WARBIRD NOTES #3 21 Mar 93 (32)
RECIPROCATING LOADS ON ROUND ENGINES

This is intended to answer a question a friend of mine recently asked. It first was asked of me about 30 years ago during an airline annual recurrent training class of DC-3 and Convair 440 pilots. My friend's question was phrased something like "seems to me a pilot can't go very far wrong by following the military manual for the aircraft he's flying, so why don't we just advance the props to climb RPM on downwind and not worry about using less than 1" of manifold pressure (MP) for every 100 RPM for a couple of minutes during the rest of the pattern." Well, I guess that sounds reasonable, doesn't it? Looking at my "good stuff" (old USAF dash ones) I see what we already know, we did it on T-6s, B-25s, C-47s/54s/97s and everything the military owned. He continued "and another thing, I just don't get that stuff about the prop driving the engine". I replied that I would try and explain it in writing although it's a lot easier to show someone with a simple training aid or two. I will add the disclaimer that I am not the maintenance expert, what follows is my experience from a cockpit perspective and an attempt to relate what many of the real experts told me as I tried to put this into printed form. Oh, as an aside, if after reading this you think you may have noticed a plug or two for the oft-maligned Wright engine, well - - so be it! At least for the garden variety ones, when you get into the later higher horsepower 1820s and 3350s that may get to be somewhat of another story.

The first operator I encountered who didn't do it was when I was just out of the USAF and a newly hired DC-3 co-pilot at North Central back in 1960. Those were Wright R-1820s, I can still recall my first experience with them. Back then I pretty much had the idea that Pratt & Whitney was all it, most of my recent experience had been with 1830s, 2000s, and 4360s. I guess I conveniently managed to forget the dependable old Wright 2600 Twin Cyclone which had gotten me through over twenty-five hundred hours instructing in B-25s with only **two** failures! So much for gratitude and yes, it does say something about taking things for granted, doesn't it? Compared to the characteristically smooth P&W double row of either fourteen or eighteen cylinders, the Cyclone's single row of nine jugs seemed shaky and, undeniably, oilier.

Well, so be it! This was the airline that hired me and, with 35 Wright powered DC-3s, they must not be all that unreliable. Besides, the newly acquired Convairs with 2800s were far beyond my seniority. With only two weeks on the pilot's list all I really cared about was not getting furloughed or fired. Both loomed as very distinct possibilities throughout the probationary first year. The first captain I flew with had flown Thunderbolts and Mustangs in WW II and after. He hired on in 1953 and he made things look very easy. During that trip I asked what he thought of 1820s and his reply was about as easy as his technique. "Well, I've never had one get carb ice or fail". That succinct comment pretty much describes the feelings I encountered those early months when I might still have been caught casting a nervous glance or two at the slightly shaky cowlings and oil spots on the ramp.

Our company procedure was to leave the props at the standard 1900 RPM cruise setting throughout the pattern and then, when closing the throttles just prior to the roundout, move the prop levers all the way ahead. Of course, done this way, there was no RPM surge since the blades were already resting against the mechanical stops and nothing changed. Quieter approach, too! It was a pretty effortless operation but I hadn't yet acquired the knowledge to really understand the benefits. All this time I'd been instructing on the C-97 Stratocruiser for the Air Guard and there, across the field, we operated military style with 2350 RPM on downwind and all.

Time passes and after returning from the Berlin crisis recall to active duty with (then) MATS (later) MAC or (whatzit now, ALC?) I was taken into the Flight Training Department to instruct on DC-3s. (And, best of all, I couldn't get furloughed). There is where I started to get an education on a lot of things including airline economics, reliability, maintenance and many other things. Earl Jackson, our power plant engineer, really believed in working with the flight operations people. I was lucky enough to spend a lot of time during those years with him in our hangars and our engine overhauler's shops. Earl was responsible for over two hundred round engines and he could usually tell by looking at something why it had failed. He kept various samples of engine abuse or neglect in his office. One I remember was a piston that showed distinct evidence of ring land problems. One day he brought a bearing and assembly over from his bailiwick to show me what master rod distress and failure looked like. I'd compare it to a piece of steel that had been held to a grinding wheel until it turned varying shades of orange and blue from overheat. He wanted to make sure that the people training the pilots knew, and could pass along, those things that would prevent an engine from achieving the expected TBO or cause a failure. In Earl's world reciprocating load was a major villain.

There are several names for this villain - "reciprocating load" / "anti-thrust side bearing loading" / "negative thrust" / "underboost" / "detuning" but only one word clearly and unequivocally describes the results, **"B - A - A - D"!** Looking back, "getting the word" on this must have been very slow for those of us involved. We routinely pulled a throttle off on students in B-25s during the middle fifties, then left the prop synchronized with the good one for many minutes on end while completing the simulated failed engine problem. We'd never heard of reciprocating load and that faithful old 2600 put up with the abuse day after day and year after year. And that's exactly what it was, abuse. I'd like to be able to know what I know now and go back in time to Reese AFB to look at what the records concerning engine shutdown rates were. Also to be present at Aerodex or the Mobile and San Antonio AMA overhaul shops when they tore the failed engines down to see what the removed parts looked like. I imagine that possibly one hand didn't know what the other was doing or maybe it was a form of job insurance for the overhauler not to say anything to the operator. At any rate, nothing was ever mentioned about it to us that I know of.

After I had finished (I thought) this article I received an excellent, highly detailed report on this exact subject written some time ago by Herb Steward. After reading it I went back and rewrote several paragraphs to include the understanding gained as a result of the research described in his article. One of the things he mentioned was that both Wright and P&W spent much engineering time and money during the big radial's heyday trying to eliminate these faults. But economics intervened and by the mid-fifties their best talent was already preoccupied with turbines. By the early sixties serious research and development on the radial had all but ceased.

During the process of writing this I had a discussion with Al Morphew, one of our long time captains, to whom I gave a B-25 type rating last fall and who now flies it regularly. Al is one of the many retired captains here who never had to shut down an 1820 in anger, only in training (the 2800 was another story). Al mentioned the experiences of his dad, Herb Morphew, who came from Douglas as a tech rep right after the big war to work with Northwest setting up their procedures for the (then) new DC-4. One of the first things Herb found was while adapting the military C-54 manual for use in airline operation. The military called for 2300 RPM to be set on the downwind leg. (As a side note I just checked my USAF -1 for the C-54, dated 31 Mar 59, which was along about the last time I ever flew one and it still called for 2300 RPM.) Herb remembers saying to himself "well, that's something that'll need changing, it's hard on engines".

In defense of the military we should remember that they were dealing with large numbers of three or four or five hundred hour pilots when these high RPM on downwind leg procedures were first promulgated. Given this level of experience they probably placed a higher priority on being ready for a missed approach. Also, and probably more importantly, the military didn't exactly overly concern themselves with cost or how many mechanics something took.

Another source I talked to is JRS Engines. They said that they can tell almost immediately upon engine teardown the habits of the pilot. This is revealed by the condition of the piston ring lands **and** by the backside of the master rod journal. Let's consider some of the thoughts they expressed.

First of all, what can you tell by studying the condition of the ring lands? When subject to a boosted compression pressure the ring is designed to form an efficient seal between the cylinder wall and bottom of the ring land. Most of the supercharged round engines have keystone (wedge) type compression rings. With this design the boosted pressure forces the ring to stay in contact with the ring land. With low MP the ring is relatively free to flutter in the groove. If sustained, this results in (best case) damaged ring lands all the way up to (worst case) broken ring lands and rings. The higher the RPM, the greater the damage potential in the above scenario.

Now, on to the master rod problems. This failure is indicated to the pilot by rising oil temperature and falling oil pressure. When you see it, it's already happened and nothing you can do will undo it. It's bad enough that the engine has reduced itself to hash and a **BIG** buck overhaul. But, the oil cooler is junk until it's cut completely apart and cleaned. No amount of flushing is going to fix it. The same is true of the oil tank. Unless it is of the very simplest design where every bit of the interior is visible, it needs to be cut apart for cleaning before reuse. The whole system needs to be really cleaned of all the associated metal contamination.

There are several common causes of master rod failure. I'll mention the more common, however since all but one fall outside the scope of this letter I'll save an extended discussion for the future.

One is metal contamination, usually from some other failure such as a burned piston, broken valve springs, etc.

Another would be improper or complete failure to pre-oil the engine after a period of inactivity or after a overhaul. This is a long subject by itself, suffice it to say a strongly recommended procedure after you have pre-oiled is to remove the front plugs, then rotate with the starter until oil pressure is noted on the cockpit gage! Related to this is the case of an air lock in the oil pump after starting, admittedly rare, but a real reason to **check** that oil pressure faithfully at startup.

For those operators who shutdown their engines with the prop in high pitch in order to prevent rust, remember to get a really good oil pressure indication after start before selecting low pitch. This is an excellent opportunity to oil starve the bearing, especially with cold oil.

A common one would be a rapid RPM acceleration with cold oil after starting. Here is one area where my friend is absolutely right about not going far wrong using the military manual! They made sure they had adequate oil temperatures before advancing RPM for runup (as long as you don't get into that stuff about oil dilution and scramble takeoffs).

Now, the cause which we want to discuss in this bulletin. This happens when the pilot pulls the throttle back to a very low MP. I'm trying to think of a good way to describe the damage that can occur. Remember that on a four-cycle engine you'll have an intake stroke, a compression stroke, a power stroke and finally an exhaust stroke. Under normal conditions the master rod thrust bearing is loaded against the crankshaft from a multiplicity of directions as all the pistons progress through their assigned firing order. Remember that all the other connecting rods are linked to this one master rod and the pressures on this master rod journal are the constantly changing resultant of all the pressures exerted by these pistons. The crankshaft is drilled on the thrust side allowing oil access to this area when under power. The heat is carried away with the oil flow. No oil hole is drilled on the anti-thrust side, it's not considered necessary since the hole on the thrust side provides constant lubrication from pressurized oil flowing around the bearing. If this series of alternating forces is severely disturbed by a large reduction in MP then the propeller in effect is turning the engine. It might be helpful here to visualize the unloaded pistons trying to throw themselves out the top of the cylinders. In this case the load is continuously applied to this one (anti-thrust side) area of the master rod journal <u>where no oil hole is located</u>. In short order this "squeeze play" situation causes oil (lubrication and cooling) starvation resulting in failure to dissipate the frictional heat. This rapidly progresses from overheating to self destruction. In some cases during teardown the bleed holes have been found wiped full of silver metal from the multi-layered plating of the master rod bearing.

They also say that, <u>while it's bad for either</u>, the Wright probably has a little better ability to withstand this than the Pratt. This is due to the fact that the Wrights (comparing approximately equal displacements) have more master rod bearing area than the Pratts. As an example, the journal diameter of the 1820 is approximately 3 - 1/4" while that of the 1830 is only 2 - 5/8". The 2800 design was improved in this area over earlier Pratts but it is still substantially less than a Wright of comparable size.

Before closing we need to consider another thing my friend mentioned. He said "and besides, it's only for a couple of minutes maximum". Well, let's analyze that for a moment. At a nominal climb RPM the engine would complete something in the order of 9200 to 9600 cycles during this period. Keep these numbers in mind when you read the very last sentence of the last paragraph of this bulletin. Obviously there are times when we simply cannot avoid operating at less than 1" of MP for every 100 RPM. One of these would be on final approach even if we do leave the props at cruise RPM. But why not avoid it whenever we possibly can? It looks to me that here is one opportunity we can easily take advantage of when it's free (and quieter too).

Actually, I think the last bit about quiet should probably be one of the first things on everyone's mind these days. In the old days the military pretty much did whatever they wanted and that was that! Nowadays, we are the minority, especially the warbirds. With residential areas encroaching upon many of the airports we use everyone operating an aircraft that might be considered out of the ordinary should constantly have this on his mind. I've spent time on the telephone or ramp trying to explain a T-6 or B-25 to an irate airport neighbor and it ain't easy, friend! So, staying at cruise RPM on downwind has a lot of advantages you might want to try.

I guess I'd be remiss in finishing this discussion if I didn't mention a situation that a very good friend and highly respected aviator, Linc Dexter, has noted since this subject has begun to receive a measure of attention. This has led him to believe sometimes the pendulum swings too far or fast in pilots now attempting to avoid even a hint of underboost. While giving formation dual in T-28s he has seen many times where the pilots have advanced the throttle without regard for the overboost limitations of the engine. He states that if he hadn't been there to grab the throttle to limit MP the limitations would have been exceeded to the point where a engine change would have been required according to USN policy. I really have to strongly reiterate that, if you need the RPM, then get it increased before you shove the throttle up. None of these pages is meant to condone or excuse overboosting, the results of this could be rather instantaneous while the results of underboost is more likely to be a longer term thing. Everyone has to learn and that was the reason for the initial WW II policy of high RPM on downwind, they were playing the percentages considering their high percentage of low time pilots. These pages are written so we can play the percentages also rather than to blindly conform to some fifty year old manual <u>but use your head</u>!.

Obviously the 1" of MP for every 100 RPM is only a rule of thumb since those are the only instruments most airplanes have. If you've got a torquemeter or BMEP (Brake Mean Effective Pressure) gauge, then you can really see what you're doing. But the 1" rule has served well over the years and enjoys wide acceptance.

So - - it's your engine and your pocketbook! A little planning should go a long way in avoiding the need to pull the throttle off and point it at the ground. You've also got the gear and flaps and sometimes another 360° turn doesn't hurt either. Another thing, if you really need less MP you can also pull the RPM back to maintain the loaded balance. This is the same thing we do when simulating a feathered prop, using 15"-1500 RPM. Formation leaders - keep in mind what your throttle movements do to your last wingman! Finally, in those rare circumstances where you simply can't avoid it, one of our most experienced engine mechanics, Don "Jingles" Dufresne, has a thought you might want to remember. He says every time you pull the throttle off you'd better remember the punch line to the old joke where the engine says, "that's **one**".