height being measured, differing from that assumed in the calibration of the instrument.

The approximate error can be determined on the navigational computor correcting indicated eight to true height. However this method falls short of the accuracy required in survey flying and more advanced methods will be discussed in the section of altimetry.

(111) Instrument Error: Is due to inaccuracies in the construction of the altimeter and is found by calibration.

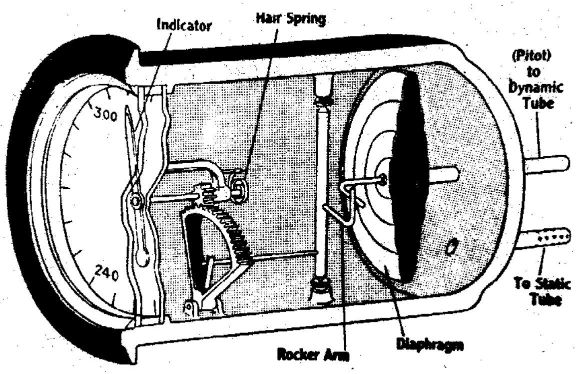
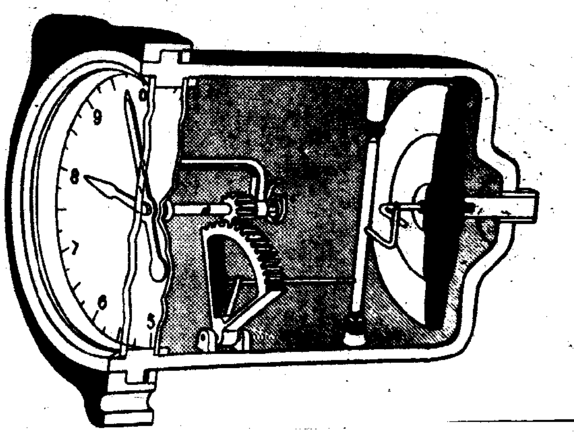


FIG. 604. The airspeed meter.



(c) The Navigational Computor. (Dalton Pattern.)

(This section will be more readily followed with an actual computor at hand.)

The Dalton computor is a personal instrument used by the airman for the following functions:

(1) To solve vector problems without recourse to plotting.

(11) To solve time – speed – distance – fuel problems.

(111) To correct the A.S.I. and Altimeter for temperature and height errors.

Vector problems are solved on the circular perspex face which overlays a moveable graph. On the reverse of the instrument is a circular slide rule used for the time/speed problems and incorporating two inset scales for the altimeter and air speed indicator corrections.

(1) Vector Problems.

We need concern ourselves here with three only of the many vector problems.

(a) To find the Hdg. And G/S for a given T.A.S., W/V and desired Tr.

Example 1. W/V 295/30, TAS 180, desired track 158°.

Turn the compass rose to read 295 at true index. This is the direction from which the wind is blowing. Count down from the centre point 30 kts. According to the scale along the centre line and draw in the wind vector from the centre point. Move the slide or graph until 180 kts, the TAS is under the centre point. Then rotate the compass rose until the required track 158° is at true index. Note the drift at the end of the wind vector. By trial and error rotate the compass rose until the drift at the end of the wind vector coinsides with the drift indicated on the drift scale against the desired track. This occurs when the drift indicated is 7°P (or left) head the true heading 165 at true index and the G/S, 200 kts. On the ground speed circles at the end of the wind vector.

(In practice it is not necessary to draw in the wind vector, a small cross at the end of the vector being sufficient.)

(b) To find the W/V for a given Hdg., TAS., track (or drift) and G/S.

Set the Hdg. Against true index and the TAS under the centre point. Pencil a cross at the intersection of the drift line and ground speed circle corresponding to the given G/S and Tr. Rotate the compass rose until the pencilled cross is on the centre line and below the centre point. The wind direction is read at true index and the wind speed is the length of the vector from the centre point to the cross according to the scale on the graph.

(c) To find the W/V by the multiple drift method.

Example 2. Given TAS 180 kt.

Hdg	130	drift	7 P
"	190	"	5 S
"	235	"	10 S

Set the TAS.

In turn set each heading against true index and then along the corresponding drift line for each heading pencil in a straight line. These straight lines represent the three tracks and intercept at one point. Rotate the compass rose until this point is on the centre line below the centre point. Read off the wind speed and direction as before. In this case W/V is 165/32.

(In most cases due to errors in the drift readings the three tracks will intercept as a small triangle. This is called a cocked hat and it's centre is taken as the wind point. If the cocked hat is not small, the W/V found must be treated with reservation until it can be checked or a new wind found).

(11) Time – Speed – Distance – Fuel problems.

These are rapidly solved on the circular slide rule on the reverse of the computor.

The slide rule has continuous logarithmic scales for the solution

Time – Speed – Distance – Fuel Problems. Contd.

of any multiplication, division or proportion. A little practical instruction and actual handling of the scales, beginning with simple problems, the answers to which are known, will soon bring proficiency in its use.

(111) Air Speed Indicator and Altimeter Corrections.

This is a straightforward procedure using the applicable sub-scale on the rotatable disc of the circular slide rule. Simple instructions are printed near each subs-scale. (One point to remember is that pressure-altitude is the reading of the altimeter with the pressure set to the standard figure of 1013.2 mb. Inspection of the computor will immediately indicate the required procedure.

THE AERIAL COMPUTER TYPE E-6B

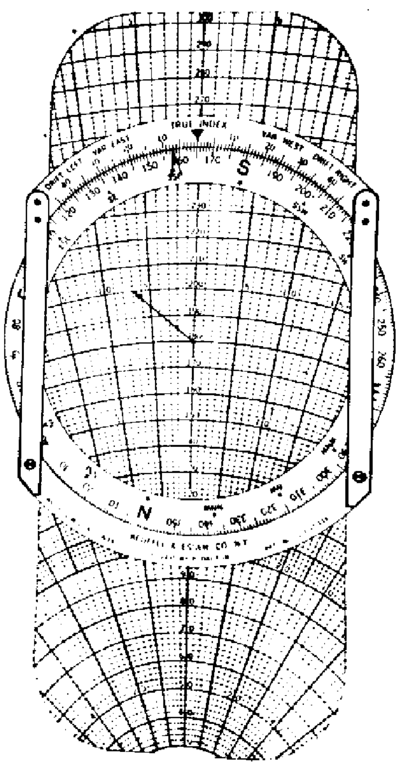


FIG. 315

DEAD RECKONING

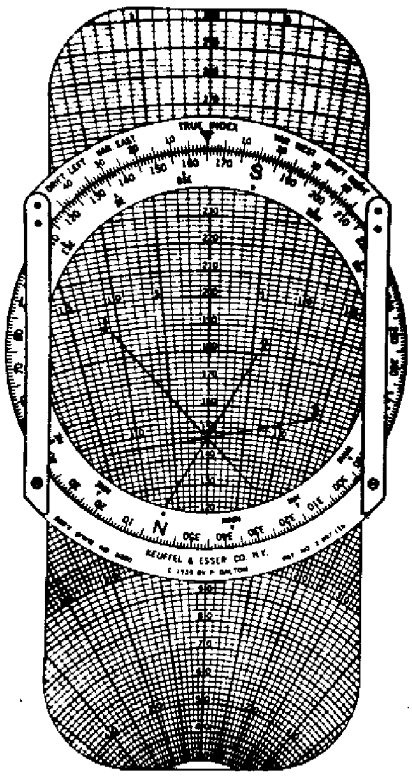


FIG. 316.

SECTION 4.

AERIAL SURVEY – THEORETICAL.

CHAPTER 1.

Introduction: Aerial Survey could be defined as the science of obtaining a series of photographs from various points in the air for the purpose of making some type of study of the Earth's surface. Survey photographs are not accurate in themselves but by using them in modern plotting machines, very accurate measurements can be made from them.

Because of this property their greatest use is in map making. They are used also for a number of other purposes such as surveys of roads and railway lines, forestry and agricultural areas, aerodromes, water conservation, flood control, town planning, geological and mining areas, etc.

Before considering any theoretical aspects of aerial photography, it would perhaps be opportune to give a brief resume of the procedures followed in a typical survey contract.

Outline of Procedures.

(a) Calling for Tenders: The organisation desiring the survey, calls for tenders for the work specifying the area, its square mileage, the required scale of photography, number and type of prints and any other relevant facts.

(b) Letting of Contract: For the agreed sum the successful tenderer contracts to complete the survey, supply the required prints, etc., and often as an additional condition, complete it by a certain date.

(c) Planning the Survey: The operator now plans the survey taking into account factors such as selection of a crew and a suitable aircraft, consideration of seasonal problems, choice of a base, availability of fuel and oxygen, etc.

(d) Flying the Contract: The techniques and methods used in this portion of the work are discussed later as a separate section.

(e) Return of Film and Processing: As the work is flown, the relevant films are returned to the laboratory. Here they are processed and rough prints are made. From these "roughs" , the accuracy of the work is checked and any additional or corrective flying determined.

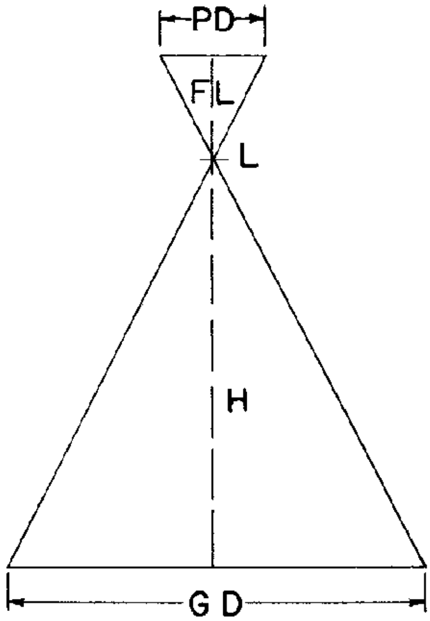
(f) The Finished Product and its Use: On completion of the flying, the final prints are run off and together with the negatives are dispatched to the client, who uses them for various purposes such as surface interpretation, mapping, mosaic construction, etc.

CHAPTER 2.

Photographic Theory.

The science of photogrammetry is involved and highly technical. The airmen engaged in survey flying however, does not essentially require this specialised knowledge and can work proficiently with a basic understanding of photographic theory.

To this end, the discussion will be limited to the so-called Camera Law and some associated formulae. (The chemistry of photography does not concern us here and will be described in a later section).



The diagram represents schematically the aerial camera at the moment of exposure.

L	=	the camera lens.
GD	=	the distance between two given points on the ground below the camera.
PD	=	the distance between the same two points measured on the film.
H	=	the height of the lens above the ground.
FL	=	the focal length of the camera (the distance between the centre of the lens and the film).

From the definition of scale given in the chapter on Maps and Charts, it will be seen that the scale of an aerial photograph is equal to the print distance between two points divided by the ground distance between the same two points or

$$S = \frac{PD}{GD}$$

Referring to the diagram it can be readily shown that

$$\frac{PD}{GD} = \frac{FL}{H} \quad \text{and that} \quad GD = \frac{H}{FL}$$

(This is the camera law or scale proportion).

Substituting we derive the formula for scale.

$$S = \frac{FL}{H}$$

Photographic Theory Contd.

Thus we have a series of equations which will solve the various photographic problems encountered by the airman during survey operations. Following are these problems and typical examples.

(a) To produce photography to a certain scale, given the focal length of the camera. At what height is the aircraft flown?

$$\text{Now} \quad S = \frac{FL}{H}$$

$$\text{Or} \quad H = \frac{FL}{S}$$

Example Desired scale of photography is 2500 ft. to 1 inch, Camera focal length is 6 inches. Find flying height.

Scale is 2500' : 1"
or 30000 : 1

$$\text{Therefore} \quad S = \frac{1}{30000}$$

$$\text{Now} \quad H = \frac{FL}{S}$$

$$= 6'' \div \frac{1}{30000}$$

$$= \frac{6}{12} \times \frac{30000}{1}$$

$$= 15000 \text{ ft.}$$

∴ Flying height is 15000' (above terrain).

(b) What is the scale of photography, the flying height and camera focal length being known?
(c)

$$\text{This is also solved from } S = \frac{FL}{H}$$

Example: Flying height, 10000' above terrain, focal length 12 inches. Find scale of photography.

$$S = \frac{FL}{H}$$

$$= 12'' \div 10000'$$

$$= \frac{12}{12} \times \frac{1}{10000}$$

$$= \frac{1}{10000}$$

∴ The scale is 1 in 10,000.

(d) What is the ground coverage of any one photograph, the format, focal length and height being known?

(Format: Formal describes the shape and size of an object. In photography it refers to the shape and size of the negatives on contact prints of a particular camera. For example the format of the Eagle IX is a square, 9" x 9", that of the RC5, a square 7" x 7" etc.)

Photographic Theory Contd.

Now in the equation $\frac{GD}{PD} = \frac{H}{FL}$

GD equals the groung coverage when
PD equals the formal size

And $GD = \frac{PD \times H}{FL}$

Example: Format is 9" x 9"

H = 20000

FL = 6"

Find the ground coverage of one photography

GD = 9" x 20000’ ÷ 6"

= 30,000'

∴ Coverage is a square 30000' x 30000' or approximately 5 ½ miles square.

Knowing: Format size.

Focal length

Height above terrain, find:

(e) The time interval between exposures to give a 60% forward overlap.
(f) The number of exposures in a given run.
(g) The flight line spacing for a given lateral overlap.

These three problems are now explained in the following two chapters.

CHAPTER 3.

Stereoscopy and Forward Overlap.

Introduction: A single photograph represents what one eye would see from the position of the camera. In normal vision however we use two eyes and are able to measure distance and appreciate shape and form because of he distance between the two pupils. This distance (about 2 ½ inches) being small, restricts our range finding or stereoscopic ability to a few hundred yards. (Beyond that limit, distance of objects are normally judged by relative size).

The same stereoscopic effect, but extending to much greater distances, is obtained from two photographs of the same object or area taken from different points of view and seen through a stereoscope.

Consider then the case when two vertical photographs are taken from an aircraft flying in a straight line, such that 60% of the terrain in each photo appears common to both, or in other words such that they have an overlap of 60%. This overlapping 60% is the same photo of ground but seen from two different points of view, ad when examined through the stereoscope, appears as a three dimensional relief model from which, vertical as well as horizontal measurements can be taken.

A pair of such photographs as described is known as a stereo-pair and its usefulness is limited to the common area covered. However if this system of overlapping photographs is carried on as the aircraft continues flying in a straight line, a large amount of country is photographed all of which can be examined stereoscopically. This is known as a line overlap.

60% is chosen as the ideal amount of forward overlap for several reasons, the main ones being:

(a) Towards the edges of photographs, a certain amount of distortion and scale variation occurs. If the overlap was a bare 50% all the ground would be covered stereoscopically but this distortion would cause considerable errors in measurement.

(b) Due to aircraft instability, few exposures are made with the camera perfectly vertical. Having a 60% forward overlap ensures that if the camera is tilted in a fore and aft direction at the moment of exposure, no portion of the ground is without stereo coverage.

The relevant problem now facing the airman is to determine at what periodic interval the camera must be fired to achieve this constant 60% forward overlap. With a little though it will be seen that as 60% of each succeeding photograph is common, the camera must be fired after the aircraft has moved over 40% of the distance covered by one photograph.

From the formulae given in Chapter 2 of this section, this distance will be 40% of GD, where

$$GD = \frac{PD \times H}{FL}$$

$$\text{or} \quad \frac{2}{5} \times \frac{PD \times H}{FL}$$

and hence the time interval in seconds will be the above divided by the aircraft's ground speed in ft./sec.

Example: What is the time interval in seconds to give a 60% overlap given the following data:

Format	9" x 9"
Ht. above terrain	24000'
Focal length	6"
Ground speed	200 kts.

Answer $\frac{2}{5} \times \frac{9}{6} \times \frac{24000}{1} \div \frac{200 \times 6080}{3600}$ T.I. = 43 seconds.

Stereoscopy and Forward Overlap Cont.

However it must be pointed out that because of the difficulties involved in determining the G/S and the height above terrain, this formula is mainly theoretical. In practice, use is made of the optical properties of the Aldis Sight which gives the required time interval by direct reference to the ground below the aircraft, irrespective of G/S or height above terrain.

The sight was described in Section 2, Equipment, and its practical handling will be explained in the section on Techniques.

A second problem is to determine the number of exposures or photographs required to cover a certain distance, assuming a 60% forward overlap.

This is found by dividing the given distance by 40% of the ground coverage of a single photograph.

Example: How many exposures will be made in a 90 mile flight line, given the following details;

PD	=	9"
FL	=	6"
H	=	24000'

Answer:

$$90 \times 5280 \div \frac{2}{5} \times \frac{9}{6} \times \frac{24000}{1}$$

= 33 exposures.

CHAPTER 4.

Lateral Overlap.

It has just been shown that a line overlap is a method of obtaining stereo coverage of a certain amount of terrain. This will appear as a strip limited in width by the average of one exposure. Now in order to survey larger areas, a number of line overlaps are flown, each having a common area with its neighbouring run on either side. This is known as having Lateral Overlap. The lateral overlap (or side lap) is also designated as a percentage.

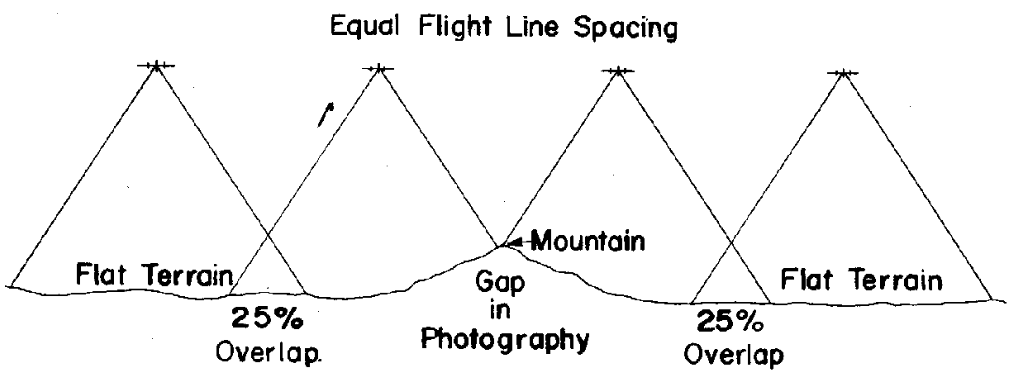
Most contracts specify a minimum and a maximum sidelap and the optimum is naturally enough between the two; this optimum if normally 25% or 30%, though some jobs require a lateral overlap of 40% and on rare occasions, e.g. for some mosaic constructions, it may be as high as 60%.

Reasons for having Lateral Overlap.

An area is photographed with each run having sidelap to allow the photogrammetrist to carry his ground control from one flight strip to the next. The optimum percentage is arrived at after consideration of several factors such as lens distortion and scale change towards the edges of the photographs, and the flying height compared to the height of the terrain.

However the most important factor is the variation in relief of the terrain being surveyed. If this variation is extreme, i.e. steep mountainous country, the average side overlap must be higher than normal to achieve a satisfactory photographic result.

This is best illustrated by the diagram which shows that a flight line spacing which achieves the required lateral overlap over flat terrain may miss out altogether over a steep range.



Flight Line Spacing.

Once the required lateral overlap is known the airman is able to determine how far apart the centre of each flight strip will be, or in more common terms, the Flight Line Spacing. For example with a sidelap of 25% two adjoining photographs will have 25% in common, thus leaving 25% on either side between the common area and the two centre points or a total of 75% of the coverage between the centres of each run.

From the basic formula this is expressed as 75% of $\frac{PD \times H}{FL}$

Lateral Overlap Cont.

Example: What is the flight line spacing for the following photography?

Format 9" x 9"
Focal length 6"
Height above terrain 16000'
Required Lateral overlap 25%

Answer: $\frac{3}{4} \times \frac{9}{6} \times \frac{16000}{1}$

= 18000'

= 3.409 miles.

Datum.

In aerial survey the datum is the assumed height of the terrain being photographed. Therefore it follows that the height H in the camera formulae is not height above sea level but height above datum.

Quite often the specifications for a contract give both the datum and the flying height (this latter above sea level) in which case H is merely the difference between the two. In other cases only one is given and the airman works out whichever is applicable. If for example only the flying height is given, a datum must be selected before the scale of photography and the flight line spacing can be determined.

To fix a datum, the best available topographical map of the area under survey is examined and all information regarding the height of terrain is noted. The datum will be a level somewhere between the average height of the area and the highest point on it. In general terms it is better to raise the datum when in doubt and have a more liberal sidelap, than run the risk of an insufficient one with a lower datum.

Example of Calculations.

Given: Focal length 10”, formal 9" x 9", scale of photography to be 2000' to 1" sidelap required is 30%. Topographical map supplied.

Find: Flying height above sea level and flight line spacing.

From the topographical map the following is noted: There are several prominent ranges in the area with spot heights of 4500’, 4300’, 4100’; the contours average generally 2000’ to 2500’.

(a) The datum selected is 3500'.
(b) Now $S = \frac{FL}{}$, and S is 24000 to 1.

$\therefore \frac{1}{24000} = \frac{10}{12} \times \frac{1}{H}$

$\therefore$ H = 20000'

$\therefore$ The flying height is 2300 feet above sea level.

(b) And with 30% sidelap, the flight line spacing will be 70% of GD or 70% of $\frac{PD \times H}{FL}$

$= \frac{7}{10} \times \frac{9}{10} \times \frac{20000}{1}$

= 12600 feet = 2.39 miles.

Air Base.

The air base is the horizontal distance between the points at which the camera takes successive photographs. As already explained, with a constant 60% forward overlap this distance is 40% of the ground coverage of one photograph.

Net Gain.

The net gain is that area on each succeeding photograph not already covered, that is either by the previous exposure or the adjoining runs.

Net gain is equal to: Air base multiplied by the flight line spacing.

Principal Point and Fiducial Marks.

The optical axis is an imaginary line vertical to the plane of the negative and passing through the centre of the lens. The intersection of the optical axis and the negative is called the Principal Point.

Its position on the photograph is usually found by joining special marks which appear on opposite edges of each photograph; these are called Fiducial Marks.

Cameras such as the Eagle IX which have a register glass between the film and the lens, are able to record the actual principal point, normally by means of a fine black cross, cut into the surface of the register glass.

CHAPTER 5.

Exposure – Aperture and Shutter Speed.

Exposure means a particular combination of lens aperture and shutter speed. The quality of the negatives and the ensuing prints depends largely on the exposure used.

The aperture of a lens is the area of the hole available for the light rays entering the camera to form an image. The lens is equipped with a diaphragm which controls the brilliance of the image by restricting or enlarging the area as needed. The bigger the aperture the more light passes and the greater the exposure, and vice versa.

The size of the aperture is indicated by its f-number, which is the ratio of the diameter of the opening to the focal length of the lens, a low f-number indicating a large aperture. The f-numbers 4, 5.6, 8, 11, 16, 22 etc. indicate successive decreases of one half the light intensity reaching the film. An aperture of f 5.6 gives twice as bright a picture as f8, and so on.

The shutter is the mechanism which, as the exposure is made, opens briefly to allow the light rays into the camera. The shutter speed is given in fractions of one second e.g. 1/100, 1/150, 1/200 etc., which indicate the length of time the shutter is open.

Selection of Aperture and Shutter Speed.

The exposure settings to be used on a particular contract are determined by the laboratory staff responsible for processing the films and will always be specified in the job details given to the crew. Normally past experience is sufficient to enable the correct settings to be nominated before the survey begins. This is done by considering the type of film being used, the latitude of the area, the season, the height of photography and most importantly the type of terrain. For example, timbered country requires a different exposure to desert, agricultural areas require different to townsites, and so on.

If a new area is to be surveyed and the type of terrain is now known, a test film is usually flown over the area, exposed at several experimental settings and returned. The laboratory staff process this test strip first and from it are able to select the correct exposure, as well as the best processing method.

A fast shutter speed is essential for low level photography to prevent image movement and resulting blurred prints. (Reducing air speed for this type of work is also advisable).

CHAPTER 6

Photographic Errors Occurring in the Air.

(a) Faulty Flying.

(i) Tilt: This occurs when the aircraft is not on an even keel at the moment of exposure and may be either fore-and-aft or lateral. The effect of tilt is to cause variations of scale over the photograph, thus giving distortion. In addition, as the photograph is no longer a vertical, the intended area is not covered and the overlaps vary.

Of course the same errors result from incorrect levelling of the camera. With normal care this should never occur, whereas in turbulent conditions some degree of aircraft tilt is usually unavoidable.

A constant check by the operator on the camera levels and the use of a pilot warning light from the camera will reduce tilt to a minimum.

(ii) Changes in Height of the Aircraft: This causes a difference in scale between consecutive photographs. Changes in height of the ground also cause the scale to alter but this is taken into account by the personnel using the photographs. To prevent unnecessary work, then, the altimeter reading should be checked regularly.

(iii) Changes in Indicated Air Speed: With cameras fired automatically by a device such as the intervalometer, (i.e. at fixed intervals) a change in I.A.S. will cause variation in the forward overlap, unless the time interval is adjusted. An aircraft normally picks up speed as its load becomes lighter; in such cases for example the forward overlap would drop below 60%.

The navigator therefore, after finding the time interval should check it frequently and the pilot should warn the navigator of any changes in speed.

(iv) Not Maintaining Steady Heading: Besides the normal outcome of wandering off the required track, this results in a series of photographs which when laid down do not overlap evenly along their lateral borders. This is known as “having a step” or “being crabbed” and such photographs appear as in the diagram below.

(b) Variations in Forward Lap.

Although this will occur when the aircraft speed changes, as explained above, a more frequent cause is change in height of the terrain.

From the equation $GD = \frac{PD \times H}{FL}$ it will be seen that as H the height above terrain varies, so GD the ground coverage will vary. This is what happens when a survey aircraft maintaining a steady altitude above sea level passes over country whose height is changing.

When H becomes less (as for example when flying over mountain range) then GD becomes less and if the time interval between exposures is not decreased, there will not be a common 60% between consecutive photographs and stereo coverage will be lost resulting in a rejected flight strip or run.

Conversely when H increases (as for example when crossing from high plateau to coastal plain) the forward overlap becomes greater than 60%. This is not considered as serious an error, though if it becomes excessive it also results in a rejected run. This is due to the unnecessarily large number of prints to be handled by the mapping personnel in such a case.

Obviously the solution is to keep a constant check on the time interval using the aldis sight. However, preflight examination of the topographical map of the area under survey will indicate regions where the relief changes and this is where the time interval should be checked more often.

(c) Errors Connected with Drift.

If an error is made either in reading the drift or in applying it to the camera, the camera will not be aligned with the aircraft's track and the result will be a stepped or crabbed run.

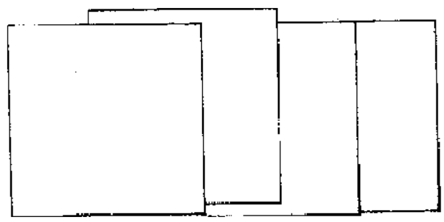
(i) Drift Read Incorrectly at Aldis Sight: In this case the aircraft heading will be wrong and it will immediately "crab" or drift away from the required track. This should normally be picked up by the navigator who will alter heading to regain and maintain track. However, if the drift error is not realised and the drift set on the camera not altered a stepped run will result.

(ii) Drift Applied Incorrectly to the Camera: If Port drift is applied to the camera instead of Starboard (or vice versa), the result will also appear similar to a stepped run except that the step will be double the amount of the drift and if this is greater than a few degrees, the run will be useless from a mapping point of view.

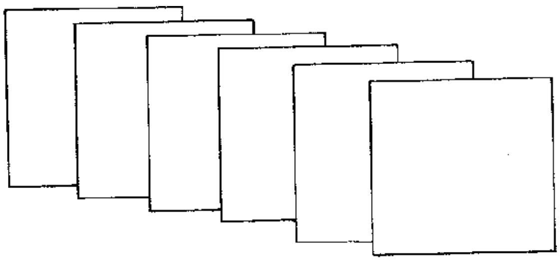
(d) Incorrect Exposure.

An incorrect aperture or shutter speed setting results in negatives of poor quality. An overexposed film is one which has received too much light and the negatives are dark and lack contrast. The underexposed negative is thin and poor in detail.

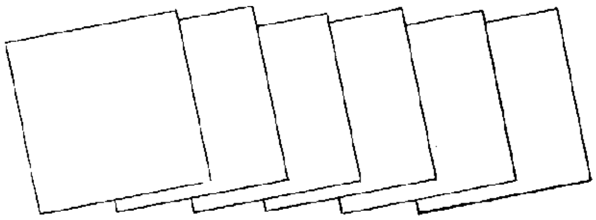
Diagram 3.



(a) Example of a Tilted Photograph



(b) Stepped Run due to Incorrect Reading of Drift at Aldis Sight, or Flying Incorrect Heading.



(c) Step due to Incorrect Application of Drift on Camera.

CHAPTER 7.

Photographic Hours and Seasons.

With the possible exception of the military use of flares at night, aerial photography depends in the light rays of the sun and is carried out during daylight hours. For survey purposes the amount of usable time is limited. The chief factor which determines these limits and also the usable or suitable hours is the altitude of the sun (or the angle it makes with the horizon).

Early in the morning and late in the afternoon, this angle is small and shadows are long; or in other words the amount of light reading the earth's surface in any particular area at these times is reduced and conditions for aerial photography are unsatisfactory.

Another important factor is the relief of the terrain. Photography can be continued for longer periods over flat country than over mountains and valleys where shadows are more pronounced.

Two further considerations are the time of the year and the latitude of the survey area. During summer months, the sun's altitude becomes greater than in winter; additionally, in lower latitudes, i.e. towards and in the tropics it again has a greater altitude than in higher latitudes.

When then are the usable hours for aerial survey? A lot must be left to the discretion of the aircrew on the spot but as a general guide it can be stated that under average conditions photography can be carried out from three hours before to three hours after local mid-day.

Now this generalisation will be modified for each particular contract taking into account the factors mentioned above, viz.

1. Type of terrain.
2. Month of year.
3. Latitude of area.

For example, in tropical areas photography can often start at 8 a.m. whereas in Southern latitudes in winter and over mountainous country, it would be restricted to the hour hours between 10 a.m. and 2 p.m.

In some contracts such as interpretative forestry work or tidal investigation, the photography must be carried out at specified hours and in such cases the information given to the crew will include these times.

Local Mid-day.

This is taken as the time when the sun crosses the central meridian of the survey area. It will be of importance only when the Standard time in use differs considerably from the true local time. Such regions are the Far West of Queensland and N.S.W. and the Eastern portion of the state of West Australia.

The Solstices.

These are the two occasions each year when the sun has reached its furthermost points North or South. In the Southern Hemisphere the summer solstice occurs on December 23rd, an on this date the sun's altitude reaches its maximum. Conversely, it is at its lowest on June 23rd, the date of the winter solstice.

CHAPTER 8.

Atmospheric Problems.

Regardless of he branch of aviation he is engaged in, the airman should have a sound knowledge of the atmosphere, the environment in which he works. A study of meteorology is beyond the scope of this manual but several aspects of it, of particular interest to the survey airman, will be discussed.

(a) Cloud.

Aerial survey can only be carried out under clear skies. The presence of cloud in as small an amount as 1/8 is usually sufficient to preclude a successful sortie. This is especially so when the cloud is below the aircraft, as apart from the shadows thrown, the cloud obscures portions of the ground from the camera.

A possible exception occurs when the cloud is of the light cirriform variety and above the aircraft. Cirrus is often sufficiently tenuous to cast no shadows and photography has on occasion, been successfully carried out under a complete overcast of thin cirrostratus.

The number of days when clear skies occur, varies from region to region. Along the West Coast of Tasmania, for example, the number of days when survey work can be done would be no more than five or six in any one year. In the dry centre of the continent, on the other hand, weeks and months often pass without cloud being seen. This is especially so during the winter months.

Diurnal cloud of the cumuliform type appearing after a clear morning and preventing further work is a common occurrence. Because of this, the earliest possible hour for satisfactory photography should be carefully estimated for each area and preflight preparations timed so that the aircraft takes-off early enough to be at height and over the area at this hour.

Cloud is a factor beyond our control. To reduce its effects to a minimum requires careful operational planning with regard to seasons and areas. In a civil enterprise however, this is not always possible and the field crew will often be assigned to an area well knowing that the probability of cloudless conditions is slight. On such occasions, the crew must be prepared to wait patiently, but keeping the aircraft and equipment fully serviceable and themselves ready to start working at first photographic light, should a cloudless day eventuate.

(b) Smoke and Haze.

This is a problem often encountered during summer months when bushfires are burning. Sometimes the smoke is sufficiently dense to obscure the ground, making photography impossible. However, the airman can use discretion whether to photograph on many occasions when visibility is poor, as the filter on the camera is designed to eliminate much of the effect of smoke and haze.

(c) Turbulence.

Low level turbulence is caused by either thermal convectional currents or by the mechanical effect of wind blowing across rough topography. Normally, either form is at a minimum early in the morning, becoming more pronounced as the sun warms the ground and the wind speed rises. For this reason, low level photography should be attempted as early in the day as possible.

Turbulence is also accentuated by high aircraft speed. Thus, if turbulent conditions are present, it is always wise to reduce air speed as far as safely possible.

Atmospheric Problems. Cont

(d) Jet Streams.

A jet stream is defined briefly as a narrow zone of extremely strong winds, in he upper air and normally associated with severe turbulence. The meteorological aspects of the jet stream are well described in the D.C.A. Manual of Met. And the airman is referred to that volume.

Our concern here is with the effect of the jet stream on the survey aircraft. The jet stream rarely occurs below 25,000 feet. Being narrow in extent it will not cover a large area. However, if one is encountered whilst on high level photography, the aircraft could pass through it several times while moving back and forth across the area.

The first indication received is normally the onset of moderate to severe turbulence (known as clear air turbulence). This is a warning to the navigator to check the drift and time interval, as the wind velocity is certain to be changing. The turbulence will usually continue as long as the aircraft is in the stream but once through it smooth flying and more moderate winds prevail again.

The aviator engaged on a travel flight and encountering a jet stream is advised to change his flight level several thousand feet to escape the stream (assuming of course that it is hindering the aircraft's progress). But this is not possible when engaged on survey as the required scale of photography demands that a constant altitude be maintained. This also means that in certain circumstances survey cannot be carried on in a jet stream, that is if the stream is flowing in an E-W or W-E direction at a sufficiently high speed.

Two actual examples of the effects of a jet stream are quoted.

Case One: A Hudson operating at 25,000 feet over a central Queensland coastal region, ran into a stream which reduced the aircraft's ground speed to zero and at times a minus quantity. The sortie was abandoned.

Case Two: A Hudson also at 25,000 feet over South-west Queensland while on a Westerly run, met a stream with the estimated velocity of 260/90 knots. In a matter of moments, the drift changed 8 degrees and the time interval, from 38 secs. To 75 secs. The stream was relatively narrow and its influence lasted approximately ten minutes. It was again encountered in the same vicinity on the neighbouring runs.

In both instances, moderate to severe turbulence was associated with the stream.

(e) High Wind Velocities.

Apart from the high level jet stream, high wind velocities are of concern to slow moving aircraft (such as the Anson). For example, a 50 kt. Beam wind causes drift of 30 degrees to an aircraft with a T.A.S. of 100 kts. This amount of drift cannot be offset on most cameras. In addition, turning on to start points is most difficult under conditions of high velocity.

(f) Condensation.

Fogging of the camera lens, filter and register glass invariably occurs after a descent from high altitudes, when the camera has become cold. This condensation will persist until the camera has reached a warmer temperature which may take quite some time.

Therefore, when photography is to be carried out at different levels, always complete the lower altitude work first.

SECTION 5.

PRACTICAL TECHNIQUES IN AERIAL SURVEY

CHAPTER 1.

Preparation.

(a) It will be obvious at this stage that aerial survey is an involved business and for this reason it should also be obvious that thorough preparation on the ground is essential before any attempt is made to fly a contract. While the navigator and pilot will be primarily concerned in this preparation it is a sound plan for all the crew to help with this preliminary work.

(b) For any particular contract the crew is provided with two copies of the flight maps and the following details:

- (i) The co-ordinates in Latitude and Longitude of the area to be covered.
- (ii) The type of camera and lens focal length to be used
- (iii) The exposure (aperture and shutter speed).
- (iv) The flying height above mean sea level. (Alternatively the required scale of photography may be given in which case the correct flying height is calculated).
- (v) The required forward and lateral overlap percentages.
- (vi) The position of the key or tie runs.
- (vii) The direction of the flight lines.
- (viii) The limiting hours for photography.

(c) Firstly the contract area is outlined on the flight maps and the following details noted:

- (i) Scale of the map.
- (ii) Orientation, i.e. is the graticule aligned with true, magnetic or grid North?
- (iii) Map detail (height of terrain, notable topographical features, number of likely pinpoints, and in particular, would the map be suitable for very fine map reading, or is the detail too sparse or poorly presented?)

In survey flying, the airman uses a great variety of chart types including the W.A.C. Series, military 1 mile or 4 mile sheets, parish and country maps, Lands Department maps, Admiralty charts etc. On some of these the topographical features are very well presented, whilst in remote areas the map detail on even the best can be poor and often misleading. Experience soon teaches the relative merits of each and then best use can be made of them. More will be said of this later.

(d) Next step is to plot the flight lines and key runs. Normally the flight lines run in the E-W direction and unless otherwise advised, the first and last runs must be positioned such that at least 25% of their coverage appears outside the North and South boundaries respectively.

To plot the first and last runs, work out the lateral coverage for the particular photo scale using

$$GD = \frac{PD \times H}{FL}$$

One quarter of this distance is the maximum the centres of first and last runs are allowed inside the boundaries. It is good practice to plot them a little closer to the boundaries than the distance thus computed.

Now set a pair of dividers to the required flight line spacing (bearing in mind the scale of the flight map) and from Run 1 step down until the Southern-most run is reached. Rarely will he last run stepped off in this way coincide with the position required. Then by trial and error reduce the spacing until this occurs. This will slightly increase the side lap which is not a fault as the chances of the sidelap falling below the minimum percentage allowed are thereby reduced.

The position of key or tie runs is normally indicated by the client and plotting them is straight forward.

(e) Once this plotting is done the crew can determine from the number of runs and their length, the amount of film required. The precomputed tables will help solve this from the column "Exposures per 30 mile run". However, the figure given is neat and does not allow for wastage, exposures required outside the boundary lead and trail lengths etc. Taking these factors into consideration, add a generous percentage to the figure calculated on the line mileage.

(f) The next stage of the preparation is the overall flight planning. Plot the contract area on the appropriate aeronautical sheet and examine the area to decide the following:

(i) Selection of a suitable forward base.

(ii) If the selected base is remote, choice of a communications centre.

(iii) The amount of travel involved between the base, the survey area and the communications center

(iv) The amount of time in the air on the actual survey. (Allowance must made here for reflying due to spoilt runs, camera faults, etc. Experience has shown that a figure of 15% of the survey time is usually sufficient to cover any reflying).

(v) From these figures, the required quantities of fuel, oil and oxygen can now be estimated and ordered. Of course, this will normally only be necessary when using a remote base with no regular refuelling facilities or access to oxygen supplies.

(g) The last stage of the preparation is to check all relevant equipment. <u>The importance of this cannot be overemphasised.</u> It is best done in the air under operating conditions and every effort should be made to air test the aircraft before leaving base. The applicable pro-forma is to be used to ensure that all required equipment is in the aircraft and that it is serviceable.

CHAPTER 2.

Daily Flight Planning.

Just as good overall preparation before leaving base is essential to an efficient operation, so thorough daily preparation in the field will ensure successful sorties.

However take off for survey without a clear picture of what is to be attempted for the day. Here the whole crew should co-operate in the daily flight plan. Take into consideration the following factors:

(i) Earliest photographic light – to give an E.T.D.

(ii) Range or endurance of the aircraft.

(iii) Work already completed on the area – to decide next start point.

(iv) Distance to selected start point – to plan climb to best advantage.

(v) Distance from end of last planned flight line to base – to ensure a reasonable safety margin. .

(vi) Length of sortie – for oxygen and film requirements.

(vii) An alternate area and flight plan, if possible – in case of cloud.

Once again the equipment pro-forma must be completed before each take off.

CHAPTER 3.

Procedure from Take-Off to Camera-On.

(a) Flight Sheet: Be meticulous in the compilation of the daily flight sheet. The information requested is essential to the personnel responsible for processing and proving the films. The navigator should carefully keep the work copies himself; they comprise his record of each day's activity and the progress of the operation. They will be referred to often.

(b) Height Correction: The subject of altimetry is constantly under review and many methods of determining an aircraft's correct height have been suggested. At t he moment, the most practical seems to be to calculate the mean temperate of the atmosphere as to the operating height and from precomputed tables, read off an indicated altimeter height to give the required true height.

These tables are computed, taking into account the following two facts:

1. The altimeter is calibrated according to the International Standard Atmosphere (v page 38).

2. Any departure form standard conditions in the actual atmosphere can be calculated as a figure in feet and adjustment made to the altimeter reading.

The temperature of the outside air is taken at each succeeding 1000' level, these readings are totalled and the total divided by the number of readings, to give the mean temperature.

The QNH over the survey area should be set on the altimeter sub-scale and the instrument will then read height above sea level.

(c) Drift and Time Interval: Once the aircraft has reached the operating altitude and has settled into normal flying attitude and T.A.S., the navigator finds drift applicable to the required track and time interval for the camera being used.

The Wild RC type cameras are fitted with various sighting devices to give the required time intervals and with these cameras, this is then the responsibility of the camera operator. When using Williamson cameras, the navigator finds the time interval from the graticule, which appears in the field of view of the Aldis Sight.

The graticule is illustrated and the method of drift finding described on Page 13, Equipment. To determine time interval, the drift sight is aligned on the correct drift and with a stop watch the passage of an object on the ground is timed between the forward and rear cross lines on the central parallel drift lines.

The distance between the cross lines, represents 40% of the ground distance covered by one photograph. Therefore, if an exposure is made each time the aircraft has covered this distance, the resulting photographs will overlap the requisite 60%.

As the focal length and format of the different types of cameras vary, there is a different sight (or more correctly – a different graticule) for each. A knowledge of the camera laws and formulae allows interpolation to be made, but it is generally safer to use the sight applicable to the camera being used.

(d) Calculation of Headings: Normally, this is straightforward,. Required track is flown as heading and the drift found is applied to give the heading for the run. However, in cases where the drift is excessive on the resulting heading; the drift will have changed and the aircraft's track will not be that required. Therefore, in all cases where drift exceeds 5 or 6 degrees, recheck the drift on the computed heading and then by trial and error, find the combination of heading and drift to give the required track.

(a) Location of Start Point: The first run flown on any area is normally the most important and the location of the start point requires care. In well mapped areas this should present no problems, as the flight lines will have been clearly marked on the map and it will simply be a matter of map reading up to the start of the required line.

However, when surveying a poorly mapped area, the airman must rely mainly on D.R. to find his first start point. This means flying over the closest recognisable feature to the area and carrying out a careful D.R. run from it to the assumed start point. This should be done at the operating altitude as D.R. on the climb is quite difficult due to constantly changing T.A.S.'s and W/V's.

Often photography has been carried out in the vicinity of the survey area and when available, this can be of value.

It must be pointed out here, that with few exceptions, all photographic runs are required to extend at least two principal points (v page 49) beyond the boundaries of the area. In other words, the camera must be turned on a certain time before reaching the boundary on the run in and left on for the same time after passing the other boundary. The time taken for these two additional exposures at each end, depends of course on he focal length of the camera and the height and speed of the aircraft.

Thus the start point of a run is not really on the edge of the area, but some distance outside it.

(b) Turning On: Once the start point has been decided on, it is now the responsibility of the navigator to position the aircraft over it on the required heading, and to have given his pilot sufficient time during the run up to it, to have the aircraft in its normal flying attitude and at the correct height and T.A.S.

The best method to achieve a good start is to fly a heading at right-angles to the flight line and turn on when the start point comes abeam. Bear in mind the wind strength and direction so that the aircraft is sufficiently far from the start point when turned on to allow time for corrections to heading and for the pilot to have trimmed the aircraft as explained above. This is particularly important, for example, during high level photography, when turning on at the Western side of an area in strong westerly winds.

As soon as the aircraft has turned on and is on the required heading, the navigator checks the tracking towards the start point using the prism of the Aldis Sight and requesting alterations in heading, when necessary, to achieve this. However, if the turn has been made too early or too late and a correction of more than five degrees will be needed to bring the aircraft over the start point, the correction should be made by S-turning the aircraft. A large alteration in heading once the camera has been switched on, is often cause for the run to be rejected.