Preheating: The Whys and Hows

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The cold weather season is upon us. Are you ready?

A single cold start without proper preheating can produce more wear on your engine in less than a minute 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!

How cold is cold?

The first question that invariably comes up is how cold it has to be before preheating is necessary. There's no hard and fast answer to that question. The amount of damage done by a cold start depends on a variety of things, including the type of engine, its age and condition, and what kind of oil is being used. (A brand new or freshly rebuilt engine is more vulnerable to cold start damage than a tired old engine at TBO.)

As a general rule, I 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 a capital offense. The colder the temperature, the worse the crime.

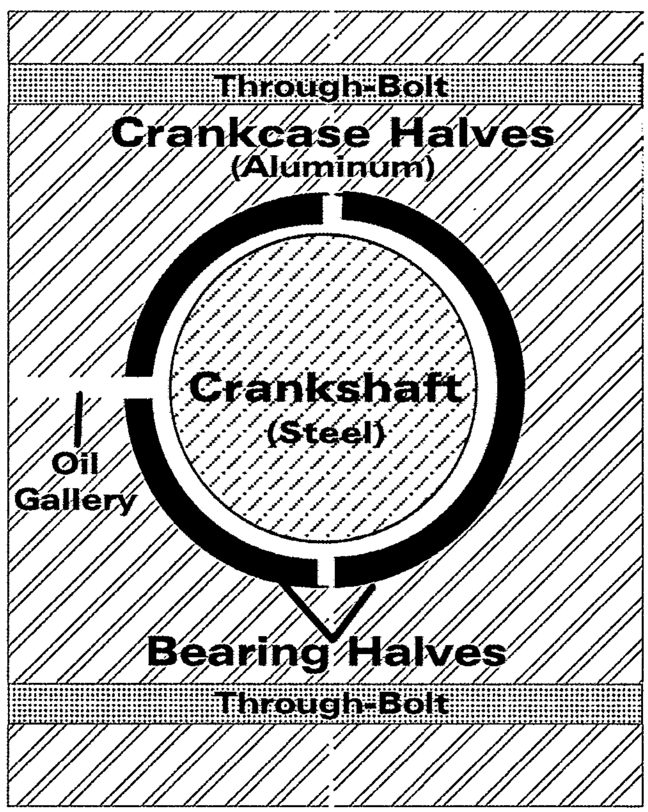
Oil pressure isn't enough!

Many pilots believe 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.

While that's true of single-weight oils like Aeroshell W100, it's not true of the modern multi-viscosity oils that are universally used today for cold-weather operations. Multi-vis oils like Aeroshell 15W-50, Exxon Elite 20W-50 and Phillips X/C 20W-50 flow extremely well even at 0°F (–18°C) or less. Pilots who use Multi-vis oils quickly observe that their oil pressure comes up quickly after starting even in cold weather, and most figure that therefore everything's okay. Wrong!

Bearings need clearance…

The biggest culprit in cold-start damage is the fact that our aircraft engines are made of dissimilar metals with very different expansion coefficients. The crankcase, pistons and cylinder heads of your engine are made from aluminum alloy, while the crankshaft, connecting rods, piston pins and cylinder barrels are made from steel. Aluminum expands about twice as much as steel when heated, and aluminum contracts about twice as much as steel when cooled. Therein lies the problem.



Main bearing diagram

Consider your 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. As ambient temperature goes down, so does the clearance between the bearing shells and the crankshaft—and 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 of oil pressure.

The Teledyne Continental IO-520 overhaul manual lists the minimum crankshaft bearing clearance as 0.0018 inch (that's 1.8 thousandths) at room temperature. What happens to this clearance in cold temperatures? Tests performed in 1984 by Tanis Aircraft Services in Glenwood, Minn. (where it gets mighty cold) showed that an IO-520 loses 0.002 inch (2.0 thousandths) of crankshaft bearing clearance at –20°F. In other words, a tight new engine built to TCM's minimum specified bearing fit at room temperature would actually have negative bearing clearance at –20°F; the crankshaft would be seized tight!

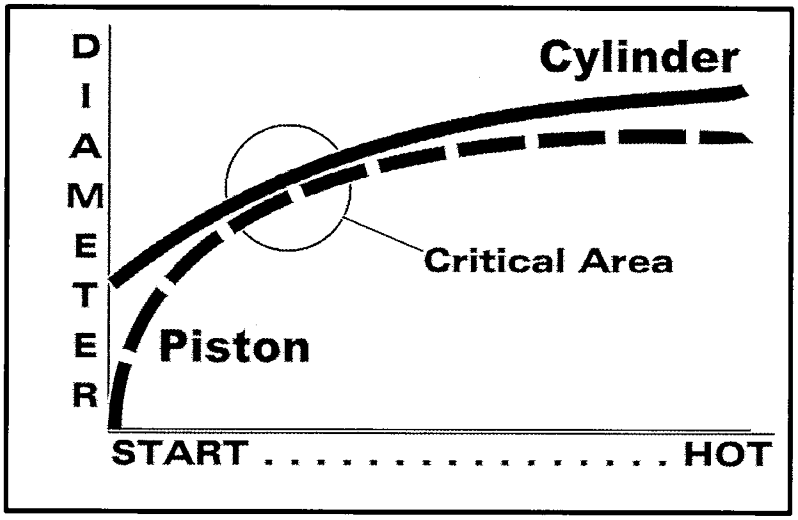
You've probably noticed how difficult it is to pull the prop through by hand before starting in cold weather. Now you know why. It's not that the oil is thick (and if you use Multi-vis oil, it's not). It's that the clearance between the crankshaft and bearings is tighter than normal. If it's cold enough,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

Start an engine in this condition and you're likely to experience accelerated bearing wear and possible scuffing of the crankshaft journals in the first minute or two of engine operation. In the extreme, 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.

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 your 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 your 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 is 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.)



Warm up graph

When an engine is started cold, the piston heats up very rapidly after start, while the cylinder barrel may take quite a long time to warm up. Why? The piston is small and light, so it heats up quickly. The cylinder is big and heavy, and covered with cooling fins bathed in frigid ambient air, so it warms up quite slowly (as you can easily see on your CHT gauge).

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 fit of the piston in the cylinder bore may quickly become tighter than normal shortly after starting when the piston has come up to temperature but the cylinder still has a 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. 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 from this discussion, 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 for a preheat to warm up the crankcase and the cylinder barrels (especially the top of the cylinder barrels near where they mate to the heads).

The world's best preheat

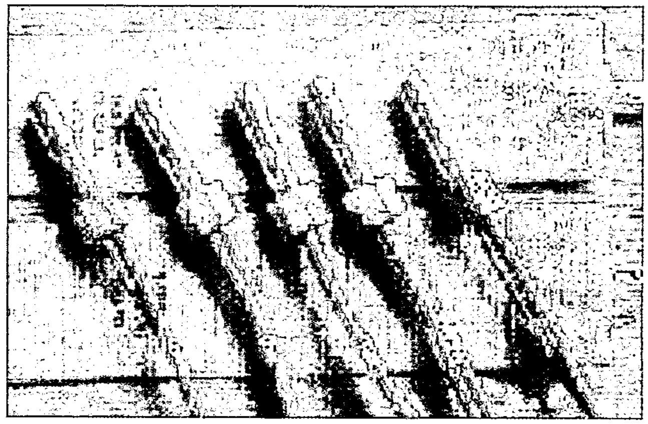
The best way to accomplish this is to put the airplane in a heated hangar overnight. Why? Because this preheats every part of the airplane to an even temperature. After 8 to 12 hours in a 40°F hangar, the oil is at 40°F, the case is at 40°F, the cylinder heads are at 40°F, the gyro instruments are at 40°F (gyros have their own cold-starting problems), the windshield is at 40°F (so it won't fog up the minute you breathe), and even the pilot's seat is at 40°F (which solves another problem).

I'm based on the California coast where the weather hardly ever gets below freezing, but when I travel to the cold country, I always try my best to use the overnight-in-a-heated-hangar method of preheating. Most FBOs seem to charge anywhere between $25 and $75 to store my twin in their heated hangar overnight. Even at $75, I figure it's quite a bargain compared to the alternative (accelerated wear of my two expensive TCM engines).

If I'll be staying at a cold-weather airport for a while, I'm generally too much of a skinflint to pay for the airplane to be hangared for the whole duration. Instead, I'll arrange with the FBO to pull the airplane into the heated hangar the night before my scheduled departure. If it's really, really cold out on the morning of departure, I've been known to preflight the airplane in the hangar, climb into the cockpit, secure the door, and then have the line crew open the hangar door and tow the airplane out onto the ramp with me in it. As soon as they unhook the tug, I start the engines before they've had a chance to get cold-soaked.

Multipoint electric heaters

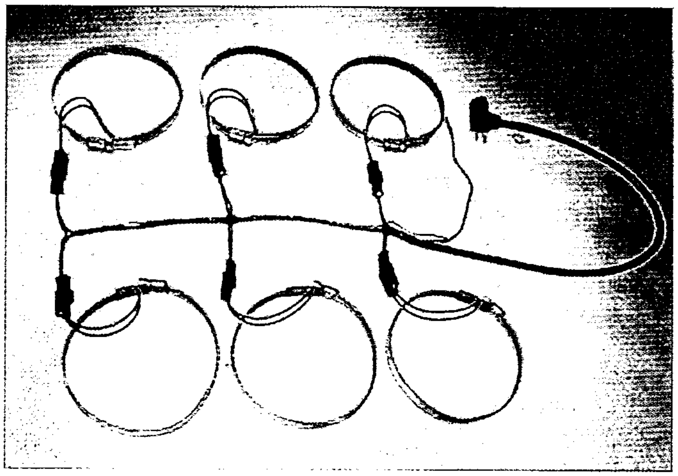
Short of overnight in a heated hangar, the best preheating method is a multipoint electric heating system that has individual heating elements attached to the oil pan, the crankcase, and each cylinder. By plugging such a system into 115V power a few hours before departure (overnight is even better), you can at least be assured of warm cylinders, a warm case, and warm oil when you start up.



Tanis heaters

The best-known multipoint electric preheating systems come from Tanis Aircraft Services in Glenwood, Minn. (*http://www.tanair.com*). The Tanis TAS100-series systems consist of eight electric heating elements connected by a wiring harness. Six 50- or 100-watt cylinder heaters screw into the threaded CHT-probe bosses in each cylinder head. The heating elements are available with built-in CHT thermocouple probes that work with most digital engine monitor systems. A flat silicone rubber heating pad is glued to the crankcase with high-temp RTV, and another is glued to the bottom of the oil pan. The wiring harness terminates at an ordinary AC plug that is usually mounted near the oil filler door in the cowling. You simply run an extension cord out to the airplane, plug in the preheating system, and let it cook for 4 to 6 hours.

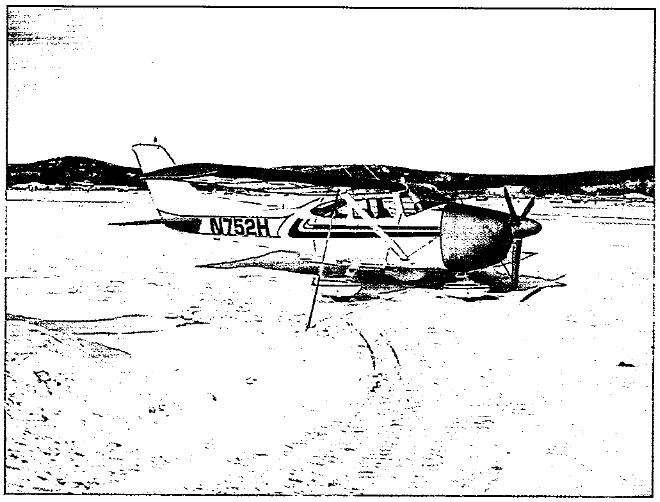
Reiff Preheat Systems of Atkinson, Wisc. (*http://www.reiffpreheat.com/*) offers a similar product called the "HotBand" system. In lieu of cylinder head heaters, the Reiff system uses 50-watt heating elements mounted on large stainless steel clamps that mount on the non-finned portion of each cylinder barrel. As a result, there's no interference with existing CHT instrumentation. The Reiff system also includes an oil pan heater, but not a crankcase heater (because the crankcase receives sufficient heat by conduction from the cylinder barrel heaters). The Reiff system is less expensive and easier to install than the Tanis, but requires somewhat longer to fully heat-soak the cylinder heads.



Reiff HotBand

Engine and prop covers

If the temperature is not too frigid and the aircraft is being preheated in a tee-hangar or other protected area, then a multipoint electric heating system is all you need to do the job. But if it's really cold, or if you have to preheat outside on an exposed ramp (particularly if it's windy), then you also need some means of insulating the engine compartment and keeping most of the heat from escaping.



Engine prop covers

At the very minimum, you'll need an insulated engine cover. Although you may be able to make do with a quilted blanket, custom-fitted insulated covers are available from Kennon Aircraft Covers in Sheridan, Wyo. (*http://www.kennoncovers.com*) and Bruce's Custom Covers (*http://www.aircraftcovers.com/*), as well as a few other firms. In intense cold or windy conditions, the propeller becomes a major source of heat loss during preheating. Kennon and Bruce's offer insulated propeller and spinner covers to solve this problem.

Another compelling advantage of insulated engine and prop covers is that using them may eliminate the need for a preheat altogether if you're going to be making a quick-turn. By installing the covers promptly after shutting down, engine heat can be retained for three or four hours even when the airplane is parked outside on a cold, windy tiedown.

Leave it on all the time?

There has been considerable controversy about whether or not it's a good idea to leave an electric preheating system plugged in continuously when the airplane isn't flying. Both Continental Motors and Shell have published warnings against leaving engine-mounted electric preheaters on for more than 24 hours prior to flight.

The concern of Continental and Shell is that heating the oil pan will cause moisture to evaporate from the oil sump and then condense on cool engine components such as the camshaft or crankshaft, resulting in accelerated corrosion of those parts. In Continental engines, we've seen numerous cases of badly corroded starter drive adapter shaftgears in airplanes whose owners made a habit of running their electric preheater 24/7. However, if the entire engine is heated uniformly by means of a multipoint heating system combined with insulated engine and prop covers, such condensation is very unlikely to occur. In fact, using an insulated cover and a multipoint preheating system that is plugged in continuously is one of the most effective methods of eliminating internal engine corrosion, particularly if the aircraft is kept in an unheated hangar rather than outdoors. If the entire engine is maintained above the dew point, condensation simply cannot occur.

Another effective way of eliminating the corrosion risk associated with continuous use of electric preheaters is to utilize an engine dehydrator (such as the Tempest AA1000 available from Aircraft Spruce for about $200). The dehydrator is even more helpful during the non-preheating season when the air is hot and humid.

Tech Topics is a monthly column written by Mike Busch of CPA's technical staff. Mike is a longtime CPA Magazine columnist, and is founder and CEO of Savvy Aircraft Maintenance Management, Inc. (www.savvymx.com) that provides professional maintenance management for Cessnas and other owner-flown GA aircraft. Mike is the National AMT of the year for 2008. Mike owns, flies and maintains a 1979 Cessna T310R based in Santa Maria, California.