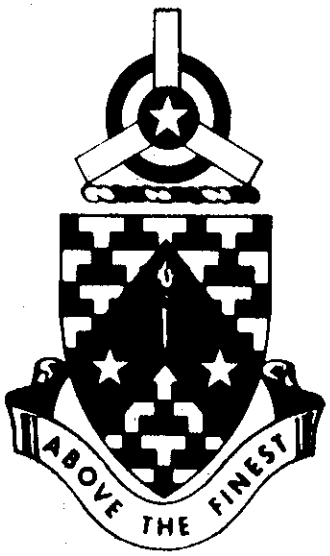
PROGRAMED TEXT

INSTRUMENT INDOCTRINATION - PART I, II, AND III

AIRSPEED, VERTICAL SPEED, AND ATTITUDE INDICATORS

AM-88



MARCH 1969

UNITED STATES ARMY

PRIMARY HELICOPTER SCHOOL

FORT WOLTERS, TEXAS

PROGRAMED TEXT

PROGRAM TEXT

FILE NO: AM-88

PROGRAM TITLE

INSTRUMENT INDOCTRINATION I, II, AND III
AIRSPEED, VERTICAL SPEED, AND ATTITUDE INDICATORS

POI SCOPE: Discussion of the airspeed indicator, vertical speed indicator, and attitude indicator to include construction, use, operation, errors, and limitations. Presentation of the theory of gyroscopes and gyroscopic action.

INSTRUCTOR REFERENCES:

TM 1-215, Ch 2

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March 1969

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INSTRUMENT INDOCTRINATION - PART I, II, AND III

PREFACE

This program concerns three of the instruments you will be using extensively during your instrument training. They are the airspeed indicator, vertical speed indicator, and attitude indicator.

When flying under instrument conditions, all maneuvers are executed at a specific rate. The type of information gained from the airspeed indicator and vertical speed indicator is rate.

The attitude indicator is an extremely valuable asset when you know how to use and interpret it correctly. To help you understand the principle of operation, the theory of gyroscopes is presented in the text.

Start with Frame 1 and work each frame in succession. Each frame will usually ask you a question. The correct answer is printed on the top of the next frame. If you were incorrect, turn back and restudy the information before continuing on to the next frame. When you have finished the text, complete the Self Evaluation Exercise. Now begin by studying the Performance Objectives on page iv.

PERFORMANCE OBJECTIVES

Upon completion of this programed text, you will be able to:

1. Select the correct statement concerning the construction, operation, and use (to include errors and limitations) of the airspeed and vertical speed indicators.

2. Select the statement which best describes the instrument indication depicted on a photograph, diagram, or an actual attitude indicator.

3. Identify the type of gyroscopic mounting employed in the attitude indicator and the errors, limitations, and uses of the instruments.

4. Identify the principles of gyroscopes and correlate them with the operation of the attitude indicator.

FRAME 1

Static Pressure

To obtain the required difference in pressure for the operation of the differential pressure instruments, static air pressure from the atmosphere is supplied to the instruments through static vents (fig. 1). The vents are installed at a point where the low pressure effect from the surrounding flow of air is at a minimum. These vents are interconnected to a common line to the instruments by a Y-fitting. By placing and connecting the vents in this manner, there is a minimum error in static pressure due to erratic changes in the attitude of the aircraft. During preflight inspection, the aviator must check the flush-type vents visually to see that they are not clogged.

Static pressure could be defined as

a. induced pressure
b. normal pressure
c. forced pressure

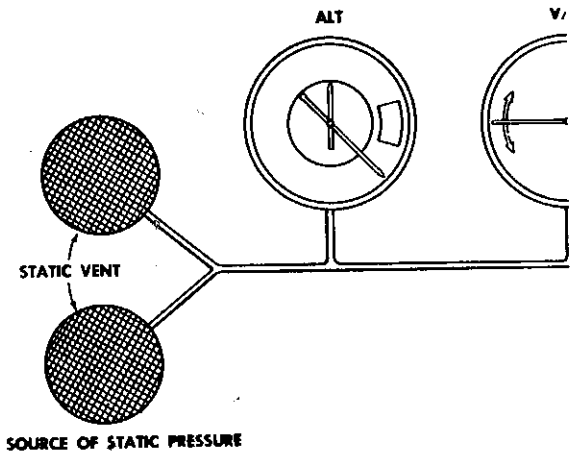


Fig. 1

TURN TO PAGE 3 FOR FRAME 2

ANSWER: b. Indicate climb or descent before the altimeter does.

FRAME 11

IVSI

The newer types of vertical speed indicators have the 6 - 9 second lag engineered out of them. This makes the error of rough air even more pronounced because it is even more sensitive to pressure changes. You can determine which type you have by reading the face of the dial. The new type has the initials IVSI printed on the dial face (Instantaneous Vertical Speed Indicator).

When using the IVSI type of indicator at the completion of a climb or descent, the needle would indicate

a. a delay of 6-9 second.
b. level flight.
c. erratic needle movement.

TURN TO PAGE 4 FOR FRAME 12

ANSWER: b. normal pressure

FRAME 2

Impact Pressure

Impact pressure is required for the operation of the airspeed indicator only. The open pitot tube is mounted on the aircraft, parallel to the longitudinal axis of the aircraft, where there is a minimum disturbance of air caused by aircraft motion. Two major parts make up the pitot tube - the impact pressure chamber with lines and the heating unit. The pitot tube receives the impact pressure of the air. This impact pressure increases with the speed of the aircraft. Since the diaphragm of the airspeed indicator is connected directly to the pitot line, it is expanded by this increase in impact pressure. The expansion or contraction of the diaphragm, in turn, controls the position of the airspeed needle by a series of levers and gears.

Impact pressure could be defined as

a. induced pressure.
b. normal pressure.
c. pitot pressure.

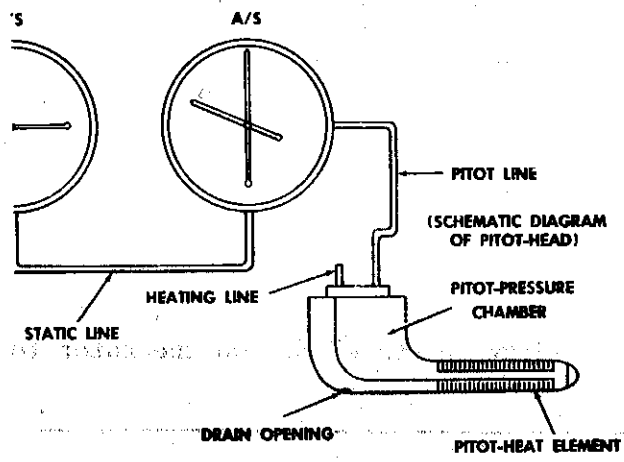


Fig. 2

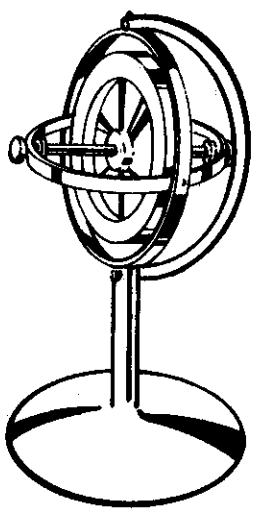
ANSWER: b. level flight.

FRAME 12

Let's review some of the basic principles of gyroscopes before getting into one of the instruments that utilizes these principles.

All practical applications of the gyro are based upon two fundamental properties of gyroscopic action: rigidity in space and precession.

Rigidity in Space. When spinning, the rotor remains in its original plane of rotation regardless of how the base is moved. The rigidity of a spinning body is determined by its weight and velocity. To obtain as much rigidity in the rotor as possible, it is designed with great weight for its size and rotates at high speed.



Therefore, "rigidity in space" allows the rotor to _____

_____

_____

ANSWER: c. pitot pressure

FRAME 3

Shown below is a diagram of the flush type pitot-static system. Pitot pressure is introduced into the system through the pitot tube. Static pressure is introduced into the system through the static ports located on either side of the aircraft.

Difference in pressure (differential pressure), causes the instruments to indicate proper readings.

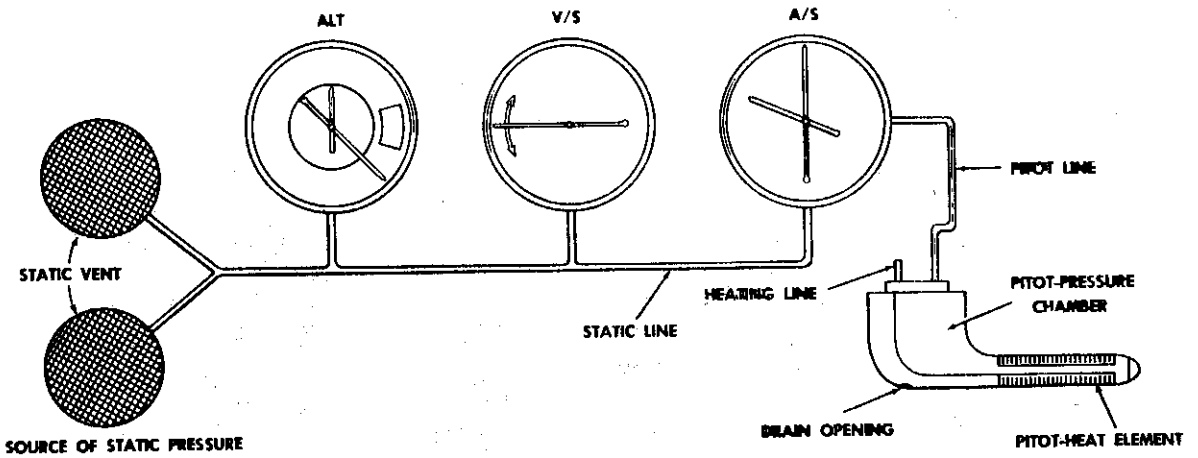


Fig. 3. Flush Type Pitot-static System

As shown by the diagram above, which instrument is the only instrument using both pitot and static pressure?

a. Airspeed indicator
b. Altimeter
c. Vertical speed indicator
d. All of the above

ANSWER: remain in its original plane of rotation regardless of how its base is moved.

FRAME 13

Precession

Precession is the resultant action or deflection of a spinning wheel when a deflective force is applied to its rim.

(1) REAL PRECESSION. Real precession is a positive deflection caused directly or indirectly by applied force or forces. Real precession is the resultant action characteristic of a spinning wheel when a deflective force is applied to the rim. The resultant force is 90° ahead in the direction of rotation and in the direction of the applied force.

(2) APPARENT PRECESSION. A freely mounted gyroscope maintains its axis fixed in relation to space, and not in relation to the surface of the earth. As the earth rotates, carrying the gyro mount around with it, the gyro spin axis maintains its direction in space. With respect to the earth, the spin axis does change direction. This change in direction is called apparent precession. As a result of the earth's rotation, the rate of direction change caused by apparent precession is 15° per hour at the poles.

Precession could best be defined as

a. a spinning wheel remaining in its original plane of rotation regardless of how the base is moved.
b. a wheel or rotor mounted to spin rapidly about an axis, and also free to rotate about one or both axes.
c. the movement of a spinning wheel caused by a force applied to its rim.

ANSWER: a. Airspeed indicator

FRAME 4

Within the flush type pitot system is a heating element. This heating element must be checked prior to actual instrument flight. Pitot heat is used any time there is visible moisture, or if icing conditions exist.

Under which of the following conditions would you not use pitot heat?

____Rain

____Snow

____Fog

✓Sunshine

____Clouds

____Smog

ANSWER: c. the movement of a spinning wheel caused by a force applied to its rim.

FRAME 14

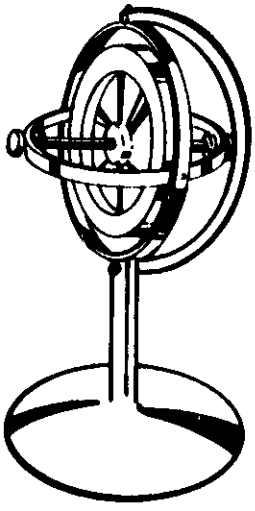
There are two general types of gyroscopic mountings - free and semirigid.

FREE

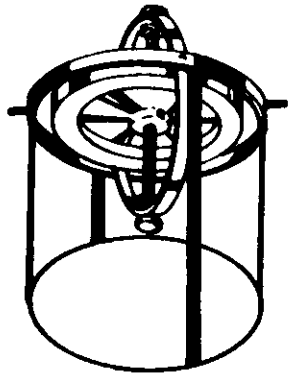
A freely (universally) mounted gyroscope has 3 planes of freedom and is free to rotate in any direction about its center of gravity.

SEMIRIGID

A semirigidly mounted gyroscope is mounted so that one of the planes of freedom is held fixed in relation to the base (2 planes of freedom).



The principle of operation is "Rigidity in Space"



The principle of operation is "Rigidity in Space" and "Precession"

The two types of gyroscopic mounts are

a. semirigid and rigid.
b. rigid and semi-universal.
c. semirigid and free.
d. free and rigid.

ANSWER: Sunshine

FRAME 5

The airspeed indicator measures the difference in pressure from the pitot source and static source. This difference is indicated on the face of the instrument as an airspeed.

An aircraft sitting on the ground with a no wind condition would produce no difference in pressure between the diaphragm and the static pressure in the case, but when the aircraft is propelled forward through the air, pitot pressure is forced into the instrument through the pitot tube into the diaphragm, causing the diaphragm to expand. Through a series of linkages, airspeed is indicated in knots on the dial.

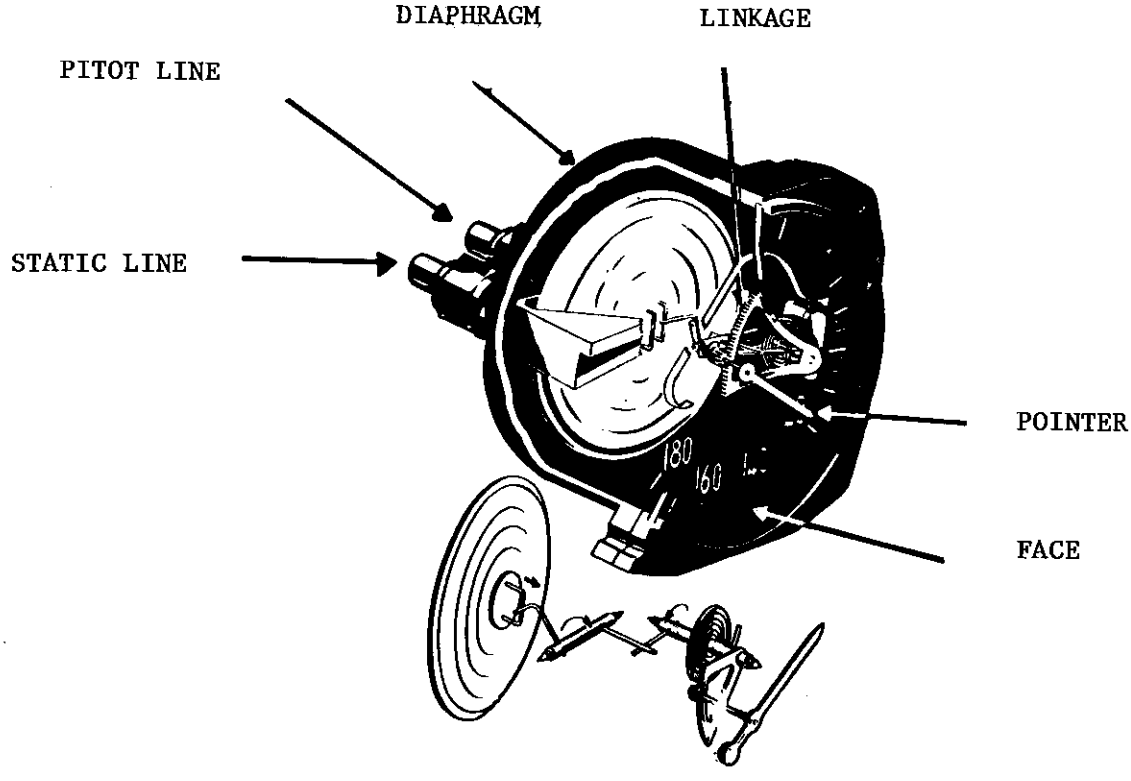


Fig. 4. Cutaway view of the Airspeed Indicator

What causes the diaphragm to expand?

a. Decreased pitot pressure.
b. Increased pitot pressure.
c. Increased Barometric pressure.
d. Decreased Barometric pressure.

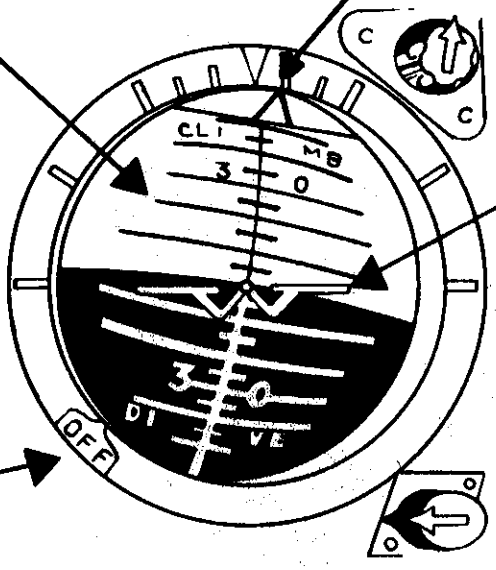
ANSWER: c. semirigid and free.

FRAME 15

Now that we are familiar with the gyroscope, let's take a look at one of the instruments that utilizes some of these principles, the attitude indicator.

Sphere. The sphere has a white background with black arcs above the zero pitch line. These arcs are spaced at 5° intervals, with the long arcs indicating each 10° of pitch. Pitch angles of 30° and 60° are also indicated by numerals. CLIMB or DIVE markings are centered on the 45° pitch circle.

Angle of bank. The angle of bank is indicated by the position of the bank index pointer relative to the 10°, 20°, 30°, 60°, and 90° markings on the case, (10° bank indicated).



Miniature Aircraft

Think of this as the acft you're in and the sphere as the horizon. Thus by the relationship between the two you can determine the attitude of your aircraft.

OFF Flag. The OFF flag on the instrument warns of power failure. The warning flag should disappear approximately 2 minutes after turning on the power. Indications are not reliable when the OFF flag is visible.

The above instrument indicates the aircraft is in a

a. climbing left turn.
b. level left turn.
c. diving left turn.
d. can't tell.

ANSWER: b. Increased pitot pressure.

FRAME 6

There are minor errors inherent in the airspeed indicator.

1. Air density. The airspeed indicator can not compensate for changes in temperature and altitude. You must use a computer to change indicated airspeed to true airspeed.

2. Installation and/or instrument error as a result of a worn or dirty instrument linkage or improper installation.

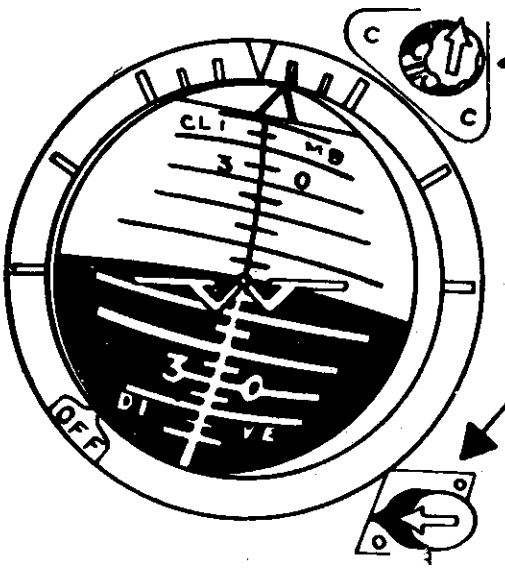
3. Flight error caused by erratic or improper flight attitude.

Which of the three errors can the pilot best control?

a. Air density error.
b. Installation error.
c. Flight error

ANSWER: d. can't tell. NOTE: Instrument is unreliable when "OFF" flag is visible.

FRAME 16



Roll Trim Knob - This knob positions the sphere with respect to the 10°, 20°, 30°, 60°, and 90° bank indications.

Miniature Aircraft Adjustment Knob - adjusts the horizon line up or down with respect to the miniature aircraft and to compensate for the aviator's different lines of vision.

Which knob is used to adjust the horizon line with respect to the miniature aircraft?

a. Lower right hand knob
b. Upper right hand knob

ANSWER: c. Flight error

FRAME 7 VERTICAL SPEED INDICATOR

Construction

The vertical speed indicator has a sealed case connected to the static pressure line through a calibrated leak. Inside the case is a diaphragm similar to that in the airspeed indicator. This diaphragm is connected directly to the static pressure line. A system of levers and gears connects the diaphragm to the indicating needle on the face of the instrument. The vertical speed indicator contains a mechanism which enables it to compensate automatically for changes in air temperature.

Operation

Although the vertical speed indicator operates entirely from static pressure, it is a differential pressure instrument. The differential pressure is established between the instantaneous static pressure in the diaphragm and the trapped static pressure within the case. When the aircraft starts a climb, the pressure in the diaphragm decreases in ratio to the reduction in atmospheric pressure. The calibrated leak retards the pressure change to the instrument case. This causes the diaphragm to contract, causing the needle to indicate a climb. The leak in the case is calibrated so that it maintains a definite ratio between the pressure in the diaphragm and the pressure in the case as long as a constant rate of climb is maintained. When the aircraft levels off, the calibrated leak requires 6 to 9 seconds to equalize the two pressures. This causes a lag of 6 to 9 seconds in the instrument. When the aircraft is descending, the pressure inside the diaphragm is increasing and the calibrated leak again maintains a constant relation between the two pressures.

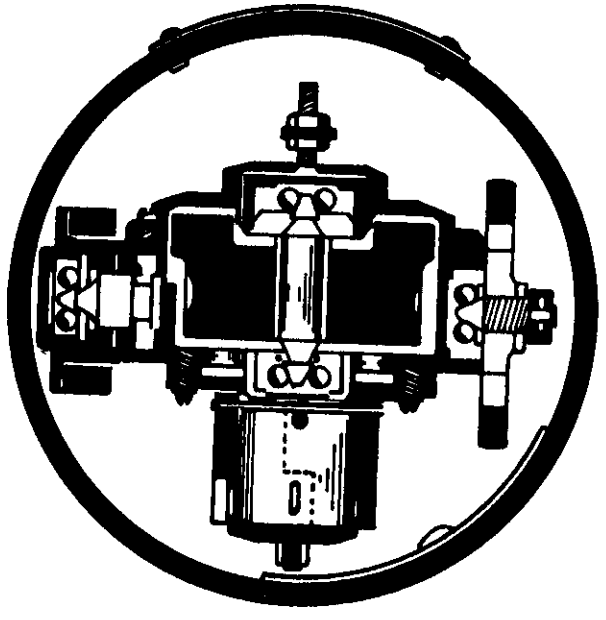
Because of the vertical speed indicator's construction, it will indicate climbing immediately after leveling off from a sustained climb.

Would this instrument be very useful for altitude control? no
(yes) (no)

ANSWER: a.Lower right hand knob

FRAME 17

The gyroscope is located within the sphere of the indicator. All the later model indicators are electrically driven, however, the older models were vacuum driven.



It is mounted so that it has 3 planes of freedom, thus it is a free (universal) mount.

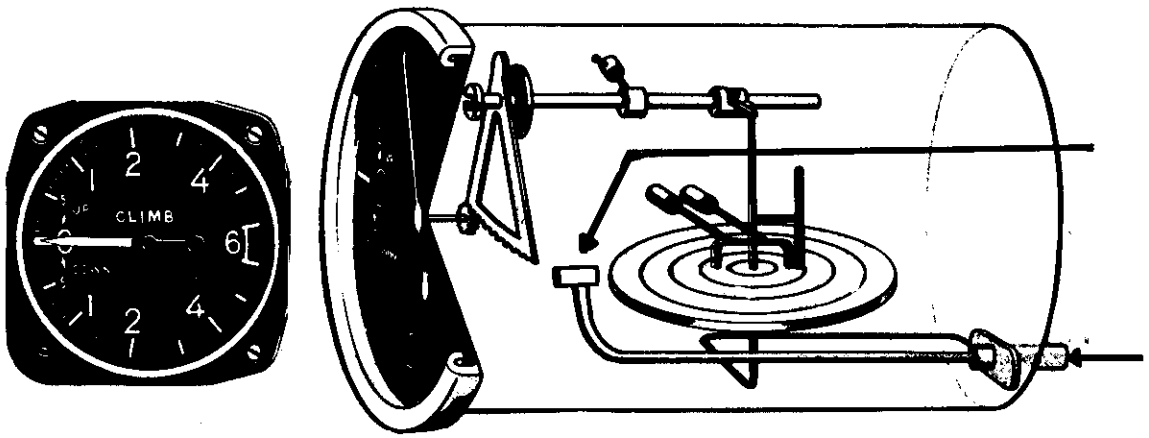
Since it is a free mount, we know that its principle of operation is

a. precession and rigidity in space.
b. rigidity in space.

ANSWER: a climb (6-9 second lag)
no.

FRAME 8

Static air is introduced through the static line directly into the diaphragm. The line leading away from the diaphragm has the calibrated leak into the air tight case. Since static pressure is introduced directly to the diaphragm, the diaphragm is allowed to expand and contract as the static pressure changes. The pressure in the case has the 6-9 seconds lag due to the calibrated leak causing the difference in pressure to show on the face of the instrument in hundreds of feet per minute climb or descent.



If the glass face of the instrument is cracked, broken, or loose, how would this affect the instrument's indication?

ANSWER: b. rigidity in space.

FRAME 18

The main purpose of the attitude indicator is to portray the attitude of the aircraft, however, it also gives the degree of bank.

Remember, when you're flying under Instrument Flight Rules (IFR) and flying in instrument meteorological conditions, you can no longer see the actual horizon to judge the attitude of your aircraft.

Study the following indications.

Straight and level flight
(Miniature acft on horizon line, wings level)

Level Climb (Nose high attitude)
(Miniature acft above horizon line, wings level)

Level Dive (Nose low attitude)
(Miniature acft below horizon line, wings level)

Right turn (Miniature acft right-wing below horizon line with no gain or loss of altitude)

To assist you in interpreting the attitude of the aircraft by the attitude indicator, the diagrams have been exaggerated. The miniature aircraft should normally be no further than TWO bar widths above or below the horizon and indicate no more than a 20° bank for safe aircraft control.

ANSWER: A loose, cracked or broken glass would allow static air to go directly into the instrument case equalizing the pressure and making the instrument inoperative.

FRAME 9

Alternate source of Static Pressure. In aircraft using the flush type static pressure source, an alternate source for static pressure is not readily available. To obtain an alternate source, the glass in one of the three static pressure instruments must be broken. It is difficult to break the glass without damaging the instrument. For this reason, it is advisable to break the glass on the vertical speed indicator since this is the least important instrument during an instrument letdown and/or landing. If the glass of the vertical speed indicator is broken and the instrument is still operating, its normal indications will be in reverse: those of the altimeter and the airspeed indicator will lag because the static pressure now comes from the cockpit and forces its way to the other instruments through the calibrated leak in the vertical speed indicator.

After breaking the glass in the vertical speed indicator, you can expect all of your instruments to give a 6 - 9 second lag.

a. True
b. False

FRAME 18 (Cont)

This indication  means you're in a

a. level left turn.
b. level right turn.
c. straight and level.

This indication  means you're in a

a. climbing left turn.
b. climbing right turn.
c. straight and level.

ANSWER: False. Only your pitot static instruments will be affected.

FRAME 10

Errors and Uses

The vertical speed indicator is used to determine rate of climb or descent. It is also used as a trend instrument for altitude control. There are two inherent errors. The 6-9 second lag and the sensitivity of the diaphragm to changes in pressure make the instrument erratic in rough air.

While flying in rough air the needle of the vertical speed indicator will fluctuate. The normal tendency for a new instrument pilot is to over correct (chase the needle).

As an instrument for altitude control, you can use the vertical speed indicator to

a. replace the altimeters.
b. indicate climb or descent before the altimeter does.
c. replace the airspeed indicator.

STOP! RETURN TO PAGE 2 FOR FRAME 11

ANSWER: b. level right turn (right wing of miniature acft is below horizon line).
a. climbing left turn (miniature acft is above horizon line, left wing below).

FRAME 19

The causes of errors in the attitude indicator are unbalance, faulty construction, friction, or dirty and worn bearings.

However, these errors are minor and seldom exceed 3 or 4 degrees of pitch or bank because of the automatic erecting device.

If you feel that you now understand the attitude indicator, complete the Self Evaluation Exercise without referring back to the program.

Review the program in any areas you do not understand.

CONTINUE TO SELF EVALUATION EXERCISE

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SELF EVALUATION EXERCISE

1. Pitot and static pressures are employed in the operation of

   a. the airspeed indicator only.
   b. the airspeed and vertical speed indicators.
   c. the altimeter and vertical speed indicators.
   d. the vertical speed and airspeed indicator.

2. What is the primary use of the vertical speed indicator?

   a. Attitude control.
   b. Altitude control.
   c. Determine rate of climb or descent.
   d. Airspeed control.

3. How long does it take the full and trapped static pressure in the vertical speed indicator to equalize after leveling off from a climb or descent?

   a. 2 to 3 second.
   b. 10 to 14 seconds.
   c. 1 to 3 seconds.
   d. 6 to 9 seconds.

4. Improper flight attitude will cause the airspeed indicator to

   a. fluctuate rapidly.
   b. give reliable readings.
   c. give erroneous information.
   d. give zero reading.

5. The instantaneous vertical speed indicator (IVSI) has

   a. 6 to 9 seconds lag.
   b. no appreciable lag.
   c. 10 to 14 seconds lag.
   d. more lag.

6. The two errors in the vertical speed indicator are

   a. installation and fog error.
   b. erratic (rough air) and lag error.
   c. lag error and air density error.
   d. installation and air density error.

7. Identification of the instananeous vertical speed indicator is accomplished by

   a. observation of the needle.
   b. checking the -10.
   c. observing age of the instrument.
   d. indicated on face of the dial.

8. If the static ports become clogged, due to foreign matter while in flight what is the prescribed source of alternate static pressure?

   a. Remove glass from altimeter.
   b. Remove glass from airspeed indicator.
   c. Remove glass from vertical speed indicator.
   d. Break static line.

9. What is the advantage of the instantaneous vertical speed indicator over the vertical speed indicator?

   a. Less installation error.
   b. Less erratic in rough air.
   c. No time lag.
   d. Less inherent errors.

10. When impact (pitot) pressure is introduced into the diaphragm, the diaphragm

    a. contracts.
    b. remains the same.
    c. expands.
    d. none of the above.

11. An instrument having a universal gyro mount utilizes which of the following principles in its operation?

    a. Precession.
    b. Rigidity in space.
    c. Magnetism.
    d. Suction

X 12. What type of gyro mounting is used in the attitude indicator?

    a. Rigid.
    b. Semi-rigid.
    c. Universal.
    d. None of the above.

13. What instrument indicates the relationship of the aircraft to the horizon? attitude indicator.

14. The errors of the attitude indicator are

a. minor and seldom exceed 3° or 4°.
b. oscillation of the sphere.
c. no errors.
d. drifts 3° per hour and must be reset periodically.

15. This indication on your attitude indicator  means you're in a

level descent.

16. How should you adjust the miniature aircraft in relation to the artificial horizon line?

a. Adjusts itself automatically.
b. Never needs adjustment.
c. Turning the knob on the lower right corner of the instrument.
d. Turning the knob on the upper right corner of the instrument.

17. "The angular relationship between a spinning body and its axis of rotation tends to remain constant" defines

a. rigidity in space.
b. apparent precession.
c. real precession.
d. automatic erecting device.

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ANSWERS TO SELF EVALUATION EXERCISE

1. a
2. c
3. d
4. c
5. b
6. b
7. d
8. c
9. c
10. c
11. b
12. c
13. Attitude indicator
14. a
15. Level dive
16. c
17. a

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