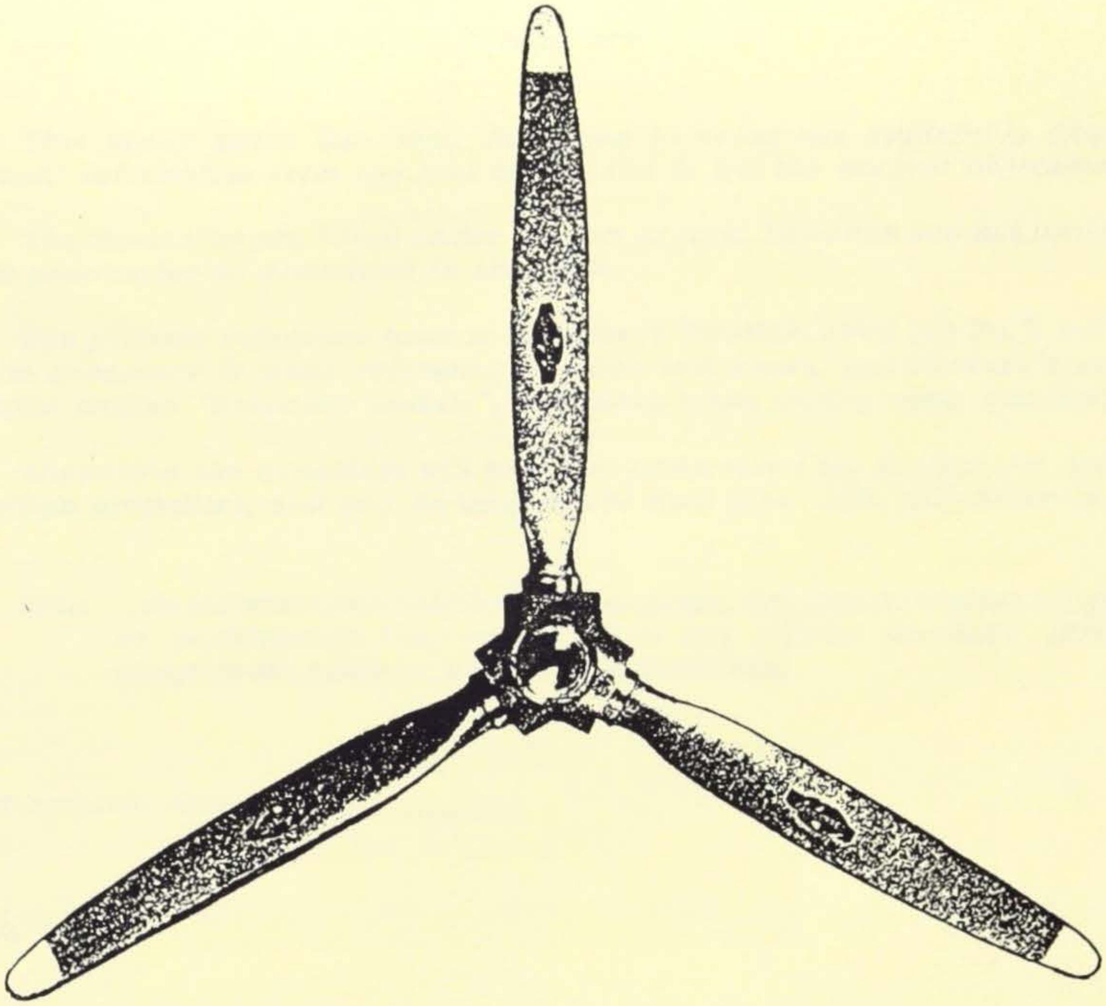
BRITISH COLUMBIA
INSTITUTE OF
TECHNOLOGY

AVIATION DEPARTMENT



PROPELLERS

STUDY GUIDE PROPELLERS

for A.M.E. Cat. A

Foreword

This study guide has been developed to assist the student in extracting pertinent information from the text books, and to list the student objectives.

The objectives are listed under subject or topic headings and not necessarily in the same order as presented in the book.

The primary reference book is "AIRCRAFT POWERPLANTS 5th Ed.", but it will also be necessary to make reference to other text books, manufacture's manuals, handouts and/or "propeller module", and notes taken during class discussions.

Answering the questions will help you understand the theory and operation of various propellers, and may be used in the final exam. with only minor changes.

Note: No information contained in this guide, handout or module supersedes or supplements that contained in any official document related to components,systems procedures described.

Latest revision date________________

STUDY GUIDE PROPELLERS

CHAP.16 PROPELLER FUNDAMENTALS

On completion of chapter 16, making use of reference material in the library or handouts, and participation in class discussions you will be able to:

1. *Identify the following: leading edge, trailing edge, back and face of blade, root, tip, blade, blade butt, blade shank, cuffs, fixed pitch wooden, fixed pitch metal, and ground adjustable.*
2. *Explain the "blade element theory", and the meaning of the term "true pitch propeller".*
3. *Define blade stations, and know the significance of the 42 inch., 30 inch., and 75% station.*
4. *Define plane of rotation, axis of rotation, and blade angle.*
5. *Define Geometric Pitch, Slip, and Effective Pitch.*
6. *State the meaning of "76 A 48 " stamped on the prop hub.*
7. *Define angle of attack.*
8. *Calculate the blade angle at a given station if the geometric pitch is known.*
9. *Sketch a vector diagram to illustrate the prop. blade angle, blade path, relative airflow, and angle of attack.*
10. *Using a vector diagram show why a propeller blade is normally twisted.*
11. *Using a vector diagram show why a variable pitch prop. is more efficient.*
12. *Given the prop. diameter, and rpm calculate the tip speed in feet/sec. and ratio to the speed of sound.*
13. *Identify the four different types of propellers.*
14. *Describe the different blade positions from reverse through to feather.*
15. *List the forces acting on a propeller blade during operation.*
16. *List the resulting stresses on the propeller blades , and state their affect upon propeller operation.*
17. *State the minimum propeller clearances as set forth in Federal Aviation Regulations.*

STUDY GUIDE PROPELLERS

CHAPTER 17 PROPELLERS FOR LIGHT AIRCRAFT.

On completion of this chapter, making use of reference material in the library or handouts, and participation in class discussions you will be able to:

1. List the types of woods used in the construction of propellers.
2. State the advantages and disadvantages of wooden propellers.
3. State how a wooden prop. may be corrected for vertical and horizontal balance.
4. Know how to perform a track check and determine if within limits.
5. Identify the three common methods of propeller installation.
6. Explain the reason for having a two piece front cone, and snap ring.
7. Given a drawing of a counterweight type propeller (fig.17-14), identify the component parts, and explain how the pitch changes(forces and stops).
8. Explain the principles of operation of an electric propeller such as the Beechcraft 215 prop. (fig.17-15)
9. Explain the principles of operation on the McCauley constant speed propeller(fig.17-23) including the forces to move to coarse and fine, and the location of the stops.
10. Identify the differences between a threaded and threadless McCauley propeller.
11. Identify the differences between a steel hub, and a compact Hartzell propeller.
12. Explain the principles of operation of a Hartzell constant speed propeller, including the forces to move to coarse and fine, direction of piston travel, and location of stops.
13. Identify the component parts of a typical governor.
14. Determine the direction of rotation of the governor drive, and location of A and/or B plugs.
15. Explain how a governor directs oil to and from the propeller during UNDER and OVERSPEED conditions, for governors that use oil to increase or decrease pitch.
16. Identify the two opposing forces acting on the pilot valve, and under what conditions are they equal.

PROPELLERS

PRACTICAL TASKS

1. *Given any propeller at the school (on or off aircraft), locate the model, serial number, T.C. number, and determine if it is approved for a specific aircraft.*

2. *Given a fixed pitch propeller, determine if is the correct diameter and geometric pitch for installation on a specific aircraft whether on wheels or floats.*

3. *Dismantle a model 12 D 40 propeller following approved work sheets, inspect all components, assemble and balance in accordance with manufacturer's instructions.*

4. *Remove and install the following propellers on an engine strictly in accordance with worksheets or aircraft maintenance manual.*

    1. *Hamilton 12D40 counterweight.*
    2. *Hamilton 23E50 hydromatic.*
    3. *Hamilton 43E60 hydromatic.*
    4. *McCauley constant speed on 0-470.*
    5. *Hartzell constant speed on 0-470.*
    6. *Hartzell feathering on Beech 18, or PT6.*
    7. *Rotol hydromatic on Viscount or Dart engine.*
    8. *McCauley fixed pitch flange mount.*
    9. *Sensenich fixed pitch on tapered shaft.*
    10. *Other propellers as instructed.*

5. *Measure blade angles with prop. installed on aircraft, and determine if within limits.*

6. *Perform a track check,and determine if within limits.*

7. *Given a damaged aluminum blade, determine if damage is within repairable limits and dress out in accordance with manufacturer's instructions.*

8. *Given a bent blade, determine if within cold straightening limits.*

9. *Perform a 100 hour inspection on any propeller installed on the aircraft following the instructions in the aircraft's maintenance manual.*

STUDY GUIDE PROPELLERS

QUESTIONS

1. *Answer review questions at the end of chapter 16 on page 383.*

2. *What is the SAE spline size on the following engines: Ranger, R985, R1340, R1830, R2800.*

3. *Is there a master spline on all of the above engines, and if so what is the relationship between the master spline location and the crankshaft throws.*

4. *What is the difference between a single and a double acting governor.*

5. *What is the function of the counterweights on a counterweight type propeller.*

6. *What important function does the piston in the 12D40 perform besides acting as a piston in the cylinder.*

7. *What is the propeller blade angle on the Harvard when the cylinder is 1. fully forward, and 2. when fully back.*

8. *On the Harvard what forces turn the blades towards fine pitch, and the opposite way into coarse pitch.*

9. *What type of governor (single or double acting) is used on :*
   - a. *Harvard*
   - b. *Viscount*
   - c. *DC 3*
   - d. *R2800 on Convair or DC 6.*
   - e. *Cessna 180*

10. *Where is the governor located on the Beech 18 (if there is one)*

11. *When the piston on the PT6 is all the way back , what position are the blades in.*

12. *What is the Beta range (in degrees) on the prop. on the Twin Otter.*

13. *What is the purpose of the snap ring , and spacer on the Hamilton 12D40.*

14. *What is used to turn the blades on the Beech 18 to the feathered position with the engines running.*

15. *What prevents the blades on the Beech 18 from turning all the way into feathered position when the engine is shut down.*

16. *On the Cessna 180 is governor oil pressure use to increase or decrease the pitch.*

STUDY GUIDE PROPELLERS

SUPPLEMENTARY QUESTIONS

1. Calculate the blade angle of a Sensenich fixed pitch stamped "82 A 52" on the hub face , at the 75% blade station.

2. Calculate the tip speed of the propeller on the Harvard at max.rpm in ft/sec.

3. What is this speed in relationship to the speed of sound {Mach. #) if the O.A.T. is : a) 85 degs. F. b) minus 20 degs. C.

4. Calculate the centrifugal force on the blade of a Hamilton 43E60 installed on a DC6 at max. rpm of 2800, with a reduction gear ratio of .45 : 1 , and the weight of the blade is 106 lbs. acting at a radius of 36 inches.

5. State the procedure for feathering the prop. on the Viscount prior to removal.

6. State the procedure for turning the prop. to ground fine on the Viscount if the red lines on spinner and prop. are not lined up.

DESCRIPTION AND NOMENCLATURE

Propeller consists of two or more blades and a central hub.

Purpose. To pull the aircraft through the air.
Designed to transform engine BHP to Thrust HP.

Principle.

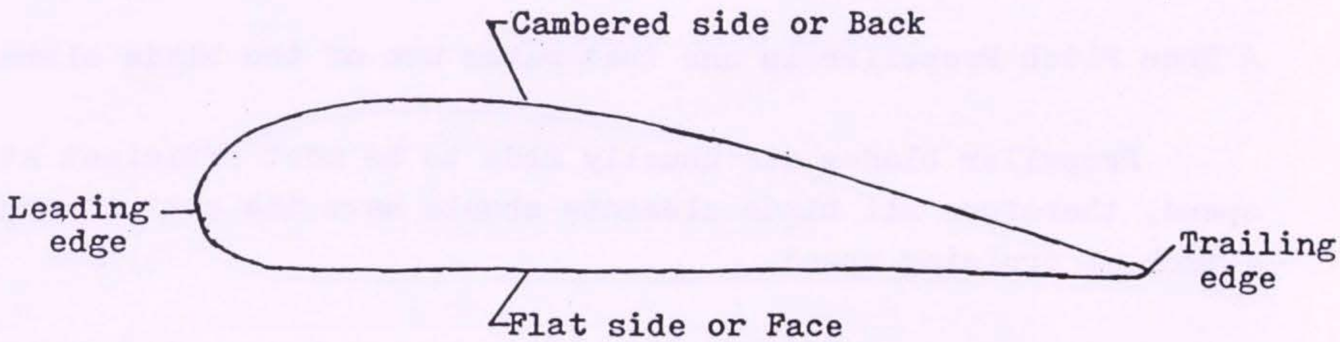
1. Screws its way through the air.
2. Aerodynamically the same as a wing, but instead of lift, we have thrust.
3. Accelerating a large mass of air rearwards. Newton's 2 nd. law. $F = Ma$

Nomenclature.

Fixed pitch prop. hub, hub bore, bolt holes, shank, blade, tip, metal tipping,

Variable pitch. hub, or barrel, dome, blade butt, blade cuff, clamps(adjustable)

Cross section of airfoil



Basic types. Tractor - In front of engine.
Pusher - At rear of engine. (Skymaster, Seabee.)

Direction of rotation is always as viewed from the slipstream.

BLADE ELEMENT THEORY

Theory assumes prop. is divided into various small airfoil sections from the shank to the blade tip.

The many airfoil sections (elements) being joined together side by side to form the blade that can create thrust when revolving in a plane about a central axis.

Each element is designed to operate at its best angle of attack to create thrust.

As the angle of attack increases lift increases. Max.approx 22 deg.

As the angle of attack increases drag increases. Note steepness of curve. (fig. 3-2 page 51)

The lift/drag ratio reaches a max. at 3 to 4 degs.

Optimum angle of attack is 3 to 4 degs.

A True Pitch Propeller is one that makes use of the blade element theory.

Propeller blades are usually made to be most efficient at cruising speed, therefore all blade elements should have the optimum angle of attack at cruising speed.

All elements have the same forward speed but their rotational speeds will all be different. Greatest at the tip and least at the root.

The blade must be TWISTED for maximum efficiency. Pitch Distributio

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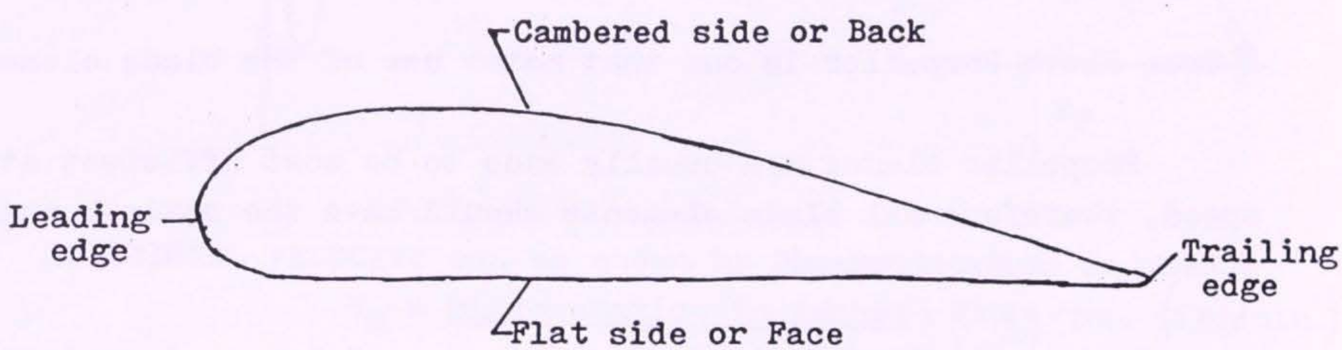

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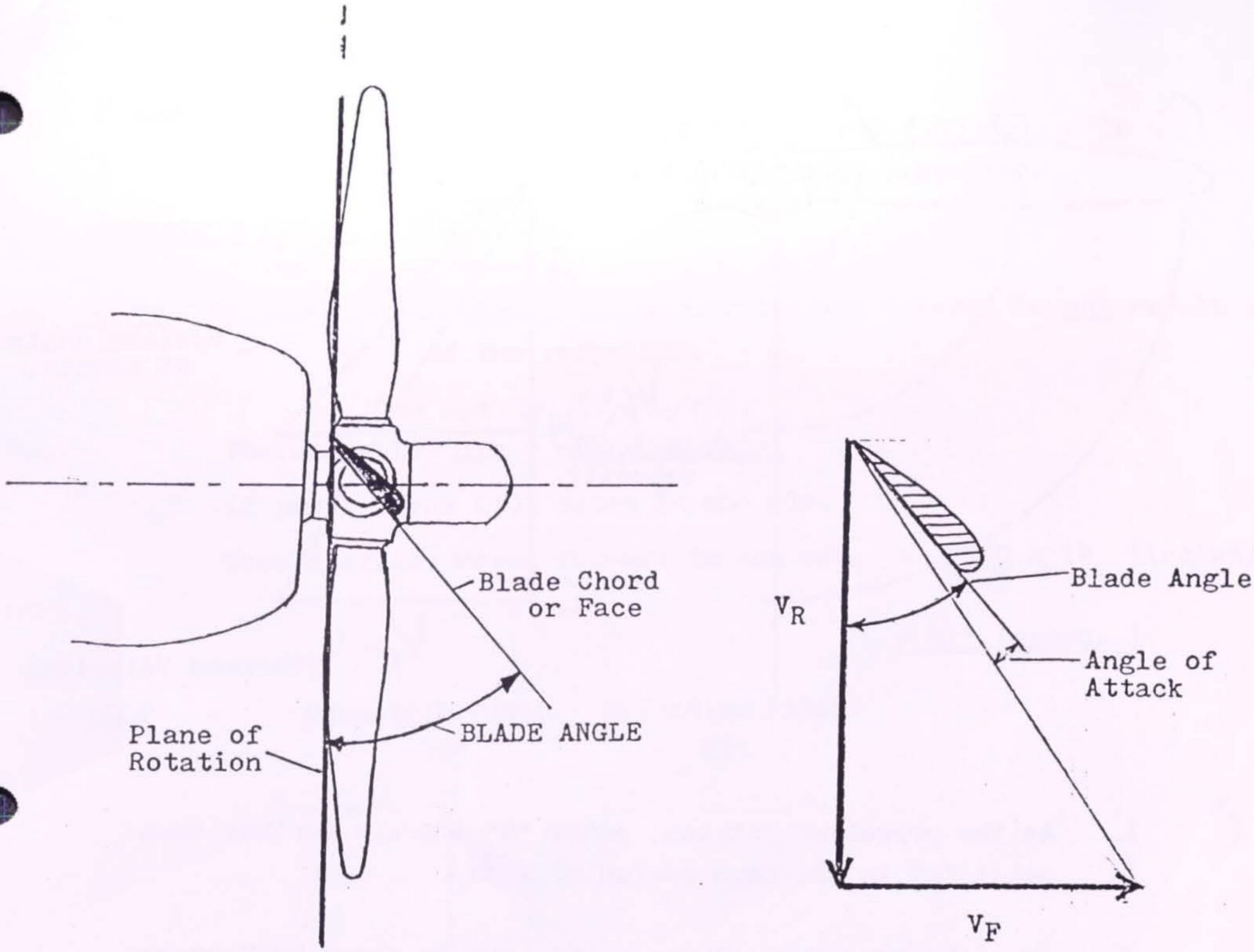


1. ROTATIONAL VELOCITY can be shown by the vector V_R.

$$V_R = \frac{\text{Blade station in inches}}{12} \times 2 \times \pi \times \text{rpm}. \ (\text{ft./min.})$$

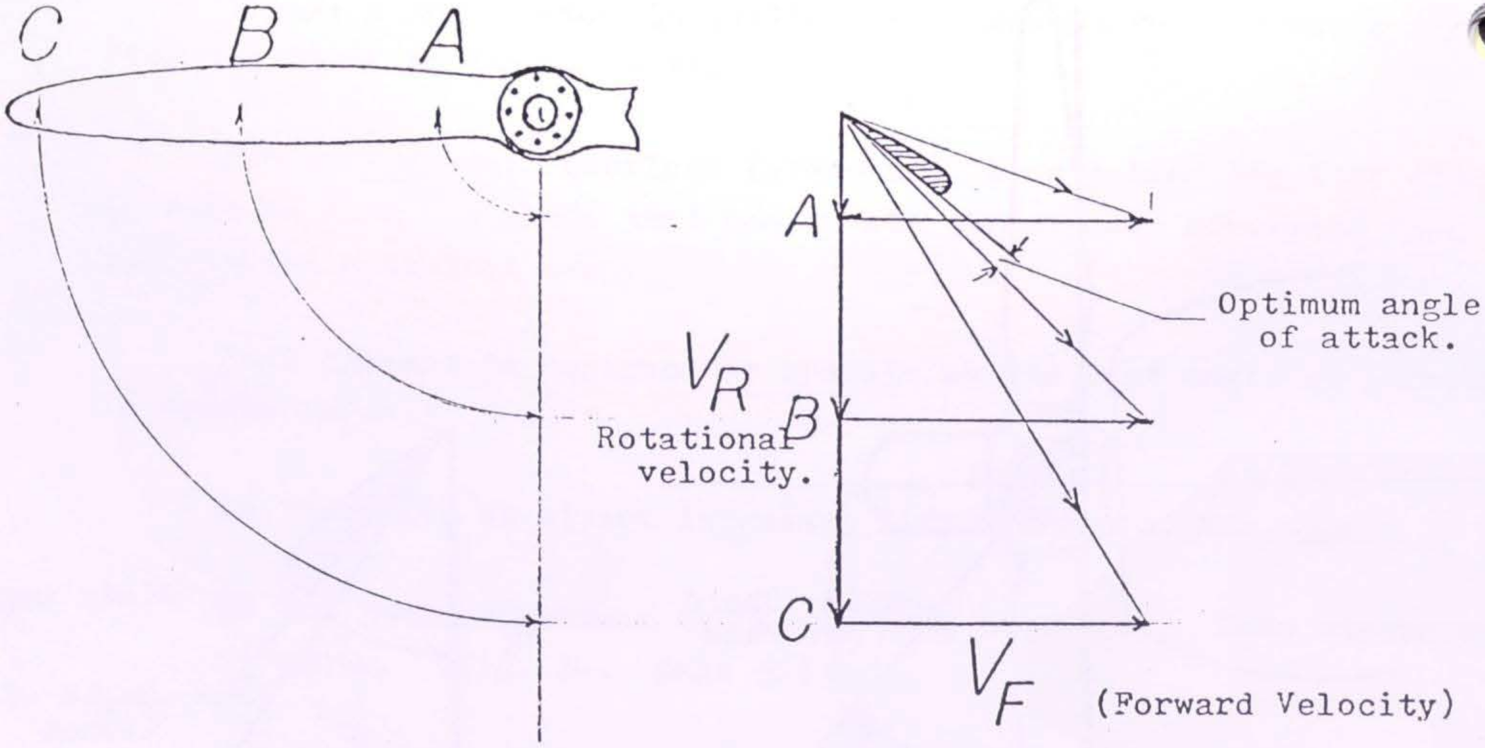
2. FORWARD VELOCITY of aircraft can be shown by the vector V_F

$$V_F = \text{Aircraft speed mph} \times 88. \ (\text{ft./min.})$$

3. The resultant of these two components is the BLADE PATH or RELATIVE AIRFLOW

4. ANGLE OF ATTACK is the angle between the blade face or chord and the relative airflow. (α alpha)

THE REASON WHY PROPELLER BLADES ARE TWISTED.



1. As the propeller rotates, point "C" travels further than point "A" in the same period of time.

2. The velocity of the three points can be shown by Vectors. "A" "B" and "C" (V_R - Rotational Velocity)

3. A given forward velocity (V_F) is shown.
   Note - It is the same for all points.

4. To maintain the optimum angle of attack of 2 to 4 degrees at a given forward velocity (V_F), the <u>blade angle</u> must be <u>increased</u> from the tip towards the hub.

5. Or - The blade is twisted.

GEOMETRIC PITCH, EFFECTIVE PITCH, AND SLIP.

Example

Cessna 150 - Cruising at 100 mph, at 2500 rpm, with a 7248 fixed pitch metal propeller.

GEOMETRIC PITCH - 48 inches.

EFFECTIVE PITCH - Distance the aircraft moves forward in one revolutio of the propeller.

One mph = 88 ft./min.

Therefore 100 mph = 8800 ft./min.

If prop. turns 2500 times in one min.

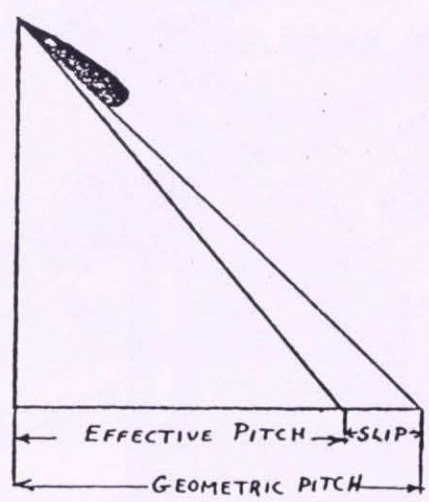
Then distance moved forward in one rev. $= \frac{8800}{2500} \times 12$ (inches)

= 42" (approx.)

SLIP - Geometric Pitch - Effective Pitch

= 48" - 42"

= 6"

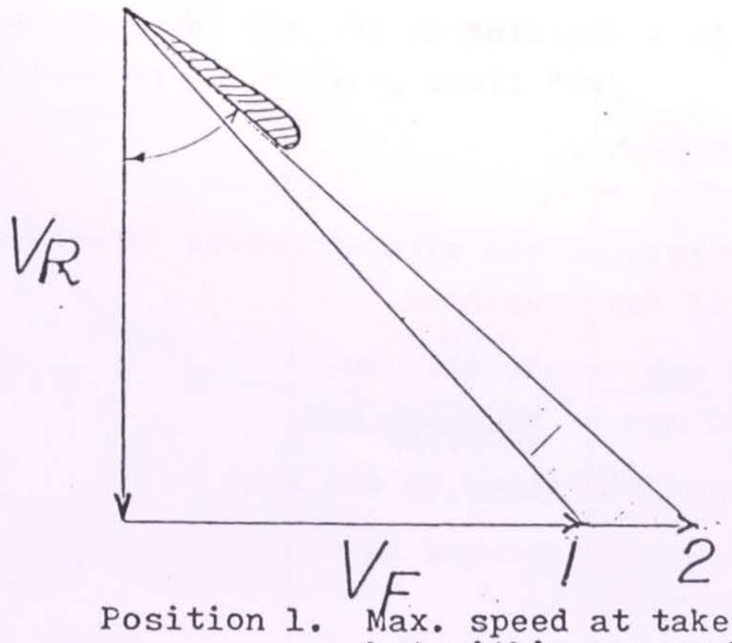


Problem #1 Using the same format, calculate the effective pitch, and slip, for the Cessna 172 at cruise fitted with an approved fixed pitch metal prop.

~~Problem #2 As above calculate the effective pitch, and slip for the Beech 18 at a) Cruise b) Take-off.~~

THE REASON WHY SOME PROPELLERS ARE VARIABLE PITCH

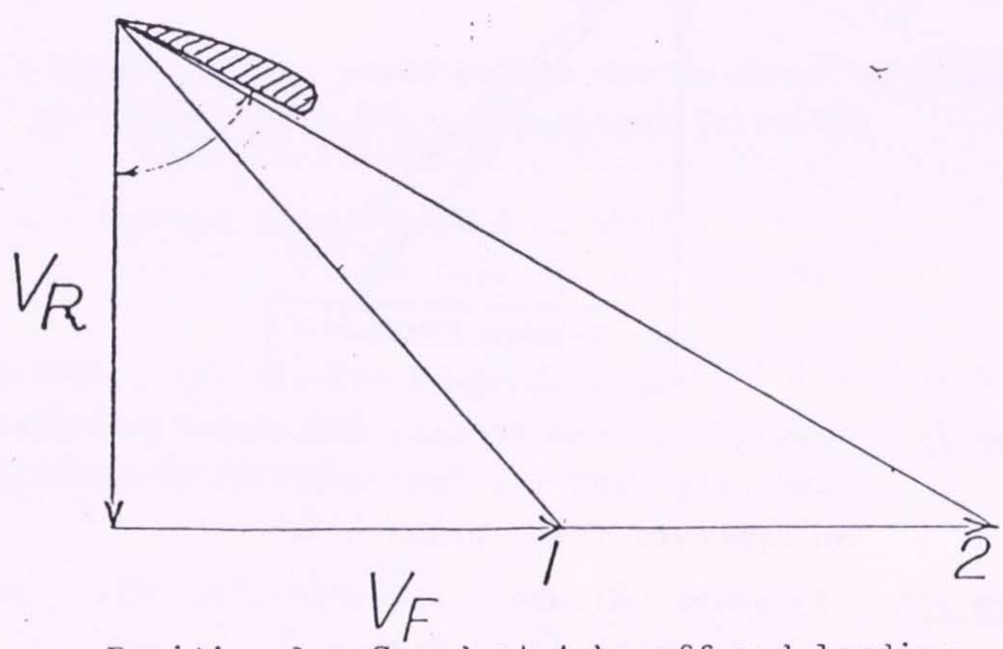
1. Light aircraft with small speed range between take-off and cruise.



Position 1. Max. speed at take-off, LARGE angle of attack but within reasonable limits.

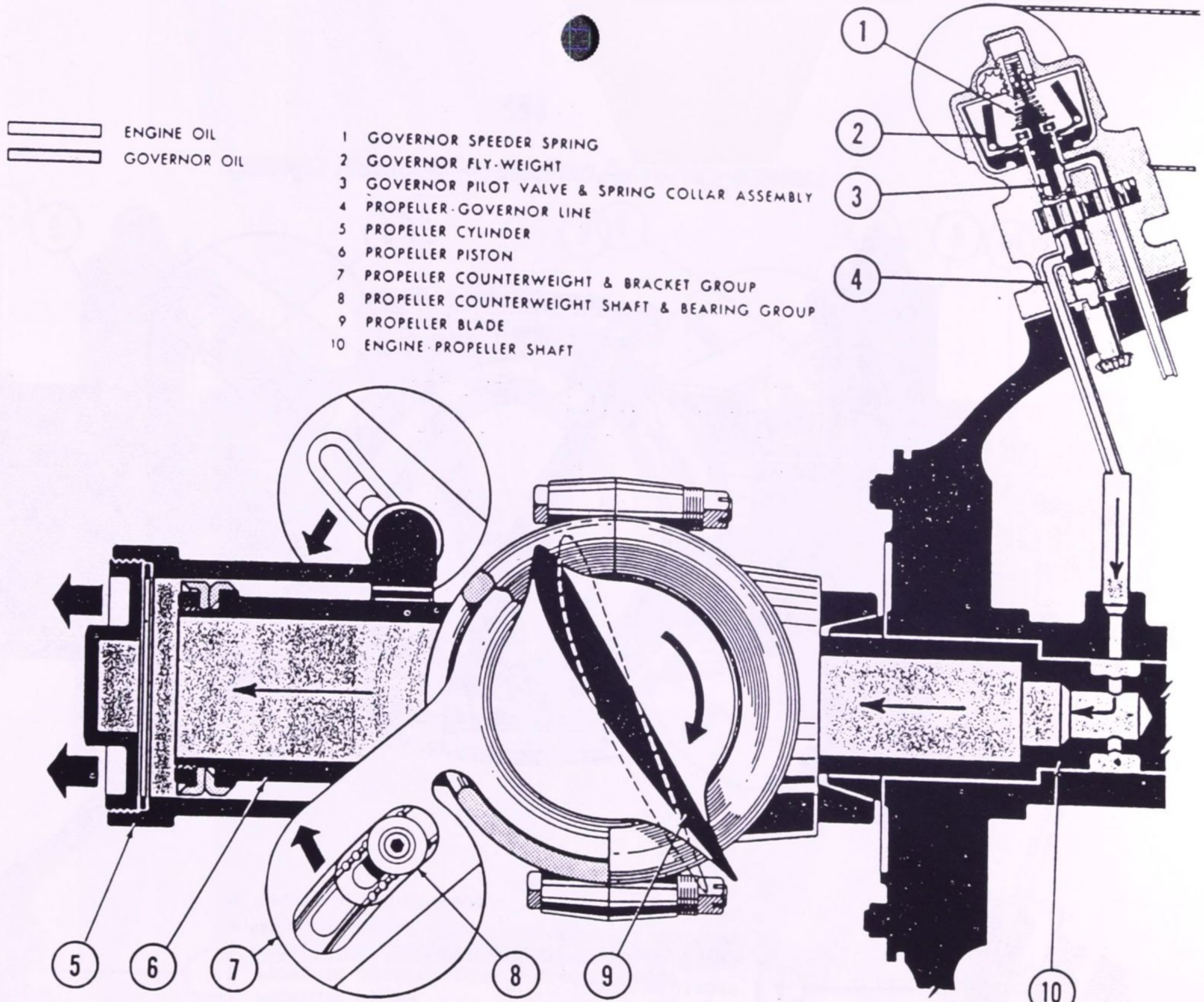
Position 2. Max. speed at cruise, SMALL angle of attack, but within reasonable limits.

2. Aircraft with large speed range between take-off and cruise.

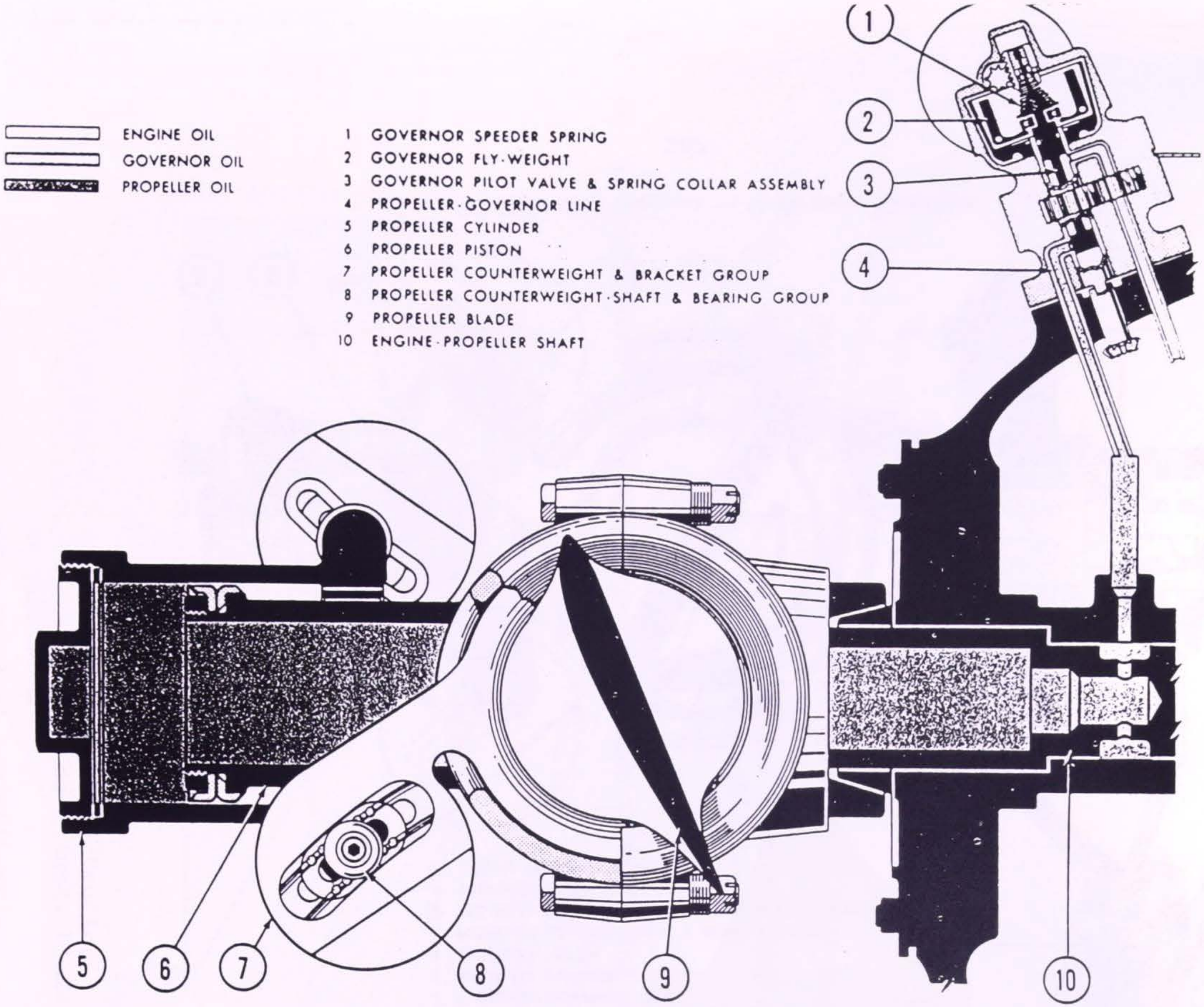


Position 1. Speed at take-off and landing. To maintain efficient angle of attack, blade angle must be DECREASED.

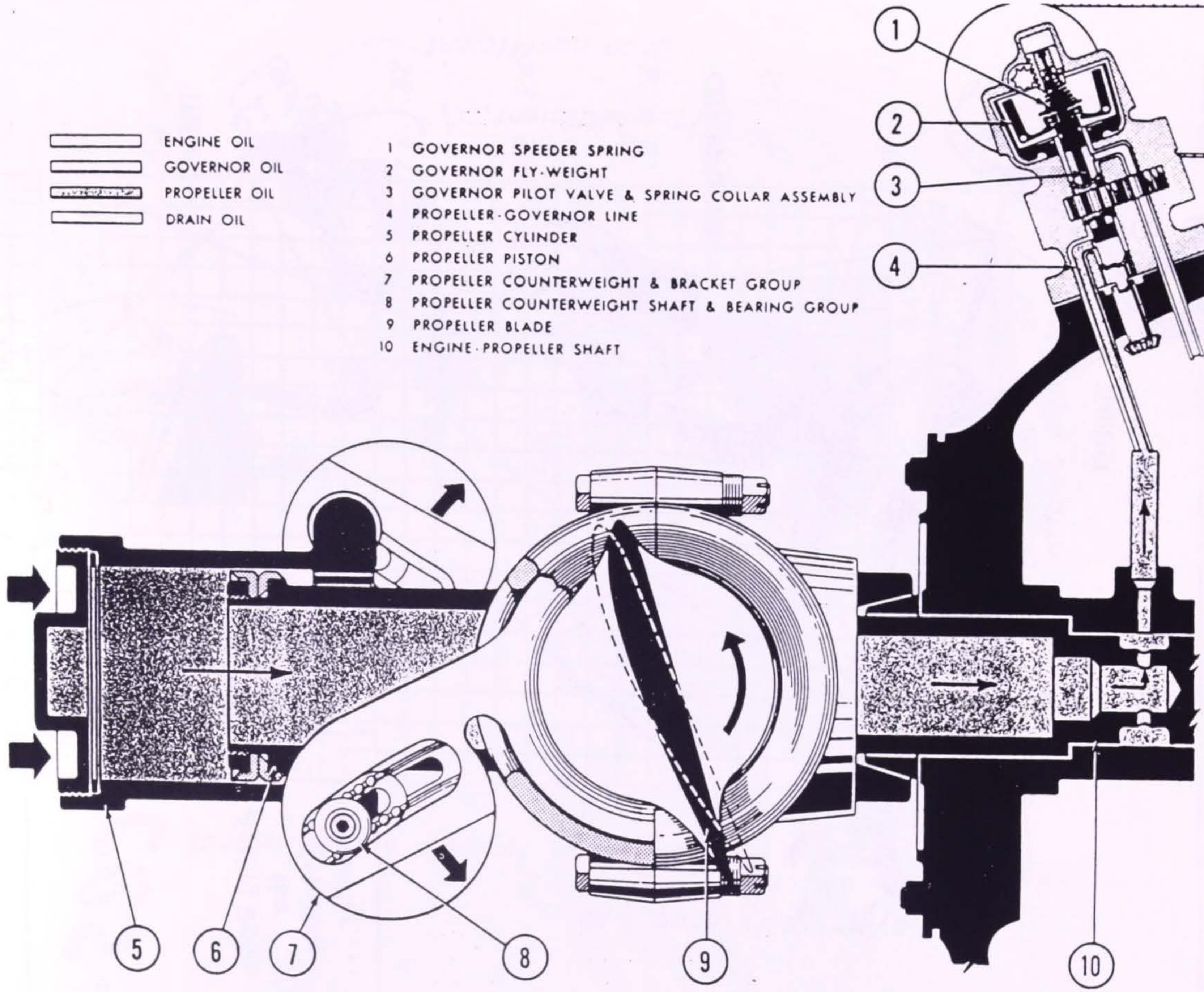
Position 2. Max. speed at cruise(high). To maintain efficient angle of attack, blade must be TURNED TO INCREASE the angle.



Propeller Operating Diagram — Underspeed Condition



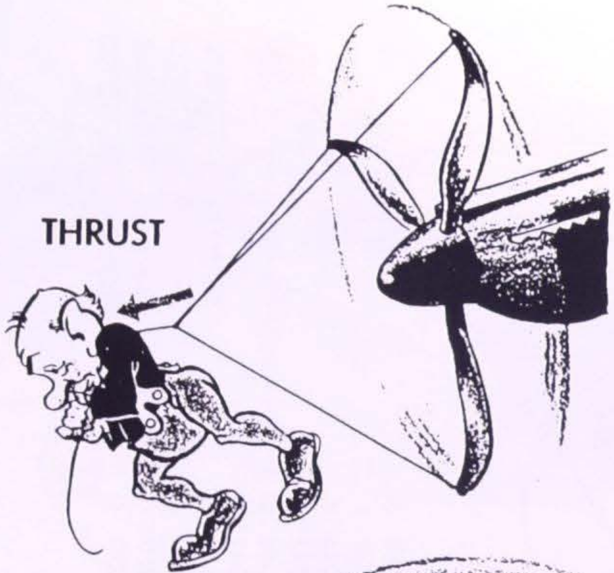
Propeller Operating Diagram — On-Speed Condition

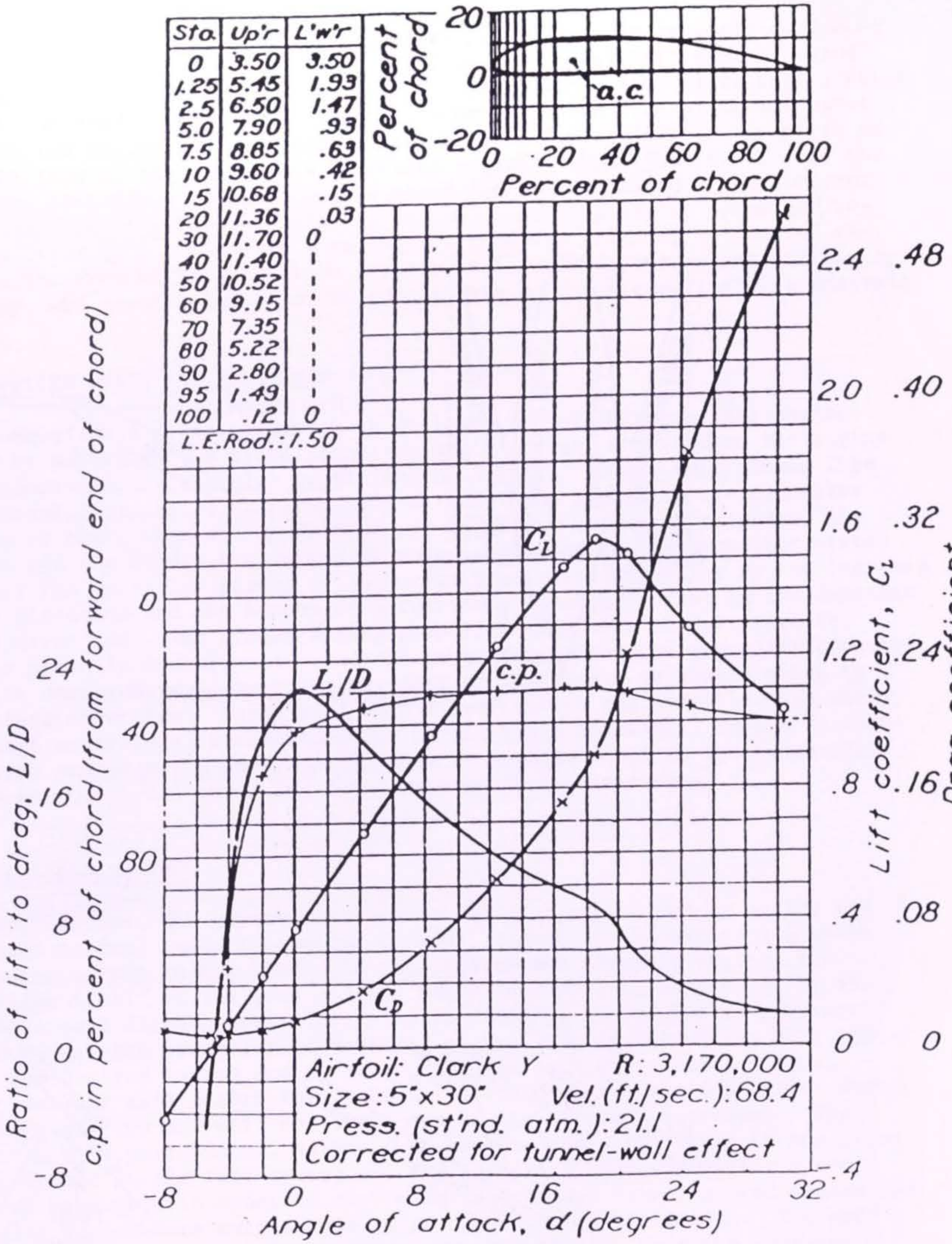


Propeller Operating Diagram — Overspeed Condition

Forces—

Acting Upon the Rotating Propeller . . .

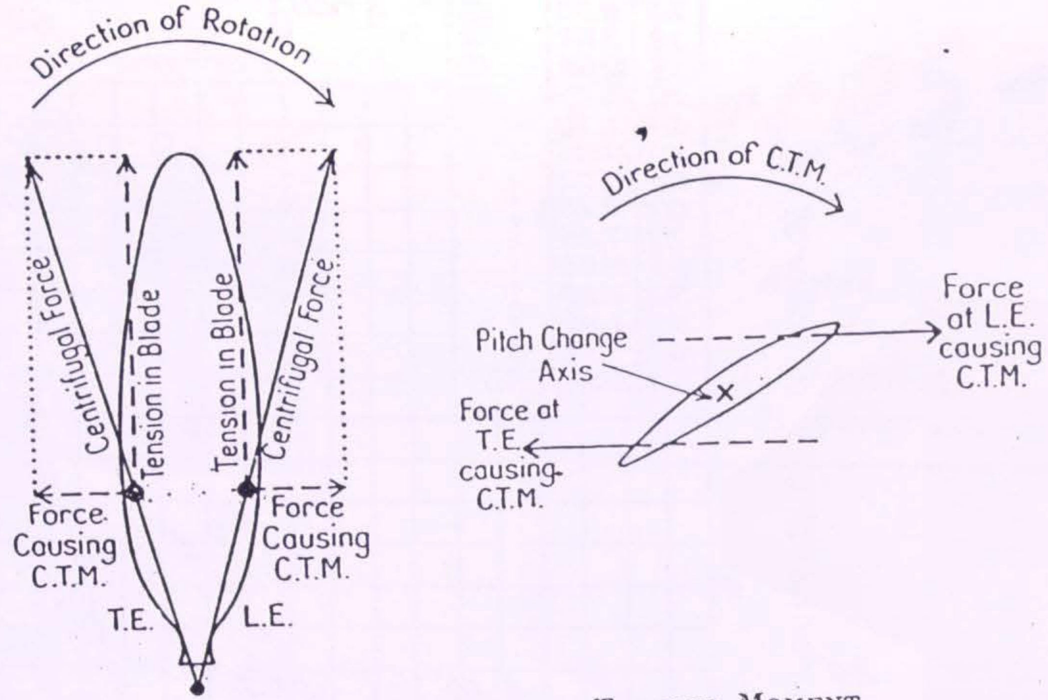




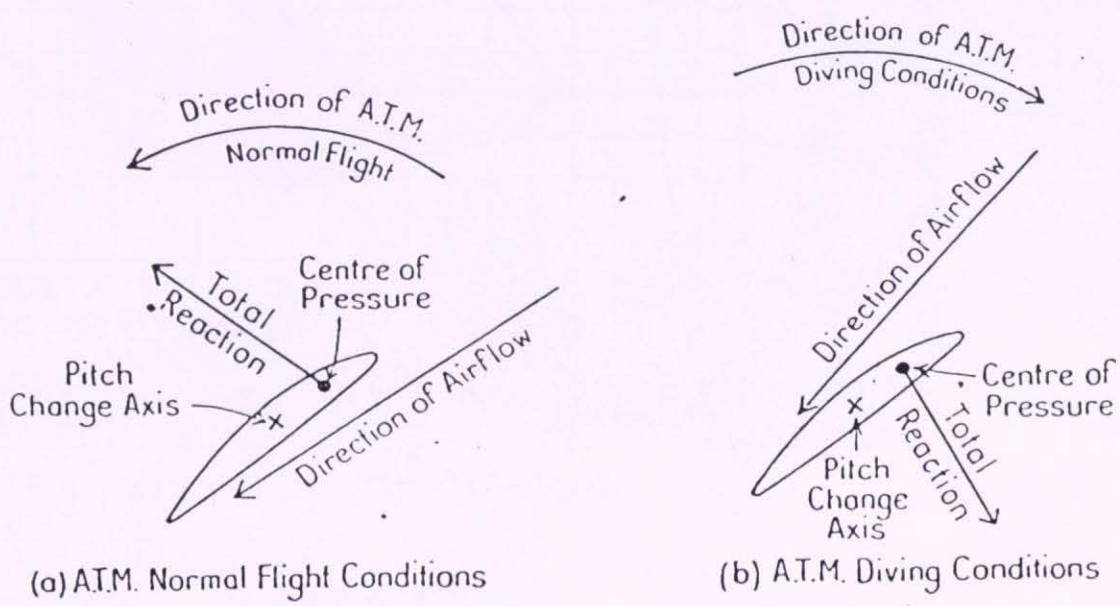
Sta.	Up'r	L'w'r
0	3.50	3.50
1.25	5.45	1.93
2.5	6.50	1.47
5.0	7.90	.93
7.5	8.85	.63
10	9.60	.42
15	10.68	.15
20	11.36	.03
30	11.70	0
40	11.40	
50	10.52	
60	9.15	
70	7.35	
80	5.22	
90	2.80	
95	1.49	
100	.12	0

L.E. Rad.: 1.50

CLARK Y



Centrifugal Turning Moment



(a) A.T.M. Normal Flight Conditions

(b) A.T.M. Diving Conditions

Aerodynamic Turning Moment

AIRCRAFT PROPELLER GOVERNORS

The primary function of an aircraft propeller governor is to regulate engine speed. Since the propeller represents the load on the aircraft engine, speed regulation can be accomplished by varying the propeller pitch (blade angle) which determines the load acting on the engine. A propeller in high pitch increases the load on the engine and decreases engine speed. A propeller in low pitch decreases the load on the engine and increases engine speed. Thus by varying the pitch of the propeller, constant engine speed can be maintained. The governor automatically varies propeller pitch to maintain constant engine speed and relieves the pilot from constantly changing the throttle settling to control engine r.p.m.This automatic regulation results in increased power plant efficiency and economy, and permits the pilot to concentrate on the aircraft flight controls.

BASIC PROPELLER PARTS AND FUNCTIONS

The controllable pitch propeller is designed to maintain constant engine speed by adjusting the propeller blade angle to vary the load on the engine in response to the changing conditions of flight. In the most common type of hydraulic propeller, a piston and cylinder are linked to the propeller blades so that, when oil under pressure is pumped into this cylinder, the piston and the blades are forced to move. Movement of the propeller piston rotates the propeller blades of an uncounterweighted propeller in the increase pitch direction and the blades of a counterweighted propeller in the decrease pitch direction. The single acting propeller thus uses oil pressure to change pitch in one direction and the centrifugal force of propeller counterweights or the natural twisting movement of the blades to change pitch in the other direction. Large ball thrust bearings in the propeller hub carry the high centrifugal blade loads and permit blade rotation. In the feathering type propeller, a heavy spring load is used to complete the feathering cycle as rotational speed and counterwieght force diminishes.

METHODS OF SPEED CONTROL

On most engines, the governor maintains constant engine rpm by moving the throttle or fuel racks to control the fuel supply to the engine and match the power output to the load. In the case of the aircraft engine, the propeller itself is the load and the power developed is determined by the pilot to suit flight conditions. The function of the propeller governor is to adjust the propeller blade angle so the load on the engine will maintain the desired engine rpm at the horsepower setting selected. Thus, the propeller will absorb full take-off power and give maximum thrust during the take-off run and will not overspeed as the airspeed increases. The advantages in performance, safety, and convenience are obvious to any pilot. The increase in aircraft horsepower and speed has made a constant speed control mandatory in order to derive full advantage from improved engine and aircraft performance over a wide range of operating conditions. The propeller control lever on a constant speed installation sets the governor speed setting, and the propeller pitch changes that result are completely controlled by the governor. Thus if the governor speed setting is increased by pushing the propeller control lever forward, the governor instantly decreases the propeller pitch until the engine speeds up to the new rpm setting. The actual blade angle required for a given rpm is determined by the horsepower being developed and the airspeed of the aircraft.

PRINCIPLES OF OPERATION

Fundamental Mechanism

To obtain the desired engine speed regulation through hydraulic control of propeller pitch, four fundamentals are required of the governor design:

(a) An oil pump to supply the pressure necessary to operate the propeller pitch changing mechanism;

(b) A pilot valve to direct the oil through the proper passage to make the correct change in pitch;

(c) Rotating flyweights positioned to move the pilot valve correctly in response to changes in engine speed; and

(d) A speeder spring to oppose flyweight force and necessary mechanism to permit adjustment of this spring.

BASIC ACTION

Assembled and operating in the governor body, these mechanisms make use of centrifugal force to automatically control propeller pitch and regulate engine speed. The L-shaped flyweights are pivoted on a disc-type flyweight head coupled to engine gears through a hollow drive-gear shaft. A pilot valve plunger extends into the hollow shaft and is so mounted that the pivoting motion of the rotating flyweights will raise the plunger against the pressure of a speeder spring or allow the spring pressure to force the plunger down in the hollow shaft. Up or down movement of the plunger is determined by the speed of rotation of the flyweights and the adjustment of speeder spring pressure. The movement of the plunger is used to direct oil from the gear pump into the proper passage to effect the change in propeller pitch necessary to keep the engine speed at the desired rpm.

FIG. 1 – GOVERNOR TYPE CSSA, RIGHT FRONT VIEW

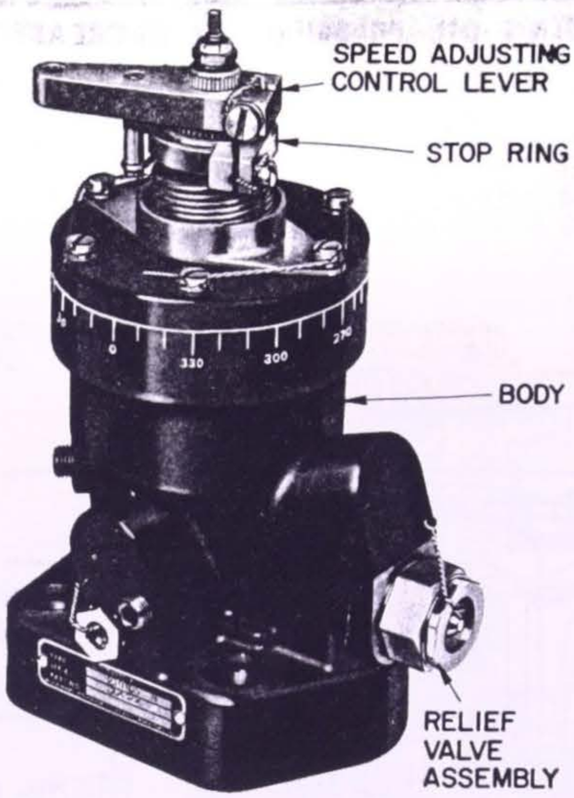
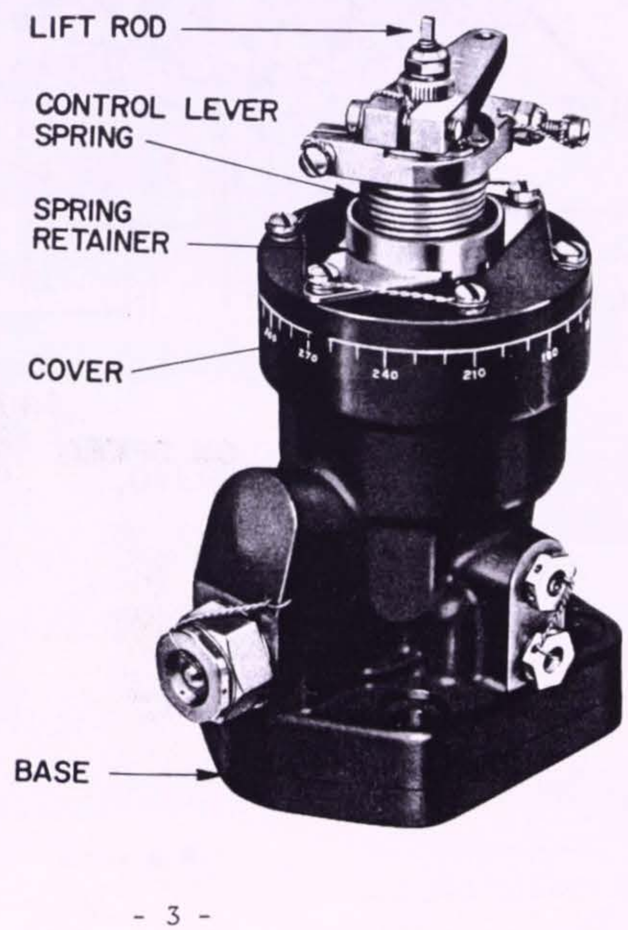


FIG. 2 – GOVERNOR TYPE CSSA, LEFT FRONT VIEW



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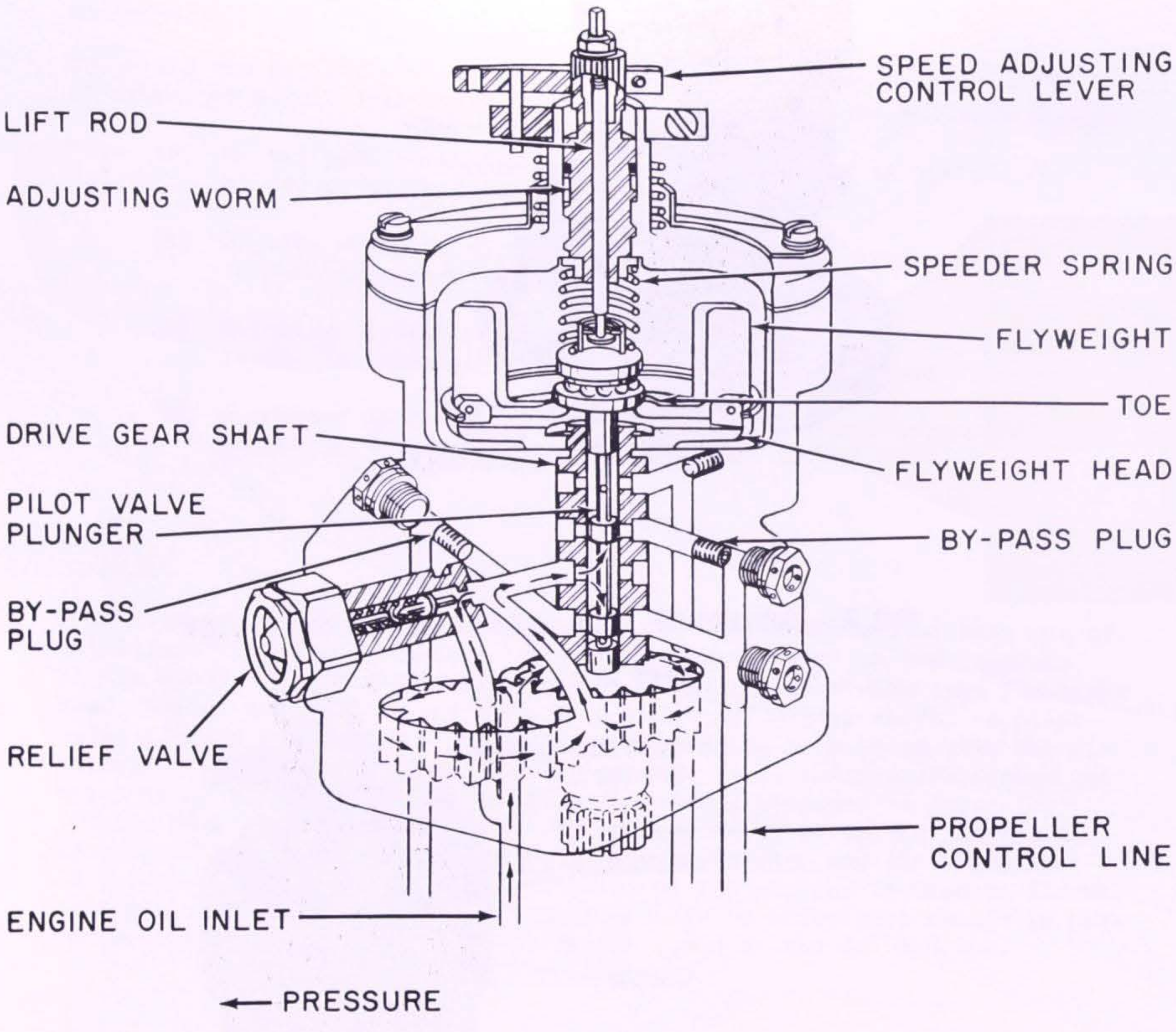
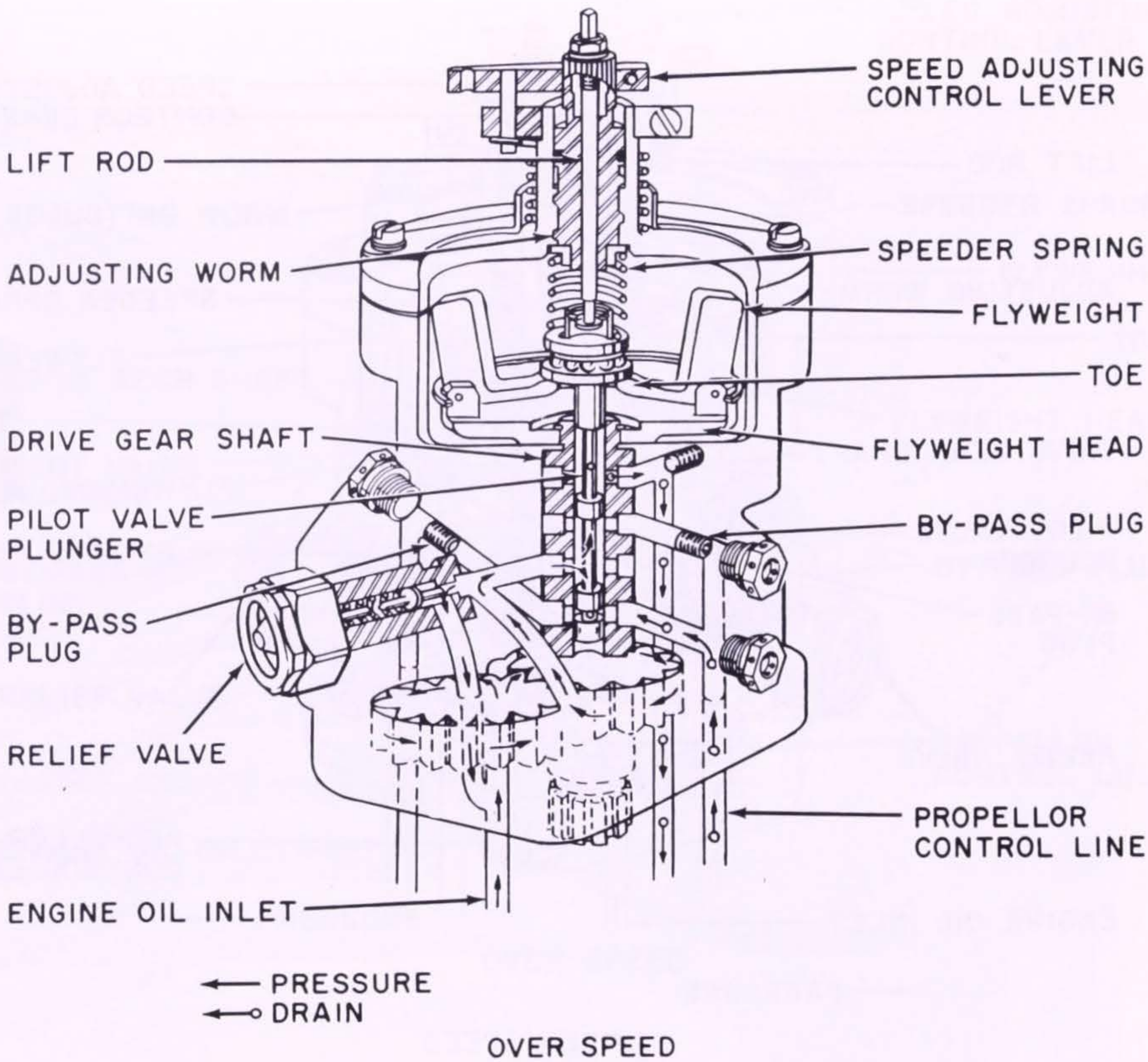
SCHEMATIC DIAGRAM, ON – SPEED
PROPELLERS USING OIL PRESSURE TO DECREASE PITCH



ON SPEED

SCHEMATIC DIAGRAM, OVER-SPEED
PROPELLERS USING OIL PRESSURE TO DECREASE PITCH



OVER SPEED

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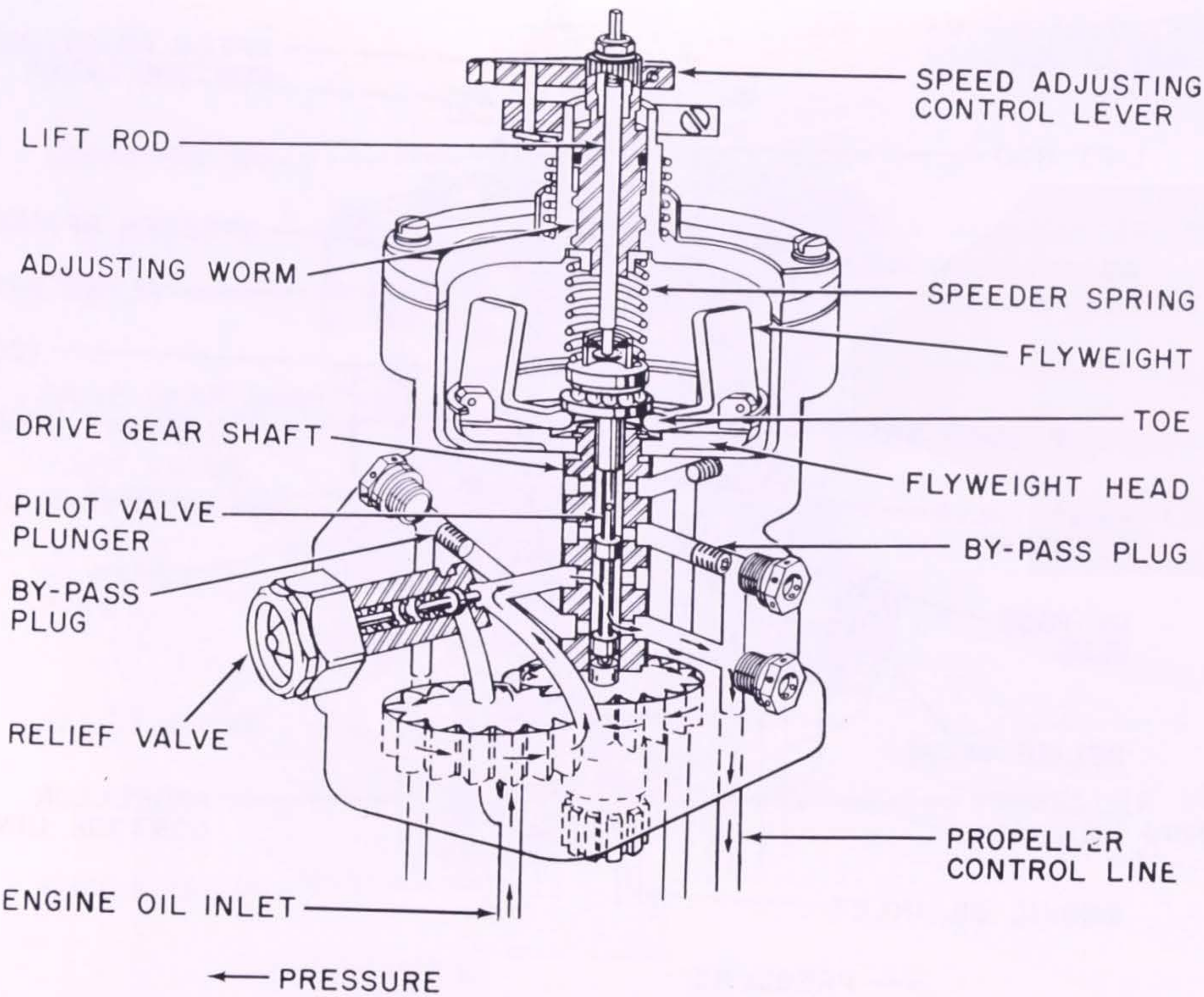
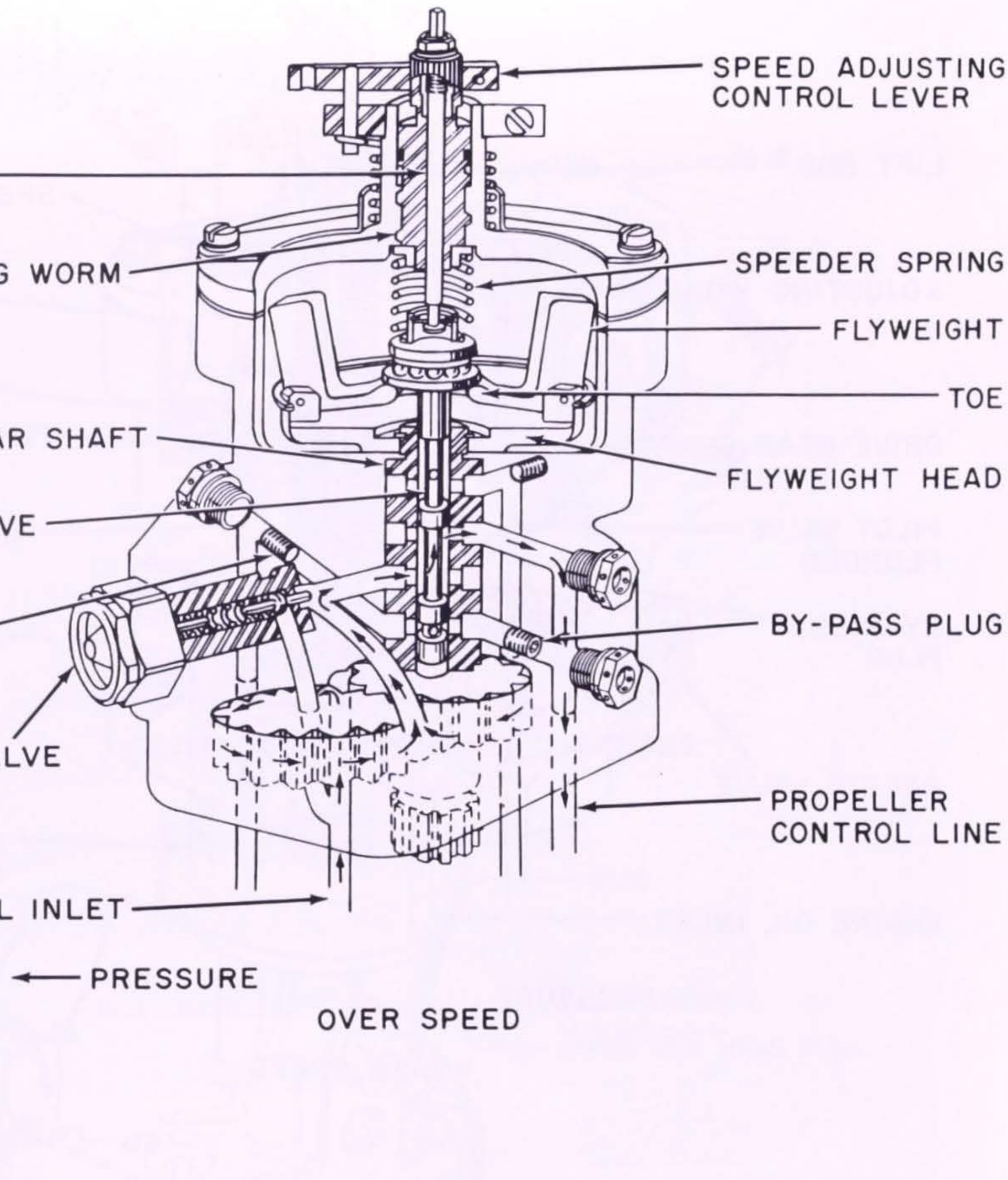
SCHEMATIC DIAGRAM, UNDER-SPEED PROPELLERS USING OIL PRESSURE TO DECREASE PITCH



UNDER SPEED

SCHEMATIC DIAGRAM, OVER-SPEED
PROPELLERS USING OIL PRESSURE TO INCREASE PITCH



OVER SPEED

SCHEMATIC DIAGRAM, UNDER-SPEED
PROPELLERS USING OIL PRESSURE TO INCREASE PITCH

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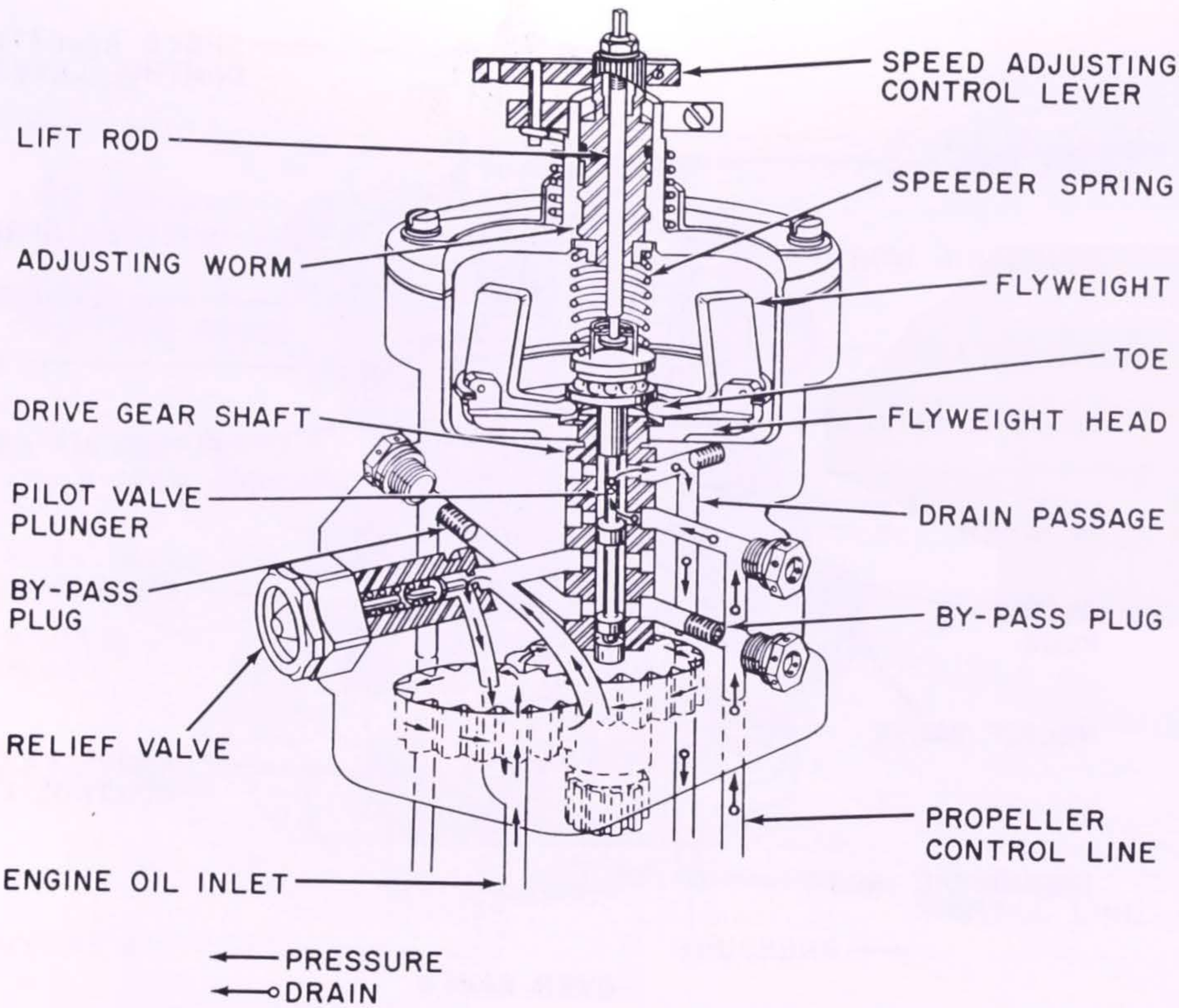
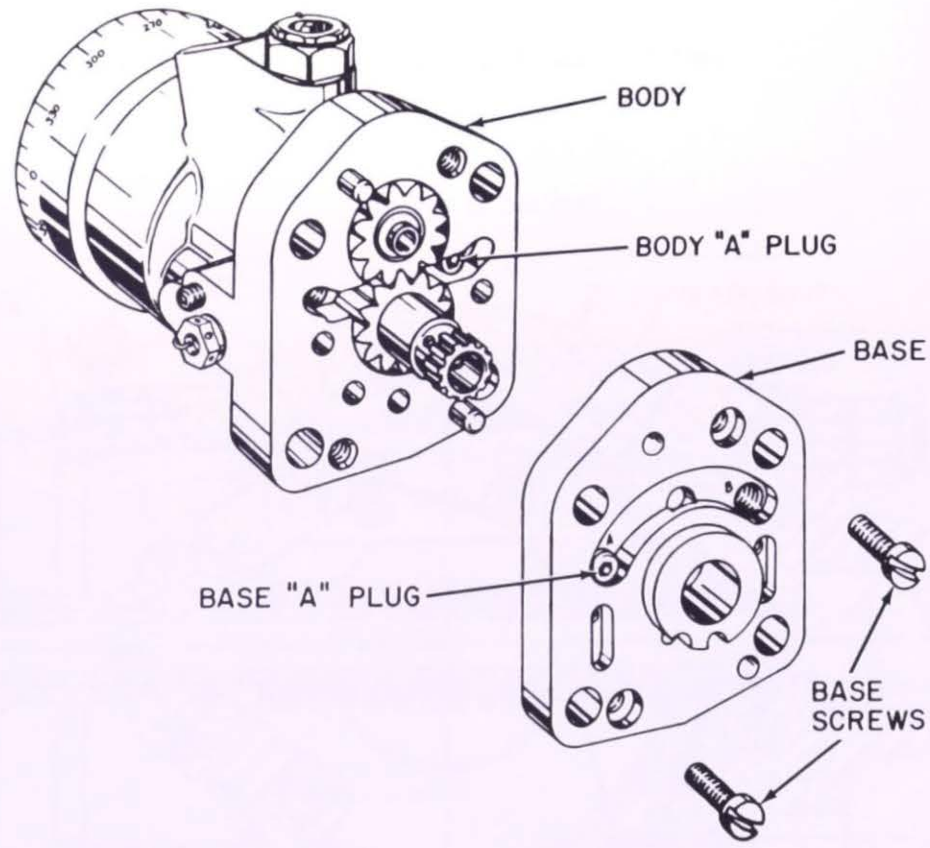
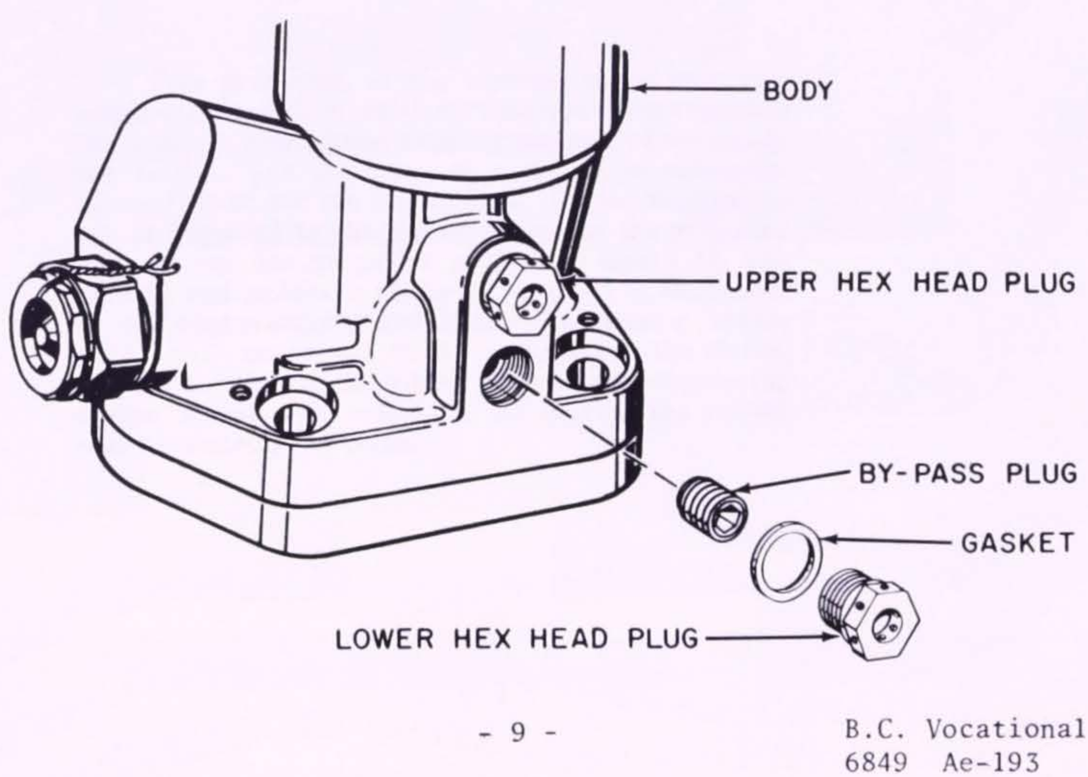


UNDER SPEED

GOVERNOR OIL INLET PLUG LOCATIONS



GOVERNOR BY-PASS PLUG LOCATIONS



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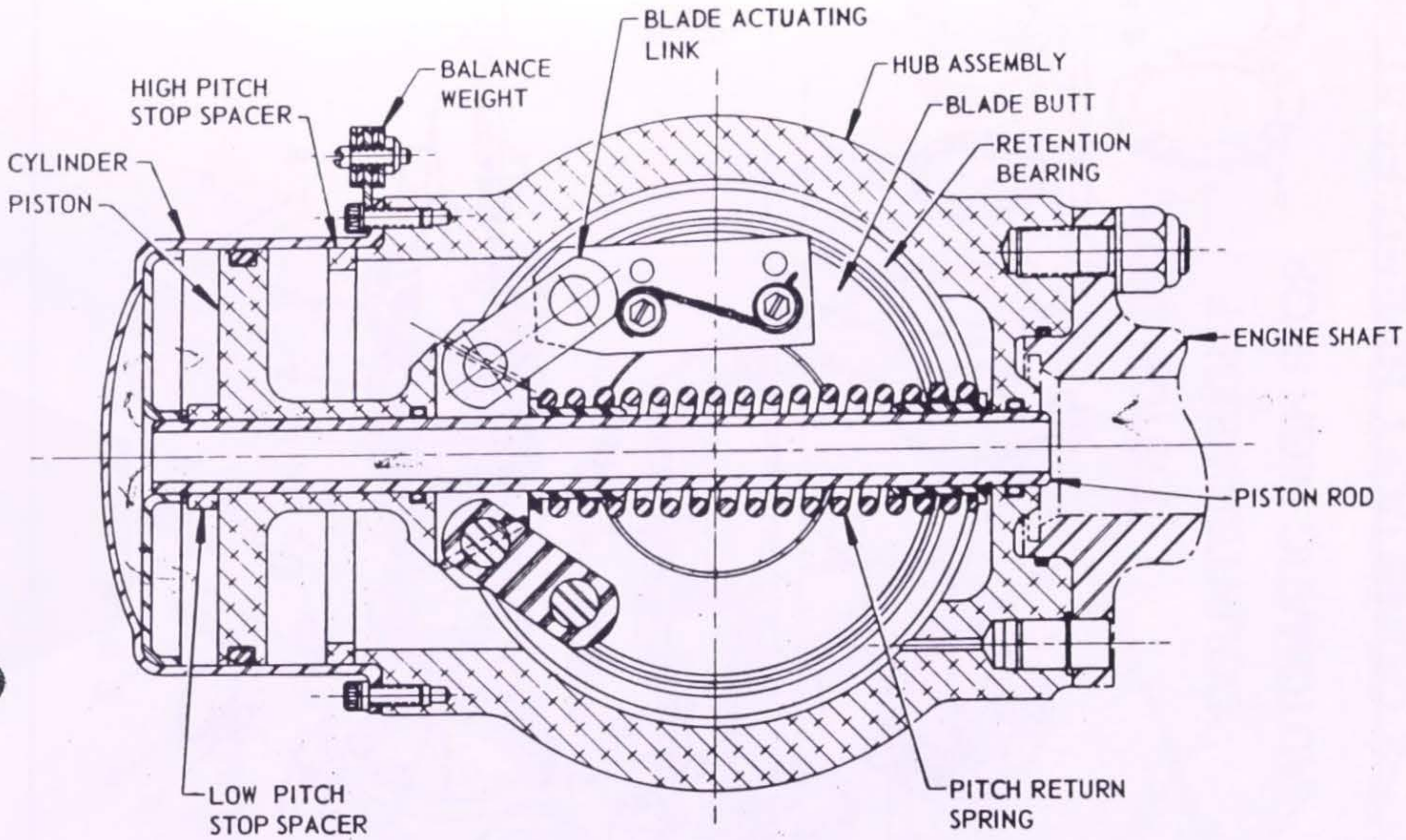
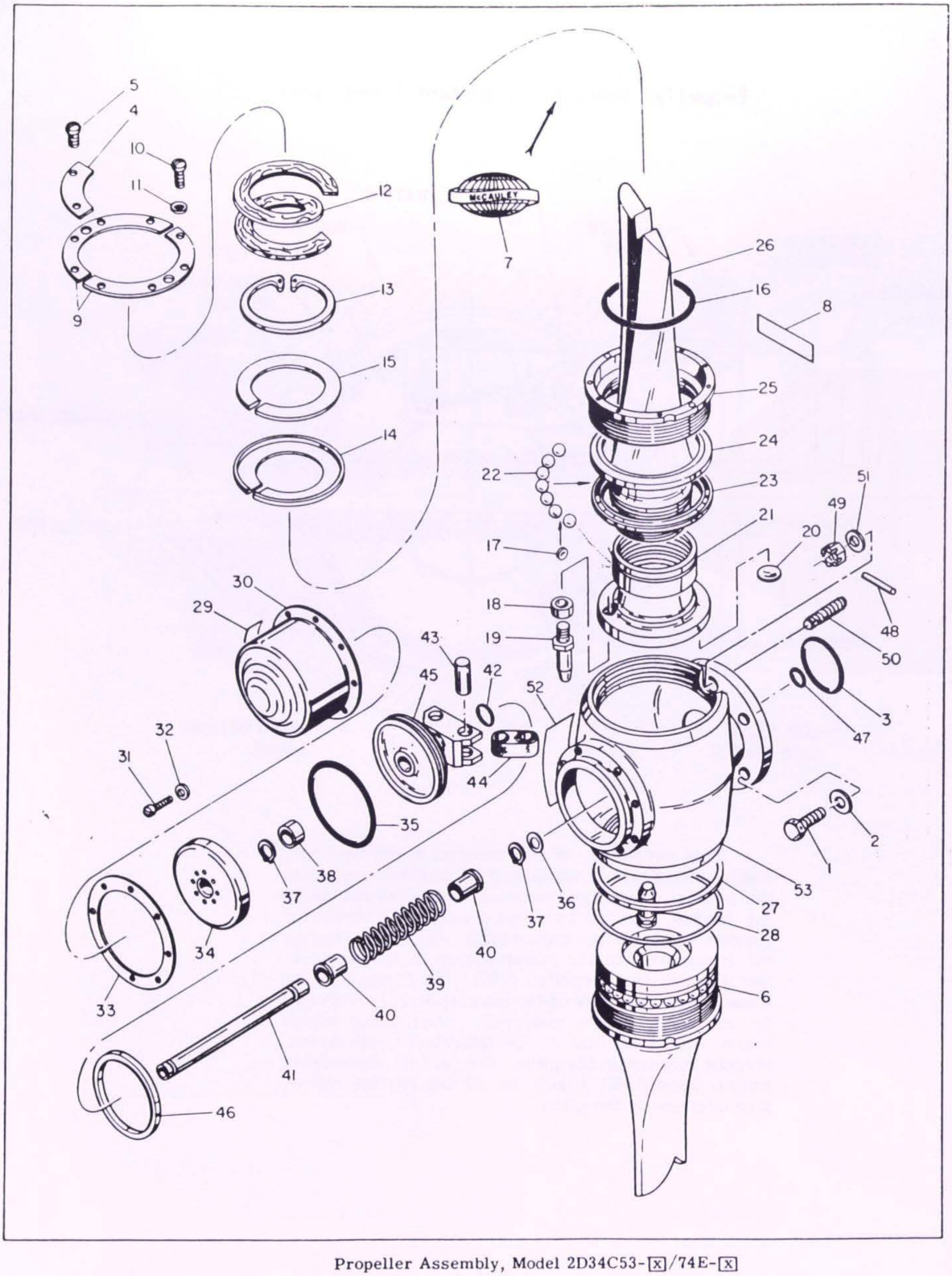
Propeller Schematic (Constant Speed Type)

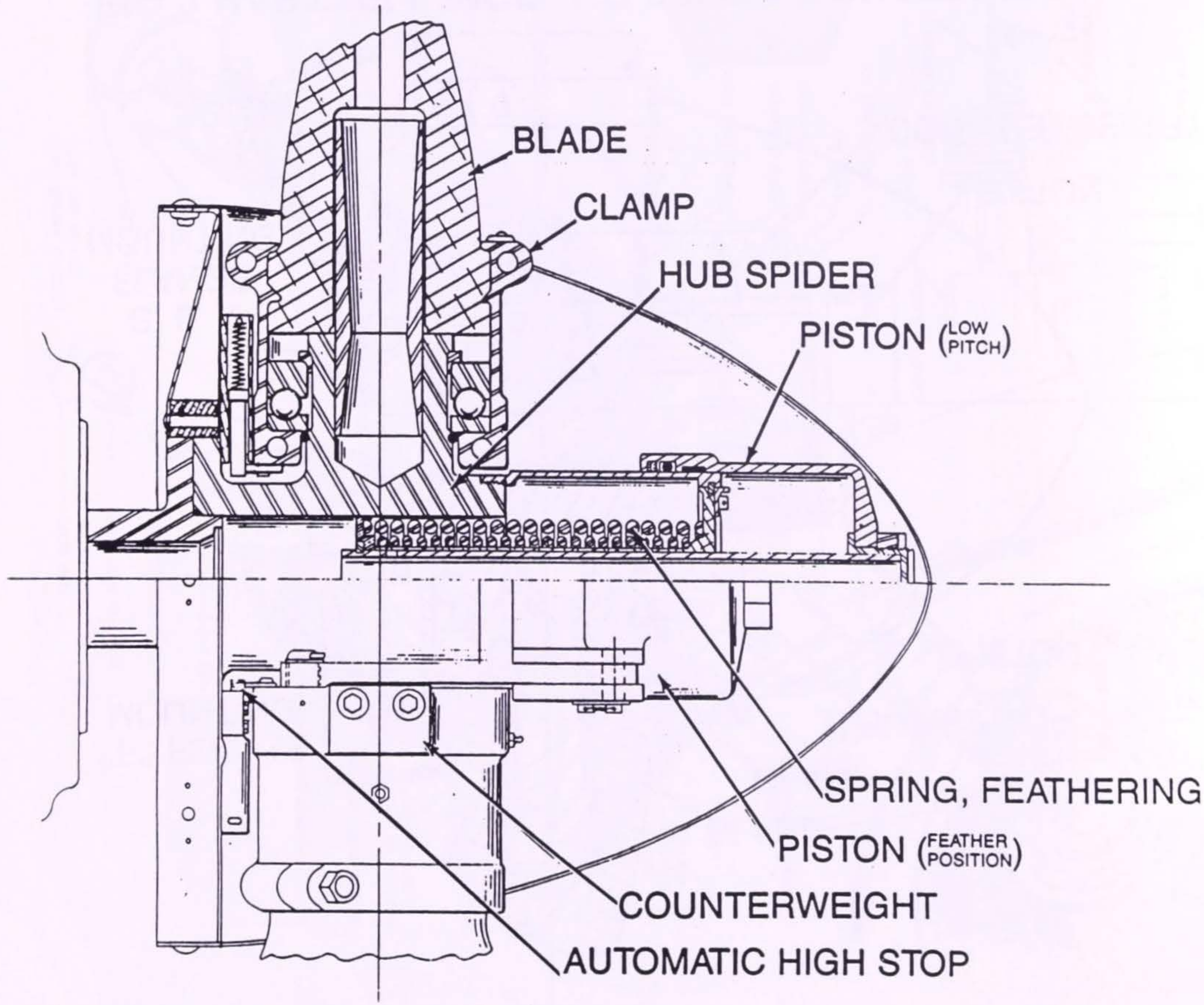


This propeller, of the constant speed type, is a single-acting unit in which hydraulic pressure opposes the natural, centrifugal twisting moment of the rotating blades, and the force of a spring, to obtain the correct pitch for the engine load. Engine lubricating oil is supplied to the power piston in the propeller hub through the propeller shaft (see figure 1). The amount and pressure of the oil supplied is controlled by an engine-driven governor. Increasing engine speed will cause oil to be admitted to the piston, thereby increasing the pitch. Conversely, decreasing engine speed will result in oil leaving the piston, thus decreasing the pitch.

22



Propeller Assembly, Model 2D34C53-[x]/74E-[x]



HARTZELL MOD. HC-82XF-2 CONSTANT SPEED-FEATHERING

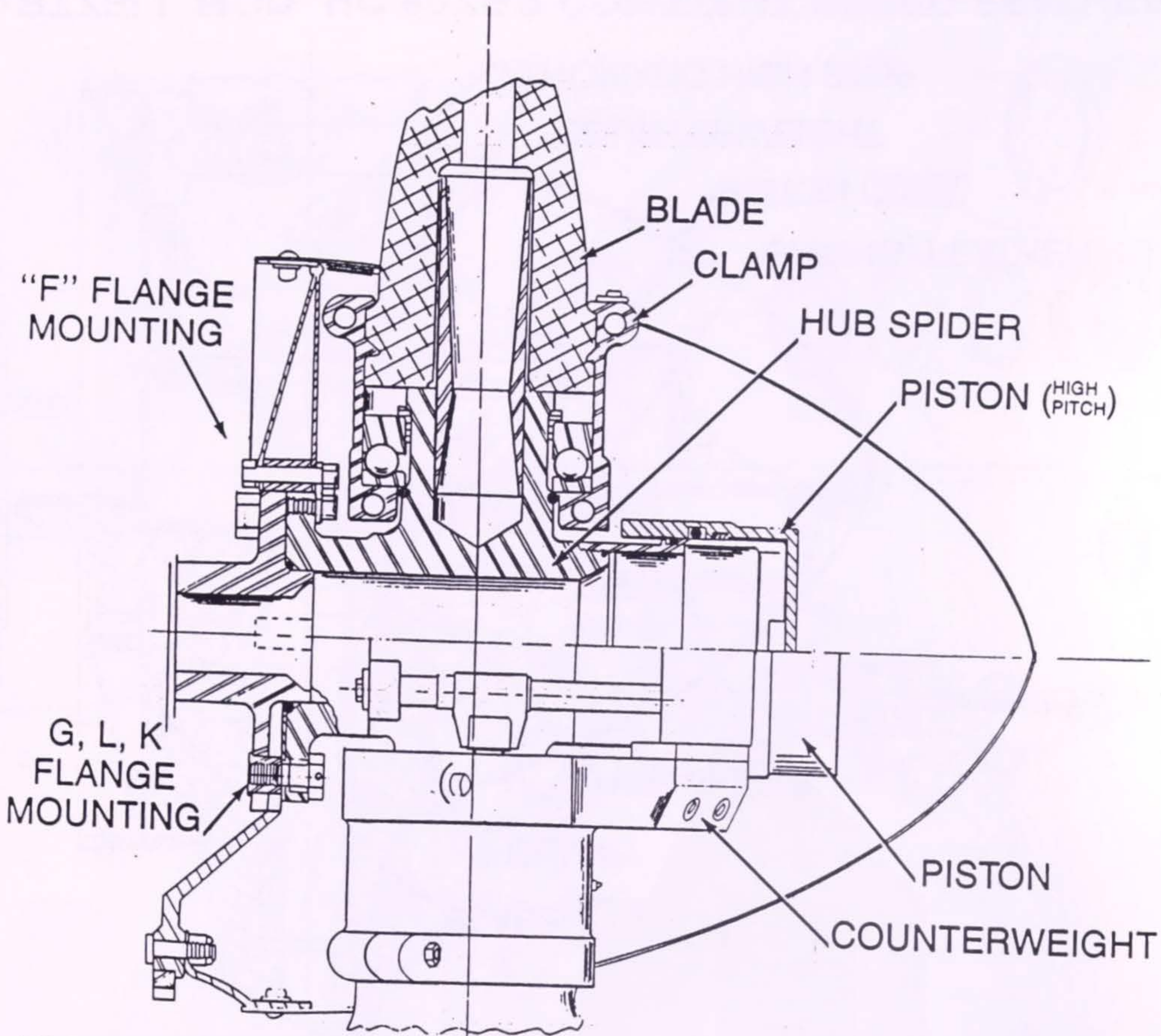
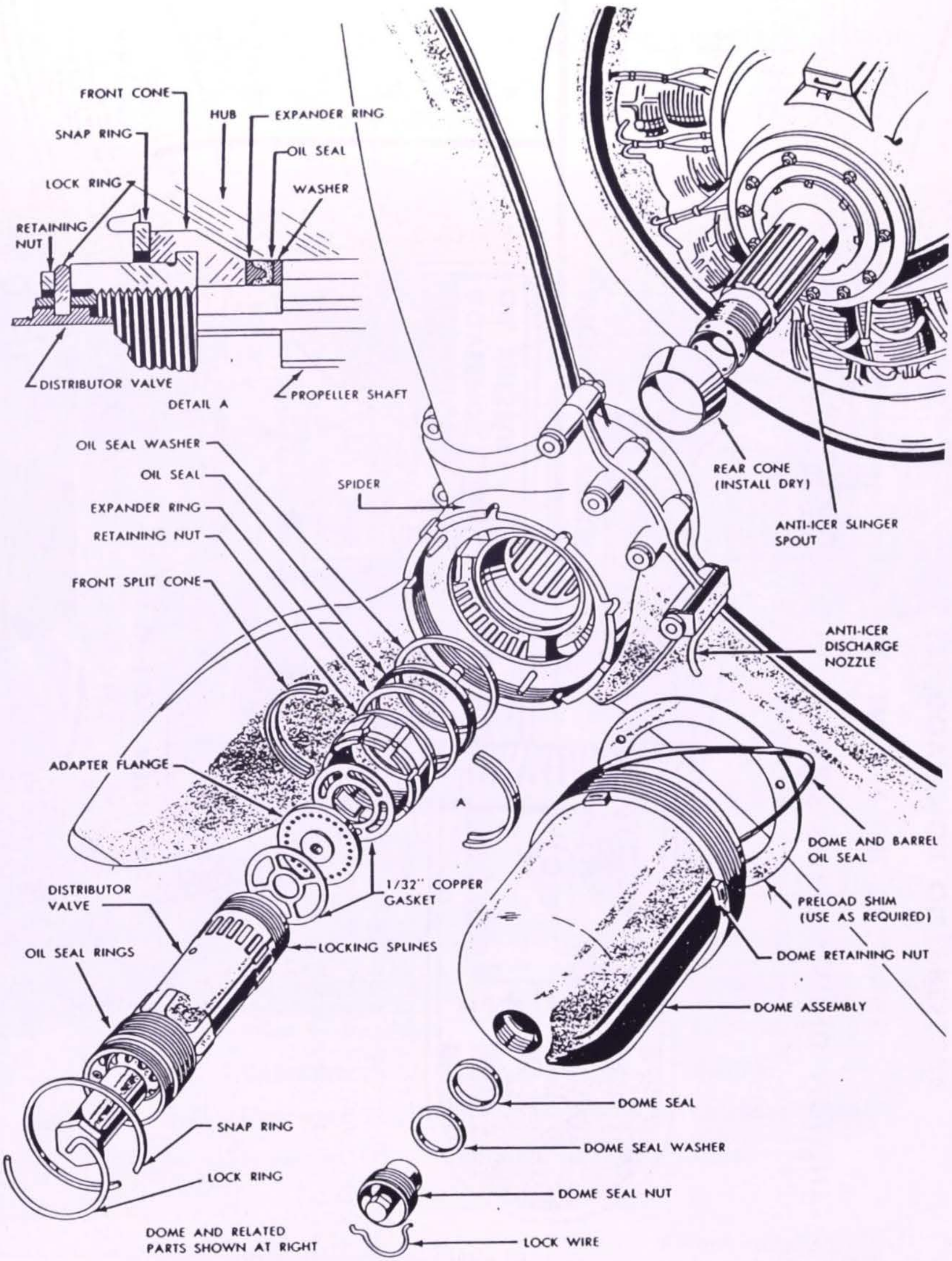


FIG 2 HARTZELL MOD. HC-82XF-1 CONSTANT SPEED

B26

24

27.



Typical Hydromatic Propeller Installation

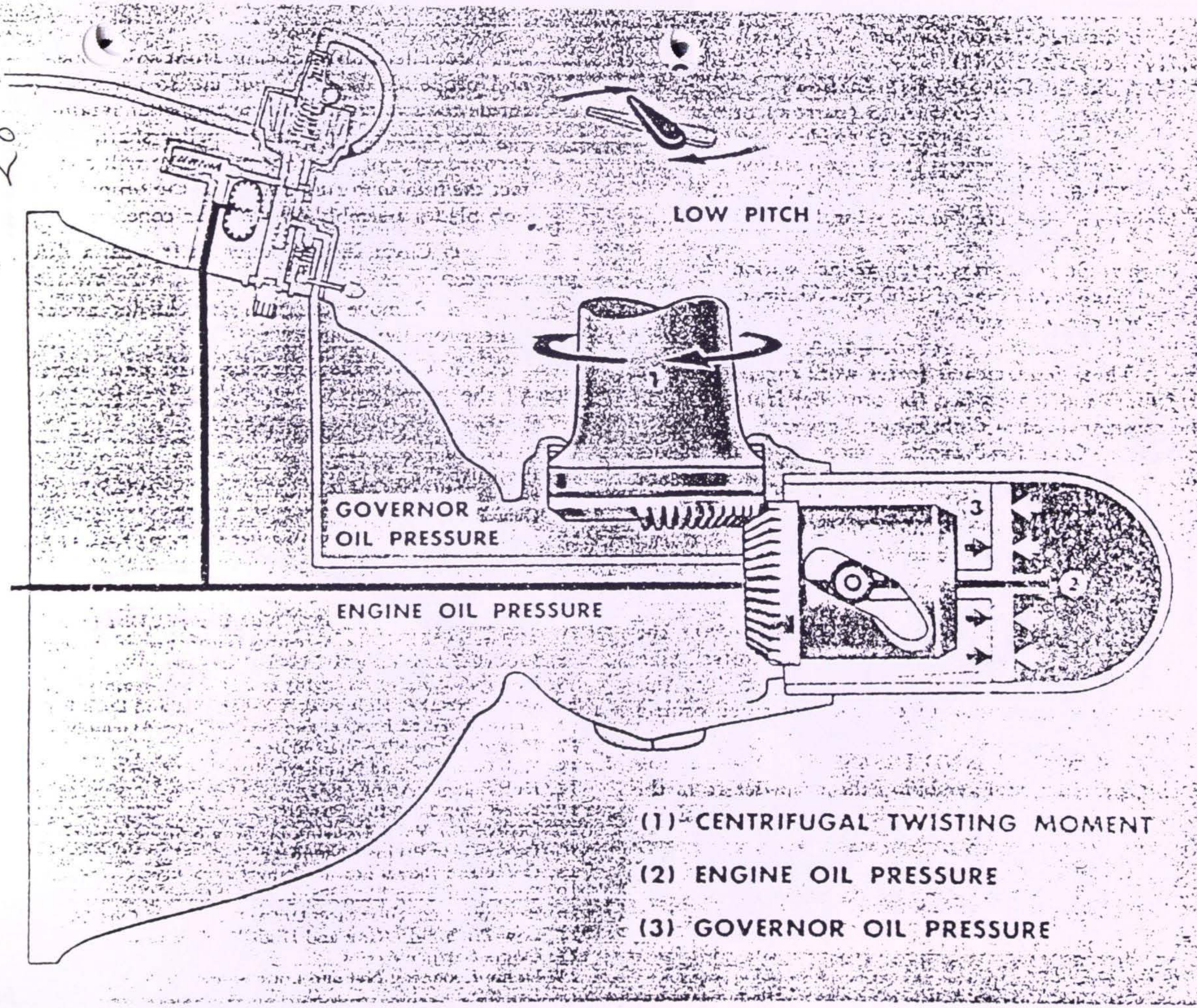
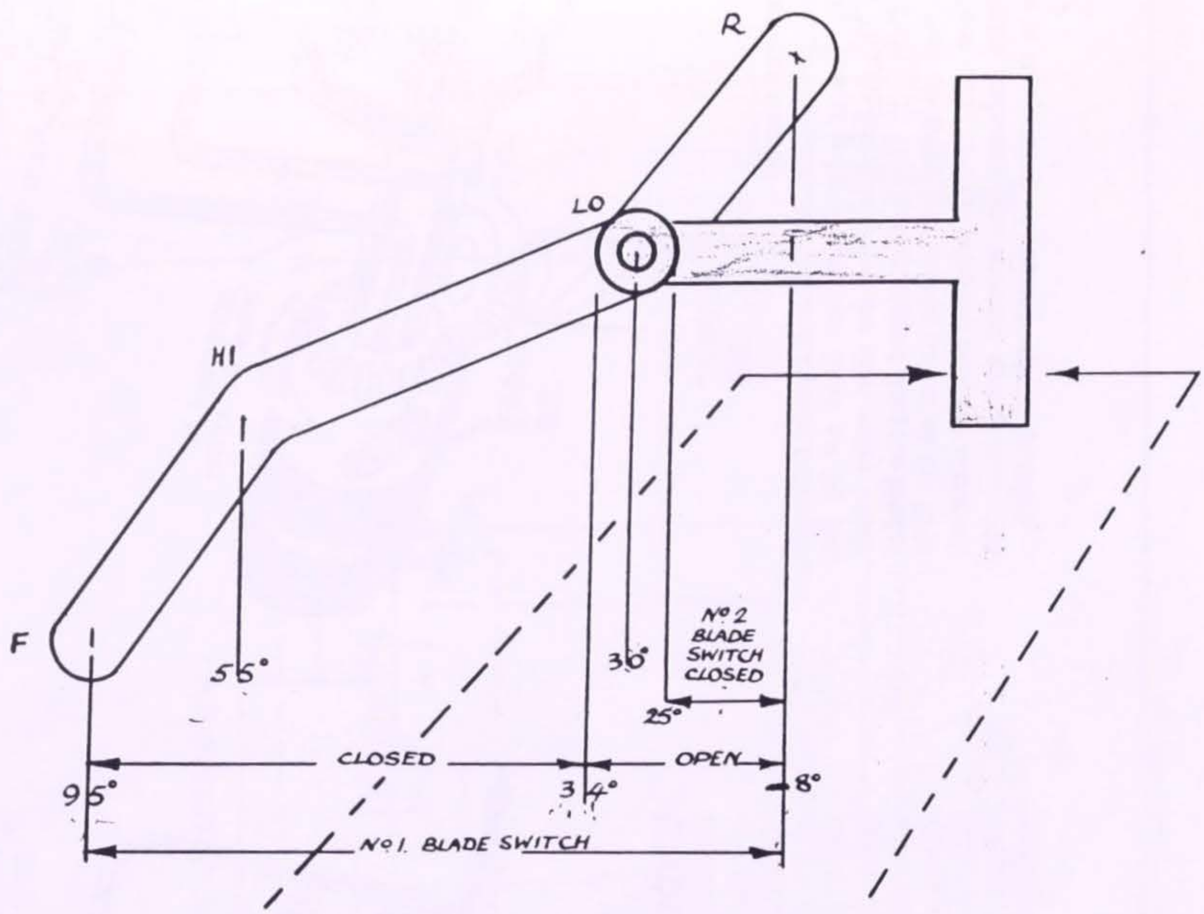


Figure 235—Propeller Control Forces

MECHANICAL ACTION OF HYDROMATIC PROPELLER (43E60)



OIL TO REAR OF PISTON

1. Solenoid Energized
2. Selector Up
3. Pilot Valve Down
4. Unfeather
5. Decrease Pitch
6. Reverse

OIL TO FRONT OF PISTON

1. Solenoid not Energized
2. Selector Valve Down
3. Pilot Valve Up
4. Feather
5. Increase Pitch
6. Unreverse

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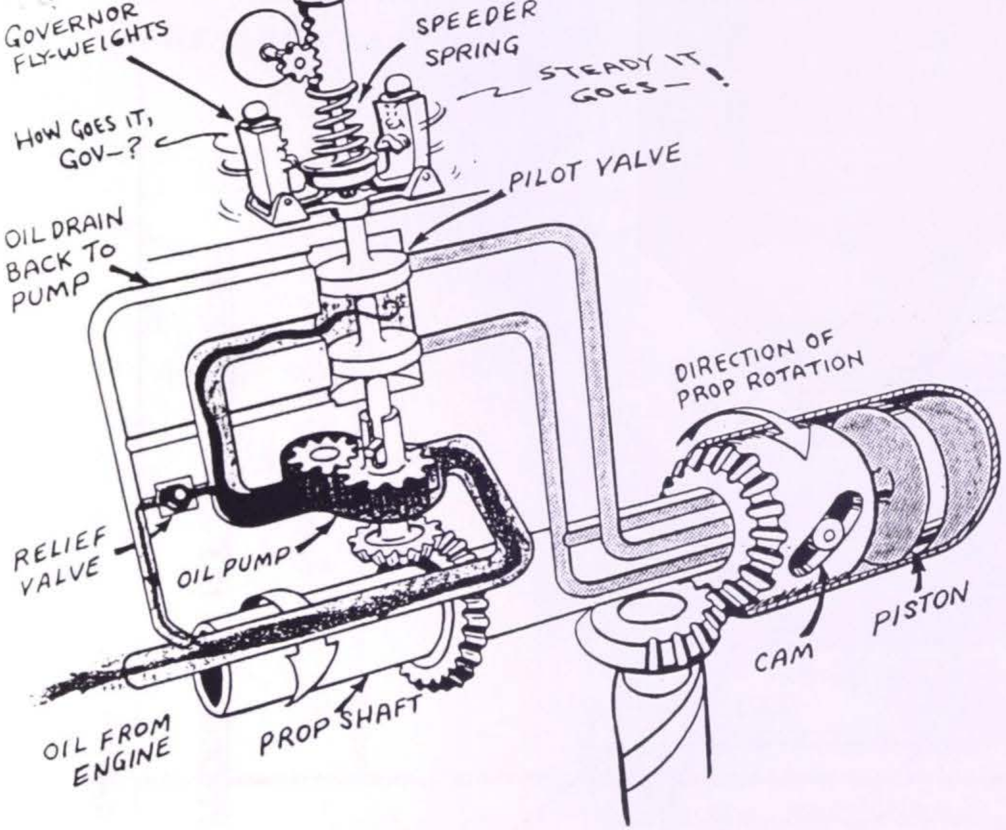
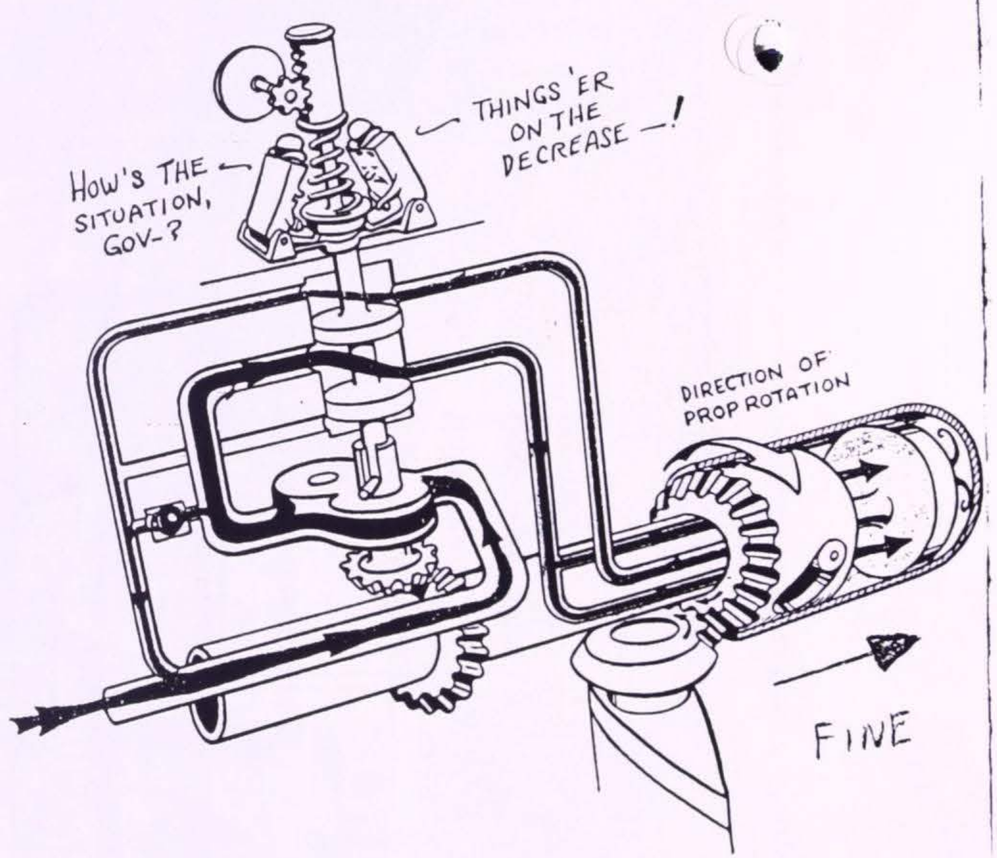




ON-SPEED (RPM remains steady)

This condition exists when the airspeed, altitude and engine power of the airplane are constant. The speeder spring has been set by the pilot for the RPM desired. The fly-weights moved the pilot valve which directed oil to the piston in the hub. This, in turn, moved the prop blades until they found a pitch that absorbed the engine power at the RPM selected by the pilot. When that moment of speed balance occurred, the forces of the fly-weights balanced the speeder spring load and positioned the pilot valve in the neutral, or constant speed, position.

UNDERSPEED (RPM decreases)

This condition results if the plane should start to climb from level flight, and the prop pitch becomes too high due to a reduction in airspeed while the power remains unchanged. In order to keep the prop turning at the same RPM while its pitch has been effectively increased, more power is required from the engine. However, as the engine power remains the same, the higher pitch in the climb will cause the engine to slow down, thus causing underspeeding. This makes the fly-weights droop, moving the pilot valve in the position shown above. Oil then flows to the inboard side of the piston. The resulting action twists the blades to a lower pitch, automatically increasing the speed of the engine to the former RPM setting.

PROPELLER SYSTEM

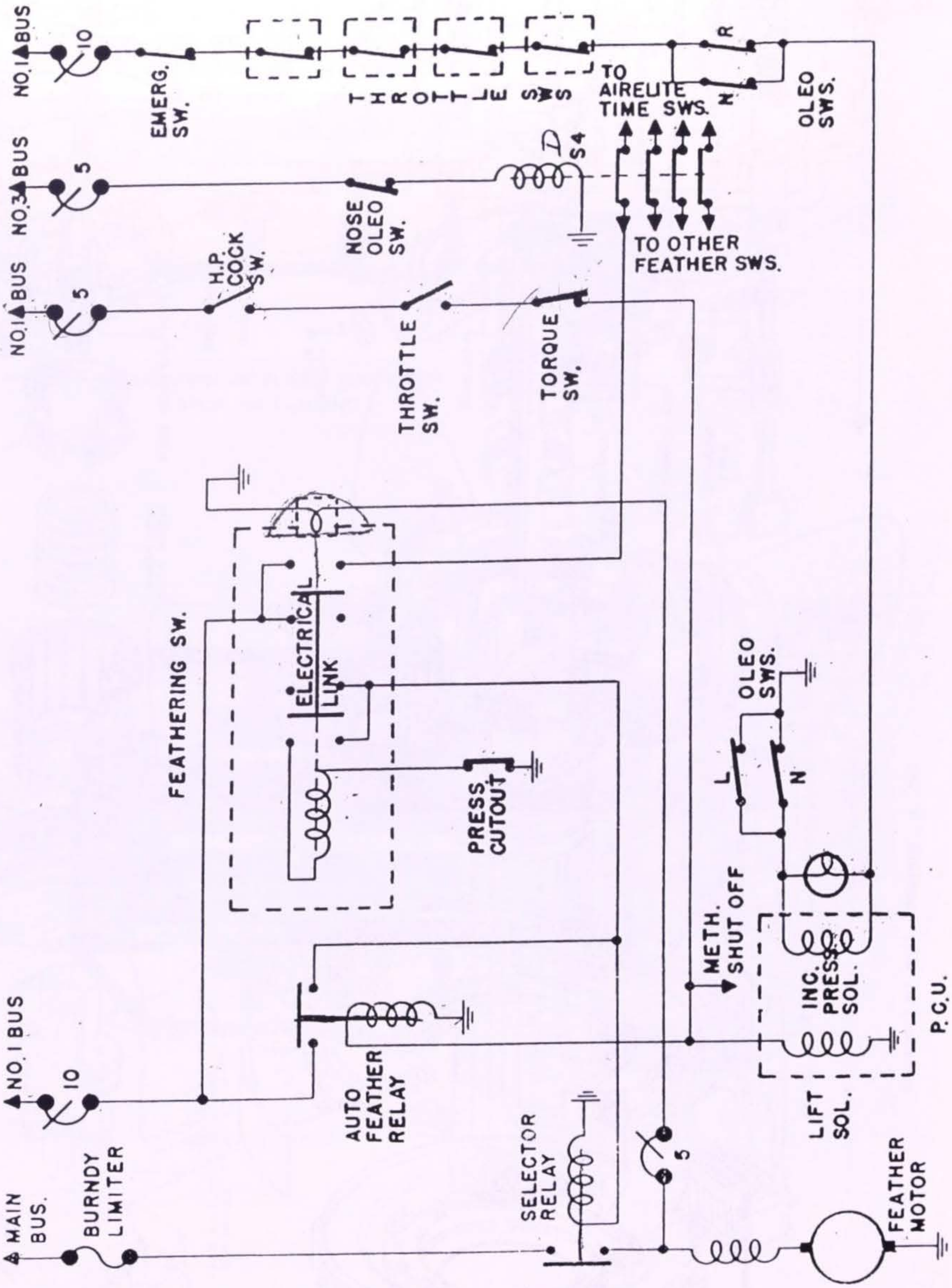


FIG. I PROPELLER FEATHERING CIRCUITS

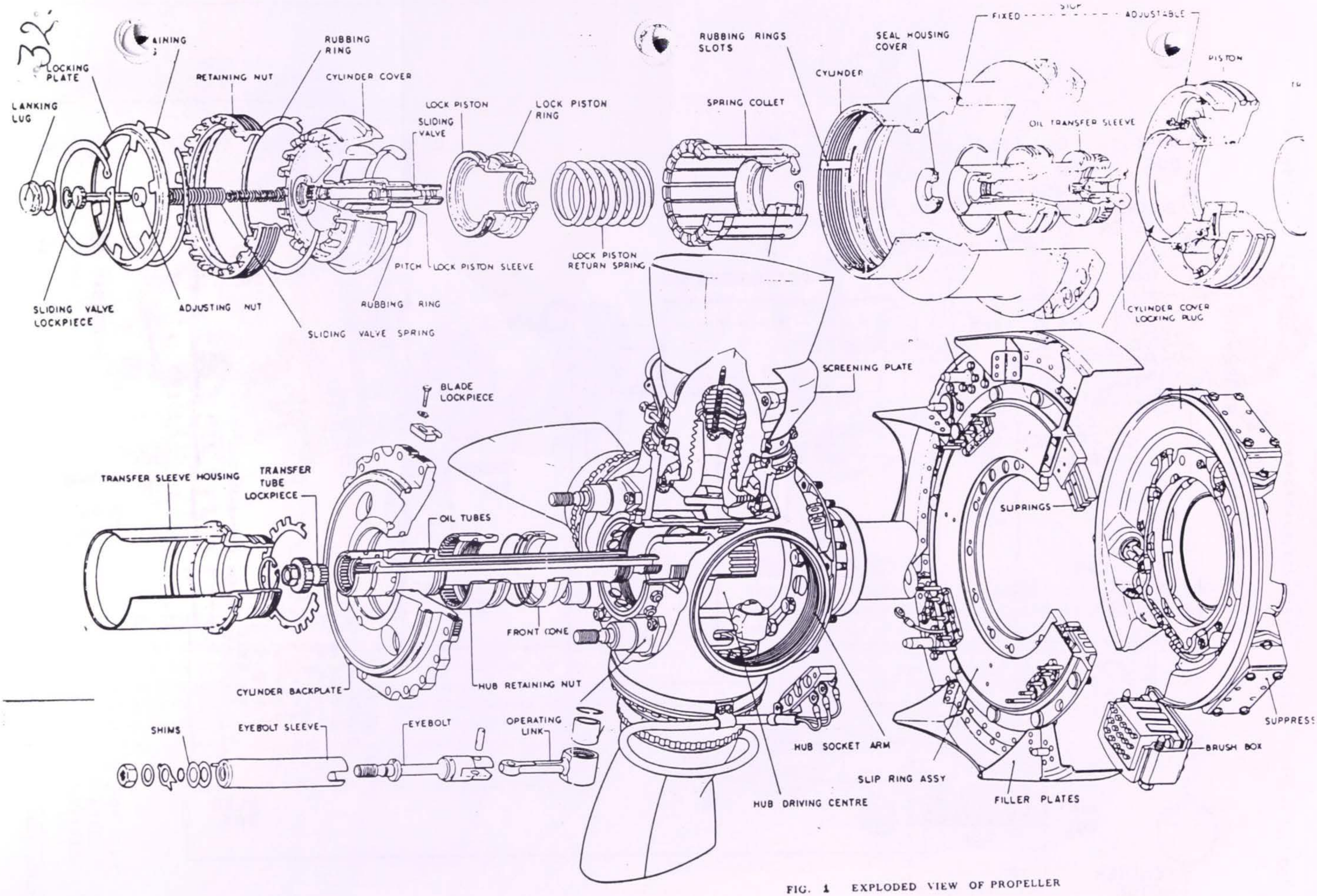
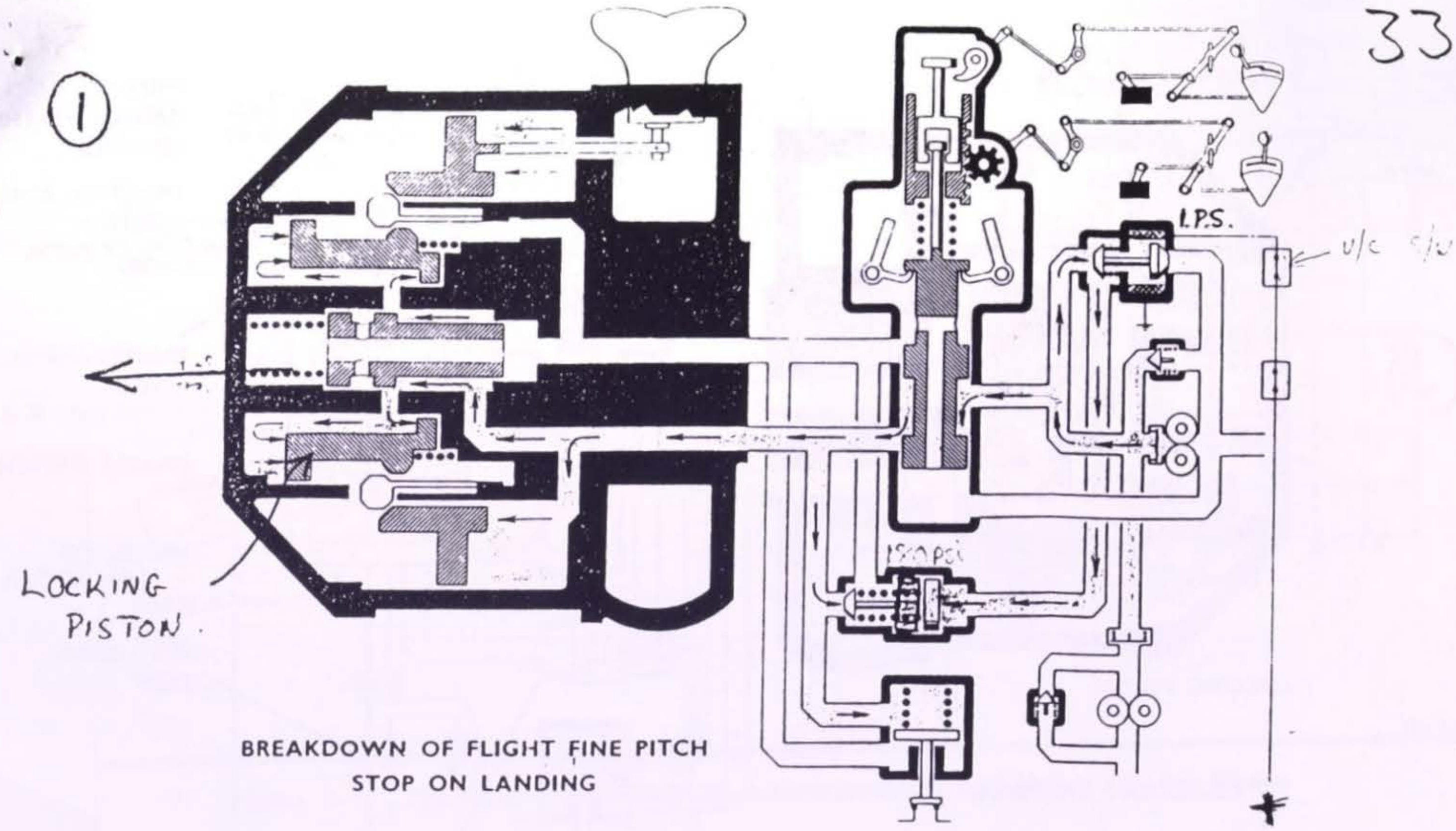


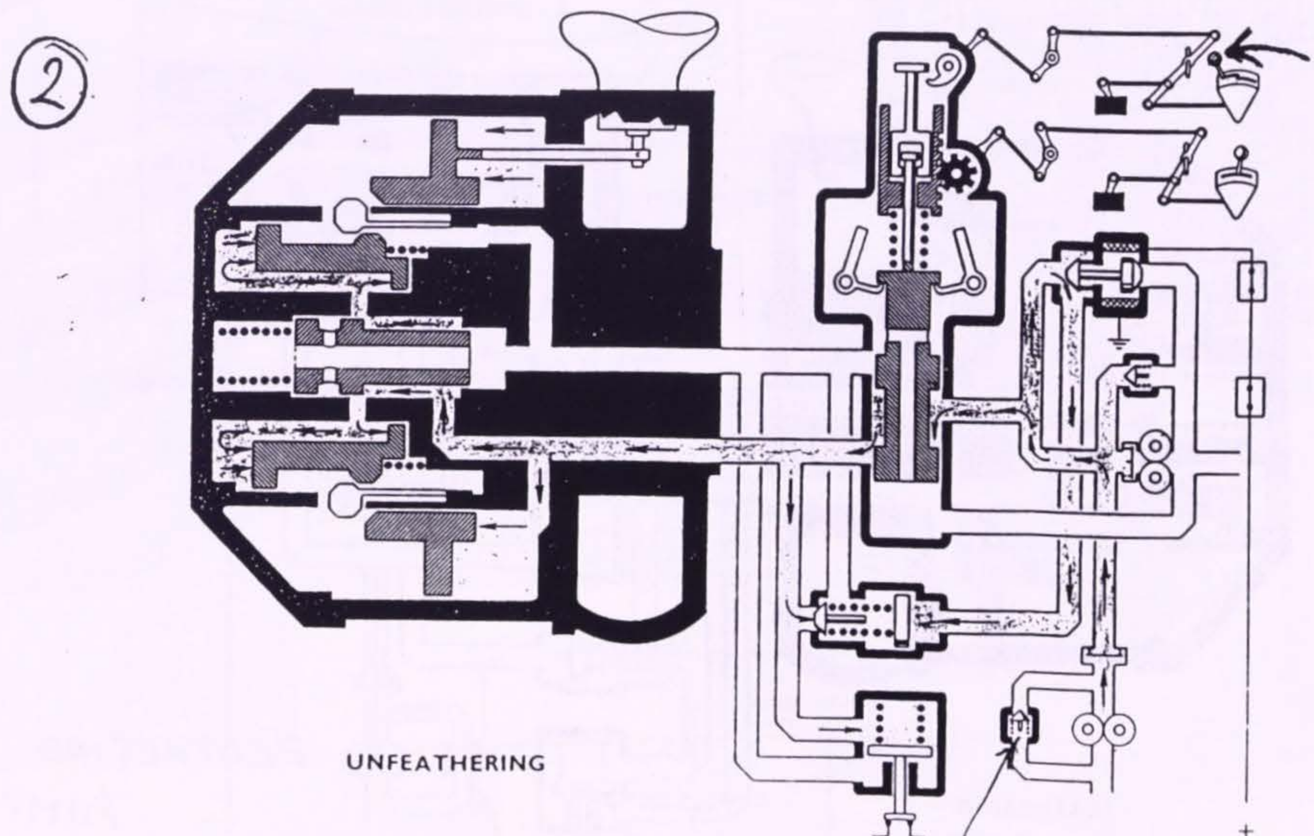
FIG. 1 EXPLODED VIEW OF PROPELLER

(1)



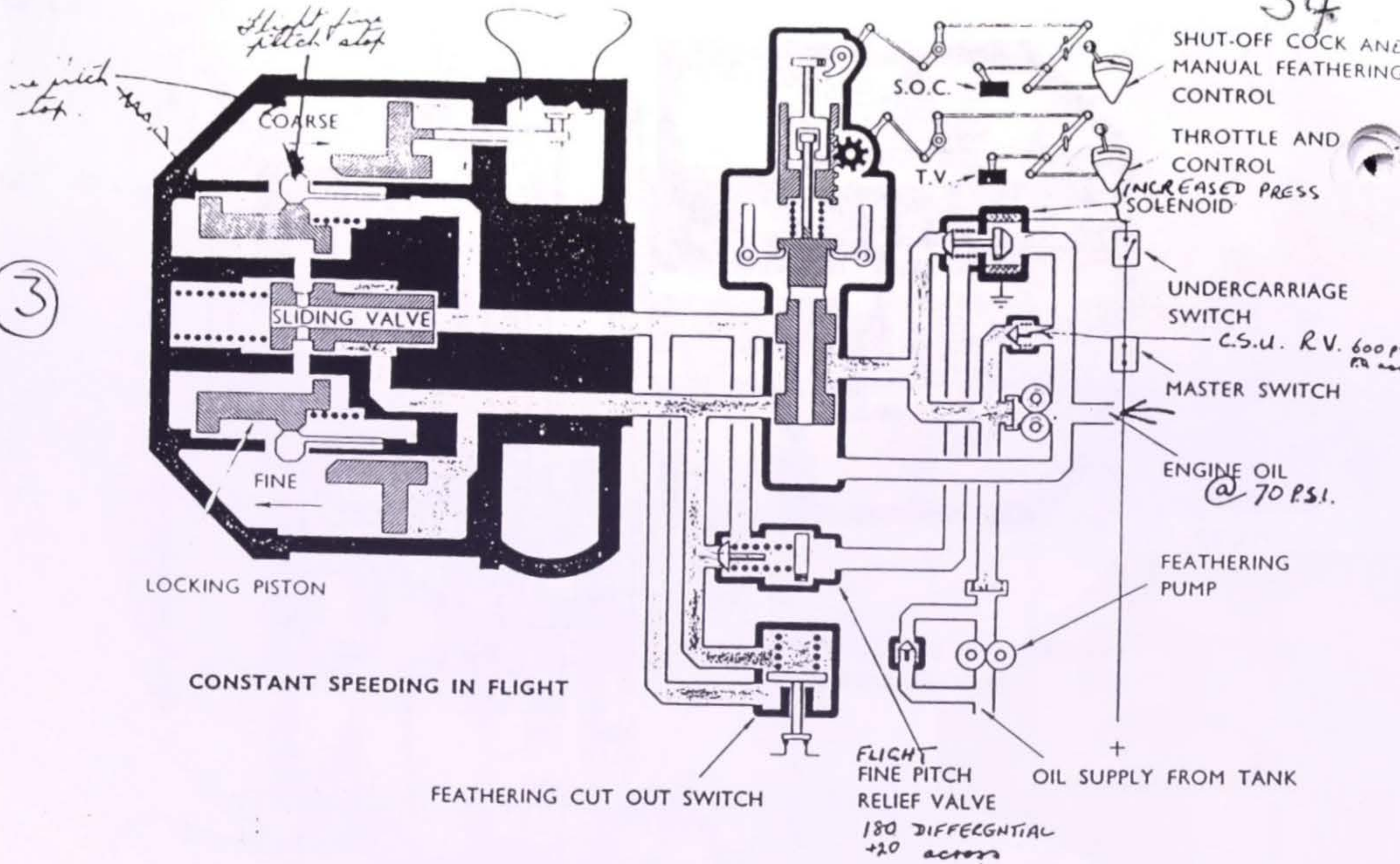
BREAKDOWN OF FLIGHT FINE PITCH
STOP ON LANDING

(2)



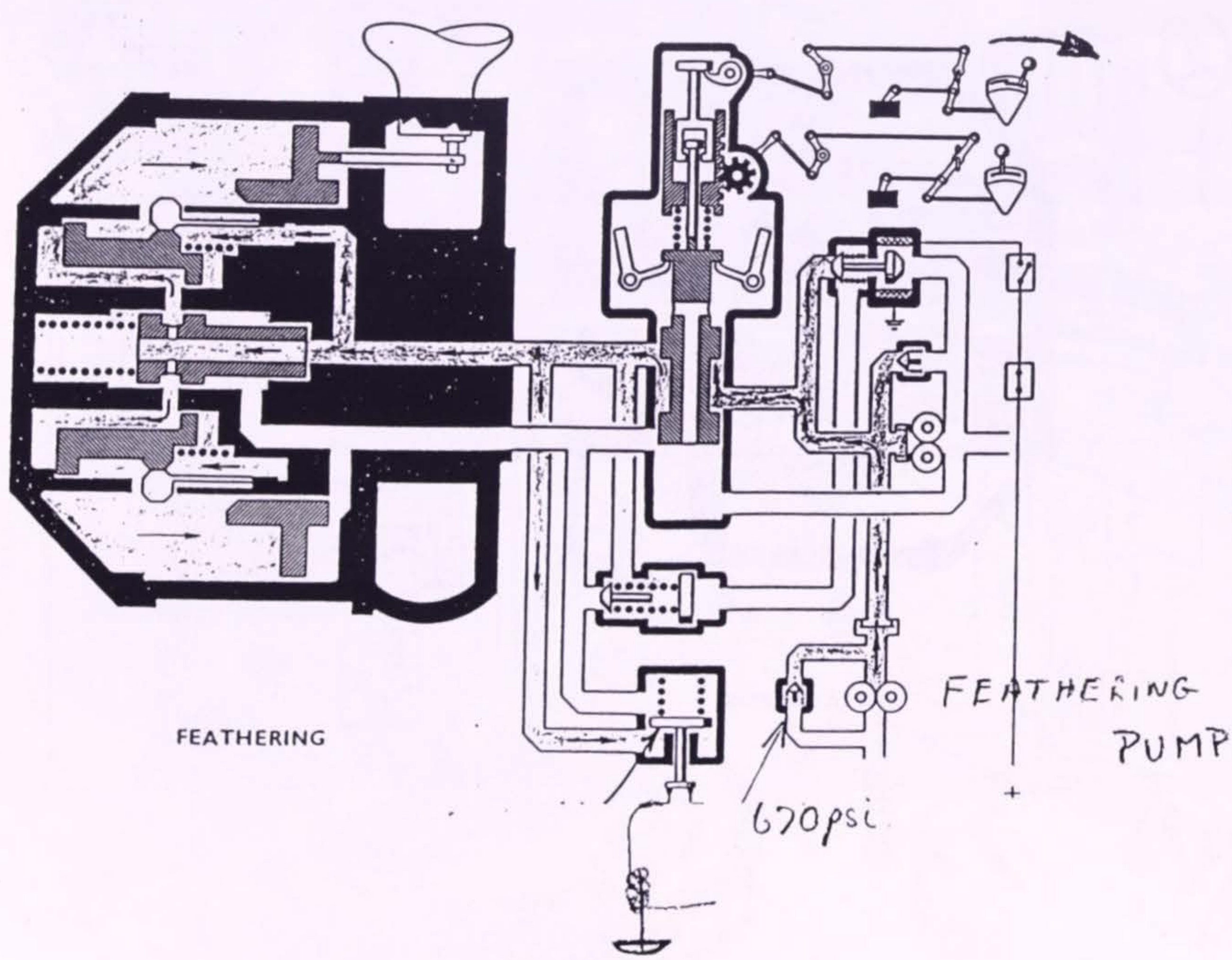
UNFEATHERING

(3)



CONSTANT SPEEDING IN FLIGHT

(4)



FEATHERING

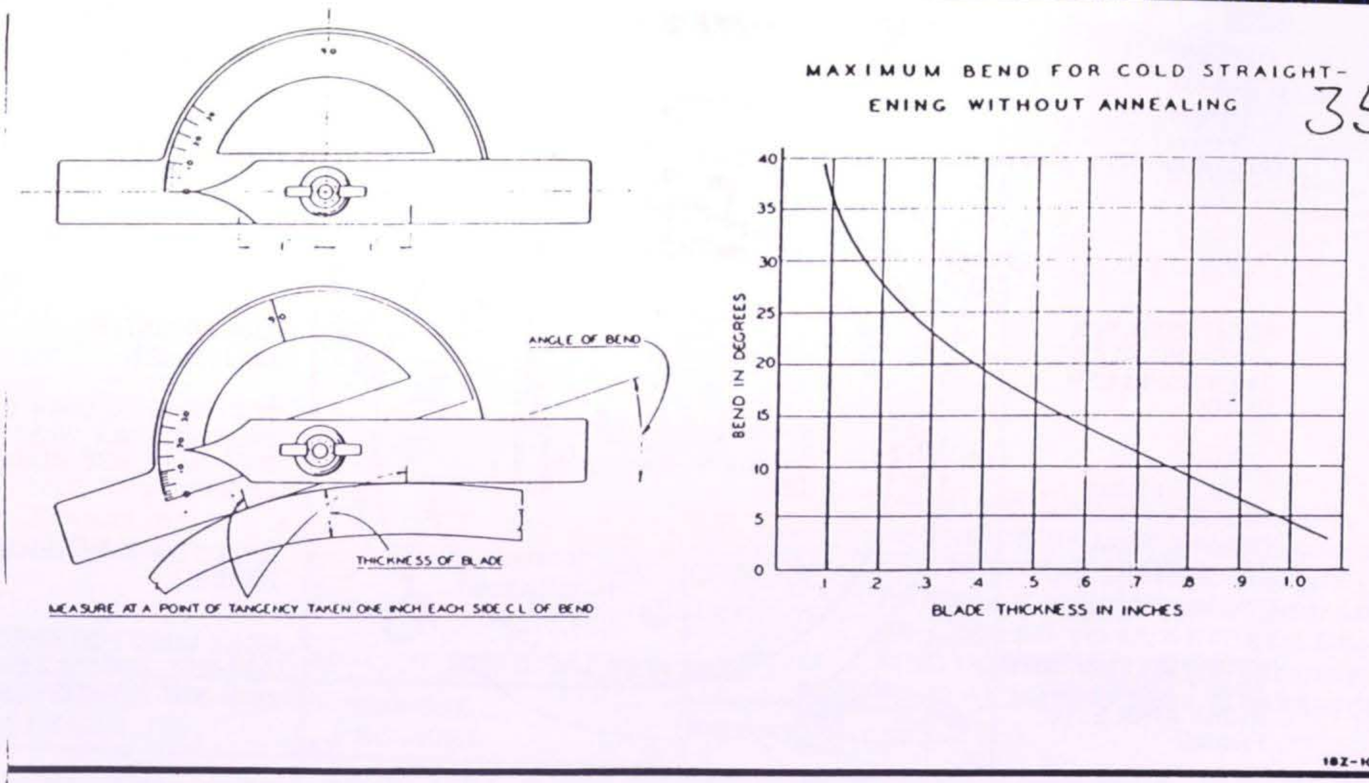


Figure 2—37. Protractor and Bending Limitations for HS-26 and AMS 4130 Alloy Blades

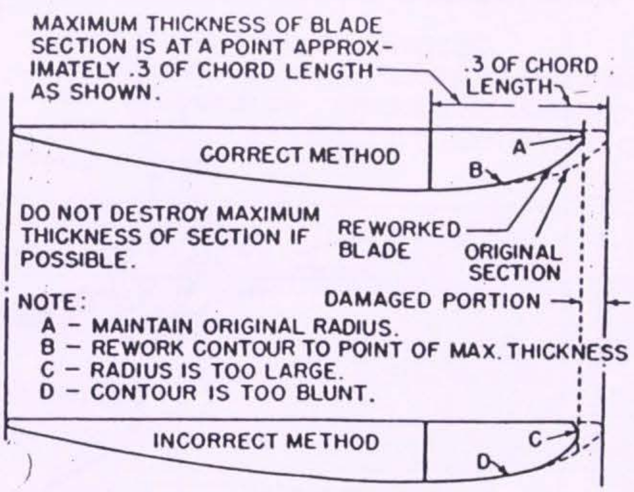


Figure 18 · 36 Rework of propeller leading edge.

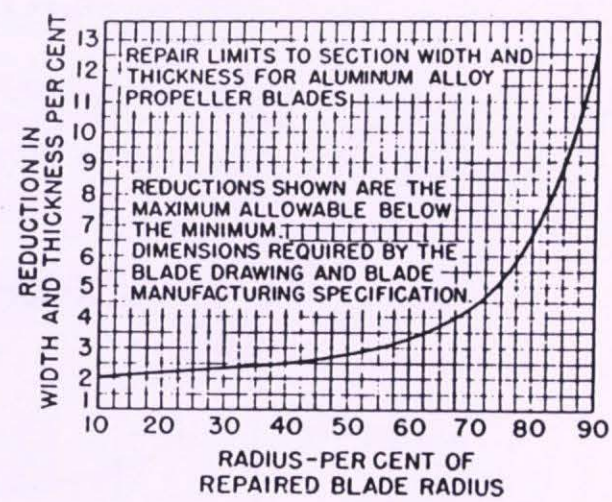


Figure 18 · 37 Repair limits.

	"A"
FACE & CAMBER SIDES	30
LEADING & TRAILING EDGES	10

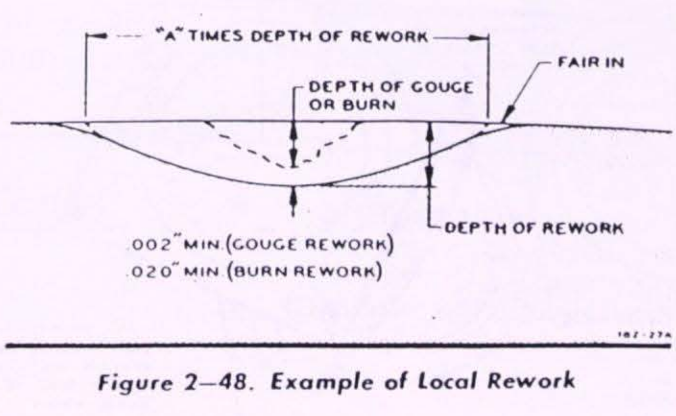


Figure 2—48. Example of Local Rework

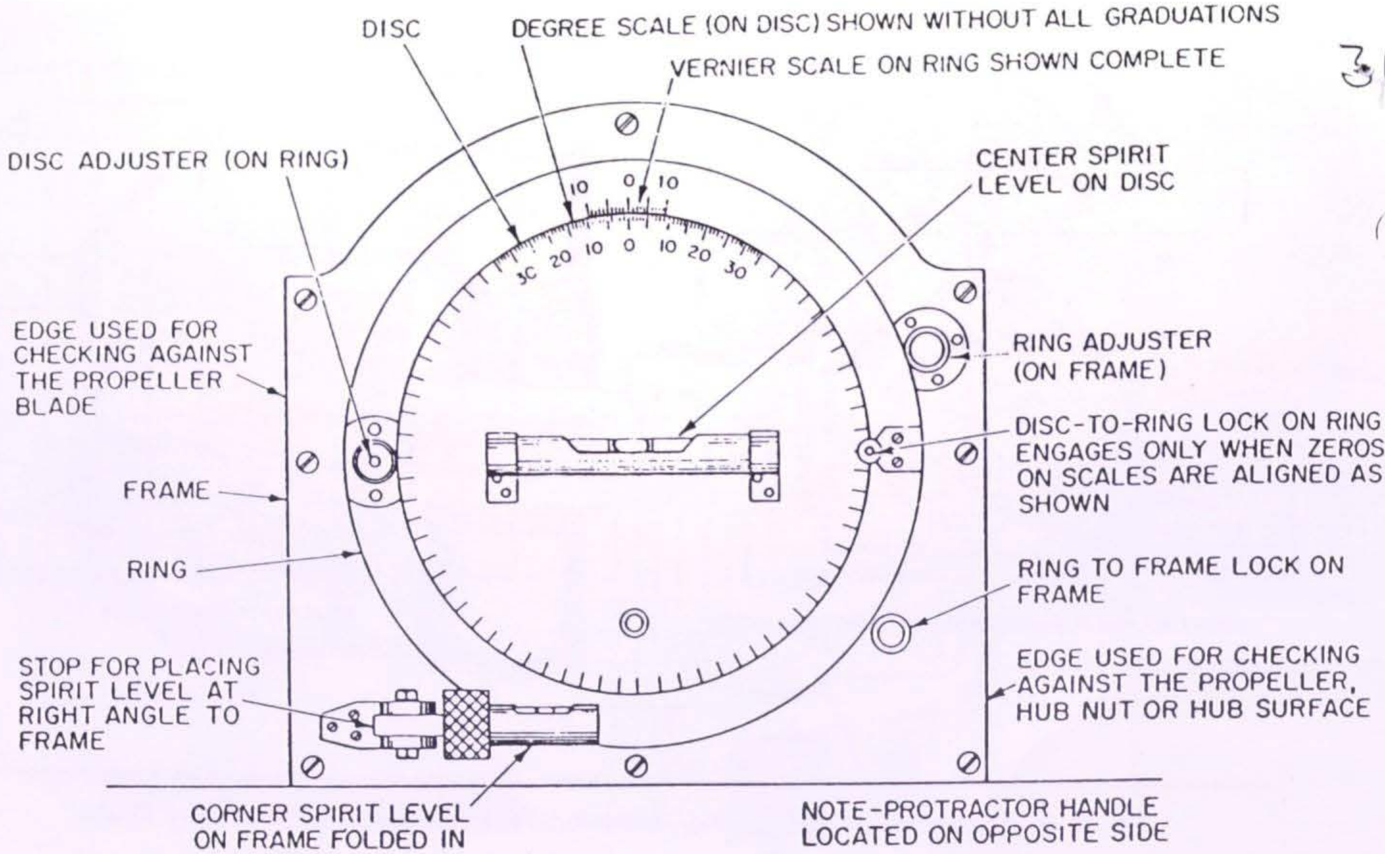


Figure 18 · 40 A universal propeller protractor.

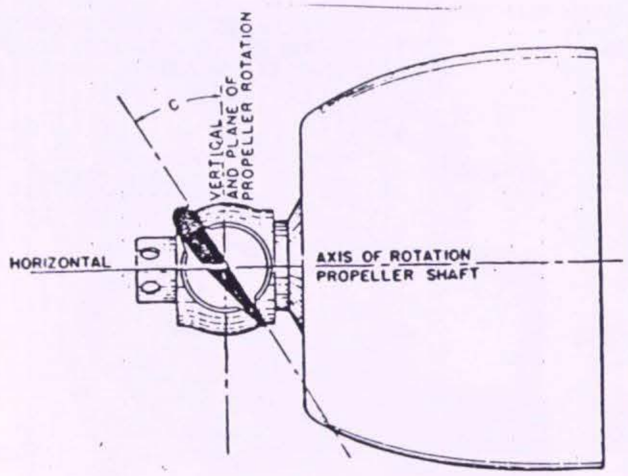


Figure 18 · 42 Measuring the blade angle.

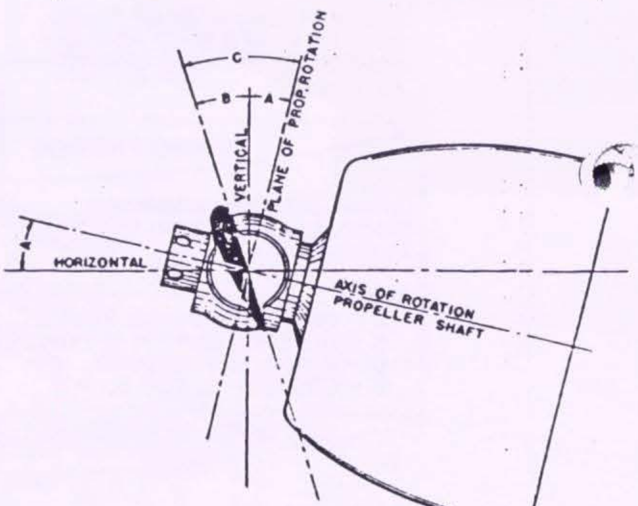


Figure 18 · 43 Effect of ground angle on measurement of blade angle.

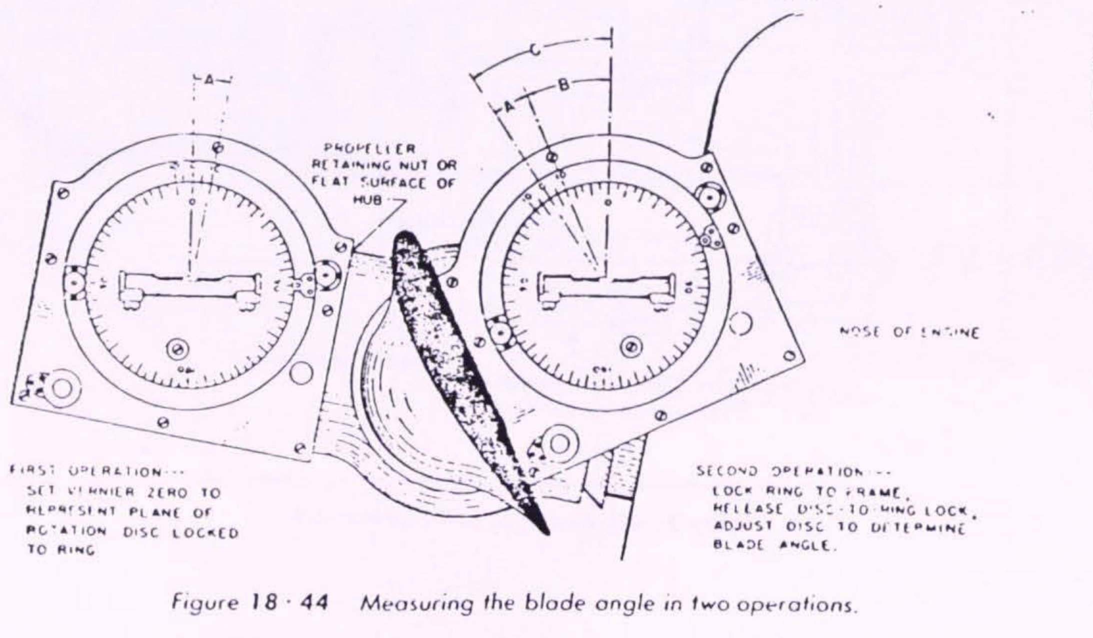
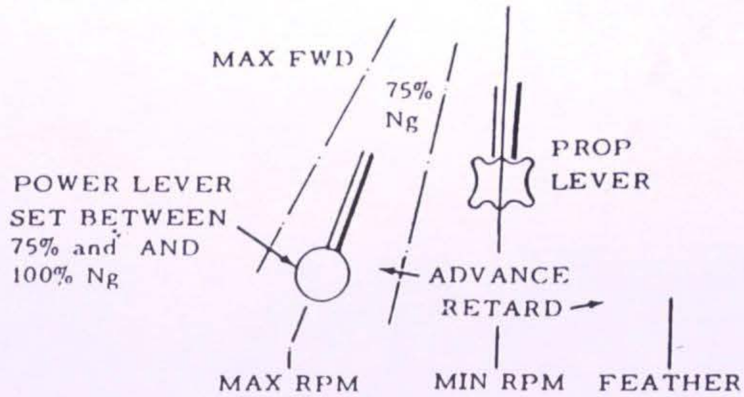


Figure 18 · 44 Measuring the blade angle in two operations.

21-2-2 OPERATION OF PROPELLER LEVER WITH POWER LEVER SET TO GIVE 75% TO 100% N



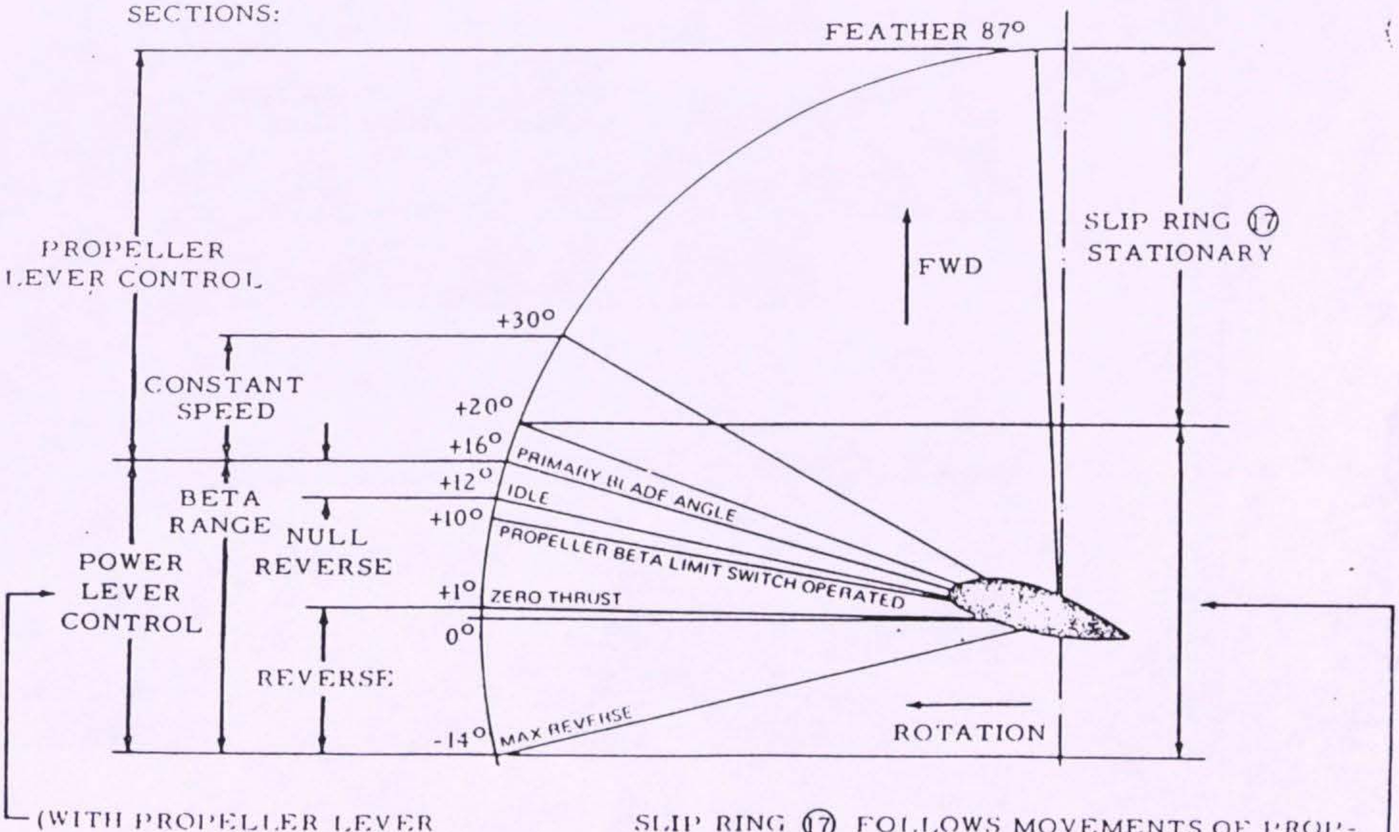
WHEN RETARDING PROPELLER LEVER FROM MAX RPM THROUGH MIN RPM TO FEATHER TORQUE PRESSURE IS INCREASING AND MUST BE LIMITED TO 42.5 PSI BY RETARDDING POWER LEVER AS REQUIRED TO STAY WITHIN THIS LIMITATION.

PROP LEVER	TORQUE PRESSURE
ADVANCE	DECREASES *
RETARD	INCREASES *

* LIMIT EITHER 17 PSI SEE PAGE 1

21-2-3 PROPELLER BLADE ANGLES

THE BELOW SHOWN BLADE ANGLES ARE APPROX TARGET BLADE ANGLES AT 30° BLADE STATION. THESE ANGLES ARE NOT MEASURED DURING ENGINE TEST RUNS, THEY ARE OBTAINED BY ADJUSTING CONTROLS AS OUTLINED IN THE FOLLOWING SECTIONS:



(WITH PROPELLER LEVER IN MAXIMUM RPM SETTING)

SLIP RING 17 FOLLOWS MOVEMENTS OF PROPELLER SERVO PISTON PROVIDING ACTUATION OF PROPELLER BETA LIMIT SWITCH AND FEEDBACK TO CONSTANT SPEED GOVERNOR.