UNDERSTANDING CONSTANT-SPEED PROPELLERS

In flight, thrust is one of the four forces acting on an airplane. In a piston-engine airplane, the engine generates power and delivers it, along a shaft, to the propeller. This engine torque, or turning effect, rotates the propeller. Because the propeller is an airfoil, or *miniature wing*, its movement converts most of this energy into an aerodynamic force, called **thrust**.

There are two main types of propeller assemblies, **fixed-pitch** and **constant-speed**.

With a fixed-pitch propeller, the blade is attached to the hub at a permanent angle. With a constant-speed—or variable-pitch—propeller, the root of the blade can rotate to any position between two limits in a range, thereby changing the angle of the blade relative to the hub.

Propeller efficiency

An airplane's airspeed affects how efficiently the blade is generating thrust. Because its blade angle can't change, a fixed-pitch propeller is most efficient at only one airspeed and engine RPM setting.

So, depending on the angle at which it is mounted to the hub, the propeller is optimized for either climb or cruise.

For an airplane whose primary purpose is to lift heavy loads off a short runway and to operate at fairly low airspeeds, a propeller with a small blade angle is most efficient. For an airplane designed to cruise long distances at higher speeds, a propeller with a larger blade angle is more appropriate.

The optimum solution would be to have a propeller whose blade position could vary dynamically to always be at the most efficient angle for any given airspeed. Lo and behold, that's exactly what the constant-speed prop does!

Fixed-pitch propellers

With a fixed-pitch propeller, once the pilot sets the throttle, the RPM will remain constant in steady-state flight. An airplane is in **steady-state flight** when there is no change in either speed or direction, as in *straight-and-level flight*, *climbs*, and *descents*.

However, whenever the pilot transitions from one steady state of flight to another, the balance of forces on the airplane and propeller changes, and this will affect the RPM *even if there is no change in the amount of fuel going to the cylinders*. This is due to the effects of air resistance, or **drag**. For example, transitioning from straight-and-level cruise to a descent will result in an increase in airspeed and an increase in RPM; to decrease RPM to the original level, the pilot must retard the throttle.

So, there are two ways in which the system RPM can change with a fixed-pitch propeller:

- The pilot changes the throttle setting.
- Changing flight conditions alter the amount of air resistance (drag) exerted on the propeller and driveshaft.

Constant-speed propellers

On the other hand, a constant-speed propeller system uses a **governor** to isolate the propeller speed (RPM) from the amount of fuel going to the cylinders.

Accordingly, the pilot selects the propeller RPM by using a *separate* propeller control and sets the engine's power—now measured as manifold pressure—with the throttle.

How the governor works

The **governor** responds to a change in system RPM by directing oil pressure to or releasing oil pressure from the propeller hub to change the blade angle and return the system RPM to the original value. The governor recognizes this RPM setting as a particular tension on the speeder spring.

Basic configuration

The basic governor configuration (Figure 1) contains a hollow driveshaft which is connected to the engine drive train. The driveshaft rotates at a speed which is directly proportional to the engine RPM. When the system is stable, rotating flyweights attached to the driveshaft provide an equal, opposing centrifugal force to balance the speeder spring tension, and the propeller maintains its RPM setting and blade angle. When forces act upon the system, the governor will always readjust the centrifugal force to match the selected speeder spring tension by changing the blade angle.

The governor uses pressurized oil to change the blade angle. An oil pump drive gear, also located on the driveshaft, boosts engine oil pressure to the propeller operating pressure. The pressurized oil is routed through passages in the governor to a pilot valve which fits in the center of the hollow driveshaft. This pilot valve moves up and down in the driveshaft in response to the action of the flyweights and thereby directs or impedes the oil flow to the propeller hub as needed.

These oil flow conditions allow the propeller blade angle to vary as required to maintain a constant system RPM.

Theory of operation

When RPM increases, the flyweights tilt outward, raising the pilot valve (Figure 2). The governor is in an **overspeed** condition because the RPM is higher than the governor speeder spring setting. When RPM decreases, the flyweights tilt inward, lowering the pilot valve (Figure 3). Then the governor is **underspeed** because the RPM is lower than the speeder spring setting. When the blade angle has adjusted so that the RPM is again the same as the governor setting, the flyweights are vertical, the pilot valve returns to a neutral position, oil flow to and from the propeller hub is blocked, and the governor is **onspeed**.

The simplified schematics that follow illustrate the basic concepts.

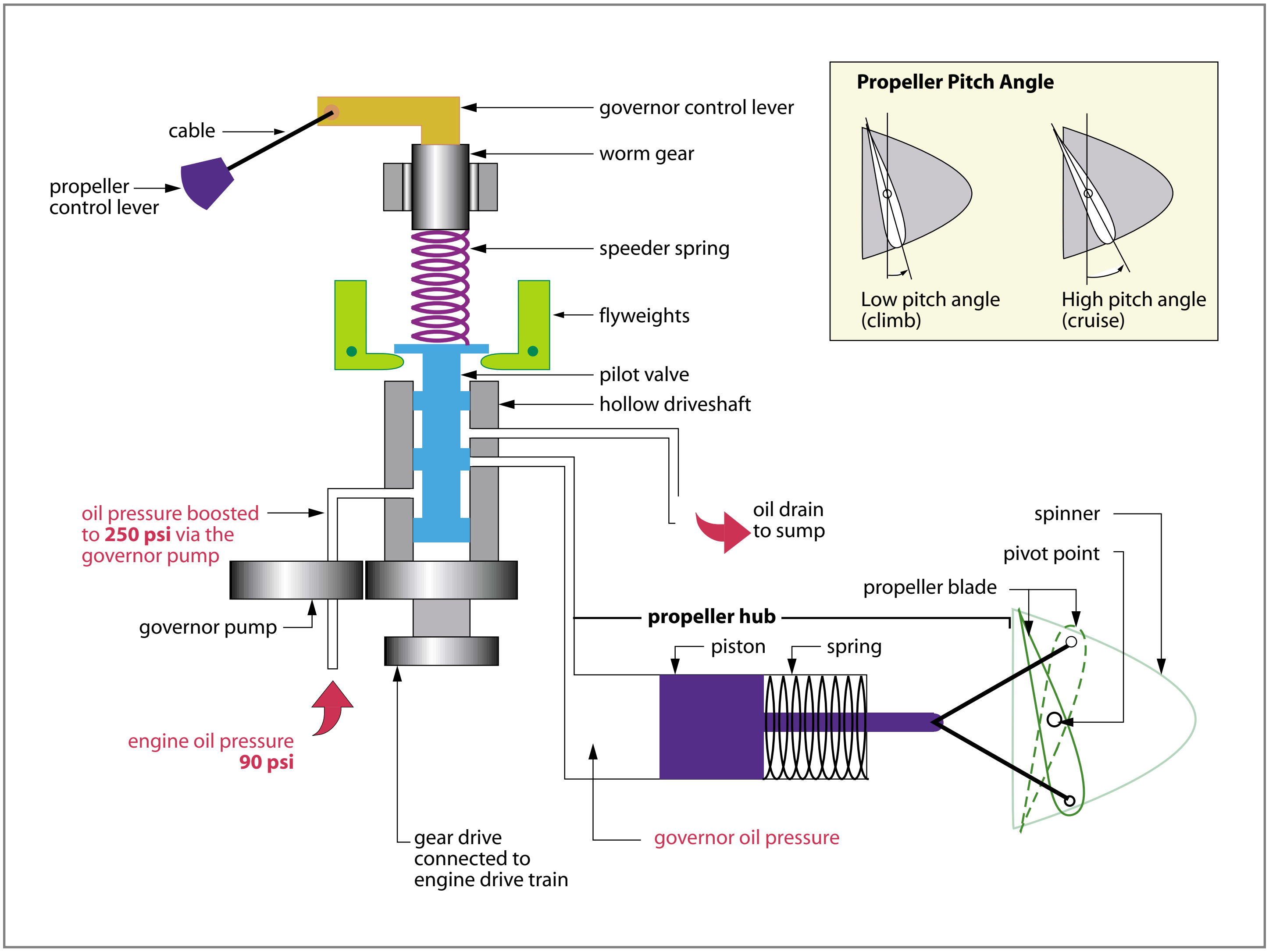
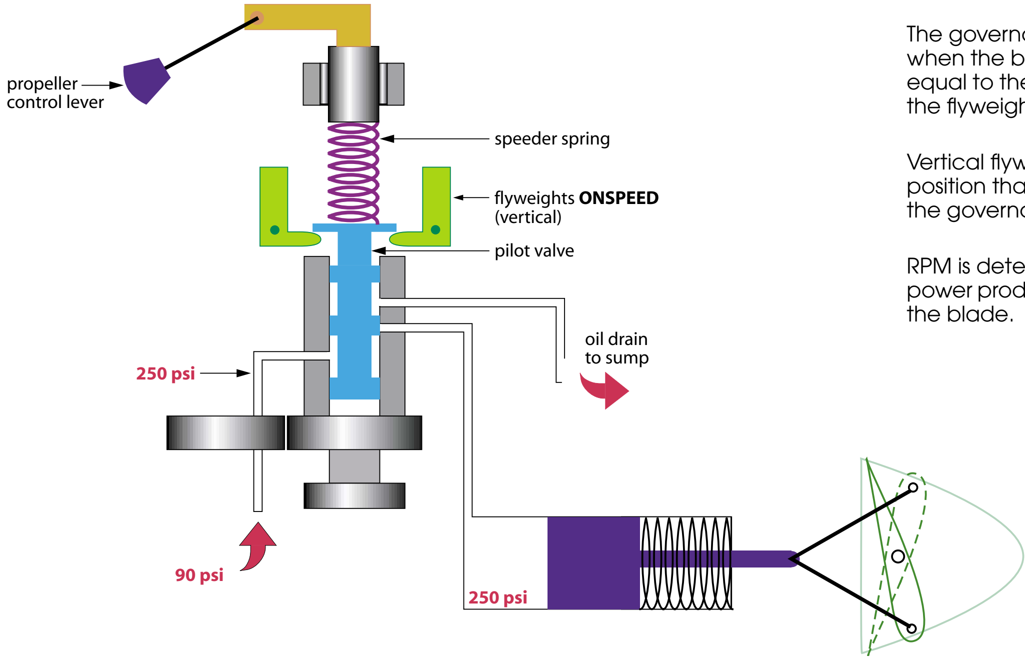


Figure 1. Governor Assembly and Propeller Hub in Neutral Position. In the neutral position, the flyweights are vertical (onspeed), and the pilot valve is positioned so that no oil enters or leaves the propeller hub.

The governor assembly adjusts the blade angle to establish a desired RPM. The governor maintains this RPM by continuously making small adjustments to the blade angle.

[Credit for portions of the initial schematic concept shown here goes to Dan Lippetti, CFI, who now flies for the airlines.]



The governor assembly is in a neutral position when the base tension of the speeder spring is equal to the centrifugal force required to keep the flyweights in a vertical position.

Vertical flyweights maintain the pilot valve in a position that allows no oil to flow into or out of the governor assembly.

RPM is determined by the balance between power produced and the air resistance against the blade.

Pilot selects higher RPM

1. Pilot moves propeller control lever forward.

2. Worm gear compresses speeder spring.

3. The tension of the speeder spring overcomes the centifugal force keeping the flyweights vertical and pushes the pilot valve downward.

4. As a result, the flyweights cant inward (**underspeed**) and the top two oil ports are uncovered.

5. **Oil flows out** from the propeller hub to the oil sump, reducing oil pressure in the propeller hub.

6. Reduced oil pressure allows the spring to push the piston aft.

7. As the piston moves aft, the **blade angle decreases** to low pitch. As a result, the power produced by the engine exceeds the propeller's resistance against the air. This allows the crankshaft, and consequently the propeller, to spin at a higher RPM.

As the **RPM increases**, the centrifugal force on the flyweights increases. This causes them to cant outward until they reach a vertical position (onspeed), lifting the pilot valve and stopping all oil flow through the governor assembly.

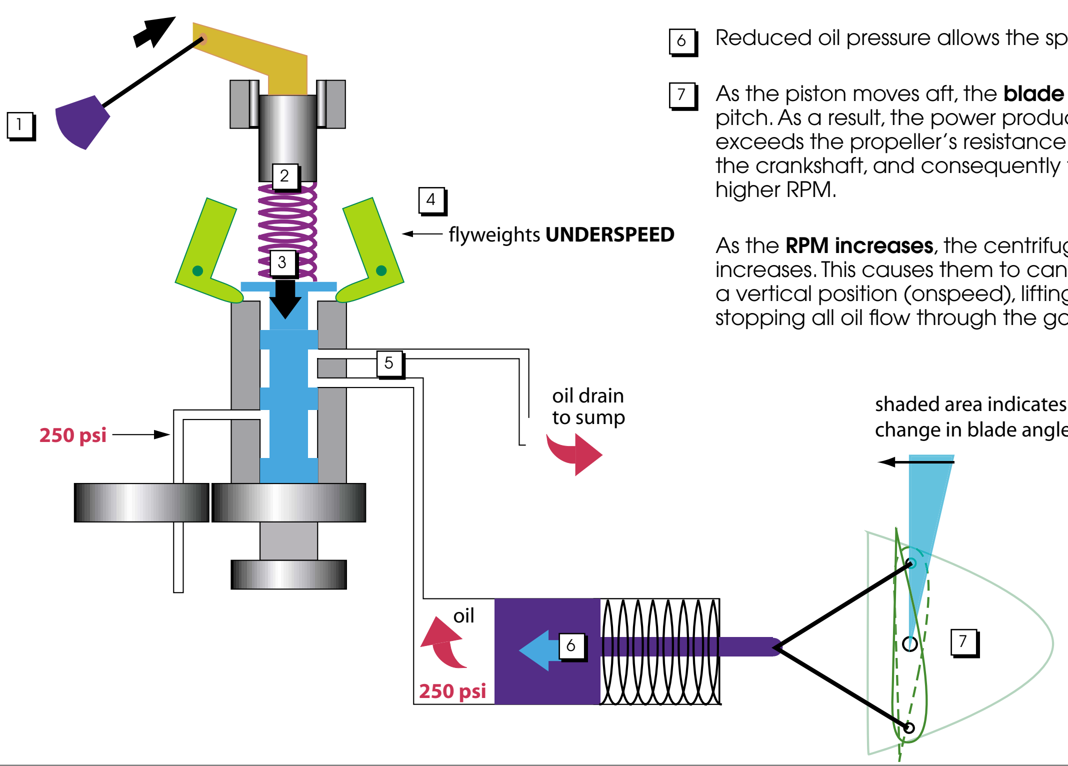
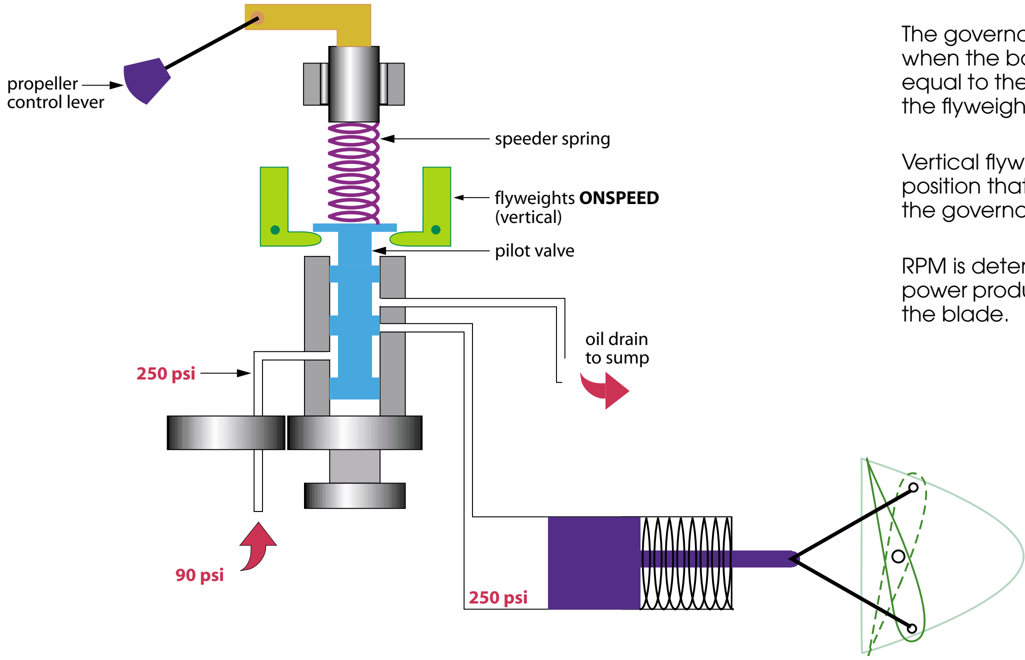


Figure 2. Pilot selects higher RPM



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Vertical flyweights maintain the pilot valve in a position that allows no oil to flow into or out of the governor assembly.

RPM is determined by the balance between power produced and the air resistance against the blade.

Pilot selects lower RPM

1 Pilot moves **propeller control lever aft**.

2 Worm gear releases pressure on the speeder spring.

3 The centrifugal force acting on the flyweights exceeds the tension of the speeder spring, and the flyweights cant outward (**overspeed**).

4 The flyweight toes lift the pilot valve upward. This uncovers the bottom two oil ports and blocks the channel to the oil sump.

5 **Pressurized oil flows** from the governor pump **into the propeller hub**.

6 Increased oil pressure pushes the piston forward and compresses the spring.

7 As the piston goes forward, the **blade angle increases** to high pitch. This creates more air resistance against the propeller and slows the RPM.

As the **RPM decreases**, the centrifugal force on the flyweights decreases. This causes the outward cant to relax until the flyweights again resume a vertical position (onspeed), lowering the pilot valve and stopping all oil flow through the governor assembly.

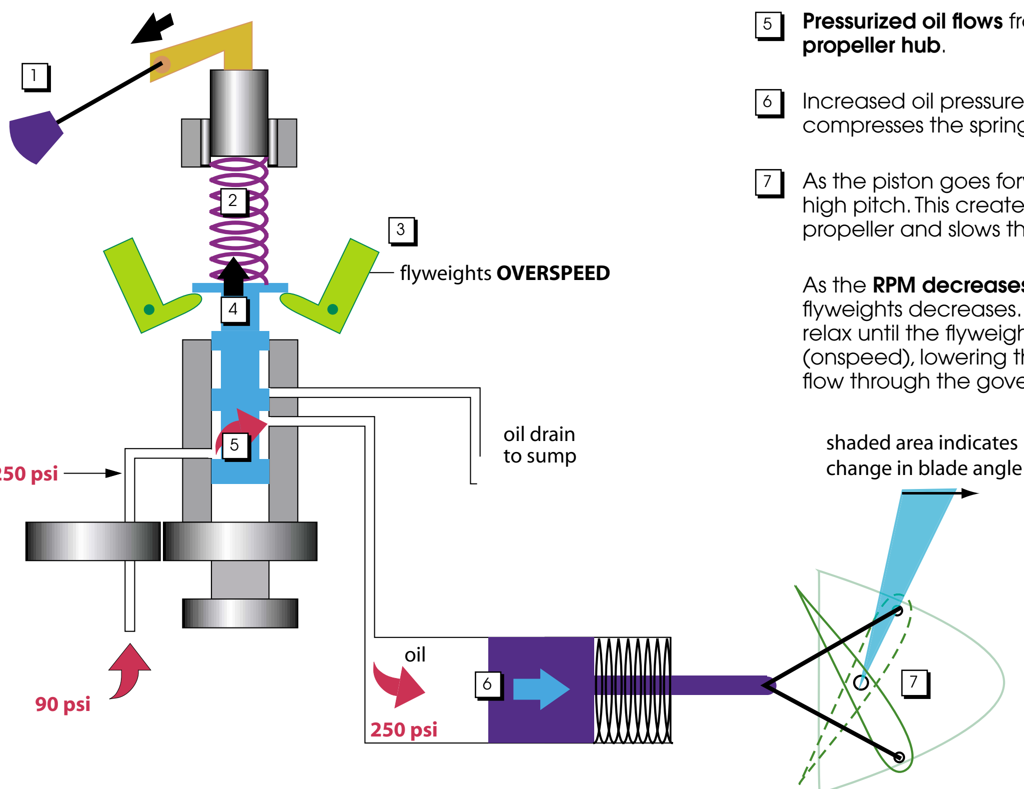

Figure 3. Pilot selects lower RPM