WARBIRD NOTES # 7 4 Nov 94 (9)
PRE-IGNITION / DETONATION

This subject comes up periodically, causing a lot of questions by pilots who have mostly a turbine heredity or background. I guess what precipitates this letter is the sometimes expressed opinion that pre-ignition and detonation are sort of one and the same. Tain't so! Really - - not so!! Pre-ignition is exactly that, ignition previous to the desired moment while detonation is an explosion (like when you detonate dynamite, B-A-N-G!) of the fuel-air mixture charge instead of the normal smooth, progressive (and productive) burning. While it's certainly true that one can progress into the other that's getting way ahead of the story. In trying to include all the research material and accumulated bits of knowledge that go into something like this I ultimately had to go way back to the first days of ground school when we were hired at the airline. Our class of neophytes was, I've figured out over the years, lucky. We, (1) were the first class of copilots who came under the new F.A.R. training requirements and (2) had C. G. "Gordy" Amundson to teach us the DC-3. Under the increased training required by the FAA, we got two weeks of ground school and far more actual flight training then the "three bounces and send them out on the line" as had been customary up until that point. In trying to write something that gets as technical as this, and still keep it readable, I'm lucky again to have Gordy as a resource (both mind and library) to help out when I just can't remember everything we've learned and taught since those early days.

I recently read a question in the American Bonanza Society's magazine to the technical editor from a reader who used the word "predetonation". Now, picture a puzzled look on my face because that's exactly what I am left with. What does he mean to convey by this? Is it the meaning one would get from the literal interpretation of the term, damage occurring previous to the detonation process? Seems to me there wouldn't be any damage if detonation hadn't yet occurred. Or does he mean detonation itself? Or possibly pre-ignition? From some further description of the damage in his letter we can make assumptions. But we just don't really know, any attempted answer to his question is always a little suspect without further questioning. I only include this to emphasize how important correct terminology becomes, I hear so much of comparing apples and oranges. Thus this attempt at explanation. I say attempt because I can find letters and articles in excruciating detail about this matter in various publications dating back to well before WW II. Truthfully, it probably never will be finally laid to a complete rest.

Before we get into the technical stuff, for the purposes of this writing we need to describe the type of engine that we normally fly in one of our warbirds. That is, a carburetor with IDLE-CUT OFF, CRUISING LEAN, AUTO-RICH and (maybe) EMERGENCY-RICH positions. (By the way, if your aircraft has this last mentioned position you can forget it, it really isn't there, these were deleted on all civil carbs by the equivilent of an A.D. note after the war when troubles with the mechanism made it more trouble than it was worth.) No provision is made for BMEP gauges or torquemeters on our types of aircraft so the procedure of manually leaning to less than best power by reference to these gauges is not an option and we won't deal with it here.

First of all, we'll need to define normal combustion within the cylinder. The combustion process is rapid but it's important to realize that it is not instantaneous. The fuel-air charge burns evenly and smoothly, the flame front advancing at a measurable rate - about 35 feet per second as combustion begins, increasing to roughly 150 f.p.s. and then slowing down as the combustion process nears completion.

With that said let's begin with detonation. If sufficiently heated and compressed, any combustible mixture of gasoline vapor and air will catch fire. Accordingly, if the temperature and pressure of the unburned portion of the fuel-air charge reach a critical value, a spontaneous and simultaneous explosion of all the remaining unburned charge occurs. This violent process is called detonation. You very likely have noticed it in an automobile, especially upon acceleration. It's audible and you've probably referred to it as "pinging" or "knocking". If you could filter out the myriad of masking noises in an aircraft the knocking would be audible if detonation was occurring. Make no mistake, just because you can't hear it doesn't mean it isn't there! It's important to realize that this spontaneous combustion occurs AFTER normal ignition and after some portion of the charge has burned. The engine is unable to convert this explosive energy into useful work and power is lost. Supersonic pressure waves are set in motion producing harmful effects on combustion chamber parts and cylinder hold down studs. Examples of damage would include dished piston tops, collapsed valve heads, broken rings and ring lands or eroded portions of valve heads, pistons or cylinder heads.

Since light detonation cannot usually be detected from the cockpit through roughness / sound / loss of power, any effective protection from its occurrence must be provided in other ways, i.e., prevention. Lighter cases of detonation may not result in as noticeable an increase of cylinder head temperature (CHT) but anything in excess of this causes a rapid rise in CHT and aggravates the conditions which caused it. If visible from the cockpit, irregular puffs of dense, black exhaust smoke will be a warning.

Detonation, remember, is caused by either excessive temperature or excessive pressure of the fuel-air charge. Control of these two factors is what constitutes avoidance of detonation. This control consists of two parts, (a) design of the engine, installation and proper servicing / maintenance and (b) operational, that which you can control from the cockpit.

In the design of the engine and installation, cylinder head cooling, fuel grade, compression ratio, ignition timing, induction charge temperature due to the supercharger, etc. are major factors affecting detonation tendencies. They all influence the temperature and pressure of the fuel-air charge just prior to combustion.

Cockpit operational control of detonation also is directed towards keeping the fuel-air charge temperature within those limits established through exhaustive testing as safe and by avoiding excessively lean mixtures at high power. Although proper fuel grade is normally considered a preflight item I do know of several operations where main and reserve tanks contained different grades or octanes of fuel, in other words some tanks were to be used for cruise power only. This takes me back many years ago to South America, however I've also seen a good amount of it since the advent of the auto-gas STC. Limits (both time and values) of manifold pressure, RPM, CHT, carburetor air temp (CAT) and blower selection must all be observed and respected. Maybe not from fear of outright immediate failure but certainly with the knowledge that exceeding the limits will cause damage(s) resulting in failure in the future (time unknown) or extremely high and/or premature overhaul costs.

Next we'll need to define pre-ignition, after that's out of the way we can then discuss how all this is related and how it applies to us. Pre-ignition is the uncontrolled ignition, by an object heated to incandescence, within the combustion chamber of the fuel-air charge before the normal ignition spark. This premature combustion results in excessive pressure being exerted on the piston during the final portion of its upward travel on the compression stroke with attendant destructive tendencies. The same excess heat/pressure conditions that result in detonation are present when pre-ignition is encountered. Unlike most detonation, pre-ignition will usually be detected by roughness and backfiring, you might possibly also detect a rapid increase in CHT. Any sustained operation, even for a brief period, in this condition can result in burned pistons, broken cylinder heads, scuffed cylinder walls and damage to the valves and sparkplugs.

Pre-ignition can be caused by several possibilities, localized hot spots, carbon deposits, machining irregularities, sharp pieces of metal, glowing spark plug electrodes or possibly an accumulation of deposits from leaded fuels. Also, although it's unlikely you'll encounter it, you should be aware that in the past valves ground with too sharp an edge at overhaul were known to initiate this malfunction.

Since some discussion of prevention was inherent in describing these two malfunctions, probably only a limited amount remains to be said about how all this applies to our operation. Some indulgence in a little "hangar flying" here with experiences of a variety of aviators who have spent lifetimes dancing around these continuing aviation nemeses might be the best way of illustrating a few points. All these are "real life" incidents and the main actors could sure tell you about it, if that were to add anything.

One of the things that might have helped cause the perception of these two being one and the same is the fact that detonation can progress into pre-ignition (and vice versa). Let's talk about how. If you let detonation exist long enough to cause damage, this damaged area (in the form of broken parts or anything that causes a sharp edge) can be heated to incandescence. This is much like a knife or chisel edge held against a grinding wheel, pretty soon it glows. Same thing here, now you've got an ignition device inside the cylinder(s) and the whole situation will get worse - rapidly. Conversely, once the pre-ignition process begins, the rapid rise in combustion chamber temperatures can raise the fuel-air charge temperature to its critical value, thereby initiating the detonation process.

I need to mention something here while on the subject. In the early sixties, we used to operate our DC-3's on the airline maintaining a constant carburetor air temp of about xx degrees. Or, more properly, I should say that we attempted to maintain a constant xx degrees. This duty fell to both pilots, but the myriad other duties sometimes intervened, with this all-important operation sometimes suffering. The theory was that this temperature formed the best possibility of efficient combustion in the Wright 1820's cylinders and delivered the most miles per gallon of fuel expended. Only problem was, if your attention was diverted, sometimes this temperature rose into a range where detonation became a distinct possibility. It didn't take long for it to happen – and it must have. Sometime in the operation, we were advised to cease all attempts to maintain this efficient CAT and just leave the carb air controls in full cold. Then, if we needed carburetor heat, we could apply it and get rid of the ice. Our detonation problems largely subsided after that.

Editor's note: Some of Mr. Sohn's Warbird Notes are works in progress. We include the following incomplete topics because they still convey important concepts.

We had also taxied out with carburetor heat on, attempting to keep the CAT's in **[a certain]** degree range. Then, just prior to applying takeoff power, we would place the carb air controls in full cold for the takeoff. Lo and behold, we found we were asking the impossible of our Automatic Mixture Controls (AMC's) in the carburetors, they simply could not contend with rapid temperature change and therefore, we were risking detonation on our takeoffs in cold weather, since we had fooled the aneroids into thinking it was a warm day outside!

The most immediate and sure counteraction for detonation is a prompt power reduction.

Remember that what combination of rpm/mp that will cause detonation **[with]** 91/96 **[octane fuel]** would not **[with]** 100/130.

It is possible that if preignition occurs at high power settings that a rapid power reduction may cause glowing particles of lead or carbon to be chipped off due to the rapid cooling of the cylinder.

Long reach **[spark plugs]** could cause pre-ignition -. Steve S.

Unapproved plugs **[can also cause preignition] -** use chart ,don't just remove/replace.

1630 degrees will cause pre-ignition.