Pete Plumb's Pegasus DP-1 O-100 Prototype

Pete Plumb with his two-cylinder O-100 engine at EAA AirVenture Oshkosh 2014

Photos and Story
By Patrick Panzera

Pete Plumb
Pegasus Power Systems Inc.
330 Aviation Street
Shafter CA 93260
661-391-9464
http://flypegasuspower.com/

Pete's aviation journey began at a young age, with his private pilot father introducing him to the joy of flight. In 1967 while Pete was in the 5th grade, his family moved from Durango CO to Whittier CA, where roughly once a month he and his father would depart Fullerton Airport in a rented Cessna 150. Pete loved every second of it and needless to say, has suffered a life-long addiction. By the time Pete turned 13 he was flying from Hemet airport in sailplanes, then on to Tehachapi where he soloed at the age of 14 and eventually earned his glider and power licenses while living in Bakersfield CA. About this same time, hang gliding was making a big advance and Pete built an early bamboo delta wing kite (covered with 4 mil clear low-density polyethylene sheeting, aka visqueen) that he still has— it now being considered an antique.

Like many of us, Pete's adolescence was filled with building and flying balsa aircraft, taking it to the next level by designing and building his own, beginning with control -line and moving up to radio control. It should go without saying that between flying sailplanes and hang gliders, building and flying model aircraft, and as working as a lineboy at Tehachapi to earn his power license and pay for all his other aviation-related pleasures, very little time was left to get into any of the usual traps teenagers see today, or even back then.

After high school and at his father's urging, Pete went on to spend a year at Colorado State University, but he still didn't know what the rest of his life would bring. In hindsight, Pete realizes that he should have gone on to San Luis Obispo for an aeronautical engineering degree but instead of that, he came back to Bakersfield in 1975 where he was hired at Vern's Wing Shop to build wooden aircraft wings. After roughly 18 months of that Pete was persuaded to open his own wing shop, Wood Wing Specialty, at the nearby Shafter airport, under another person's IA (inspection authorization) who would sign off his work. A few years later, the FAA recommended that he get a repair station certificate— which he did. Since then, he's built a LOT of Stearman wings, among others.

Not long after Pete got started at Shafter, Paul MacCready also set up shop at Shafter, building the Kremer Prize winning *Gossamer Condor*, of which Pete became a part. That put Pete in good company with some great aerodynamic mentors who assisted in the process of freeing his mind to come up with his first full-scale flying aircraft, the single seat Cracker Jack.

Pete at the controls of his original design, wood and fabric Cracker Jack sport plane.

With his business maturing, and with drooling over the notion of owning a Cub but not really feeling he could afford one, he decided that he could build an all wood Cub-like homebuilt. What pushed him over the edge was seeing his first one-half Volkswagen engine. With some actual butcher paper from Albertson's grocery store, Pete designed his Cracker Jack, taking cues from the Piper Cub, the Aeronca Champ and the Cessna 150— since those are the planes that he was most familiar with.

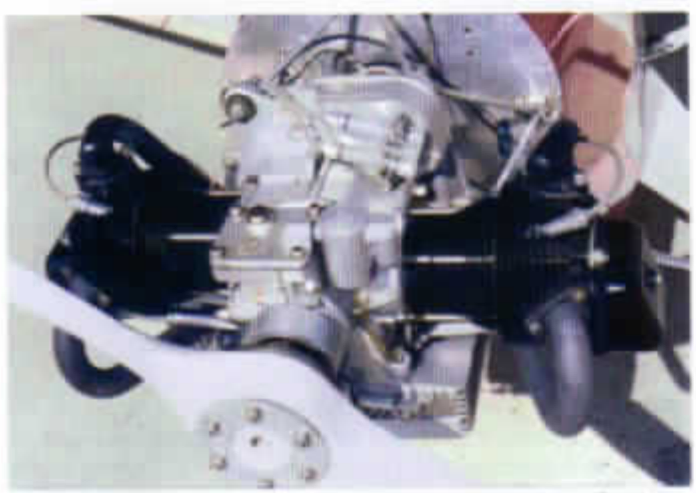
The proverbial napkin scrawl that became the Cracker Jack

Beginning with the tail feathers, Pete moved on to build the fuselage and then the wings. Not being a welder, Pete sought out help from his friend David Massey for all the chromoly bits including the landing gear, control stick, cabanes and struts for his little parasol taildragger. Interesting side note, before covering his prototype Pete hadn't ever covered a wing he built— now he does all the time, so one could say that building his little plane was a great business decision. The first flight of the Cracker Jack took place in October 1982, just after bringing it home from debuting it at Oshkosh. Pete was very pleased with its flying characteristics, having spent over 200 hours at the controls, and he even sold plans to the aviation community. After a poor decision to move his business and young family to Tehachapi, and after being done fiddling with the engine he had chosen to for his little plane, Pete ended up putting the whole Cracker Jack program on the back burner until such time that he could devote the proper amount of time to nurture the design and come up with a better engine to power it with. And in Pete's own words, "that time is now."

THE DAF ENGINE

The whole time Pete flew the Cracker Jack he knew it was underpowered with the little horizontally opposed, air-cooled twin engine he chose— that being an automobile engine pulled from the *DAF Daffodil*, a very compact little car built from 1961-1967 by a Dutch truck manufacturing company in Eindhoven, Netherlands.

According to *Wikipedia.com*, the 746 cc four stroke air cooled two-cylinder engine has a 65 mm stroke with a bore of 85.5 mm. Power output was advertised as 30 bhp (22 kW), and a maximum speed of 105 km/h (65 mph) was claimed. 0-50 MPH time was a 29 seconds, as tested by the Consumers Union in the United States.



The little DAF Daffodil engine was used to power the prototype, but even after increasing the 746 cc engine to 950 cc, it still didn't make the power Pete was hoping for. Note how similar the engine is to the 1/2 VW.

But Pete's engine was only based on the DAF 844 case, crank and heads and used VW (Cima/Mahle) 90.5 mm cylinders and pistons, bringing the displacement up to 950 cc. In order to make them fit the case, he had to turn roughly 0.025 inches off the cylinder skirt to fit into the case and add a 0.060 inch thick sleeve around the top of the cylinder to fit the head. The stock head studs fit the cylinder perfectly. He also had Carrillo make a set of H-beam rods with the DAF big end and VW small end and specified a longer center-to-center length to achieve the compression ratio of 8:1 that he needed.

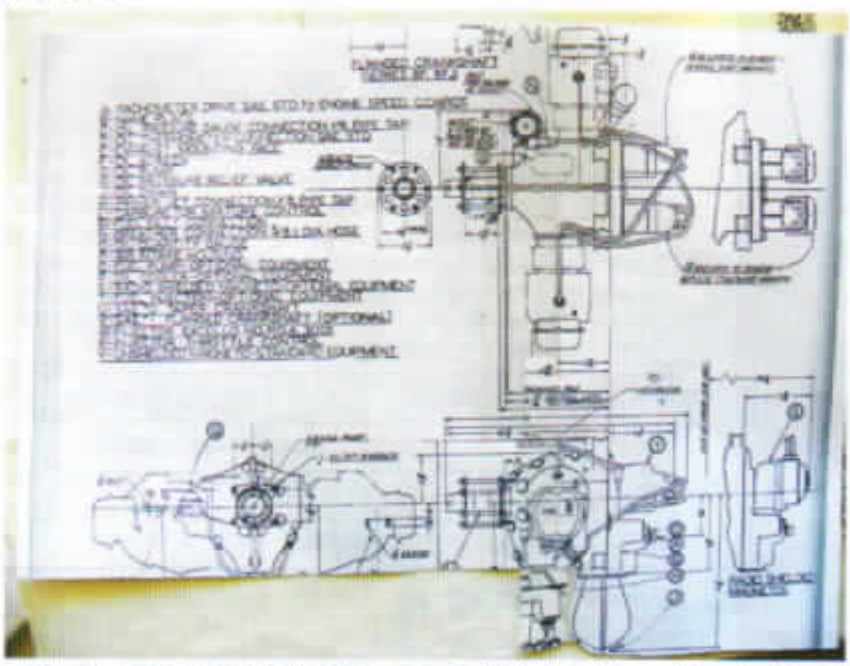
After all that effort to recreate the DAF, Pete just wasn't satisfied with the performance of his Cracker Jack. He wanted it to carry more weight, operate out of higher altitudes, and wanted it to have a higher service ceiling. He was already running the engine at 4,000 rpm so there just wasn't any more power available from this little engine; it was maxed out. Forced induction would have been an option, but there were too many unknowns, plus the little DAF engines weren't readily available in the US.

AN IDEA IS BORN

One day while walking past an open hangar, Pete got a good look at the Continental A-65, which started his wheels turning. He pulled out his trusty tape measure and started going over the engine with a fine-toothed comb, trying to figure out just how to go about cutting the thing in half to make a two-cylinder engine from it. The quandary was that if he cut the back off the engine, he would lose the accessory case, but if he cut the front off, he would lose the huge front bearing. "How about the middle," he thought? Cut it out, weld the case back together, bingo! A two cylinder case could be made from a four. Realizing that O-200 parts are easier to buy new than those for the A-65, and that it certainly couldn't hurt to have the extra cubic inches, the idea for the O-100 was born.

Pete with his crew and the Pegasus O-100 at OSH 2012

This epiphany came to him in the mid 1990s— so he's been kicking it around for quite awhile. And it was during that multi-decade gestation period that Pete realized it would be easier in the long run to go into the production of building this engine in quantity using brand new, purpose-built engine cases than it would be to cut and weld old ones. So Pete began learning about what it would take to cast custom parts. On January 3, 2012 Pete started building the patterns for his O-100 crankcase and by July of that year he had a full mockup of the completed engine, including a prototype casting of one half of the case. About two weeks later he debuted his engine concept at Oshkosh in order to gain feedback from potential customers and hopefully connect with people who could assist in the manufacturing process. That's where I had the pleasure of meeting Pete, and I've been following his progress ever since.



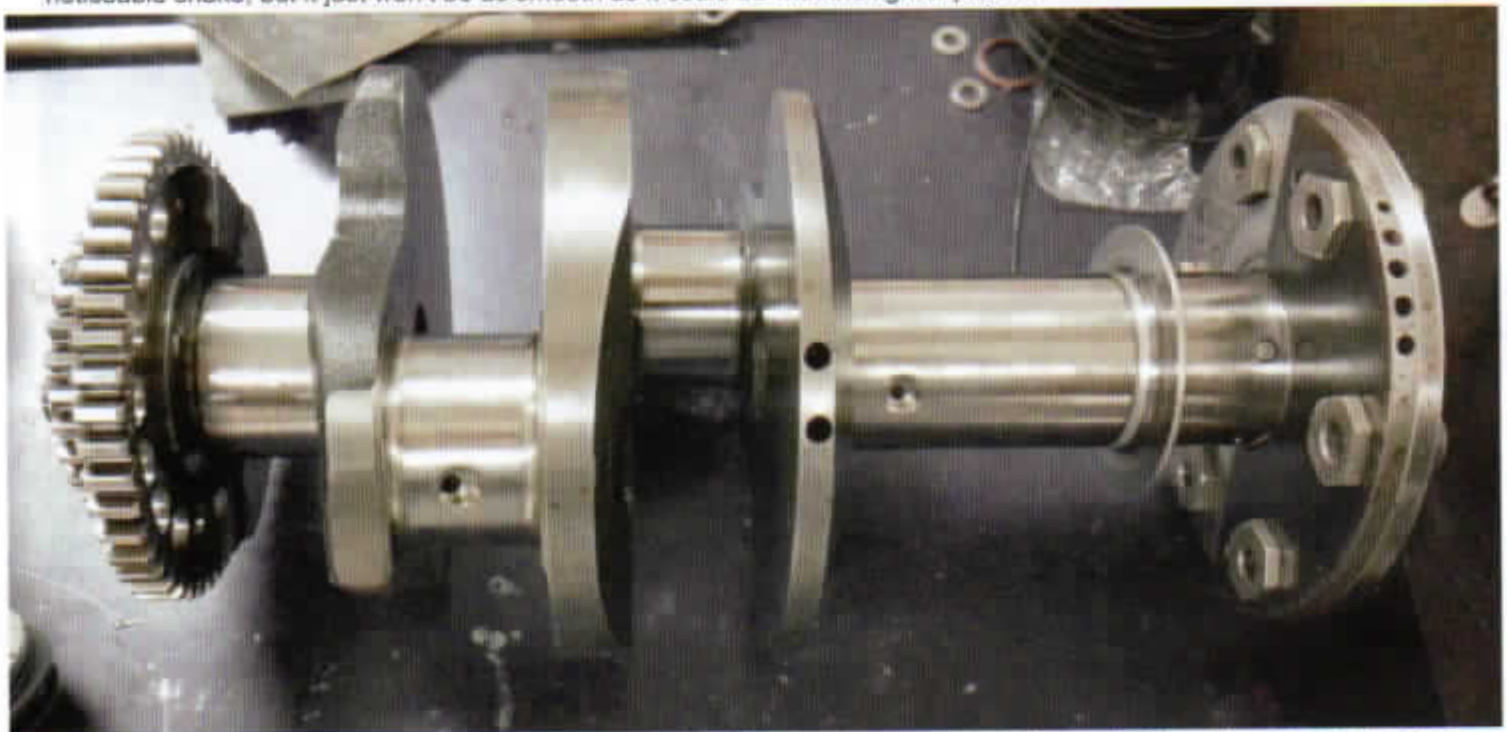
Early on, Pete found this line drawing of a little Continental that he literally cut and taped back together to verify the geometry of his idea.

IT'S A KIT ENGINE

From the first thought of going into production, Pete knew it would be best to simply offer the custom parts, leaving the customer responsible for rounding up the balance of the pieces to make an engine. The idea was for the builder to find a core O-200 and rather than cut the case and crank, he'd simply purchase Pete's proprietary parts kit and bolt together his new 1/2 O-200.

The prototype engine Pete ended up building and running on his test stand has a 0.3-inch longer connecting rod than specified (for all the right reasons), using a shorter, lighter piston. Pete has since backpedaled on that concept in order to give the builder the choice of using a Continental piston if they so choose. This is mostly to hedge against those who might accuse Pete of taking advantage of his customers by forcing them to buy a piston from him, so the kit will be offered both ways.

Should the customer elect to use the Continental piston, they'll only have a 7:1 compression ratio as opposed to the 9:1 that the engine is designed to take advantage of. Unfortunately for Pete, the project has now gone from one basic kit for the masses to two or three optional kits. When they're dynamically balanced during the production process, they will be balanced with Pete's custom piston. Using the slightly heavier Continental piston will not cause the engine to have a noticeable shake, but it just won't be as smooth as it could be with the lighter piston.



The original prototype crankshaft as pulled from the test stand engine

THE CRANKSHAFT

The entire year following Pete's 2102 Oshkosh adventure was spent working out the crankshaft issues. Not wanting to cut and weld on a $4,000 O-200 crankshaft, he hit the library and taught himself how to design a crank from scratch using the book, *The Internal Combustion Engine in Theory and Practice: Vol. 2* by CF Terry. He used it as his "Bible" as it has formulas, empirical data, and everything else needed to feel confident with a clean-slate crankshaft design. What's not covered in the book is ADI (Austempered ductile iron), which is the material chosen to use for the crank after much research—and after taking a lot of flak from his peers. When one thinks aircraft crankshafts, they usually think forged steel, not cast iron. A lot of the people who gave him the most grief don't realize that in heavy manufacturing, ADI is being used to replace the forging process, even in automobile applications.

A thorough, joint Motor Industry Research Association / Cast Metals Development Laboratories study on ADI cranks concluded that properly fillet rolled ADI crankshafts exhibited fatigue properties comparable to, or better than, the best forged and heat treated steel cranks.

In another documented crankshaft study conducted at the Manchester (England) Materials Science Center, the authors demonstrated the performance capability of ADI crankshafts in one cylinder commercial and four cylinder automotive engines. They noted a 10% rotating weight reduction and an estimated 30% cost savings.

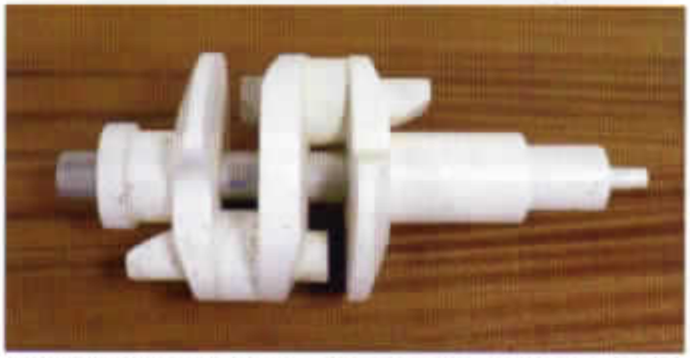
As of this writing ADI crankshafts are employed in high volume commercial applications and low volume automotive applications. As the specific power requirements for automotive engines are increased, ADI may become a more viable alternative to the heavier, more expensive forged steel crankshaft.

So Pete went forward and designed his crank to be cast with ADI using a set of patterns and molds he hand-

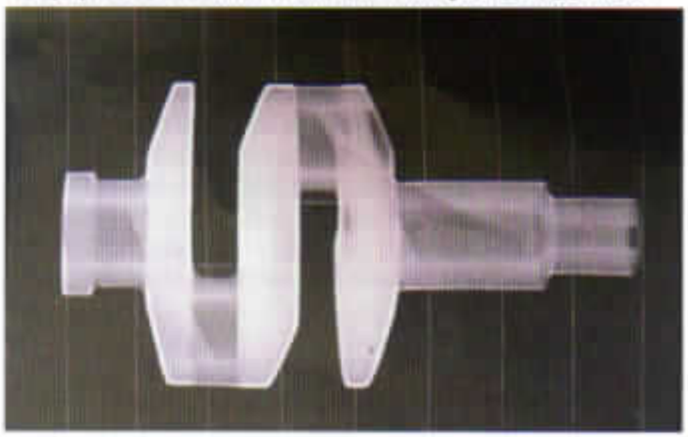
Engines being developed by the automotive industry require weight reduction in parts that will be required to handle increased power. Automotive design engineers have evaluated ADI as a candidate for both the replacement of forged steel crankshafts and the upgrading of existing ductile iron crankshafts. The Ford Motor Company made an exhaustive three year study of ADI crankshafts and concluded that they met all design criteria. During this study, the importance of fatigue testing was identified, and the following results were obtained:

Fatigue Test Method	Fatigue Strength	
	ksi	MPa
Constant Strain Amplitude	55	380
Rotating Bending	65	450
Reversed Bending	60	415
Reversed Bending (fillet rolled)	90	620

made in his shop and had two castings produced. Admittedly they were rough, as it was a learning process. Not knowing exactly where and how much it might shrink in the casting process or grow in the austempering process, to be on the safe side Pete elected to err on the side of being oversized and machining it back to tolerance. Another decision to try and use the Continental prop flange on his new crank proved to be more trouble than it was worth so the second generation crank has the flange cast into the final product, including the counterweight that's bolted to the prototype prop flange.



Here's Pete's original crankshaft pattern. The extra bits you see are core prints used for locating the cores that make the part hollow. Note the lack of a flange. His new pattern has the flange cast integrally. Below is a photo of a paper printout of the x-ray of his first crank. I note that it's paper to account for the distortion you can see here.



Using the factory O-200 crankshaft specifications, Pete made an exact duplicate, especially with respect to the generous radii and fillets at each 90-degree intersection. Other than losing two journals and adding some counterbalance to make up for the weight of two missing pistons and connecting rods, the crank is nearly identical. Besides the desire to stay compatible with all other factory parts, the reason for this is because it works. The only intentional deviation from the O-200 blueprints is the width between the webs of the crank's rod pin. While the rod journals remain "stock" for an O-200, the rod pin width is 0.003-inch narrower, as measured between the webs, so that a stock Continental rod can't ever be installed. This for two reasons; the first being that the crankshaft is balanced with the rods and pistons in place that will be shipped with the engine, and the second is that the new H-beam rods (seen in the photo at right) are far lighter than the Continental's.

Factory 7:1 compression ratio O-200 piston on the left, Pete's custom 9:1 short-skirt piston on the right.

Needless to say, in each case bad things would happen if an owner decided to replace one or both of the rods with a stock Continental rod, but even with this narrowed tolerance and in keeping with the desire to use stock O-200 parts, the stock rod bearing still works with the custom connecting rod.

Another deviation from the factory specifications of the Continental crankshaft is the flywheel in the center of Pete's crank. The center cheek of the crank is totally round, six inches in diameter and is 3/4-inch thick solid ADI. The original idea was simply to give it some rotating mass, and to offset this added weight, the crank pins are hollow, unlike the on O-200 crank. Part of Pete's teaching himself how to design an engine disclosed that a round center cheek makes for a strong crank and that

same book also gave him the formulae to determine the ratios for the diameter of the crank pin lightening hole. While it might seem obvious that this center cheek would be useful for removing material for balancing, that's not what it was used for. The machinist balanced the crank on the internal and external counterweights.

Pete Plumb at his shop in Shafter CA, showing the pattern for casting the inside of the crankcase.

When Pete made his original patterns he basically free-handed it. Now that he's got it all modeled in Solid Works (a professional CAD program), the next generation pattern will literally be digitally printed to very close tolerances, eliminating a lot of the need for balancing. The way it'll work is the printed pattern will be used to make a mold from which a pattern made from a more durable material will be created. The close tolerance pattern will also reduce the amount of material that will need to be removed from the machined surfaces.

INTAKE

The carburetor of choice for the DP-1 O-100 is the up-draft, Marvel Schebler MA-2 so the intake manifold that comes with the kit will be cast with a matching flange and a 1-3/8-inch diameter inlet. And as you might imagine, instead of the "spider" having four legs, this one will only have two. It is also designed to hook right up to the standard intake tubes and connecting rubber couplers—another reason for starting with a donor engine. The spider will also be bolted to two of the case half bolts, similar to the way the welded spider is attached on the prototype engine in the photo at right.

The prototype's welded-aluminum oil tank can be seen just behind the Zenith carb that was used for testing only.

OIL SYSTEM

Nothing in the O-100 oil system is modified from the O-200 configuration, including the O-200 accessory case; the difference is with the oil tank. Originally Pete was going to use a stock A-65 oil tank as it only holds four quarts, but he just wasn't happy with how far down it hung. He designed and built a low-profile tank that he's not completely set on using— but it worked well on the prototype and ultimately it's up to the engine owner anyway. If need be, the stock 0-200 tank and pickup tube can be used, but it would just be a bit excessive. In fact, any oil tank from the A-65 through the O-200 will fit. Pete simply used a 12-inch length of 4-inch diameter thin-walled aluminum irrigation tubing capped off at both ends with a flange in the middle that mounts to the bottom of the engine in the stock oil tank location, and with an 1-1/4 inch tube welded next to it for filling. Since the engine case is smaller than an O-200 it only holds about half a quart, so Pete made his prototype oil tank hold three quarts total when the engine isn't running.

ACCESSORY CASE

Needless to say, utilizing the stock O-200 accessory case gives the engine flexibility to all the accessories that the engine needs, such as a way to hang the magnetos or any other ignition system designed to replace the

mag, (such as the E-Mag we covered in issue 106), an electric starter and an alternator— in addition to the oil pump, oil tank, and mechanical tachometer drive. The new engine case is machined to accept the donor engine's accessory case— it just bolts on.

THREE DIFFERENT KITS

The first kit offering will include the case halves (and studs), the custom H-beam connecting rods, the ADI crankshaft complete with the cam gear which also runs the starter, alternator and the magnetos, and the cast two-cylinder intake manifold. Another kit will have everything listed above but will also include the custom pistons. The final kit will include every single part necessary to build the engine— excluding oil, fuel and electricity for the optional starter. The plan is also to bring online a website that has every single piece one might want, that you can just click and add to your shopping cart— including a turn-key engine. While the shopping cart section of the website isn't open yet, the web address is: www.flypegasuspower.com

FUTURE OF THE CRACKER JACK

For the past 20 years the drawings of the Cracker Jack have been going through a revision process that brings to the table the literal decades of learning that Pete's gone through. So the plans are that once the engine is ready, Pete will build Cracker Jack II which will look like and measure about the same as the original, but will have a new airfoil, a higher gross weight, and just be more refined in general. Pete commented that it was "a little bit drafty with that open cockpit!" and went on to say that Cracker Jack II will have a fully closable cockpit complete with cabin heat. Once it's proven with the new engine, Pete will once again go back to offering plans as he did before.

The prototype was hauled back from Tehachapi when Pete moved back to Shafter and was stored in pieces for many years. Not long ago, he knocked the dust off, put it back together, and took it for a very short hop. There's a video of this flight on YouTube:
www.tinyurl.com/cracker-jack-flight The little Cracker Jack sport plane is now retired and resting safely in the rafters of Pete's hangar, over his Aeronca.

PEGASUS DP-1 O-100 SPECIFICATIONS

Type: Four-cylinder, air-cooled, horizontally opposed	
Bore:	4.06 in (103.1 mm)
Stroke:	3.88 in (98.6 mm)
Displacement:	100.5 in³ (1.65 L)
Length:	Not Available
Width:	31.56 in (801.6 mm)
Height:	23.18 in (588.8 mm)
Dry weight:	Not Available
COMPONENTS	
Valvetrain:	Hydraulic lifters, two pushrod-actuated valves—one intake, one exhaust—per cylinder
Fuel system:	Updraft carburetor with manual mixture control
Fuel type:	Not available
Oil system:	3 US quart (2.85 L), wet sump
Cooling system:	Air-cooled
PERFORMANCE	
Power output:	57 hp ESTIMATED (74.57 kW)
Compression ratio:	9.0:1 optional 7.0:1

BASIC KIT COMPONENTS

- Heat Treated A356 Cast Aluminum Case w/studs
- State-of-the-Art, Super Strong, Fully Engineered, ADI, Flanged Crankshaft
- Fully Assembled, Dynamically Balanced Crankshaft/ Gear Assembly
- Custom, Light Weight "H" Beam Rods
- Custom, Light Weight, Forged 9:1 Pistons w/Rings
- Custom Two-Cylinder, Flange Mount Manifold
- Assembly Instructions and Video

The designation "DP-1" is a tribute to Pete's nephew, David Everett Plumb, who was lost in a mid-air collision with a Hawker Sea Fury TMK 20 that was overtaking his Cessna 210E on April 27, 2014. The Sea Fury, named "Dreadnought," regularly competes at Reno.

David was 33.