Matching Pistons and Crankshafts for Warner 165 Super Scarab Engines

By W.B. Richards

Following the failure of my 165D Warner SS from lack of oil, I found myself involved with the rebuilding of several Warner engines. The engine failure caused a forced landing of my Bucker Jungmeister in a mountain-side clearing of the Santa Cruz Mountains. The failure resulted from the oil tank flop tube hanging up in the inverted position during aerobatic flight. This caused the master rod bearing to seize, the master rod to fail, and a complete wipe-out of the master rod, link rods and crankshaft, plus substantial damage to the cylinder skirts and pistons.

The search for repair parts coupled with my research and experiments to rediscover the engine balancing formula for radial engines uncovered several interesting aspects of the 165 Warner engines previously unknown to me. I feel this information may also be of interest to others flying behind or rebuilding Warner engines.

There has been much discussion of "light weight" and "heavy weight" 165 SS crankshafts, coupled with the observation that some had bronze counterweights while others used cast "Meehanite". Actually there is something to all this.

Warner 165 SS engines were made in four different models. The 165B and D models were designed for use with two-position or constant-speed propellers and used a longer nose case and a crankshaft about one inch longer than the basic 165 and 165A models. In reviewing all available literature including overhaul manuals, factory balance data, service bulletins, parts lists and textbooks, plus my own measurements of numerous 165 crankshafts, I can discover no differences in the balance of the engines due to the factory's use of bronze versus Meehanite for the counterweights. The choice of material for the counterweight seems to have been dictated by materiel availability. Shape of the counterweight was apparently dependent on the material selected, its density, desired finished weight and the crankshaft/engine design which required the counterweight center of gravity to be at a particular radius from the centerline of the crankshaft.

Pistons, however, are another story. Early 165 engines used a 3-ring piston (Warner part no. 7939) that weigh an average of 784.7 grams. Later 165 SS engines were equipped with a considerably heavier 4-ring piston (Warner part no. 8549) that weigh an average of 905.3 grams and also used heavier piston pins (Warner Assembly No. 8605). Warner Service Letter No. A-13 dated July 26, 1943, recommends that engines with the #7939 pistons be overhauled every 300 hours. The letter advises that the heavier pistons and piston pins can be installed in these earlier engines but requires the installation of new counterweights and rebalance of the crankshaft. These pistons are further physically distinguished since the #7939 is smooth, flat-topped with a chamfered edge at the top while the #8549 is domed with valve clearance cutouts and no chamfer.

To further confuse matters, a number of 165 SS engines were sent to Australia and other countries as both original equipment and spare engines for Fairchild 24W aircraft during World War II. Numerous of these engines, which appear to be basic 165D models, have been brought back in recent years and, in fact, the engine in my Bucker Jungmeister was one of these “Australian” engines. These engines used still another type piston that seems to be identified as the B-5881. This is a 4-ring piston that is flat-topped, has the top-edge chamfer plus valve clearance cutouts, and weighs 825 grams. (All piston weights given here are less rings and piston pins). This “Australian” piston also uses the later piston pins.

So there are three different pistons of three different weights, which obviously means crankshafts of three different weight counterweights. Since the engines were factory balanced for their originally installed pistons, any change to late #8549 pistons in either the early model or the “Australian” engines, without rebalance of the crankshaft, will probably result in an unacceptably rough running engine.

Warner engines were factory balanced using a formula (Warner Engineering Report A-8-1, dated 5-18-45) of:

$$(1)\ W_x = .865\, W_r + .5\, W_p$$

Where: W_x = total bob-weight to be hung from the crankpin
W_r = total master rod/link rod assembly weight
W_p = total piston weight including rings and piston pins

The weight of the counterweights were then fine-tuned by drilling out or adding weight to the four balance holes in the counterweights using a “radius factor” of .642 to account for the difference between the crankpin radius and the longer counterweight drilling hole radius (W_{cw} = .642 W_x). Finally, the Warner factory mounted the engine on a “jiggler” stand and spun it as operating speed with a DC motor. Adjustable weights placed on a disc mounted on the prop shaft allowed final balance adjustment to minimize engine vibration on the stand.

Application of classical balance formulas to the Warner engine gives a formula of:

$$(2)\ W_x = W_{rot} + .51\, W_{recip}$$

Where: W_{rot} = total weight of the rotating part of the master rod/link rod assembly
W_{recip} = total weight of the reciprocating parts of the master rod/link

rod assembly + pistons, piston pins, and piston rings

Formula (2) is somewhat more precise than the factory formula. Applying the factory formula (1) to measured engine weights nearly always yields bob-weight values lighter than actually measured.

Therefore, we find we have three different piston weights; three different crankshaft weights and they shouldn't be mixed without rebalancing the crankshaft. Weight to be added to or removed from the counterweight can be calculated by either formula (1) or (2), although formula (2) will be more precise. Whatever combination is used, however, should probably be noted in the engine logbook to aid whoever overhauls the engine next time.

Finally, it is understood that the factory formula (1) applies only to Warner engines since it is a function of the particular design and weight distribution of the Warner master rod/link rod assembly. The Warner factory formula, if modified to apply to a Kinner, for example, would become:

$$(3)\ \ W_x = .855\, W_r + .5\, W_p$$

But would still not be as exact as the classical formula for Kinners, which is:

$$(4)\ \ W_x = W_{rot} + .508\, W_{recip}$$

(See Engine Balance – Part 1) which is based on vector analysis of reciprocating engines.