

lems must be worked out on an individual flight basis, preferably in advance. The performance graphs and discussion of cruise control in Section 3 will assist you in preparing a flight plan which will assure you the maximum utility from your airplane. In general, cruise power settings up to 65%, which you can obtain from the power setting tables, will prove most economical; the added speed obtained with 70% power, as a glance at the fuel consumption graphs will show, is obtained at an appreciable increase in fuel consumption.

ENGINE OPERATION IN FLIGHT

Except for the fuel system, the power plant systems and equipment are automatic in operation, and the engines will require little attention in flight. However, you should glance at all of the engine instruments occasionally, to note any periodic fluctuation or surge in the temperatures or pressures.

Mixture control is automatic. *The mixture controls must be placed in the full forward position for all operations. Never lean manually, except in an emergency.*

FUEL SYSTEM OPERATION IN FLIGHT

Excess fuel from the carburetor is returned to the main tanks through the vapor-return lines. To provide space for this returned fuel, the fuel for starting, warm-up, take-off, and the first hour of flight should be drawn from the main tanks. If this procedure is not followed and fuel is drawn from the auxiliary tanks before space is available in the main tanks, the fuel returned from the carburetor will be forced overboard and wasted. After one hour of cruising on main tanks, space will be available for the returned fuel. The engines then may be supplied from the auxiliary tanks.

The cross-feed system enables fuel to be cross-fed from the auxiliary tanks only. In event of an engine failure, fuel in the main tank next to the dead engine will not be accessible. Hence it is obviously sound practice to use up fuel in the main tanks, reserving the auxiliary tanks until the last. However, you should not overlook the fact that fuel is being returned to the main tanks constantly, and you should switch from auxiliary to main occasionally if you wish to use all your fuel.

The fuel consumption of each engine can be checked and compared if the fuel for each is drawn from corresponding tanks. The cross-feed should be used only to balance the fuel load in each wing if engine consumption is unequal, and during engine failure.

NOTE

When the fuel selector valve is turned, be sure valve seats in new position. A definite "click" can be felt when the valve is properly aligned. If the valve doesn't seat, the flow of fuel may be cut off or at least restricted, causing loss of

power and possible engine failure. After switching tanks, observe engine instruments closely for a few seconds, to make certain fuel flow from the new tank is satisfactory.

FLIGHT CHARACTERISTICS

The Twin-Bonanza is an easy airplane to fly, with no unhappy characteristics; it performs precisely the way an airplane should. Control forces are comfortably light, but feel is good; anti-servo tabs on the elevator improve feel during maneuvers and increase elevator power at low airspeeds.

Extending and retracting the landing gear causes only slight changes in control pressure. Likewise, the changes in control pressure which result from changes in power settings or the position of the wing flaps are easily manageable. Thus, the controls do not become uncomfortably heavy at those times when you will be busiest with other matters.

Although it is not abnormal in this respect, the Twin-Bonanza, like any other aerodynamically-efficient airplane, will build up speed rapidly during a dive. If you plan to operate in instrument weather, you should be aware of this characteristic and on guard against inadvertently diving the airplane beyond its limit.

STALLS

The stall characteristics of the airplane are normal and there is adequate stall warning. The intensity of the warning symptoms is increased in power-on stalls. In addition to the inherent stall warnings, a stall warning indicator will inform you of an approaching stall. Since it is triggered at five per cent above stalling speed, you will have ample opportunity to prevent the stall.

Indicated Stalling Speed at Maximum Gross Weight (7000 lb.):

	<i>Power-Off</i>				<i>Power-On</i>
Angle of Bank.....	0°	20°	40°	60°	0°
Gear & Flap Up.....	91	97	104	129	72
Gear & Flap Down..	79	84	90	112	63

These are the minimum speeds at the various conditions stated. However, when flying at speeds near stalling, abrupt control movements can precipitate a stall. Make smooth flight control movements and adjustments in power when practicing stalls.

The airplane is easily controlled throughout the entire maneuver, having no unconventional or bad characteristics. As you approach the stall, you will notice that the airplane has an unusually high stalling angle. This serves as another precaution against inadvertent stalls. However, forward visibility remains good throughout the stall due to the sloping nose contour.

As the stall is approached, the airplane will have no tendency to drop a wing if directional control is main-

- d. Move the propeller control through its complete range to check operation and return to full low pitch position. Full feathering check on the ground is not recommended, but the feathering action can be checked by running the engine between 1500-1700 RPM and momentarily pulling the propeller control into the feathering position. Do not allow the engine speed to drop below 1000 RPM.
- e. A proper magneto check is important. Additional factors other than the ignition system, affect magneto drop-off. They are load-power output, propeller pitch and mixture strength. The important thing is that the engine runs smoothly, because magneto drop-off is affected by the variables listed above. Make the magneto check in accordance with the following procedures.
 - (1) With the propeller in minimum pitch angle, set the engine to produce 50-65% power as indicated by manifold pressure gauge. Mixture control should be in the "Full Rich" position. At these settings, the ignition system and spark plugs must work harder because of the greater pressure within the cylinders. Any existing ignition problems will be apparent under these conditions. Mag checks at low power settings will only indicate fuel-air distribution quality.
 - (2) Switch from both magnetos to one and note drop-off. Return to both until engine regains speed and switch to the other magneto and note drop-off. Then return to normal operation. Normal drop-off is 100 RPM. Drop-off should not exceed 175 RPM, and the difference between drop-off of both magnetos should not exceed 50 RPM. A smooth drop-off past normal is usually a sign of a too lean or too rich mixture.
 - (3) Do not operate on a single magneto for too long a period; 2 or 3 seconds is usually sufficient to check drop-off. This will minimize plug fouling.

7. OPERATION IN FLIGHT.

a. Take-Off and Climb.

- (1) Limit take-off and climb to five minutes at 3400 RPM. Supercharged engines never exceed 48 in. manifold pressure at 3400 RPM.

NOTE

Although take-off power may be used for a maximum of five minutes, it is advisable to throttle back to rated power as soon as take-off obstacles have been cleared, as take-off power is intended to be used in emergencies only.

- (2) *Supercharged Engines Equipped with Simmonds Fuel Injectors* – The emergency rich fuel supply is to be used only in two engine continuous climb, full throttle operation above 15,000 feet, and when cylinder head temperatures exceed 435°F (224°C).
- (3) *Leaning Fuel/Air Mixture* –
 - (a) All subject engines except IGSO-480-A1D6, -A1E6, -A1G6 – These engines are equipped with either pressure carburetors or automatically controlled fuel systems and manual leaning is not recommended.
 - (b) IGSO-480-A1D6, -A1E6, -A1G6 – The manual mixture control should remain in the full rich position. However, during take-off from high elevation airports or during climb if loss of power results from over-richness; adjust mixture control only enough to obtain smooth operation.

SECTION 3 OPERATING INSTRUCTIONS

LYCOMING OPERATOR'S MANUAL GO-480, IGO-480, GSO-480, IGSO-480 SERIES

b. Continuous Cruise Operation.

- (1) *Supercharged Engines* – Never exceed 45 inches manifold pressure at rated speed (3200 RPM).
- (2) When increasing power, first increase the RPM with propeller governor, then increase manifold pressure with throttle. When decreasing power, throttle back to desired manifold pressure, then change propeller governor to desired RPM.

NOTE

These are high out-put engines demanding smooth operation of the throttle to avoid detuning the counterweights. Avoid rapid opening or closing of the throttle and high RPM, low manifold pressure settings.

- (3) *Cruise Power Settings* – Consult the airframe manufacturer's handbook for manifold pressure and RPM for various power settings.
- (4) *Manual Leaning Procedures* – All subject engines except IGSO-480-A1D6, -A1E6, -A1G6 are equipped with either a pressure carburetor or an automatically controlled fuel system and manual leaning is not recommended.

IGSO-480-A1D6, -A1E6, -A1G6 – The manual mixture control should remain in the full rich position unless the aircraft is equipped with either an approved fuel flow meter or an exhaust gas temperature gauge. The recommended leaning procedures are as follows:

LEANING PRECAUTIONS

Never exceed the specified maximum cylinder head temperature.

For continuous cruise operation, for best service life of the engine, maintain cylinder head temperatures below 435°F (224°C).

Do not manually lean engines equipped with pressure carburetors or automatically controlled fuel systems.

Always enrich mixture before increasing power.

a. Equipped with an Approved Fuel Flow Meter.

- (1) *Lean in accordance with power/fuel flow curve.*

b. Equipped with an Exhaust Gas Temperature Gauge.

- (1) *75% Power Cruise* – Never lean beyond 150°F on rich side of peak EGT. Monitor cylinder head temperatures.
- (2) *65% Power and Below* – Operate at peak EGT, or if desired, drop 50° on rich side of peak EGT.



DETONATION

Tips

WHAT IS DETONATION?

Detonation is the abrupt combustion or explosion of the fuel charge inside the cylinder. During normal combustion, the spark plugs ignite the fuel charge and the fuel has a consistent and even burn as the piston moves through the power stroke and chemical energy is efficiently converted to mechanical. In simplified terms, when detonation occurs, the fuel charge ignites quickly in an uncontrolled explosion, causing a pounding or hammering force on the piston rather than a steady push. Light detonation may not show any indication in the cabin of the aircraft. Moderate to severe detonation could be noticed as engine roughness, vibration or loss of power and eventually engine damage. A pilot should always be looking for unexpectedly high Cylinder Head Temperatures (CHTs) or Exhaust Gas Temperatures (EGTs) which may be a sign that detonation is occurring.

WHAT CAUSES DETONATION AND HOW CAN IT BE PREVENTED?

The combustion process inside a piston engine is quite dynamic and there are many things that could contribute to detonation. This article will touch on a few of the more common causes rather than a concise list.

First, let's assume that the aircraft and engine have been fueled correctly and that the octane rating of the fuel meets or exceeds the octane demand of the engine. Lycoming's Service Instruction 1070 provides a comprehensive listing of what fuels are approved for our engines along with other important information.

With the given that the fuel is the correct choice for the engine, for a pilot the number one cause of detonation is excessive leaning at high power settings. The pilot should always stick to the guidance in the approved pilot's operating handbook for correct leaning and power settings. To review Lycoming's recommendations, reference the current revisions of the appropriate Lycoming Operator's manual and Service Instruction 1094. If the pilot believes the engine may be detonating, he or she could take the following actions.

Increase the engine mixture.

Reduce power to a lower setting.

Reduce or stop climb and increase forward speed for greater cooling.

For a mechanic, the number one cause of detonation would be any issue that would cause a cylinder to run unexpectedly lean. This is most commonly caused by a partially clogged fuel injection nozzle or an intake air leak. Any time fuel nozzles are removed, they should be cleaned and flow checked. During inspections, the mechanic should be looking for signs of an intake leak; usually noted by blue fuel staining on intake pipes. Any anomalies should be corrected before further flight.

We've also seen cases where cracked or otherwise damaged spark plugs create a "hot spot" in the engine and detonation occurs. This is why it's never a good idea to use a plug that's been dropped on a hard floor or otherwise damaged.

Lycoming engines meet or exceed the FAA guidance for detonation margin. Therefore, if an engine is maintained and operated in accordance with our published guidance, the engine should never experience detonation.

HOW WOULD MY MECHANIC OR ENGINE OVERHAUL SHOP KNOW DETONATION HAS OCCURRED?

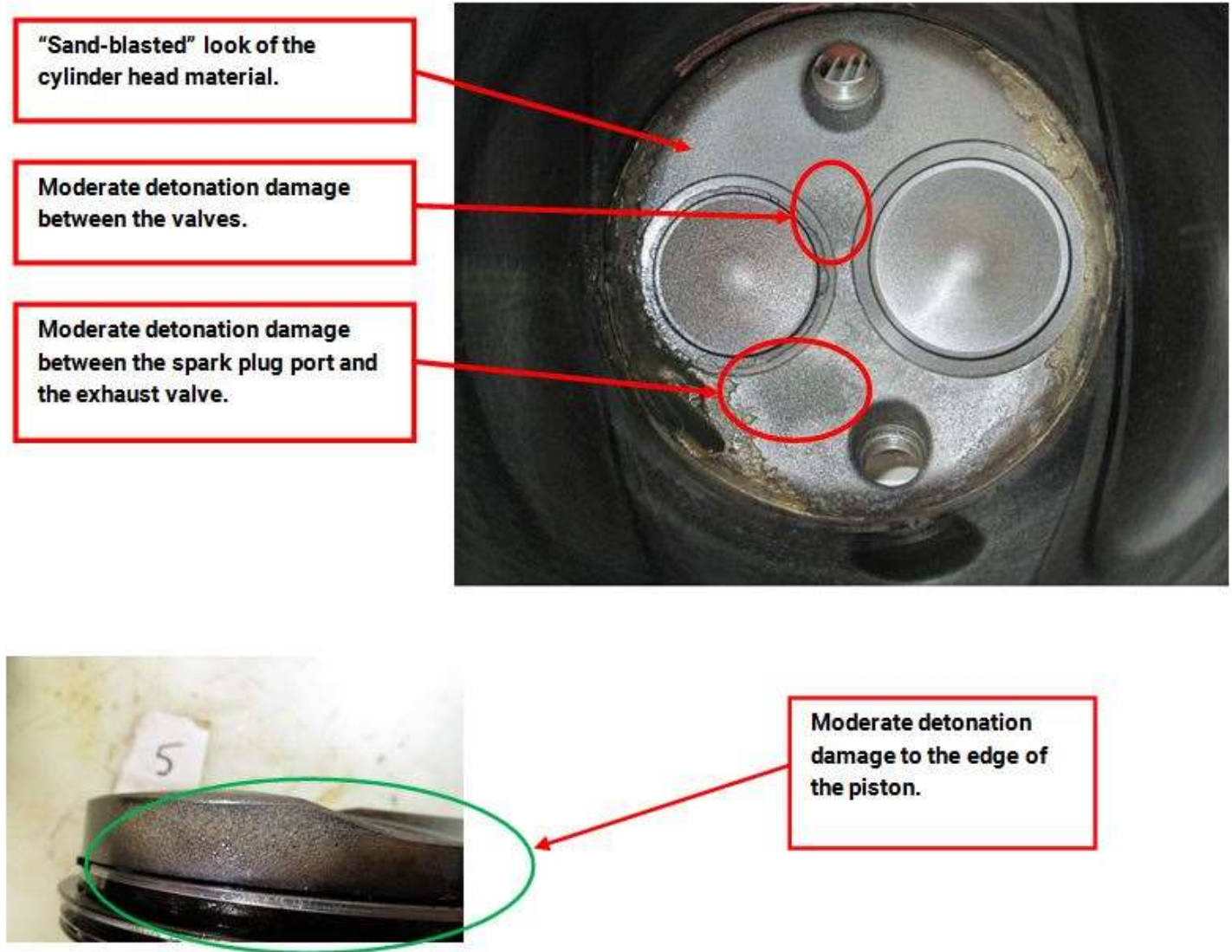
Detonation has negative effects throughout the engine. Light detonation may cause premature wear on bearings and bushings. Severe or prolonged detonation can cause damage to the cylinder head and pistons. In some extreme cases, the connecting rod can be bent or broken, the cylinder head may crack or fail, or the piston ring lands may break.



Whenever a cylinder is removed, your mechanic should take the opportunity to inspect the cylinder and pistons for signs of trouble. Here are some things that can be inspected for.

While it may not look good, lead build-up or combustion deposits are normal in Lycoming engines. The lack of these deposits is not necessarily a good thing, either. The cylinder head and piston should be inspected for a “sand-blasted” look. Lack of deposits or a clean head and piston face could indicate detonation has occurred. When using unleaded fuels the deposits should be...

Detonation damage usually shows in the edges of pistons and on the cylinder head between the spark plug ports and valves.



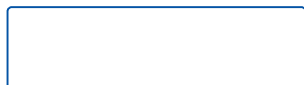
For further questions about the care and maintenance of your Lycoming engine, please contact our technical support team at: technicalsupport@lycoming.com or by calling +1-800-258-3279.

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Use our Engine Exchange Program to order a new, rebuilt, or overhauled engine to experience more airtime and less downtime.



Detonation and Pre-Ignition

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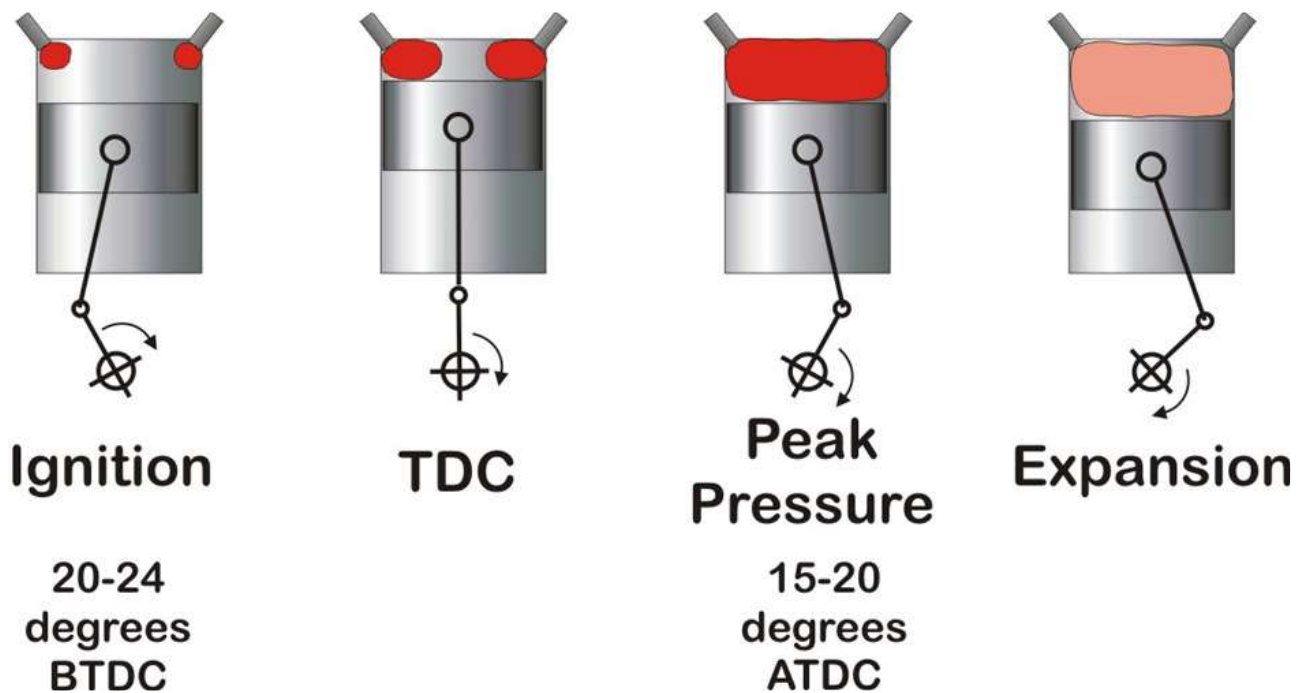
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Often confused and misunderstood, these two abnormal combustion phenomena are as different as night and day.

by Mike Busch

Although we often hear people describe what goes on inside the cylinders of an Otto-cycle engine as being an explosion - i.e., a violent, nearly-instantaneous event - it's not. The air-fuel charge does not explode when ignited by the spark plugs, but rather burns in an orderly fashion, starting at the spark plugs and progressing across the combustion chamber until it is quenched upon reaching the cylinder walls and piston crown when air-fuel charge has been completely consumed and there's nothing more to burn. The combustion event takes a significant period of time - roughly 6 milliseconds or 90° of crankshaft rotation, give or take.

Figure 1 illustrates this. Note that ignition occurs 20° to 24° of crankshaft rotation before the piston reaches top-dead-center (TDC), but that the peak combustion pressure doesn't develop until 15 to 20° after TDC. In an engine turning 2400 RPM, each crankshaft rotation takes 25 milliseconds, so the elapsed time from ignition to peak pressure (which takes about 1/8 of a rotation) is around 3 milliseconds.



It's crucial that peak pressure occur well past TDC, because the geometry of the crankshaft and connecting rod near TDC does not permit combustion pressure to be converted into useful work (i.e., crankshaft rotation), but simply generates excessive stress on the cylinder, piston, connecting rod and crankshaft. Figure 2 attempts to dramatize this point.

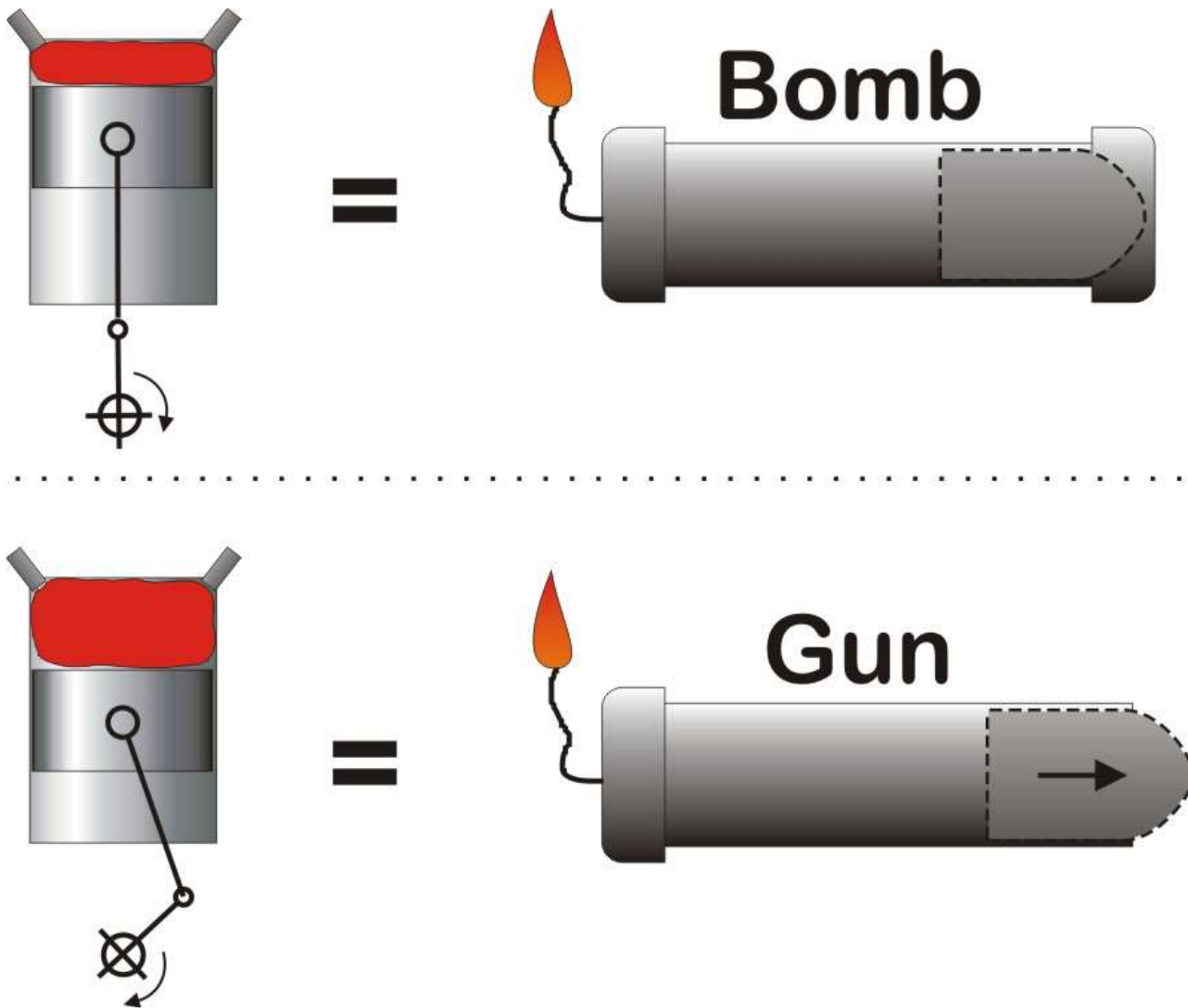
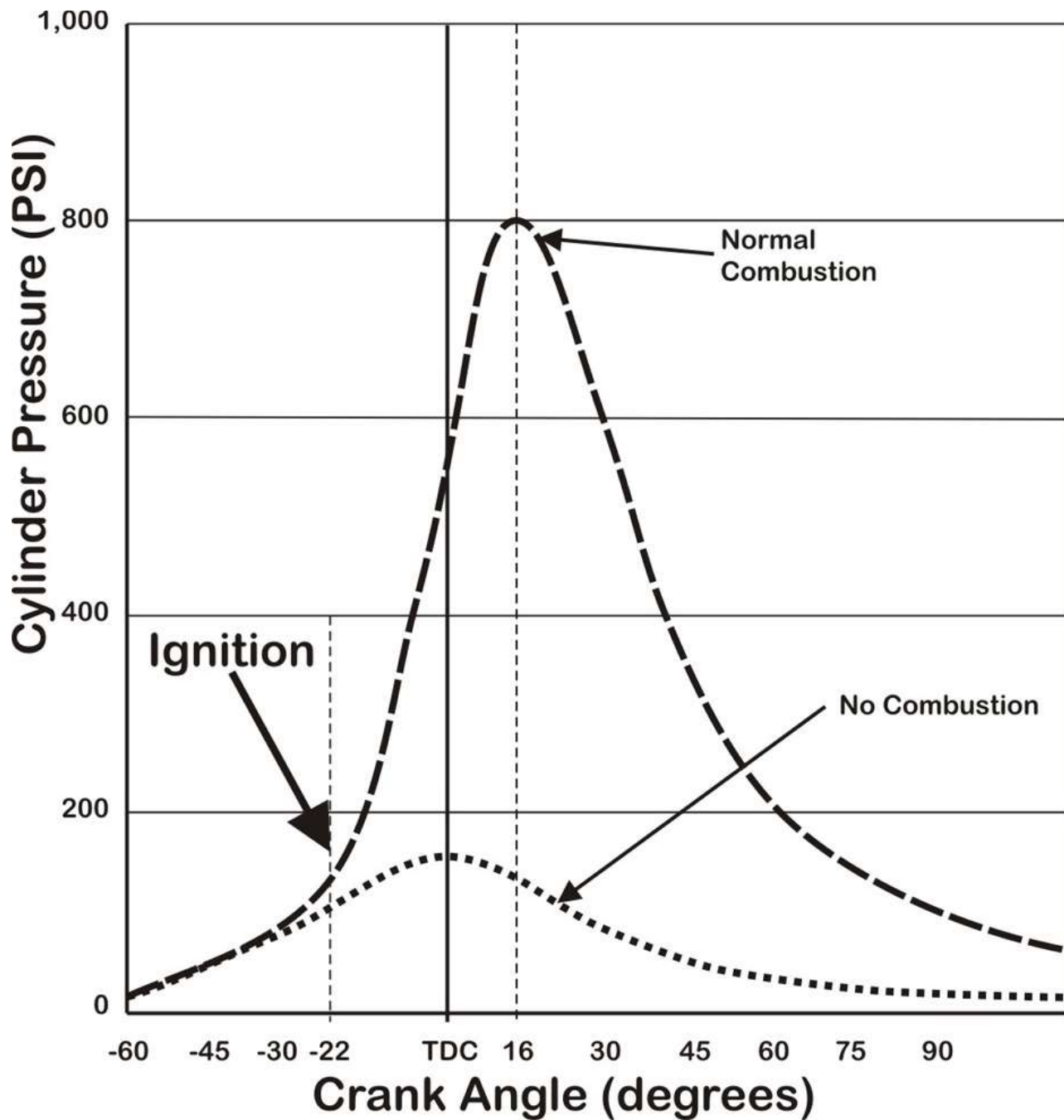
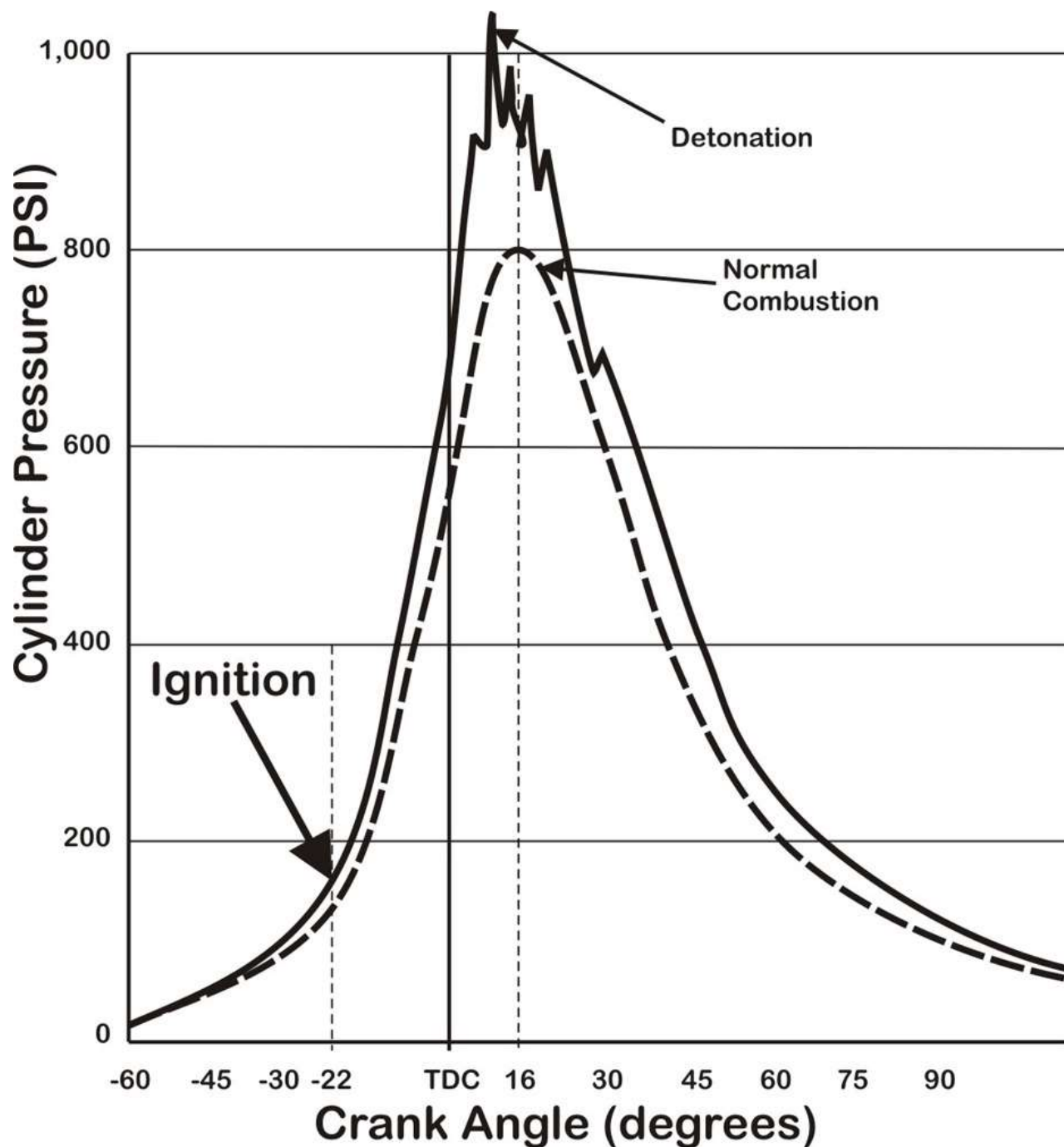


Figure 3 shows the pressure inside the cylinder as the combustion event progresses. If we crank the engine without supplying fuel or ignition (so there's no combustion), the compression stroke of the piston produces a modest pressure peak (perhaps 120 PSI) right at TDC. On the other hand, if we provide a combustible fuel/air mixture and fire the spark plug at 22° before TDC, combustion causes the pressure to build to a much higher value - typically 800 PSI in a normally-aspirated engine, and sometimes 1,000 PSI or more in a turbocharged engine - that peaks 15° to 20° after TDC, just as the piston, connecting rod and crank have reached a position where that pressure can be converted into crankshaft rotation with reasonable mechanical efficiency.



Detonation

But if the combustion process moves too fast and the pressure peak occurs too early, the result can be excessive pressure, excessive temperatures, and unstable pressure pulses known as "detonation." That's because when the piston is in the immediate vicinity of TDC, it can't move downward in the cylinder to relieve the pressure (and accomplish some useful work in the process). The ragged, spiked appearance of the upper trace in Figure 4 is the characteristic pressure signature of detonation.



In an automobile, we can usually hear detonation in the form of audible "knock." In an airplane, we can't - there's too much noise - but we can observe it on an engine monitor in the form of excessive CHT and depressed EGT.

Detonation is something that occurs near the peak pressure point in the combustion event, after the air-fuel charge has been ignited normally by the spark plugs. It is characterized by abnormal pressure spikes near the peak pressure point, caused by spontaneous combustion of end gas due to excessive temperature and pressure.

Contrary to what your CFI or A&P may have told you, detonation is not necessarily harmful. Many engines operate in light detonation quite regularly, and some can withstand moderate detonation for extended periods of time without damage. Detonation is not an optimum situation, but it's not necessarily destructive. The higher the specific output of the engine, the more likely it is to sustain detonation damage. An engine that produces 0.5 hp/in³ (horsepower per cubic inch of displacement) - as is typical of most carbureted aircraft engines - can usually sustain moderate levels of detonation without damage, but highly-boosted turbocharged engines rated at 0.625 hp/in³ or more can be damaged fairly quickly by detonation.

When detonation damage does occur, it typically manifests itself in the form of fractures (of spark plug electrodes and insulators, and sometimes piston rings and lands), pitting (typically of the piston crown), and/or heat distress (often piston skirt scuffing and piston corner melting).

As pilots, we can usually avoid such damage by being alert for the excessive CHT and depressed EGT that is characteristic of detonation, and reacting promptly by reducing power and going to full-rich mixture. An engine monitor is essential here - otherwise you cannot see the CHT of five of the six cylinders-and programming the CHT alarm to go off at 400° will help get your attention and take the appropriate action.

Pre-ignition

"Pre-ignition" is another abnormal combustion event that is often confused with detonation, but in fact is completely different. Pre-ignition is the ignition of the air-fuel charge prior to the spark plug firing. Anytime something causes the mixture in the chamber to ignite before the spark plugs fire, it is classified as pre-ignition. The ignition source can be an overheated spark plug tip, carbon or lead deposits in the combustion chamber, or (rarely) a burned exhaust valve-any of these things can act as a glow plug to ignite the charge prematurely.

Such a hot spot in the chamber can ignite the charge while the piston is very early in the compression stroke. The result: For a significant portion of the entire compression stroke, the engine is trying to compress a hot mass of expanding gas. This obviously puts tremendous mechanical stress on the engine and transfers a great deal of heat into the aluminum piston crown and cylinder head. Substantial damage is almost inevitable.

Detonation causes a very rapid pressure spike near the peak pressure point for a very brief period of time. Pre-ignition causes tremendous pressure that is present for a very long time - possibly the entire compression stroke. Not only is pre-ignition far more damaging, but it's also much harder to detect. In fact, typically you find out about it only after the engine has been damaged catastrophically.



Engines can tolerate detonation for substantial periods of time, but there is no engine that can survive for very long when pre-ignition occurs. The engine will not run for more than a few seconds with pre-ignition. If you see a piston crown that looks sandblasted or a ring land that has fractured, it was probably caused by heavy detonation. If you see a hole melted in the middle of the piston crown, it was probably caused by pre-ignition. Other signs of pre-ignition are spark plugs with melted electrodes or insulators spattered with molten metal. Figure 5 shows an example of extreme damage caused by pre-ignition.

Detonation-induced pre-ignition

Although detonation and pre-ignition are two completely different phenomena, it is possible for heavy detonation to induce pre-ignition. If the engine is operating in heavy detonation for a significant period of time, the excessive temperatures and pressure spikes (which disturb the usual protective boundary layer) can cause spark plug electrodes and other things in the combustion chamber to overheat to the point where they start to glow red hot. At that point, the glowing item can cause pre-ignition and rapid destruction of the cylinder. Upon teardown, forensic analysis would reveal the tell-tale signs of both detonation and pre-ignition damage, although it's the pre-ignition that ultimately did the engine in.

In a different article, we'll look more closely at the normal combustion event, and explore how our use of the engine controls - throttle, mixture and prop - affect what happens inside the cylinder.

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