ENGINE PRE-HEAT, WHY?

In less than a minute, a single cold start without proper preheating can produce more wear on a piston aircraft engine than 500 hours of normal cruise operation. If it's cold enough, a single cold start can cause the catastrophic destruction of an engine shortly after takeoff. This is serious! Below is what pilots need to know to make it through the cold-weather flying season without damaging the engine.

How cold is cold?

The first question that invariably comes up is how cold it has to be before preheating is necessary. Of course, there's no hard and fast answer to that question. The degree to which a cold start will damage an engine depends on a variety of things, including the type of engine, its age and condition, what sort of cylinders it has (steel vs. chrome), and what kind of oil is being used.

Interestingly enough, a brand new factory reman is considerably more vulnerable to cold start damage than a tired old engine near TBO. Surprised? Keep reading and you'll find out why.

As a general rule, we consider any start in which the engine is cold-soaked to a temperature below freezing (32°F or 0°C) to be a "cold start," and any start below about 20°F (-7°C) to be nothing short of a capital offense against your power plant. The colder the temperature, the worse the crime. CAP aircraft engine pre-heat is mandatory if temp is 20°F (-7°C) or below.

Oil pressure isn't enough!

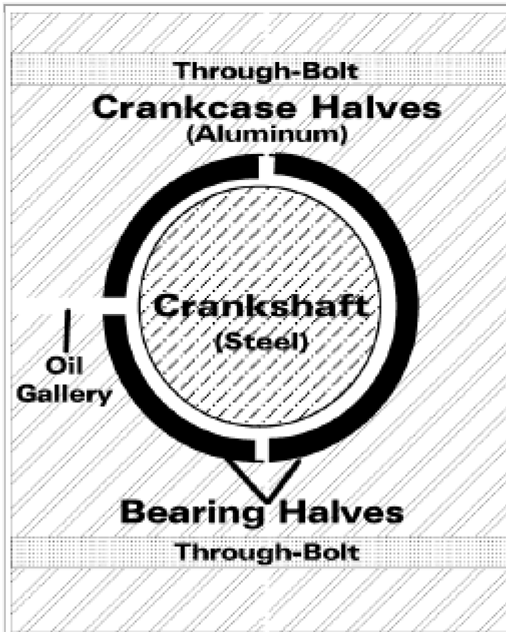
Most pilots seem to think that the main reason cold starts are bad for engines is that the engine oil is thick and viscous and doesn't flow well. Since it takes longer for oil pressure to come up when the oil is cold, the engine sustains excess wear in the early seconds after start because of inadequate lubrication. That might have some historical validity, but not today. Nearly everyone who flies in cold weather nowadays uses multi-viscosity oil. These oils flow extremely well even at 0°F (-18°C) or less. CAP uses Exxon 20W-50.

Consequently, pilots observe oil pressure rises quickly after starting, even in cold weather, and figure that therefore everything's okay. Big mistake!

ENGINE PRE-HEAT, WHY?

Bearings need clearance...

The real culprit in cold-start damage is the fact that aircraft engines are made of dissimilar metals with radically different expansion coefficients. The engine crankcase, pistons and cylinder heads are made from aluminum alloy, while the crankshaft, camshaft, connecting rods and cylinder barrels are made from steel. When heated, aluminum expands about twice as much as steel. Likewise, when cooled, aluminum contracts about twice as much as steel. And, therein lies the problem.



Crankshaft bearing clearance.

Consider the steel crankshaft, which is suspended by thin bearing shells supported by a cast aluminum crankcase. As the engine gets colder, all of its parts shrink in size, but the aluminum case shrinks twice as much as the steel crankshaft running through it. The result is that the colder the temperature, the smaller the clearance between the bearing shells and the crankshaft. That clearance is where the oil goes to lubricate the bearings and prevent metal-to-metal contact. If there's not enough clearance, then there's no room for the oil, regardless how high the oil pressure gauge reads.

How significant is this problem. Well, engines used in many Cessna singles, the overhaul manual lists the minimum crankshaft bearing clearance as 0.0018 inch (that's 1.8 thousandths) at normal room temperature.

What happens to that clearance when you start cooling the engine down? Tests performed in 1984 by Tanis Aircraft Services in Glenwood, Minn. (where it gets mighty cold) indicated that an engine can lose 0.002 inch (2.0 thousandths) of crankshaft bearing clearance at -20°F. An engine built to minimum specified bearing fit at room temperature would actually have negative bearing clearance at -20°F-in other words, the crankshaft would be seized tight!

You've probably noticed how difficult it is to pull the prop through by hand before starting in cold weather. Now you know why. It's not that the oil is thick (because if you use multi-vis oil, it's not). It's that the clearance between the crankshaft and bearings is tighter than normal. If it's cold enough, you might not be able to pull the prop through at all.

Starting an engine in this condition will likely cause accelerated bearing wear and possible damage to the crankshaft journals in the first minute or two of engine operation. If bearing clearances are small enough, it's even possible for the bearing shells to shift in their saddles-a so-called "spun bearing-misaligning the oil feed holes and starving the bearing from lubricating oil.

ENGINE PRE-HEAT, WHY?

Ironically, this problem is at its worst with a fresh-from-the-factory engine built to the tightest new-engine tolerances. A tired, loose, high-time engine with worn bearings might well have plenty of clearance even at subzero temperatures.

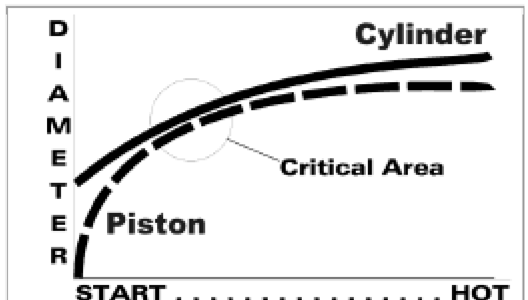
But, even if the engine is approaching TBO, you can't afford to be complacent about cold starts. That's because inadequate bearing clearance is only one of several evils associated with cold starting.

...And pistons do, too

Consider what happens to pistons and cylinders when you cold-start an engine. Here, the situation is the opposite of the one we just talked about: instead of a steel crank inside an aluminum case, we have an aluminum piston inside of a steel cylinder barrel. So the clearance situation is reversed: piston-to-cylinder fit is loose when the engine in cold, and tightens up as the engine comes up to full operating temperature. (This is why compression tests are normally done when the engine is hot.)

So why would cold starting be a problem for the engine's top end? Several reasons.

When an engine is started cold and comes up to temperature, the piston and cylinder barrel don't warm up at the same rate. The piston heats up very rapidly after start, while the cylinder barrel may take quite a long time to warm up. Why? Well, for one thing, the piston is small and light, while the cylinder his big and heavy, so when both are exposed to the heat of combustion, the piston heats up a great deal faster. In addition, the cylinder has a very effective mechanism for shedding heat-it's covered with cooling fins bathed in what is presumably frigid air-while the piston's only real cooling comes from the splash of engine oil, and the low RPMs of start and idle there's not a whole lot of splash oil available.



Piston-to-cylinder clearance.

The result is that the piston expands to its full operating dimension quite quickly after start, while the cylinder takes a lot more time to expand to its full operating diameter. The colder the OAT, the longer it takes for the cylinder to reach operating temperature. The result is that although the fit of the piston in the cylinder is quite loose when the engine is cold, it may quickly become tighter than normal shortly after starting when the piston has come up to temperature but the cylinder still has a long way to go. If it's cold enough, the piston-to-cylinder clearance can actually wind up going to zero, resulting in metal-to-metal scuffing between the piston and cylinder barrel.

This problem is made worse by the fact that most cylinder barrels are designed with a taper or "choke" in the top one-third of piston travel. This is done to pre-compensate the barrel for the fact that, as the engine comes up to operating temperature, the top of the cylinder (where the combustion process takes place) is a lot hotter than the bottom of the cylinder, and therefore expands considerably more. If cylinders were perfectly cylindrical at room temperature, then

ENGINE PRE-HEAT, WHY?

they'd become flared at the top when the engine was hot, resulting in loose fit between the piston and cylinder barrel right where a tight fit is most needed-at top dead center. By giving the cylinder barrel a slight taper at the top when at room temperature, the cylinder winds up being cylindrical at operating temperature.

When an engine is started in cold weather, the cylinder choke starts out considerably greater than normal. After start, the piston starts being repetitively forced up into the choked-down area at the top of the stroke. As the piston quickly comes up to temperature but the cylinder is still relatively cold, it's easy to see how severe scuffing can occur at the top of stroke.

As you can see why warming up the engine oil is definitely not enough to avoid cold-start damage. All the warm oil in the world won't help if the crank-to-bearing or piston-to-cylinder clearances go to zero. To avoid this, it's essential to preheat and warm up the crankcase and the cylinder barrels (especially the top of the cylinder barrels near where they mate to the heads).

IT PAYS TO REALLY WARM THAT ENGINE PRIOR TO START. FLY SAFE!

Thanks to avweb's Mike Busch for the above info.