

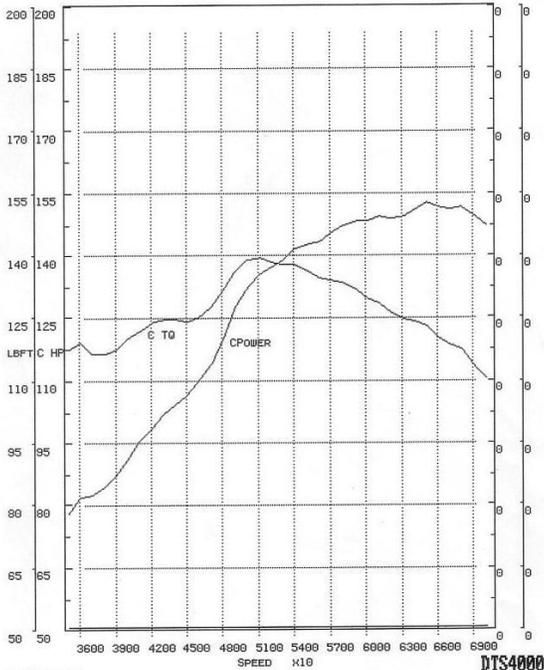
DYNO TESTS (for twin plug engine development tests, please read the Engine Development Article)

The dyno tests on these pages are the result of several years of testing. Below is a sample of the original data as it is printed from the DTS dyno computer, but most of the tests are charted in a standard Excel format to make them easier to compare. Keep in mind that most tests shown are the best runs once jetting and timing were optimized unless specifically noted. All tests include the specifications of each engine and all have been run using standard Premium pump gas available in California unless otherwise noted. All tests are run using stock timing advance of 36 degrees unless otherwise noted. Other components are stock unless noted. Camshafts are listed as measured by us at .050", not as advertised.

The test curves are plotted using a full throttle sweep from the beginning RPM to the max. RPM. Depending on the specific engine and the desired maximum RPM, the chart may begin sooner or later. For most lower

RPM engines the sweep begins at 3000 to 3200 RPM and ends at 6000. In order for the computer to plot the test numbers it's necessary to rev the engine approximately 300 RPM past the shown maximum. For this reason, some of the tests are limited to under 6000 RPM. Most engines won't accept full throttle below 3000 RPM with the static dyno load, that's why the tests begin at or above 3000.

SAMPLE DYNO SHEETS:



POR356I.D35
 T11:31 D05-21
 Engine PORSCHE 356I 1925cc
 TIMING:25DEGREE TORQUE
 AFTER OILCHANGE TO SYNTHETIC
 C_TQ 139.29 lbft @5100
 CPower 152.31 C_HP @6500
 0 @0
 C_TQ 0 lbft @0
 CPower 0 C_HP @0
 0 @0

CAROLU Engineering LLC
 925 West 16th Street
 Newport Beach, CA 92663
 949-722-3917

Date 05-21-2004 Time 11:31:38

T11:31 D05-21 Engine PORSCHE 356I 1925cc
 Timing:25peak torque After Oilchange to Synthetic
 updated with motec

FileName : POR356I.D35
 Mode : A-Sweep

Speed	CPower	C_TQ	Oil	Oil°	A/F	A/F	Fuel_P
rpm	C_HP	lbft	psi	°F	Left	Right	psi
3500	78	117	47.7	182	12.93	13.86	60.3
3600	81.6	119.1	48.6	182	12.62	13.44	60.3
3700	82.1	116.6	49.2	182	12.44	12.99	60.3
3800	84.2	116.4	49.7	182	12.36	12.87	60.3
3900	87.3	117.5	50.2	182	12.35	13.02	60.3
4000	91.3	119.9	50.6	182	12.38	13.09	60.3
4100	95.3	122	50.9	182	12.41	12.9	60.2
4200	98.9	123.7	51.2	182	12.46	12.75	60.2
4300	101.8	124.3	51.5	182	12.45	12.66	60.2
4400	104.3	124.5	51.7	182	12.41	12.6	60.2
4500	106.2	123.9	52	182	12.21	12.41	60.2
4600	109.4	124.9	52.2	182	12.09	12.31	60.2
4700	114.2	127.6	52.4	182	12.02	12.29	60.1
4800	120.2	131.5	52.8	182	12.05	12.28	60.1
4900	127.1	136.2	53.1	182	12.16	12.37	60.1
5000	131.9	138.6	53.5	182	12.35	12.48	60.1
5100	135.3	139.3	53.8	182	12.5	12.59	60.1
5200	136.8	138.2	54.2	182	12.64	12.63	60.1
5300	138.7	137.5	54.5	182	12.61	12.67	60
5400	141.5	137.6	54.8	182	12.49	12.81	60
5500	142.7	136.3	55	182	12.36	12.87	60
5600	143	134.1	55	182	12.21	12.71	60
5700	145.1	133.7	55.1	182	12.18	12.74	60
5800	147	133.1	55.2	182	12.13	12.71	60
5900	148.1	131.8	55.4	182	12.1	12.6	59.9
6000	148.2	129.7	55.6	183	12.23	12.52	60
6100	149.3	128.6	55.7	184	12.3	12.58	59.9
6200	148.5	125.8	55.9	184	12.43	12.45	59.9
6300	149.3	124.5	55.5	184	12.47	12.67	59.9
6400	150.6	123.6	55.4	185	12.51	12.85	59.9
6500	152.3	123.1	55.8	185	12.6	13.06	59.9
6600	151.1	120.2	56.6	186	12.46	13.15	59.9
6700	150.9	118.3	56.2	187	12.43	13.3	59.9
6800	151.6	117.1	55.7	188	12.3	12.88	59.9
6900	148.8	113.3	55.5	189	12.18	12.56	59.9
7000	146.9	110.2	55.6	189	12.11	12.53	59.9

[Average data]
 5250 126.1 126.1 53.4 183.2 12.36 12.76 60.1
 [Inertia factor] .81 [Time] 7.6 Secs

1735cc Hot Rod 356 SC engine

129hp@6200 / 121ftlbs@4900

86.5mm cast iron cylinders w/custom JE forged pistons w/ 10.2:1 CR

Scat lightweight crankshaft 74.0mm

Carrillo rods

10.5lb flywheel

911 piston squirters, full flow oiling system

5" front pulley

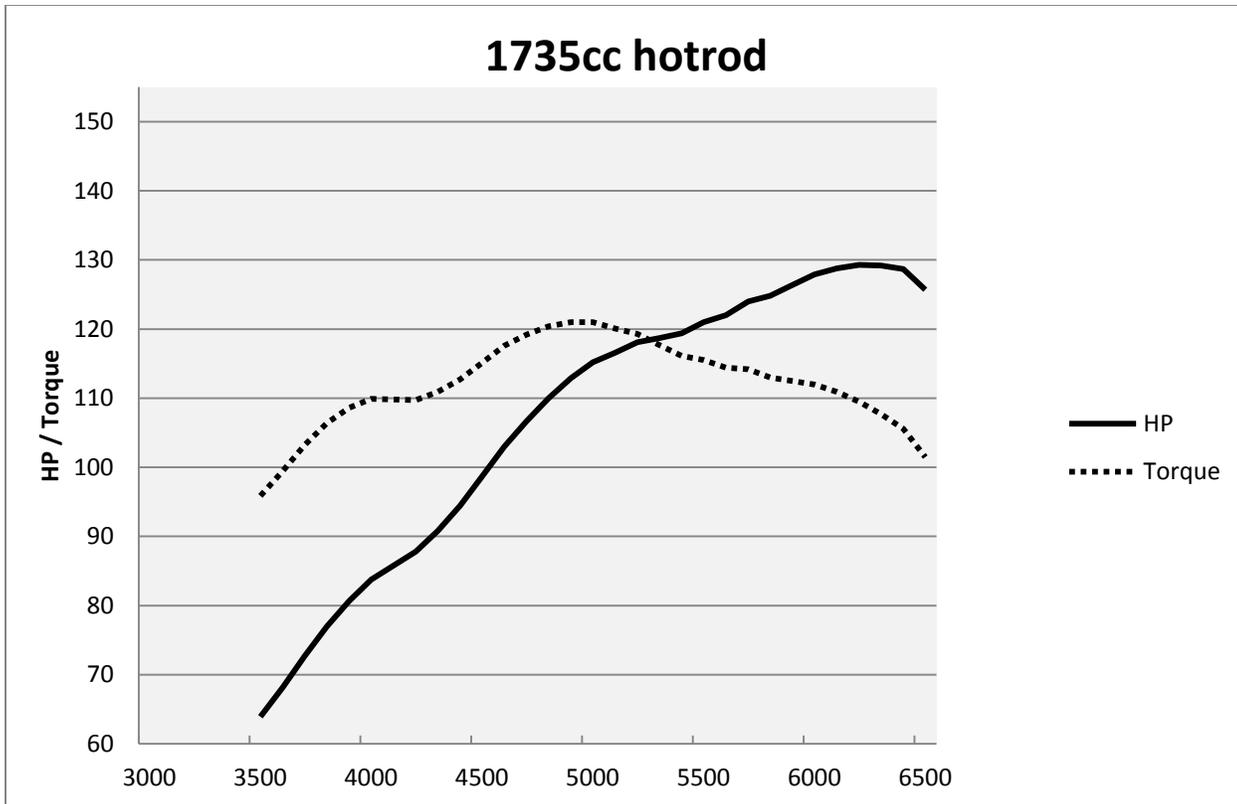
44IDF Webers w/36mm venturis

Custom 5" aluminum air horns (no air cleaners)

Elgin 7208 HL camshaft 248 degree, .370" lift

42mm Type-4 intake valves / stock 34mm exhaust valves, double springs, ti-retainers

Custom WR 4:1 header with 36x1.5" primaries and 10" stinger/resonator



This was the first engine we dyno tested at Carobu. The intakes were ported to flow into the valves, and the chambers were unshrouded, but the intake manifolds at the gaskets were kept stock. Peak flow at .500" was later tested at 176cfm. The long primary pipes of the WR 4:1 header gave an excellent boost to the mid range torque, but with a VERY sporty sound.

1720cc Twin Plug (1720TR)

131hp@6400 / 121ftlbs@5300

248-degree camshaft with .370" lift (Elgin 7208 HL)

Special LN Engineering 86mm "Nickies" cylinders using custom JE forged pistons with 10.50:1 compression ratio.

Bored case with 911 piston squirters installed, full flow oiling system.

Scat lightweight crank with Carrillo rods.

WR 10.5lb Flywheel kit with aluminum 200mm pressure plate.

Aluminum 5" front pulley.

Custom twin plug distributor using a MSD CDI box firing two Bosch CDI coils. 25 degrees maximum timing advance.

42mm Type-4 intake valves / stock 34mm exhaust valves, double springs, ti retainers

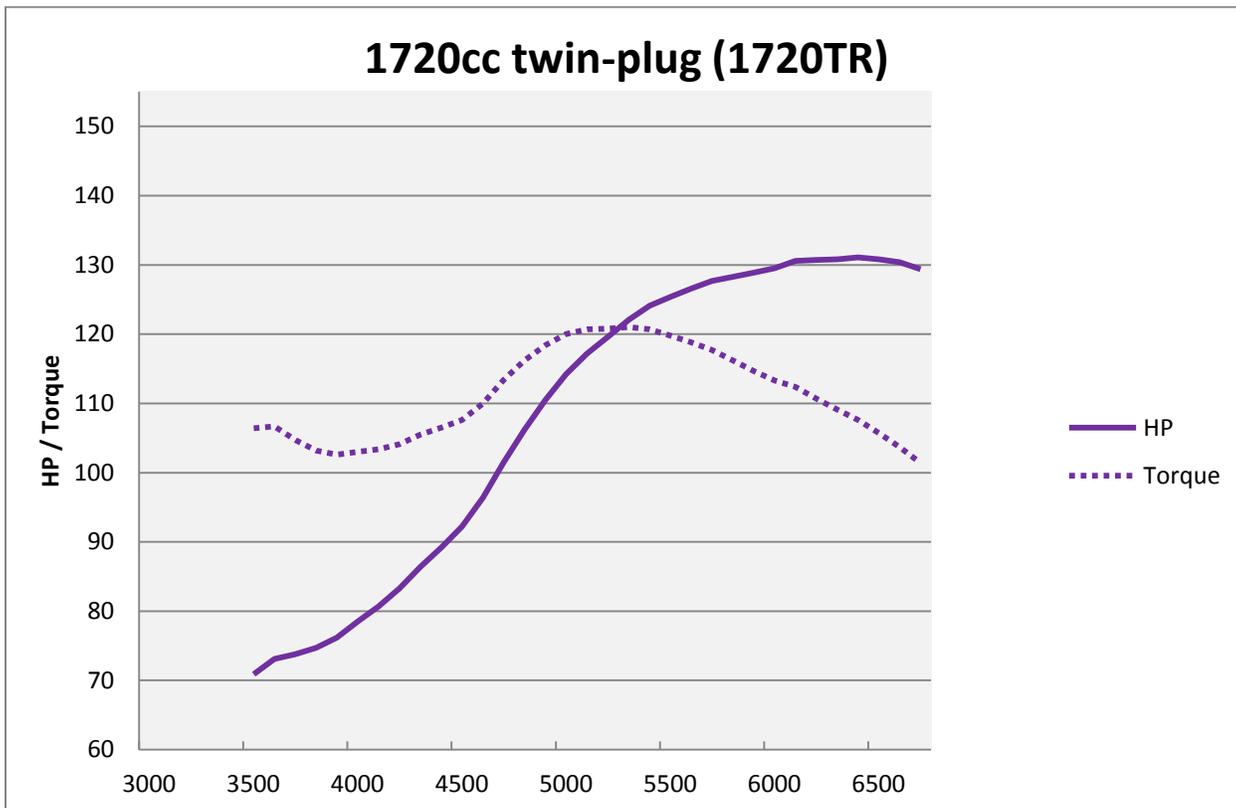
Weber 44IDF carbs with 36mm venturis and 2.25" airhorns w/K&N air filters.

Crankcase ventilation in the case and heads.

Special aluminum pushrods.

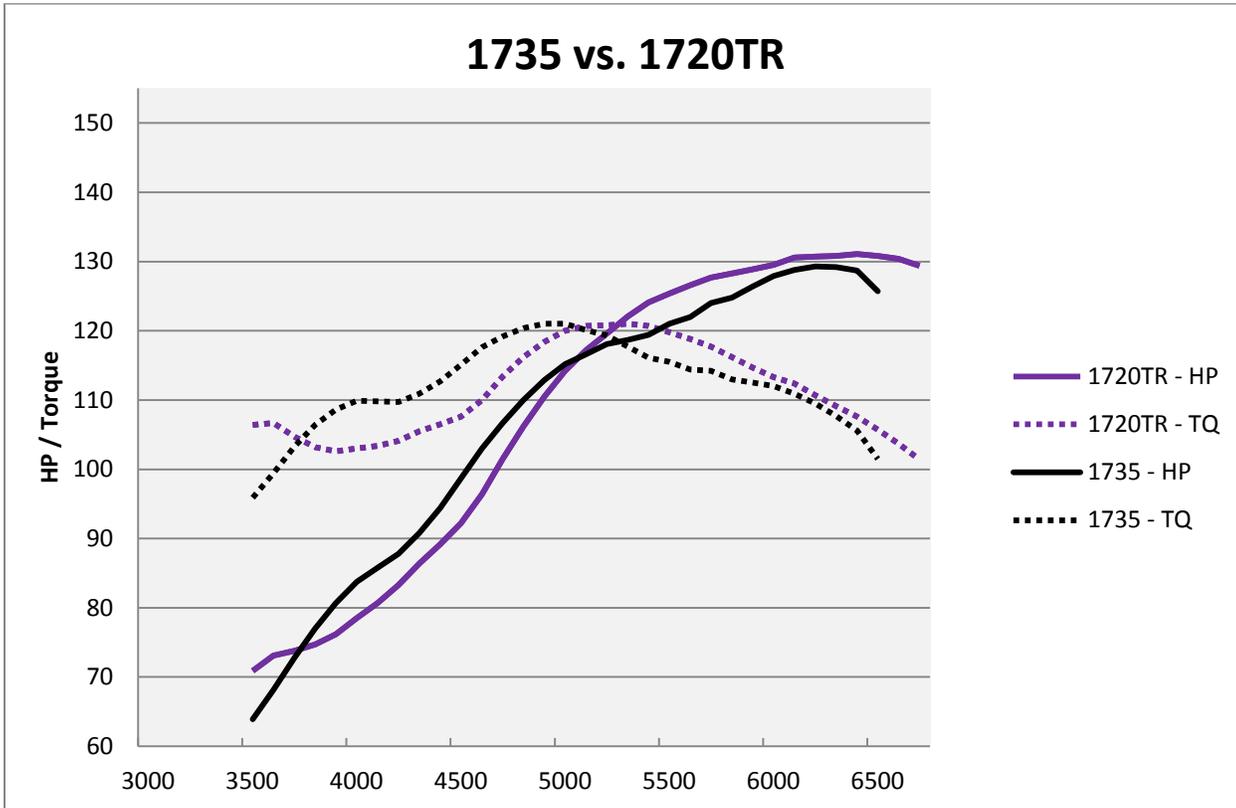
Raceware cylinder head studs.

WR Sport Exhaust for twin plug.



This was basically the 1735cc engine above that we later converted to a twin plug with some of the other TR upgrades. The owner wanted to keep the engine as a 1720cc (the 86.5mm cylinder walls of the 1735cc were somewhat thin and we wanted to use the LN Eng cylinders). Also, the 4:1 exhaust was very loud, and the air horns looked cool but did nothing for filtering out dirt. The cylinder heads were unchanged except for the addition of the 2nd plug. Even though there were some compromises made in performance, the owner was thrilled with the dyno results. Despite the smaller size the engine made (almost) the same power but was much more quiet, and the throttle response was improved by the twin plug.

A comparison of the two engines is shown below:



As you can see in the graph, the tuning affect of the long primaries and the taller air horns boosts the torque between 3500 and 5500rpm, but the TR set up with the WR Sport Exhaust and the stock Weber 2.25" air horns and air cleaners are much more reasonable for street use, and also boost power above 5000rpm. We also tried the TR engine without the K&N air cleaners and recorded no gain in power.

1925cc Test #1 – Stock vs. WR 4:1 exhaust

129hp@5900 / 122ftlbs@5200 STOCK

128hp@5800 / 124ftlbs@4400 WR 4:1

240-degree camshaft with .385" lift.

Modified VW cylinders bored to 91mm using custom JE forged pistons with 10.25:1 CR

Bored case with 911 piston squirters installed, full flow oiling system.

Lightened 912 connecting rods.

356C crankshaft.

11 lb flywheel with aluminum 200mm pressure plate.

Aluminum 5" front pulley.

Custom twin plug distributor using an M&W CDI box firing two Bosch CDI coils. 25 degrees maximum timing advance.

Stock C/SC/912 cylinder heads with 38mm intake and 34mm exhaust valves, drilled for twin plug, bored for the 91mm cylinders w/unshrouded intake valves

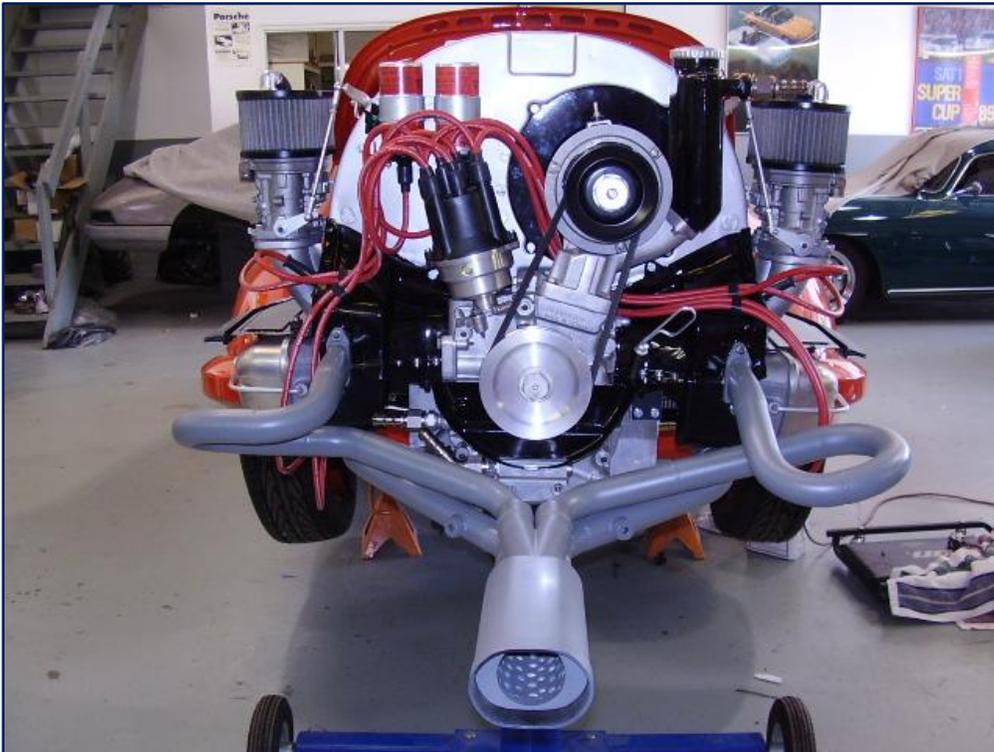
Weber 44IDF carbs with 34mm venturis and 2.25" airhorns w/K&N air filters.

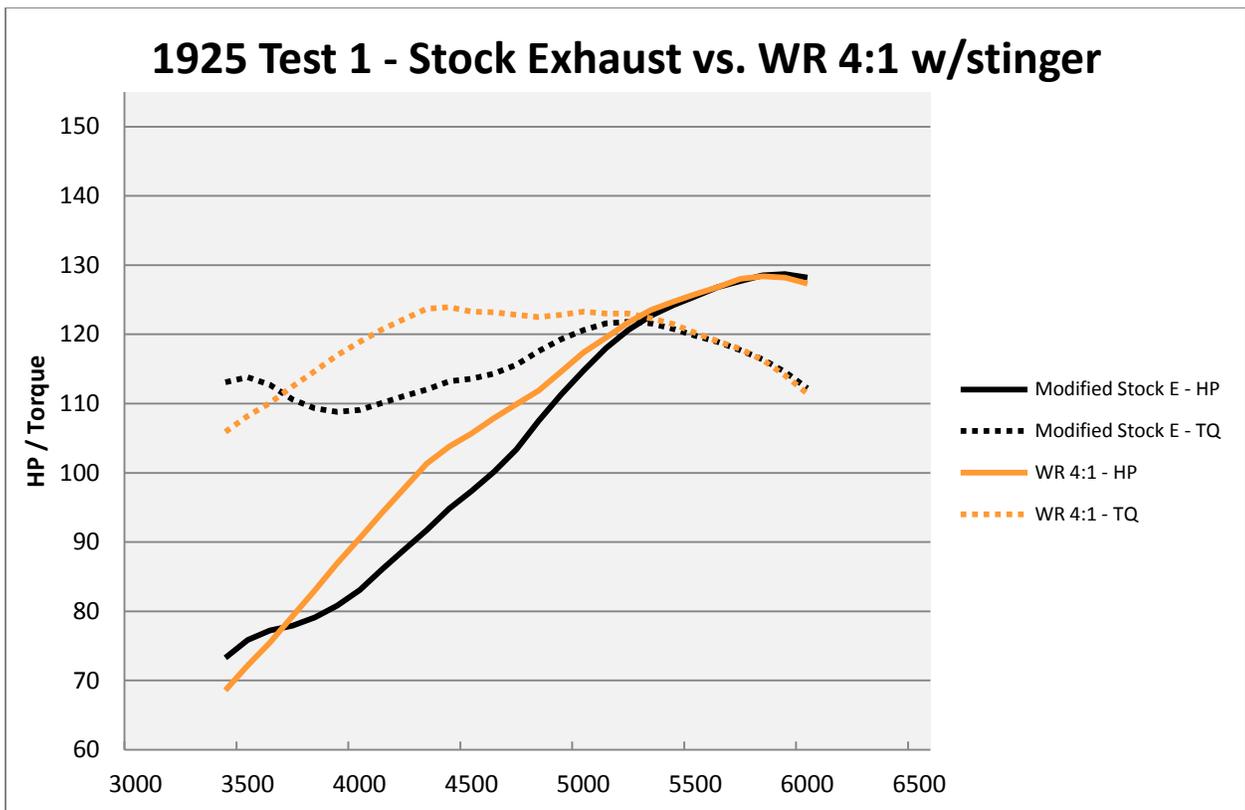
Crankcase ventilation in the case and heads.

Chromoly pushrods.

Stock cylinder head studs.

Stock factory muffler modified for twin plug compared to WR 4:1 with same specs as above engines.





The WR 4:1 header with the 10" stinger/resonator provided an amazing boost in the mid range torque – right in the driving range. Some low end torque is sacrificed (below 3800rpm due to the lack of back pressure), and above 5800 (due to the resonating length of the primaries).

These tests were done with the first 1925cc twin plug engine and the owner has driven the car over 13M miles with the 4:1 system. The car is a lightweight C Coupe with no insulation, and the many long distance drives that have been made in the car have taken their toll on the owner’s hearing and his love of the “sport” sound. Even though the tuning of the header can provide an excellent boost in power when done correctly, the look of a 4:1 on a 356 has never been popular when a “quiet” muffler is added to the system. The next step with engine #1 is to install the WR Sport Exhaust and bring the noise level down. As with any “street” performance engine, certain trade-offs have to be made.

1750cc - FULL RACE

179hp@7100 / 139ftlbs@5600

- 279-degree Elgin race cam, .370" lift, with straight cut cam gears.
- Cast iron cylinders bored to 87mm (machined for copper head sealing gaskets) with special JE pistons 11.0:1 CR.
- Case modified for piston squirters, full flow oiling system, deepsump.
- Scat lightweight crank, Carrillo rods.

10.5lb flywheel.

4.0" front pulley with custom harmonic balancer.

Race heads modified with Del West titanium 7mm stem valves w/40mm intake and 34mm exhaust, titanium retainers and double springs.

48IDF Weber carbs with 40mm venturis , 2.25" air horns, and ITG air cleaners.

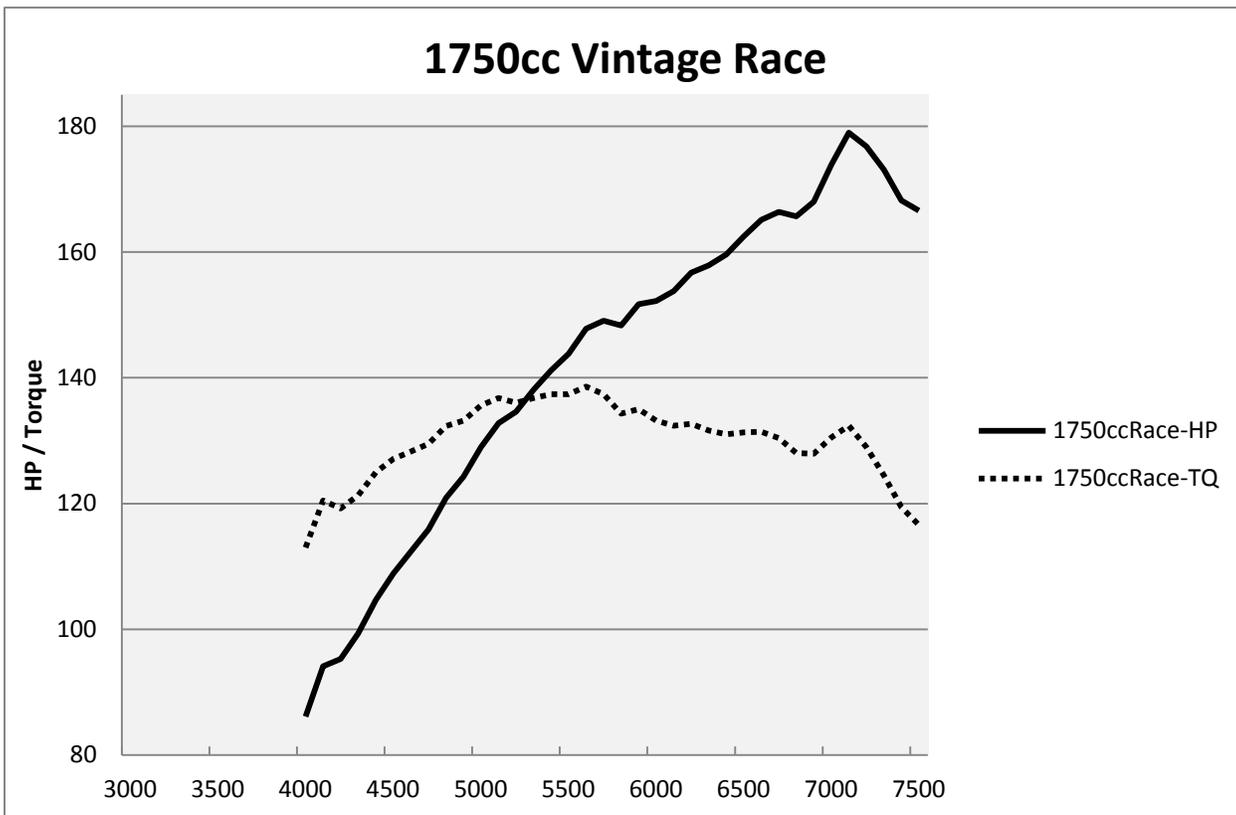
WR 4:1 stainless header with 1.5" diameter primaries and 12" reverse cone megaphone.

Crankcase ventilation in the case and heads.

Chromoly pushrods.

Raceware cylinder head studs.

110-octane race fuel.



This was an incredibly strong runner. The big cam combined with the big carbs moved the torque and hp curve way up. We couldn't load the dyno below 4000 or the engine would stall. It would be interesting to explore other possibilities with a "legal" vintage race engine. This one ended up going to a customer in the UK who was going to use it for "track days" so the 1750cc size and the 48mm carbs weren't a problem. The bump in the curve at 6900RPM was the result of the reverse cone megaphone.

1500 Super – Modified

78hp@5300 / 88.5ftlbs@4000

This was the engine built for the Azure Blue America Roadster that is shown on the website. The purpose was to build a dependable engine that could be used for the street and occasional vintage racing. In the 1500lb Competition Roadster, with crashbox transaxle, it was a blast. Details about the build can be found in the “Articles” page of the website.

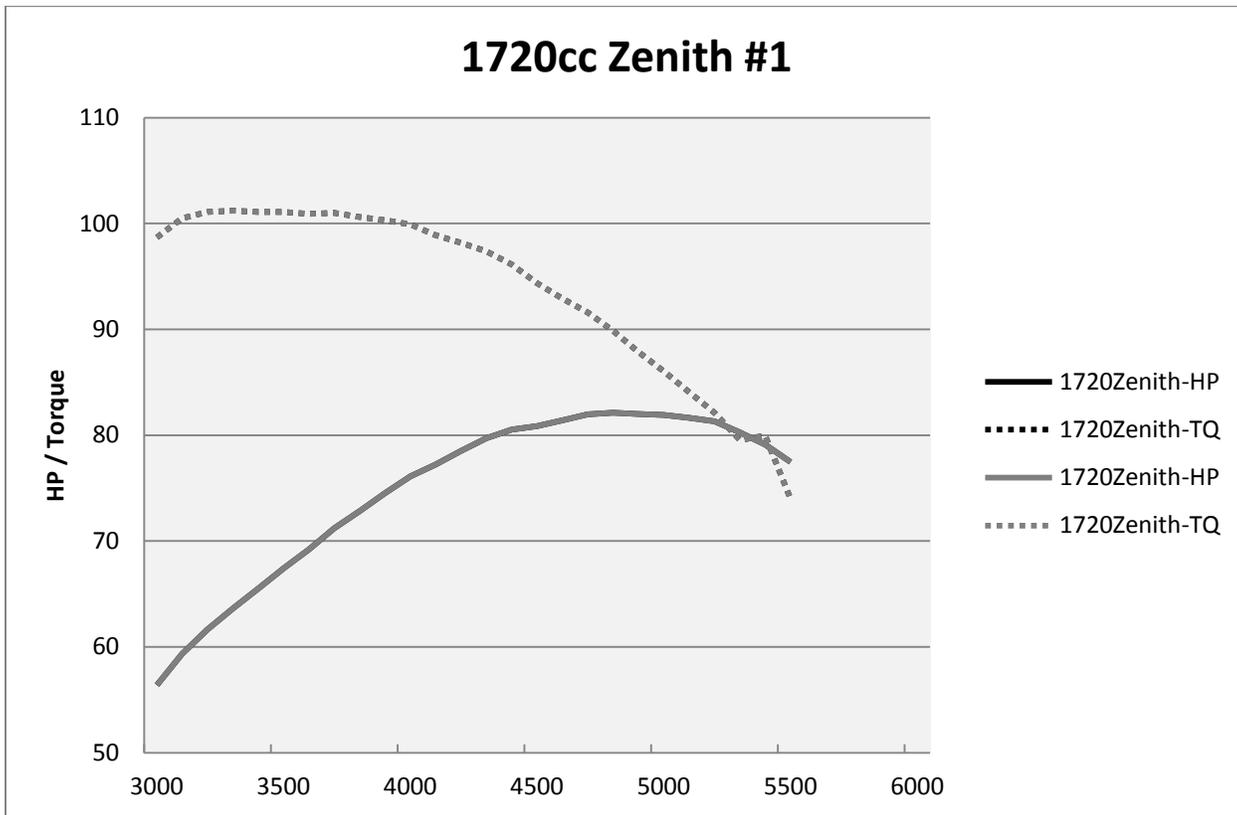


Porsche listed the power output of the stock 1500S at 70HP@5000 / 80ftlbs@3600. Our torque and HP peaks definitely moved up, but not at the expense of low end performance (the 80ftlbs were already there at 3000)

1720cc #1 with Zeniths

82hp@4800 / 101ftlbs@3300

215 degree Elgin cam (the Maestro grind) with .303" lift.
 Cast iron cylinders bored to 86mm with JE forged pistons 9.5:1CR.
 Stock 356B crank and 912 rods.
 Stock exhaust.
 Stock 356B heads (38I/31E with Super intake ports) with early rockers.
 Stock Zenith 32NDIX carbs with 28mm venturis and mesh air cleaners.



This engine was an excellent runner with much improved low end torque. Since it started life as a 1600 Normal, the owner was happy with the added torque, but the power fell off very quickly due to the short duration cam, lower lift early rockers, and Zenith carbs.

1720cc #2 with Zeniths

This next test shows that the Zeniths carbs were definitely not the limiting factor on the last engine. The engine started life as a 1600S but used many late model parts and a much better camshaft.

96hp@5400 / 102ftlbs@4000

241 degree Elgin cam 7008 with .333" lift.

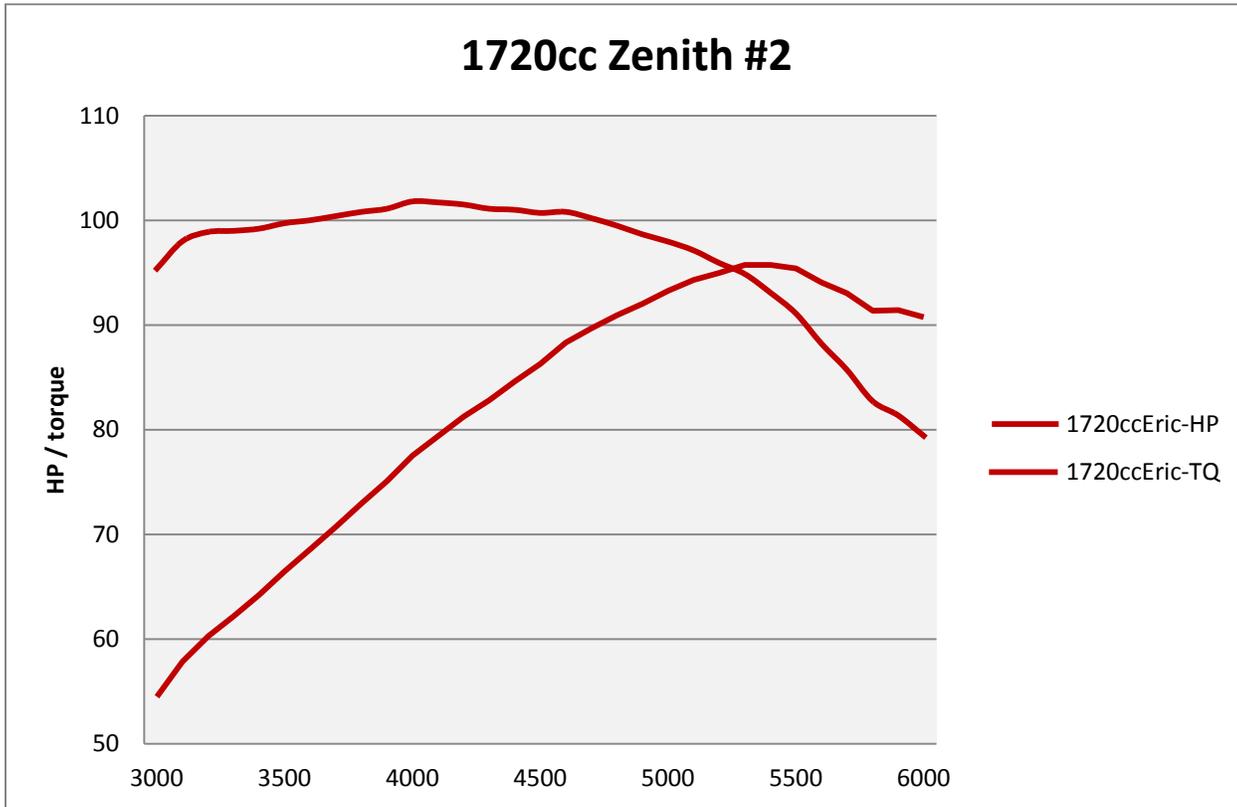
Cast iron cylinders bored to 86mm with JE pistons and 9.5:1CR.

SC/912 counterweighted crankshaft with late connecting rods.

Stock exhaust.

Late C/SC heads (38I/34E) with late high-lift rockers.

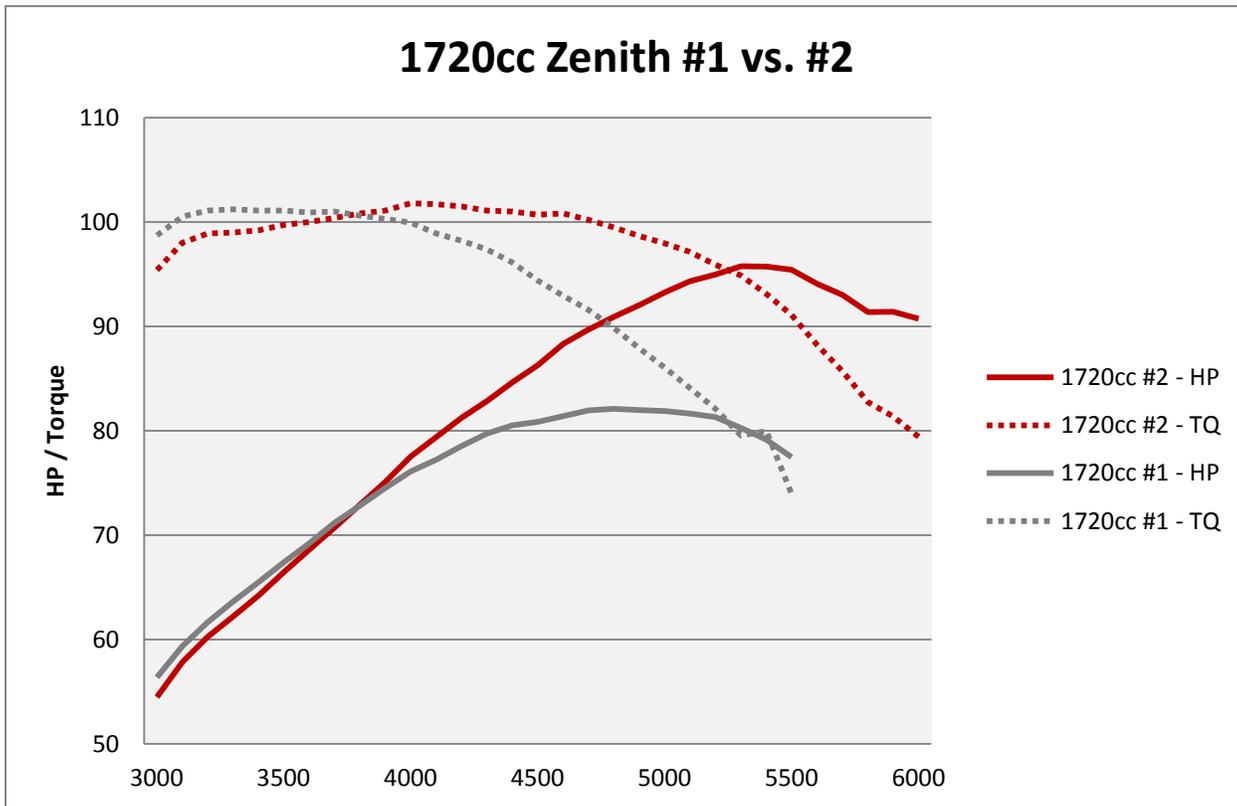
Stock Zenith carbs with 28mm venturis and canister type air cleaners.



This engine was as responsive as the #1 version but pulled the power much further. The bigger cam definitely helped with the top end. It's obvious that more intake lift and duration is what engine #1 needed. The added lift of the late rockers helped a lot.

The mild cam does help the very low end, and if around town driving and maximum fuel economy is what you're after this might be the cam you want.

A comparison of the two tests is shown below:



1720cc #1 with Webers

This was basically a stock, big bore SC engine with Weber carbs. We used 28mm venturis in the Webers which boosted the bottom and mid range torque when compared to the Solexes with 32mm venturis.

95hp@5300 / 102ftlbs@3900

Elgin "improved" SC #16 camshaft (see Elgin website for specs)

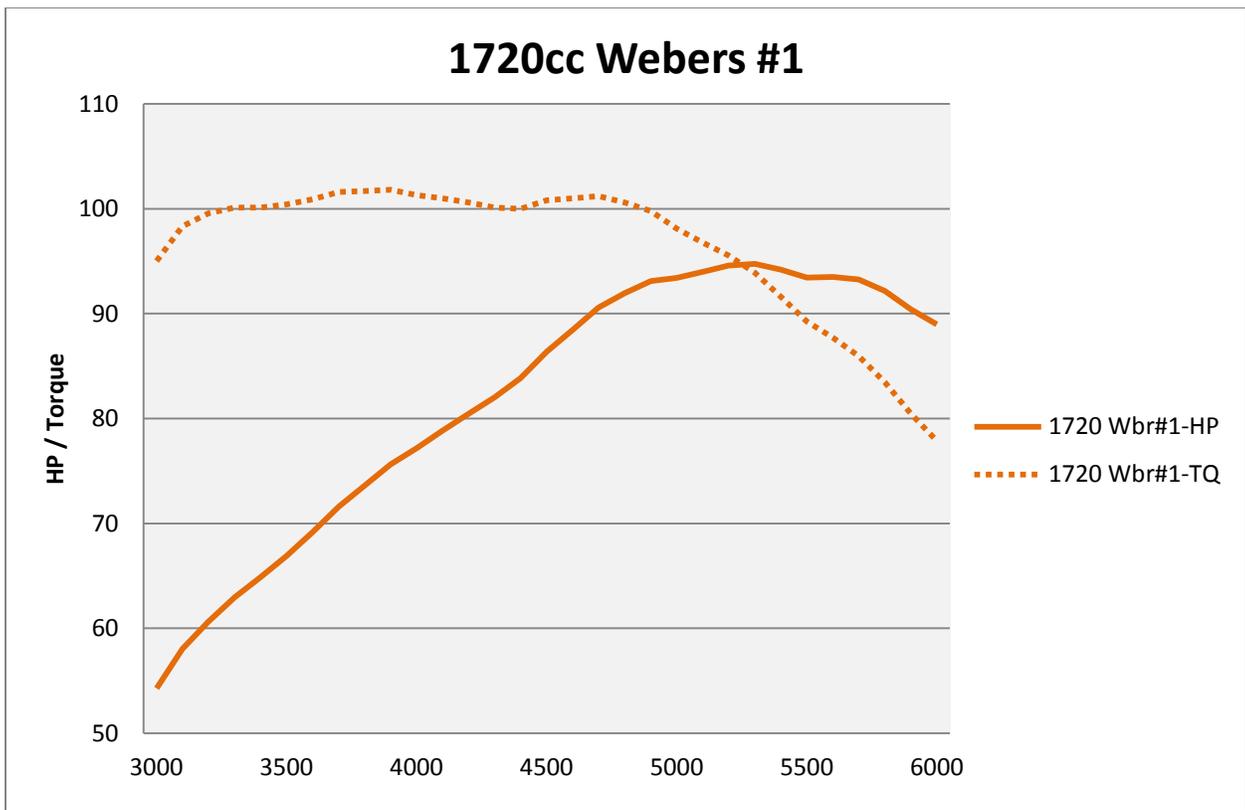
Cast iron cylinders bored to 86mm with JE pistons and 9.5:1CR.

Stock SC crankshaft and rods.

Stock exhaust.

Stock SC cylinder heads (38I/34E) with intake ports matched to Weber manifolds.

Weber 40IDF carbs with 28mm venturis, 2.25" air horns and K&N air cleaners.



This engine was a strong runner which provided excellent low end and midrange with a basically stock power curve. The torque curve was almost flat from 3700 to 4700.

1720cc #2 with Webers

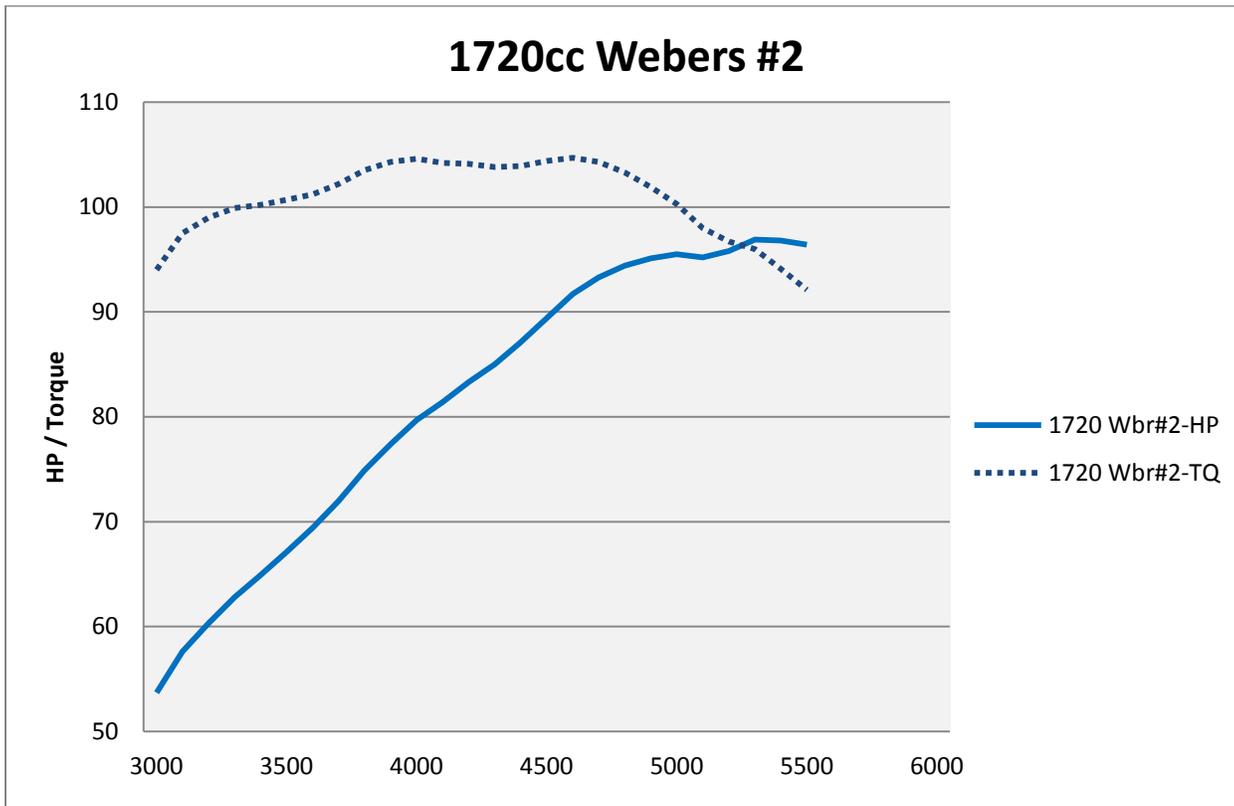
On this next test of a Weber carbureted SC engine, we matched the camshaft and venture size for a little more top end performance. This test was also interesting because we used modified 356B heads which retained the smaller 31mm exhaust valves. At the owners request we limited the maximum dyno test RPM to 5500. During the test we tried 28mm venturis and lost the significant bump in power between 3800 and 4800 rpm, so the 32s obviously help with cylinder filling at lower rpm as well as above 5K. This shows that venturis size ALSO needs to be tested on the dyno.

97hp@5300 / 105ftlbs 4600

- All specs the same as #1 except for:
- 241 degree Elgin 7008 camshaft with .333" lift.
- 32mm venturis.
- 86mm LN Eng. Nikasil coated aluminum cylinders.

WR aluminum pushrods.

Modified 356B heads (38I/31E) with SC intake ports matched to Weber manifolds.

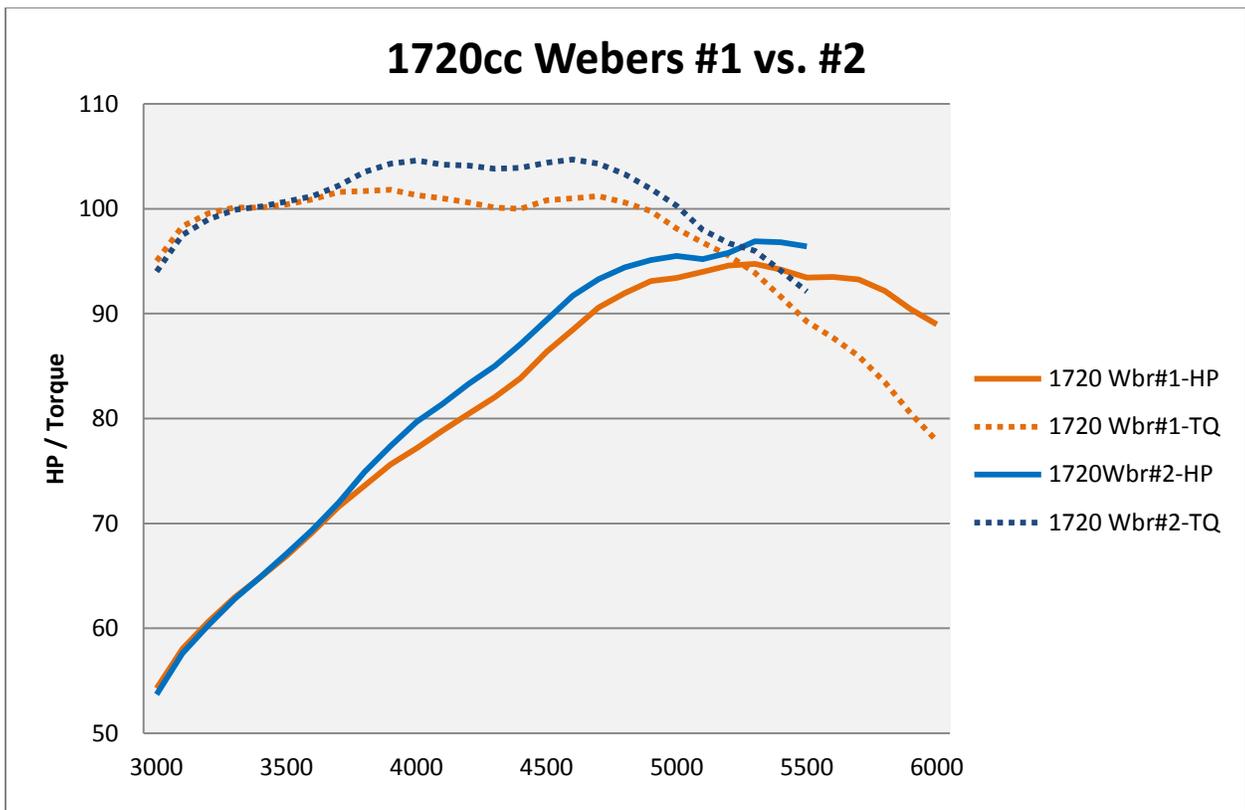


The bigger cam and venturis boosted performance everywhere except below 3300 RPM. Since these engines are so close in design a good test comparison was in order. From test driving both cars back to back (the milder engine installed in a Coupe the hotter in a Cab,) it felt like the milder engine might have somewhat better throttle response below 3000 RPM, and a slightly milder idle, but the increased torque is definitely there when needed, and the hotter engine pulls to redline faster. Both engines should be very equal after 5500 RPM. It would be up to the individual owner whether the stock cam or the sport cam was chosen.

EXHAUST VALVES - 34mm vs. 31mm ?

It's obvious from the last two tests that the exhaust valves seemed to have little effect on the performance of the two engines. Typically, a larger exhaust valve will increase higher RPM performance if all other specs remain the same. It's possible that installing the larger 34mm exhaust valves in test #2 engine would have pushed the top end power up slightly. The smaller exhaust valve will also typically improve low end power and throttle response

A comparison of the two tests is shown below:



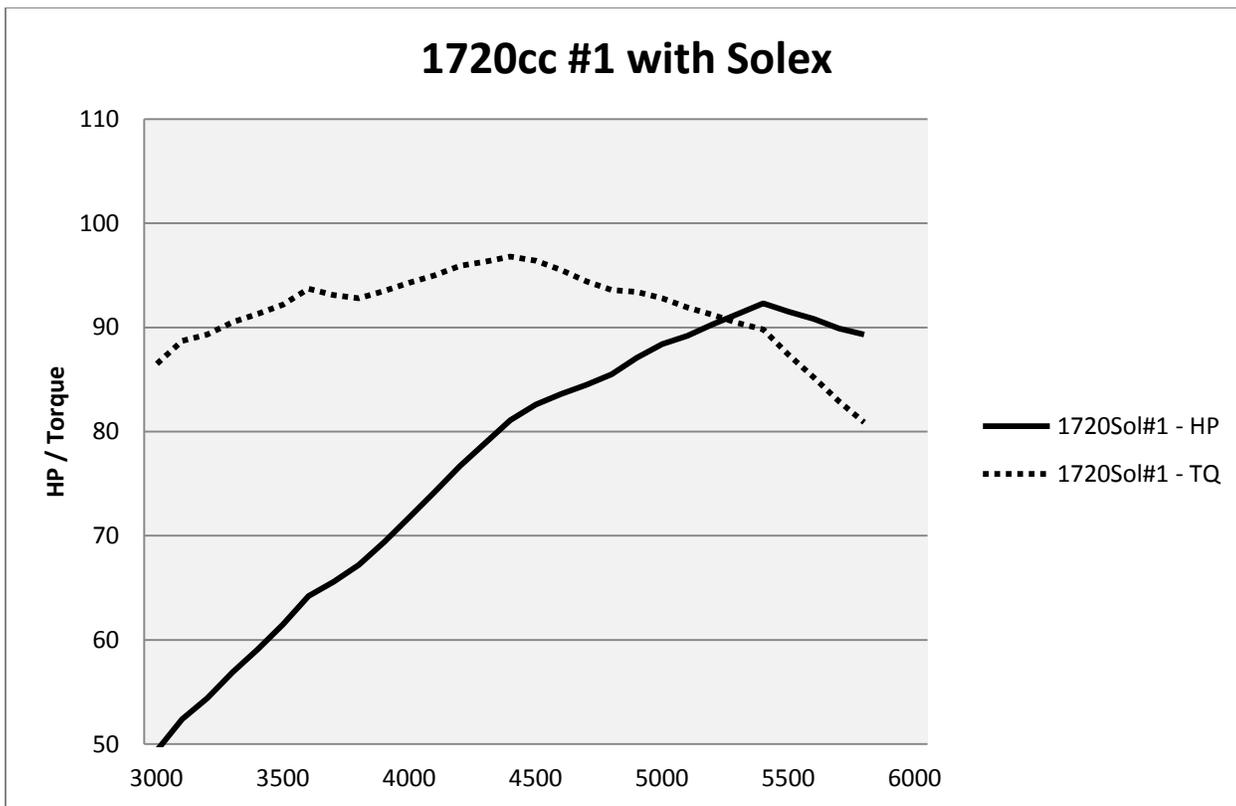
1720cc #1 with Solex

The next two tests are very similar engines to the Weber and Zenith tests. A close look at the specs will show the slight differences. Some interesting comparisons will be shown below.

97hp@5400 / 97ftlbs@4400

(this engine was not built by WR and the specs were provided by the engine builder)

- 215 degree Elgin cam (the Maestro grind) with .303" lift.
- Cast iron cylinders with 86mm big bore pistons (unknown manuf.) 9:1CR.
- Stock SC crank and rods.
- Stock exhaust.
- Stock SC cylinder heads with 38I/34E 8mm stemmed stainless valves with double valve springs.
- Chromoly pushrods.
- Stock Solex 40P11s with stock 32mm venturis and stock mesh air cleaners.



This was a good runner, with a nice flat torque curve. The performance was somewhat compromised by the very mild duration, low lift cam, and the 8mm stemmed valves with stiffer double springs and chromoly pushrods were probably wasted on this engine. The Elgin “Maestro” cam is almost identical to the 356C camshaft, and is great for an engine with small carbs and venturis, especially the early Solex 32s. This engine would have performed much better with Zenith carbs and gave away some low rpm torque because of the large Solex 40s. Even though the engine builder stated that the compression ratio was 9:1, I’m guessing that it was probably lower, especially because of the poor low rpm performance.

1720cc #2 with Solex

This was basically a stock, big bore SC engine with stock Solex 40P11 carbs with 32mm venturis.

95hp@5600 / 96ftlbs@4600

(this engine was not built by WR and the specs were provided by the engine builder)

Stock #16 SC camshaft with 234 degrees and .325” lift.

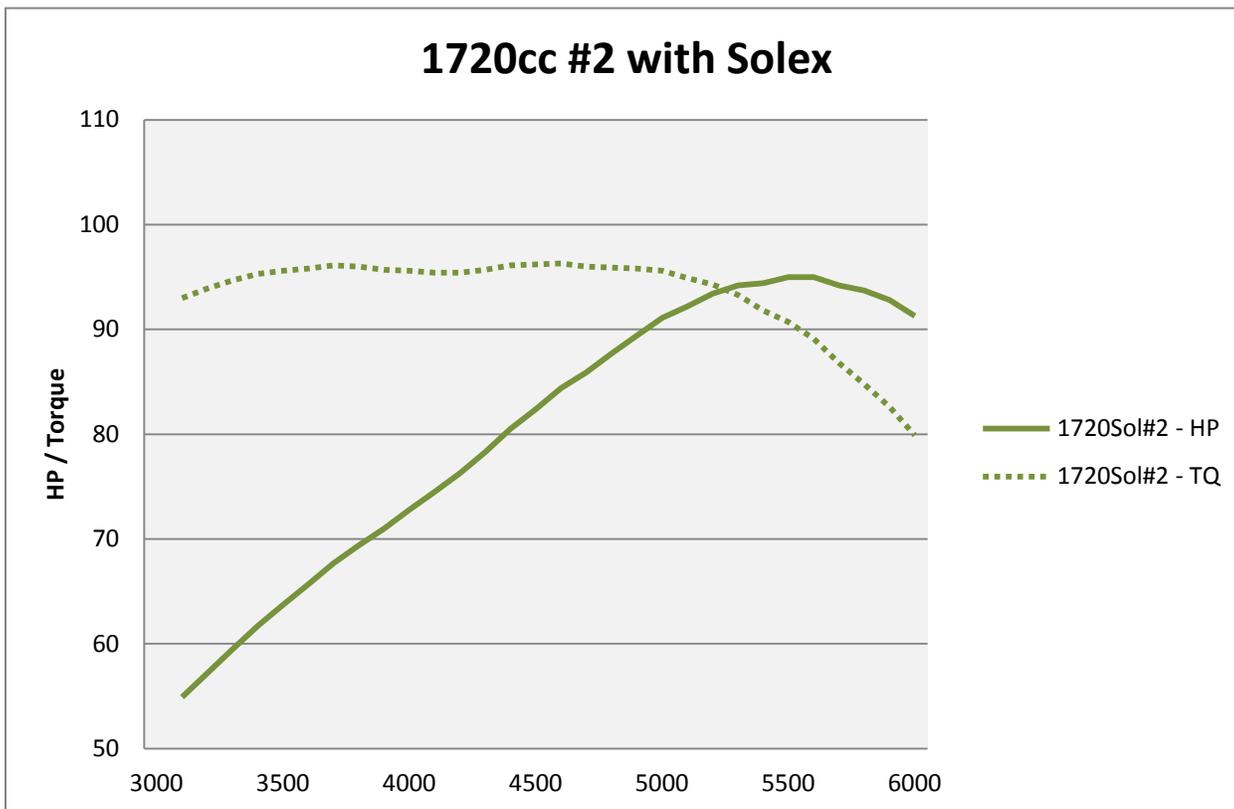
Cast iron cylinders bored to 86mm with JE pistons and 9.5:1CR.

Stock SC crankshaft and rods.

Stock exhaust.

Stock SC cylinder heads (38I/34E) with intake ports matched to Solex manifolds.

Stock Solex 40P11s with stock 32mm venturis and stock mesh air cleaners.



Comparing this test to the #1 test engine shows the advantage of the “Super/S90/SC/912” camshaft. It’s much better suited to the larger Solex carbs than the milder low lift cam.

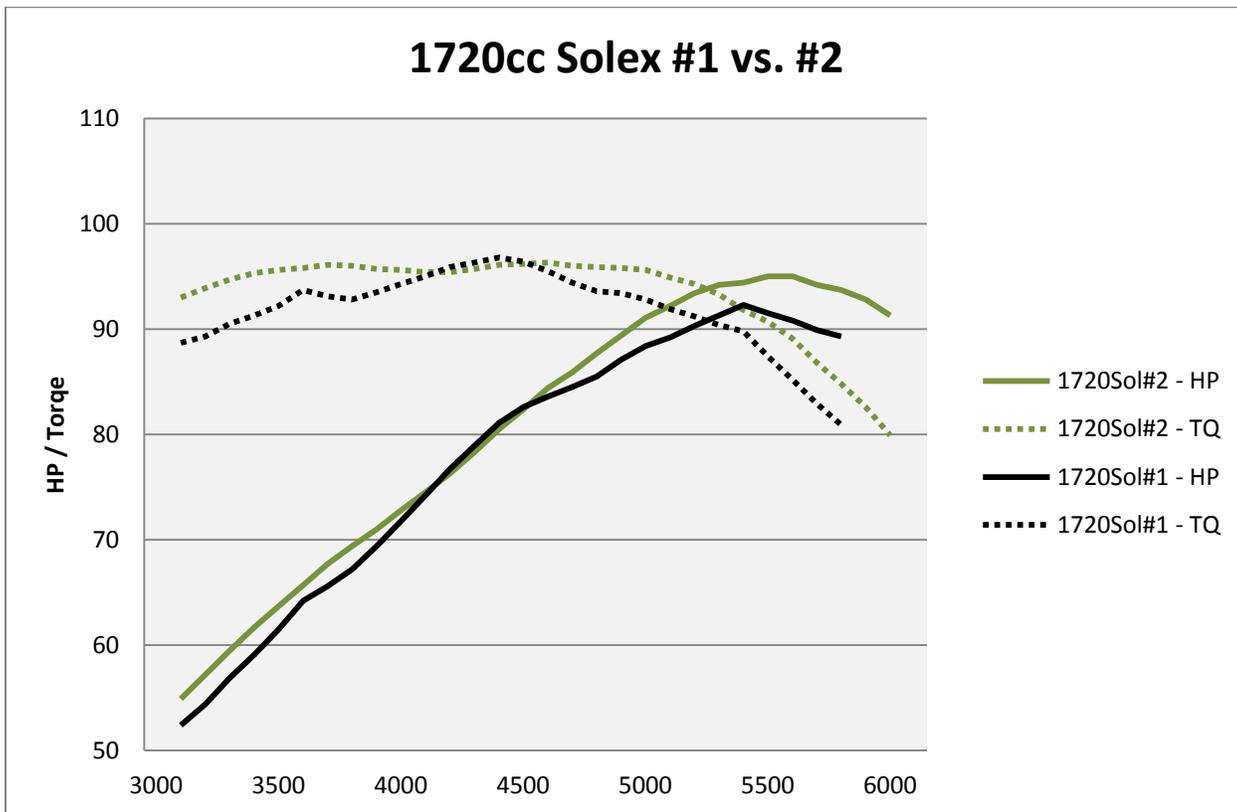
COMPRESSION RATIO?

These two Solex tests show the importance of matching all engine components correctly. All cam grinders should supply recommended compression ratio and carb set ups with their camshafts. Unfortunately, most of the piston and cylinder kits available off the shelf, assume a standard combustion chamber volume for their compression ratios. Because most of our engines have had multiple valve jobs which usually change the combustion chamber volume, the off the shelf kits can vary easily by one-half compression point. The kits are usually designed for the smallest normal chamber volume, so very often your actual compression ratio will be lower than what is shown with the kit. That’s why at WR we don’t offer pre made kits. All of our pistons are custom made to the chamber volume specs so that the correct compression ratio is achieved.

WHAT ABOUT AIR HORNS?

An important option with the Weber carbs is the 2.25" air horns. They increase the resonating length of the intake channel and improve cylinder filling at low and mid range rpm. Much of the improvement when comparing Weber and Solex performance figures is due to the additional length provided by the Weber air horns.

A comparison of Solex engine #1 and #2 are shown below:



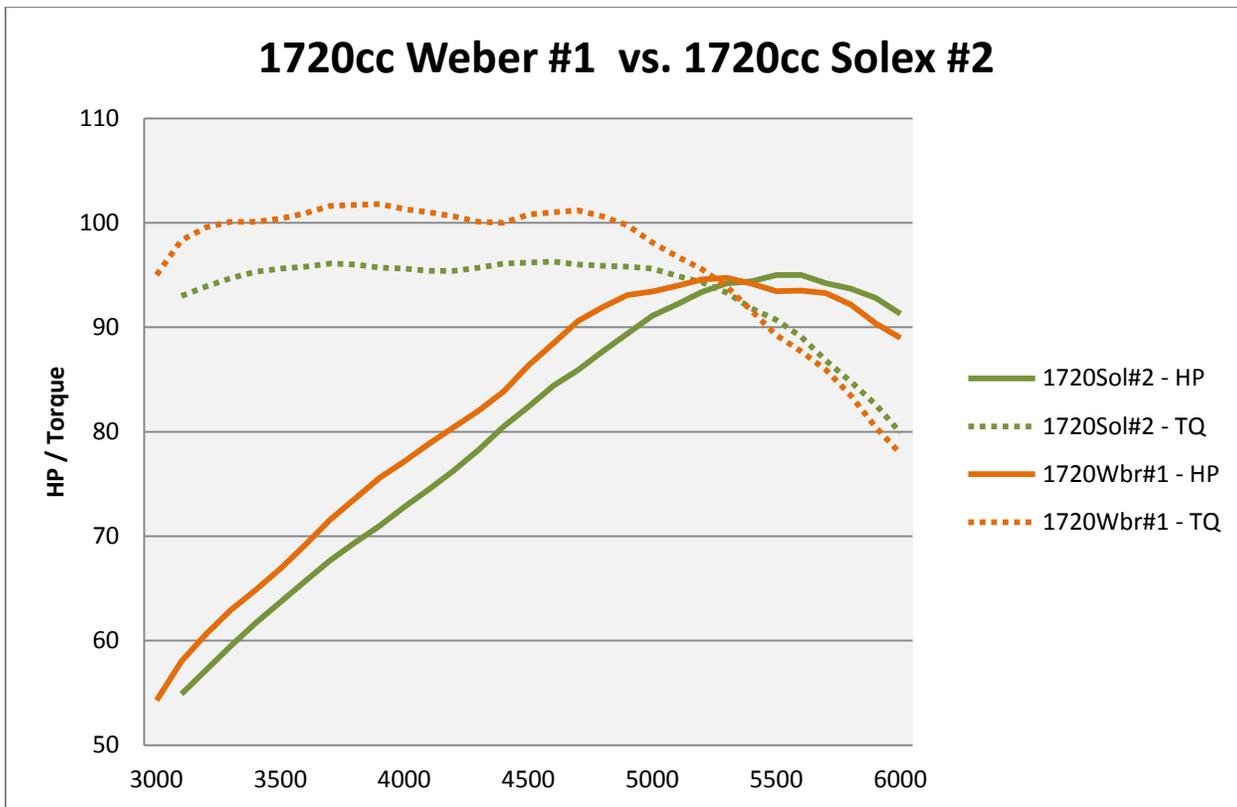
SOME INTERESTING COMPARISONS

1720cc Weber #1 vs. 1720cc Solex #2

The first chart below compares two basically stock SC engines from the above tests (Weber #1 and Solex #2) built to 1720cc – one with Webers, the other with Solex. In this comparison the trade off is obvious: Much better hp and torque below 5500RPM...right in the driving range. The air horns also boost the low/mid torque.

95hp@5300 / 102ftlbs@3900

95hp@5600 / 96ftlbs@4600



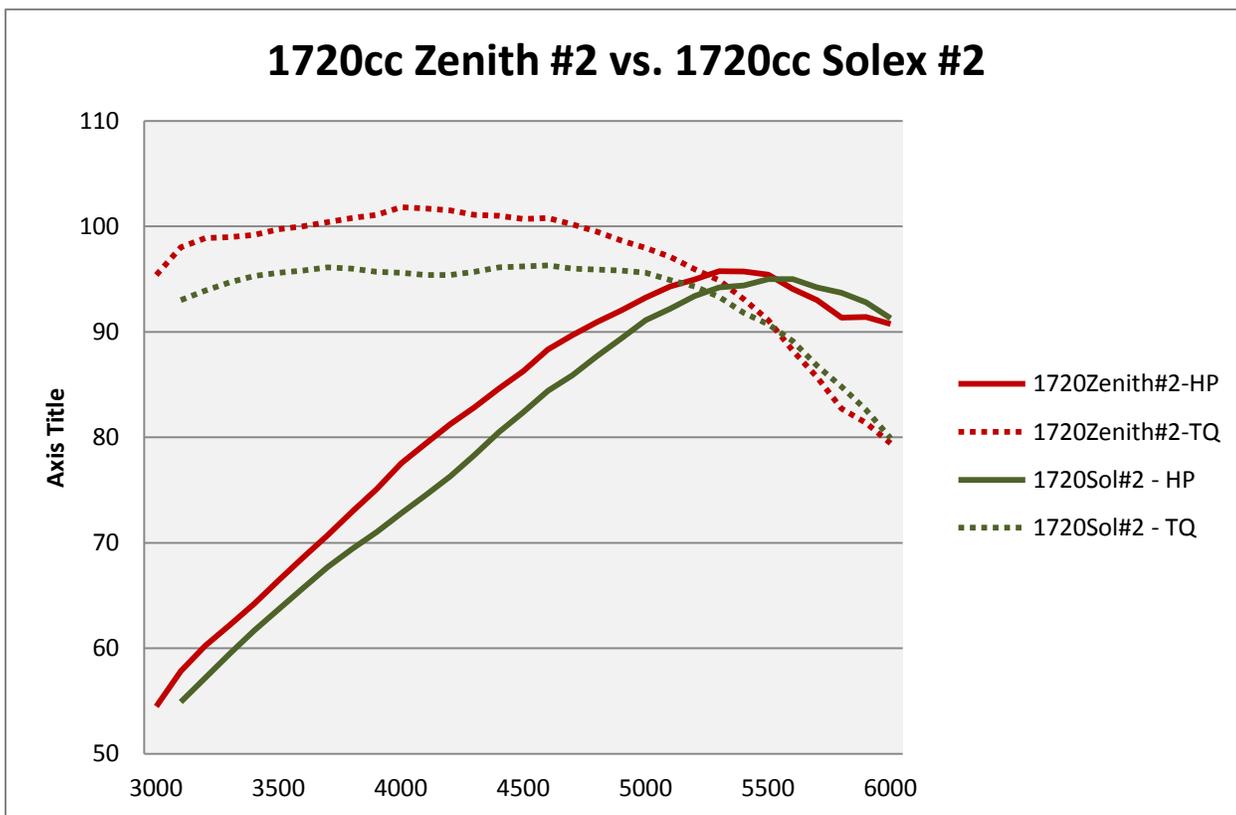
1720cc Zenith #2 vs. 1720cc Solex #2

This comparison shows two very similar engines but with the stock Zenith carbs vs. the stock Solex carbs. The Zenith equipped engine had the advantage of a slightly bigger cam, which helped it in the upper rpm range, but because of the smaller size of the Zeniths, maintained very good low rpm numbers.

Don't swap-out those "small" Zeniths for something bigger unless you plan on increasing the engine size and camshaft.

96hp@5400 / 102ftlbs@4000

95hp@5600 / 96ftlbs@4600



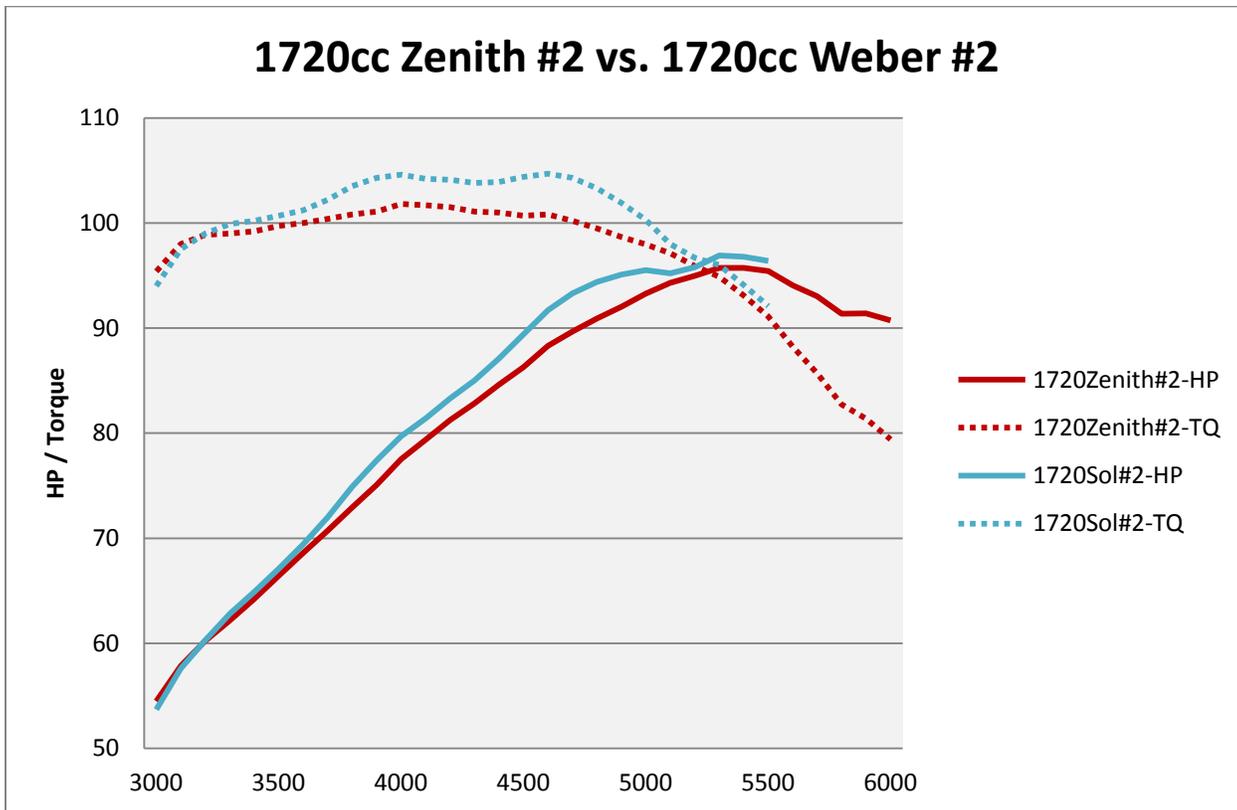
1720cc Zenith #2 vs. 1720cc Weber #2

This comparison shows the difference between Zenith and Weber carbureted engines with otherwise very similar specifications. The Weber engine used the LN Engineering aluminum cylinders, and also had the smaller 31mm exhaust valves. It's unclear what difference these two specs made, but it is clear that the Weber engine had more torque in the midrange.

Testing is planned with the Zenith #2 engine (which now shows about 3500 miles) with our new 36mm modified Zeniths with 32mm venturis. The results should be interesting.

96hp@5400 / 102ftlbs@4000

97hp@5300 / 105ftlbs 4600



1925cc Single Plug (Webers)

This was the first single plug 1925cc engine tested on the dyno. We used the 44IDFs because the 40s weren't available at the time. The WR60 cam was chosen since in development it showed very good results with the engine simulation. It has an intake duration of 242 degrees with .365" of lift, but uses a stock "Super" exhaust profile of 234 degrees and .325" of lift. The lobe separation is 108 degrees and it is installed straight up with no advance. At the moment we have no comparison to other single plug big bore engines, but we can certainly compare to our best 1720cc street engine. This engine is installed in a B Coupe, and the increase in power is VERY noticeable...and, it idles like a stock 1600N but pulls easily to 6K.

116hp@5800 / 116ftlbs@4800

WR60 camshaft 242 degree, .366" lift Intake / 234 degree, .325" lift Exhaust
91mm LN Eng, Nikasil coated aluminum cylinders and JE pistons with 9.5:1 CR.

WR aluminum pushrods.

Stock SC crank and rods.

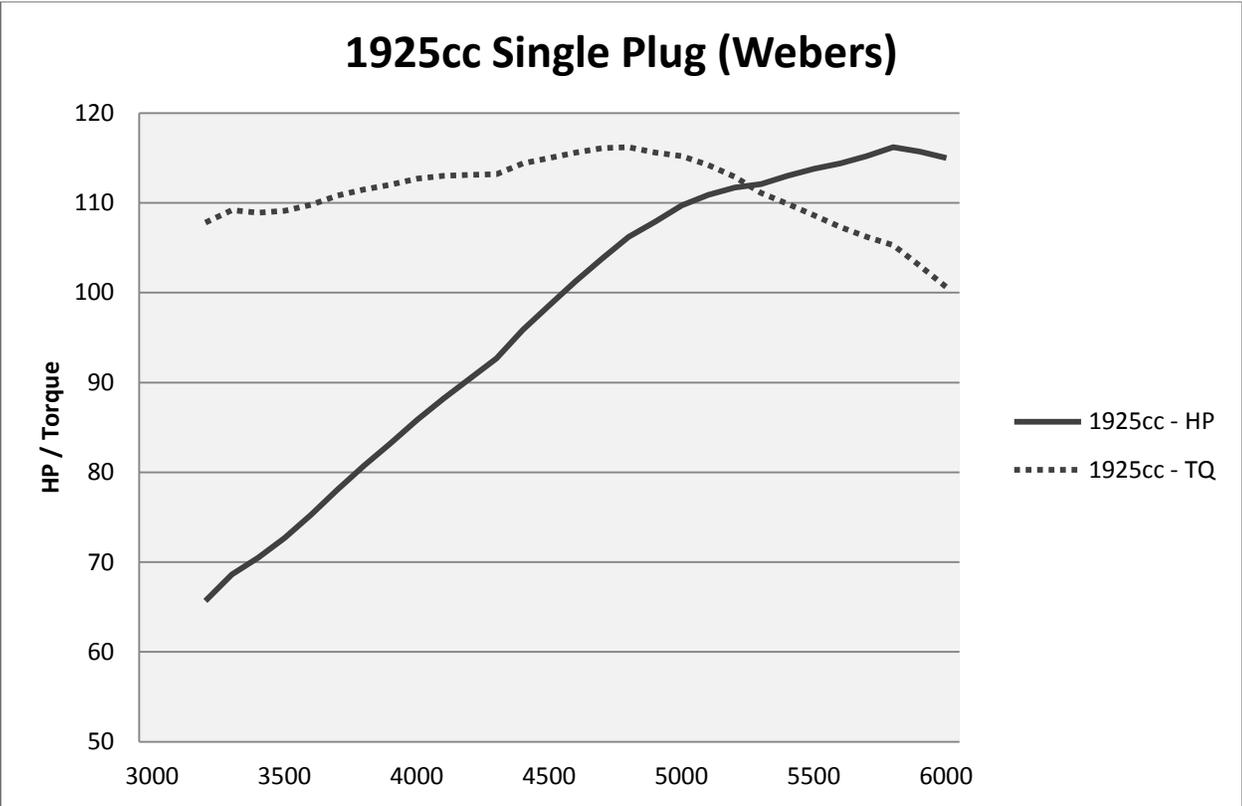
Stock exhaust.

Modified cylinder heads with 40I/34E stainless valves, double springs on intake only.

44IDF Webers with 32mm venturis and 2.25" air horns. K&N air filters.

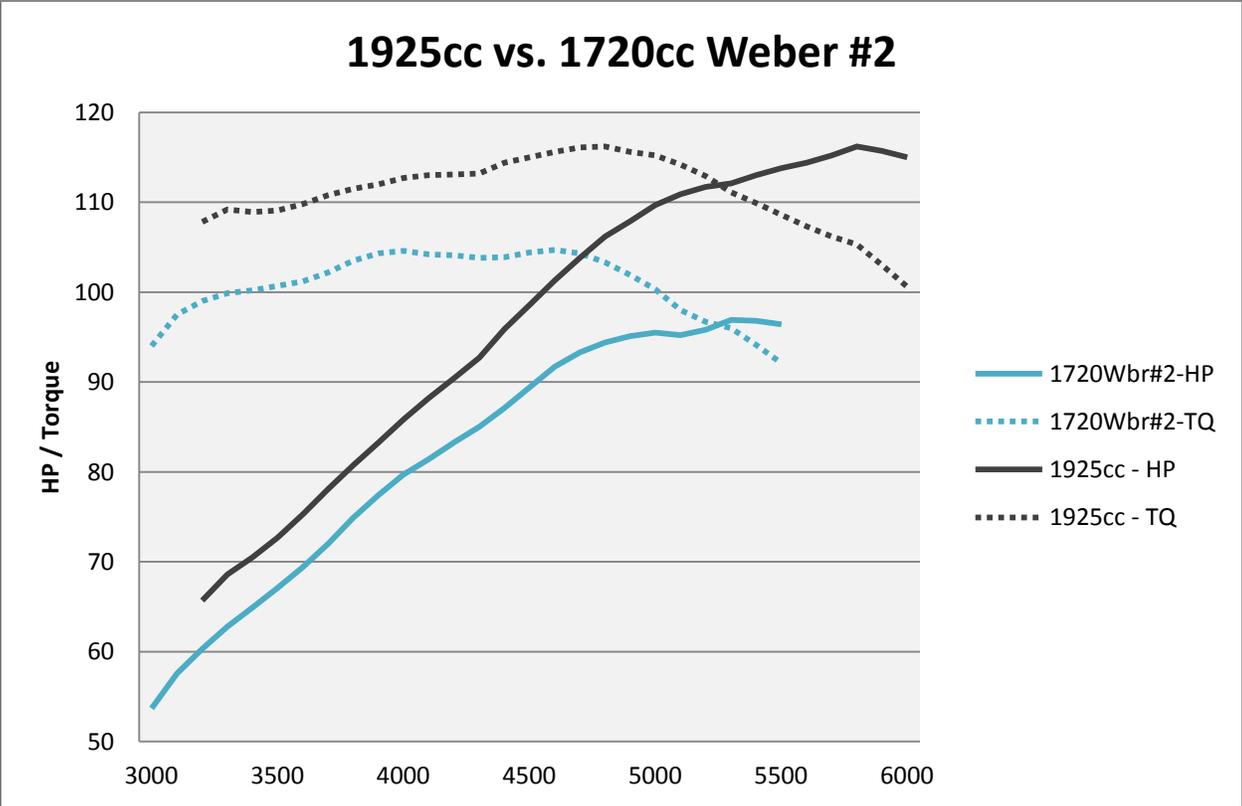
WR CDI ignition kit.

1925cc Single Plug (Webers)



A comparison of the 1925cc twin plug engine and the top performing street engine in the 1720cc form is shown below:

1925cc vs. 1720cc Weber #2



You can see from the graph that the 1925cc engine is already beating the 1720s maximum torque at the beginning dyno test rpm of 3200. This graph shows that engine size is the best way to increase power.

THE NEXT STEP – 2002cc

91 millimeters is the largest reasonable piston size for the 356 engine. With the 74mm crankshaft, 1925cc is then the largest engine size possible. Stroking is a possibility but the cam to rod clearance is the issue. At 74mm the rod to cam clearance with stock rods is already dangerously close (<1mm). The only way to make the crankshaft stroke longer is to either reduce the size of the connecting rod big end or the camshaft lobe. The camshaft base-circle is already somewhat small, and must be made smaller for high lift cams. That leaves the rod bearing.

The 356 rod bearing at 53mm is relatively large by today's standards. By changing to a smaller diameter 2.0" (50mm) Clevite type bearing we are able to have special rods made that allow the extra clearance for a 77mm stroke crankshaft. In addition to being smaller in diameter, the rod bearings are now approximately 1mm wider which actually provides more oil cushion than the stock 53mm bearing. The rod length is stock and the wristpin is simply pushed up into the piston an extra 1.5mm, which is made possible by the super thin rings that we now use with the Nikasil cylinders from LN Engineering.

With a 77mm stroke the engine size has been pushed to 2002cc. A longer stroke in a street engine has the advantage of increasing the torque throughout the entire rpm range. In a race engine piston speed becomes

an issue at high rpm, but since we're not looking to push the limit much above 6K, piston speed is not a real concern.

There are several 2002cc engines in the works at the moment, and we should have the test results available very soon. The first test engine is shown below. The results are impressive.

2002cc – Original Look - SC Engine

The specs of this engine are listed below. Since it was being installed in a very rare Porsche race/rallye car, it needed to look completely original.

248 degree Elgin 7208 high lift camshaft with .370" lift

91mm LN Eng Nikasil cylinders and JE pistons with 10.3:1 CR.

77mm Scat lightweight crankshaft with special Carrillo rods.

WR 10.5lb flywheel kit with aluminum pressure plate.

WR aluminum pushrods.

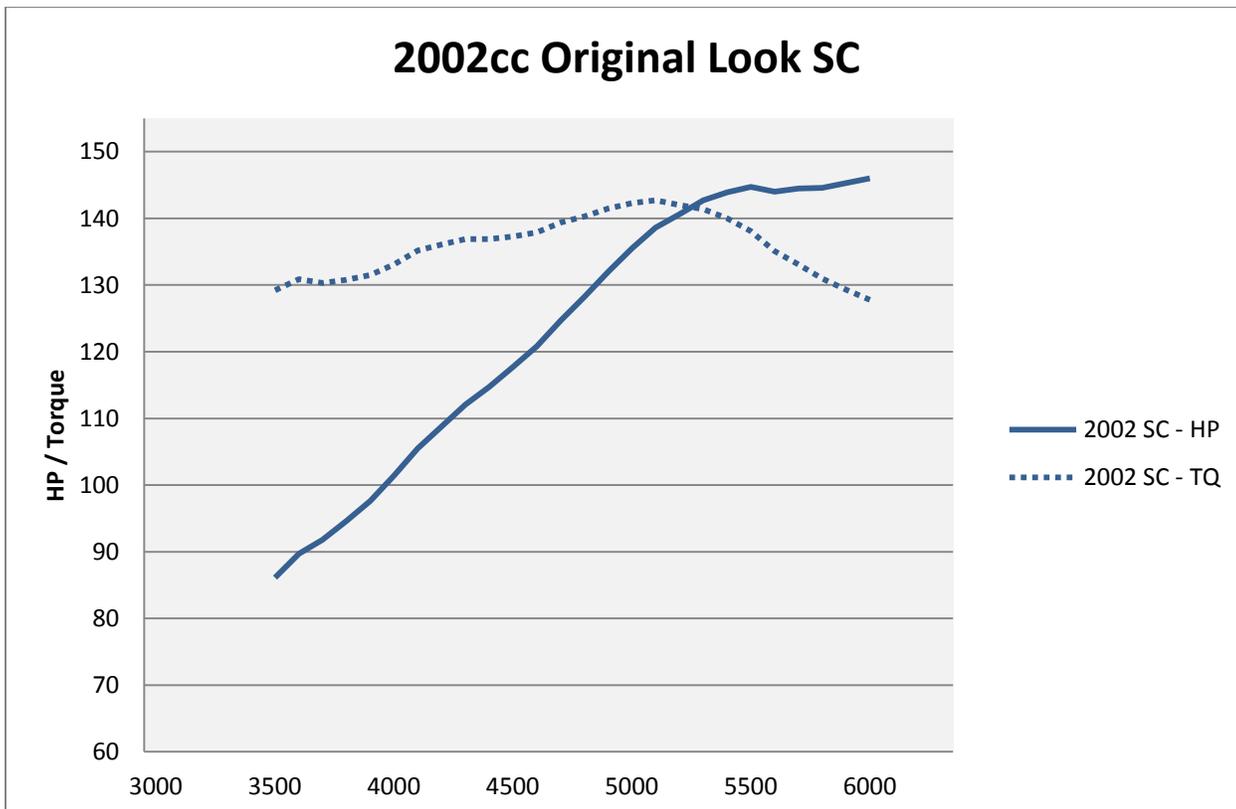
WR High Flow cylinder heads with 44I/34E stainless valves, double springs, ti retainers.

Solex 40P11s modified to 44mm with 36mm venturis.

Stock exhaust.

WR CDI ignition kit.

146hp@6000 / 143ftlbs@5100



We held the test rpm limit at 6000, but the engine definitely was still pulling strong at that point. The modified 44mm Solexes performed very well and the fuel curve was excellent (this was a big question going into testing because there are no optional emulsion tubes for the 40P11 carb). Keep in mind, the goal of this engine was a completely original look, we needed to run on pump fuel, and the exhaust system had to be original. These were somewhat limiting factors, especially the stock exhaust (designed for a 1600cc engine with a 6K redline). The test shown is with factory Solex air horns installed (the way the car will be run). The stock Solex mesh air cleaners reduced the performance by about 2% overall.

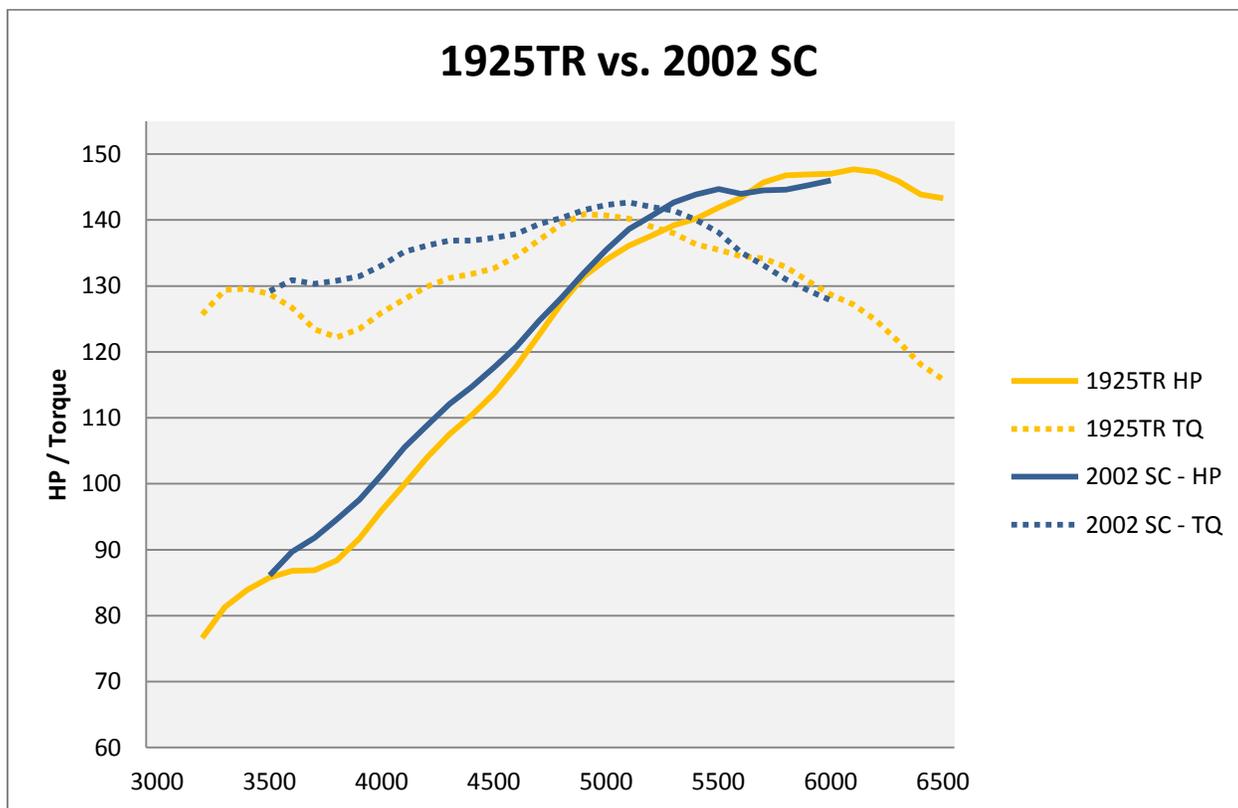
The car is one of the 5 factory delivered SCGTs, with aluminum panels, plexiglass windows, etc, and weighs in at under 1800lbs. It's equipped with its stock BBAB gearbox (probably a little short for the 2L engine). The acceleration is impressive! The car has no limited slip, and with race tires it's still possible to break the tires loose when taking off from a start. The engine idles like a stock SC and can be driven just like a normal car. There is no "loud" exhaust, and it actually feels a little too "stock" considering its potential. Amazingly it is only slightly less docile than the 1925cc Single Plug shown above.

Below is a graph comparing the 1925TR engine and the 2002-Original Look-SC. For specs of the 1925TR please look on the Engine Development PDF file.

1925TR vs. 2002cc SC

148hp@6100 / 142ftlbs@4900

146hp@6000 / 143ftlbs@5100



1925cc - Original Look – 356B Normal

This engine was built for a 62 Roadster and also needed to have a completely original look. Since the oem engine was a Normal/60, it meant the engine would have to use the smaller Zenith carburetors. Based on tests, the stock Zenith 32 NDIX will flow about 120cfm. This works fine with the 1600cc and even the 1720cc engine, as can be seen in past tests, as long as peak power doesn't move beyond 5500RPM. We were going to keep the heads completely stock and use the new WR60 camshaft, so I wanted to at least match a carb to the stock intake valve flow at .475" of lift (the WR60's .365" x 1.3 rocker ratio). After flow testing we determined

that the stock 38mm intake valve could flow just under 140cfm at .475". I asked Jim Kaufmann at Caburetor Rescue if he'd like to try and machine a set of 32NDIXs out to 36mm. After some experimentation by Jim we had our first set of 36NDIXs and tested them on the flow bench with the stock heads and ported Zenith manifolds. The results were exactly what I wanted! The carbs were able to flow the full 140cfm and lower lift flow numbers were also improved. Since the small intake valves were going to be the limiting factor, I installed the WR60 camshaft with 3 degrees advance, which moved the powercurve down about 300 rpm. Since the intake valve closing point was now the same as a stock "Super" camshaft, I kept the compression ratio at 9.25:1.

The engine was assembled with the specifications as shown below. The results of the test were very close to what was expected based on the engine simulations. Some driving impressions follow the dyno graph.

1925cc – Original Look – 356B Normal

WR60 camshaft 242 degree, .366" lift Intake / 234 degree, .325" lift Exhaust (advanced 3 degrees).

91mm LN Eng, Nikasil coated aluminum cylinders and JE pistons with 9.25:1 CR.

WR aluminum pushrods.

Stock C crank and rods.

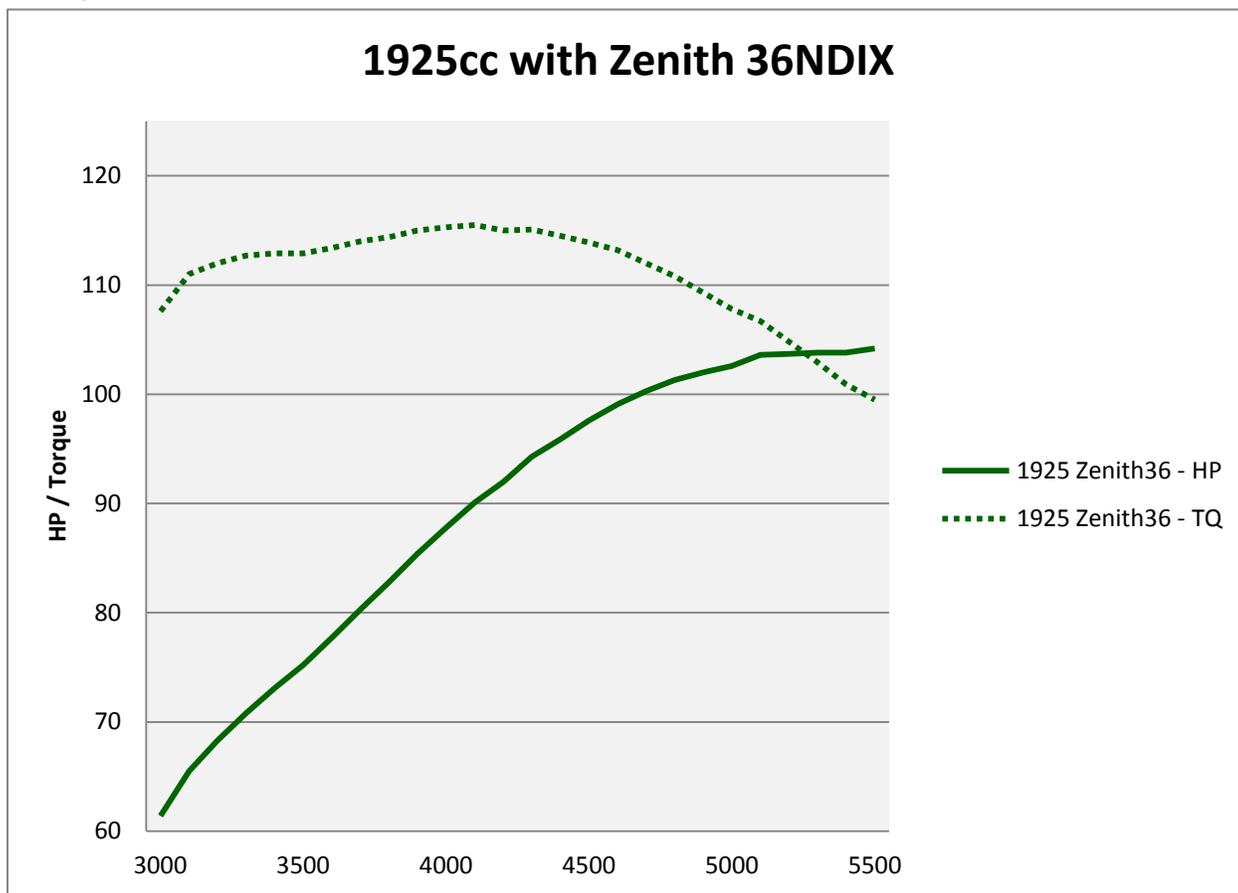
Stock 356C/SC heads with stock valve springs.

Zenith carbs modified to **36NDIX** with ported manifolds and stock air cleaners (**these carbs were tested on the dyno but were later changed to stock Zenith carbs because of drivability issues...a back to back test of the 36 Zeniths is shown later in this article**).

Stock exhaust.

WR CDI ignition.

104hp@5500 / 115ftlbs@3900



This was a fun car to drive with excellent power and good overall performance. I was very satisfied with the results and the owner loves the car. The engine looks completely correct and is concours acceptable.

The limitations of the Zenith carbs are obvious, and the comparison chart below is a good way to see the difference that larger carburetors can make on an engine of this size. If you like the sensation of a Super 90 or SC, or an engine with a sport camshaft, this engine might disappoint you. Even when modified to 36mm, the Zeniths carbs just don't flow enough air to feed an engine this size in the upper rpm ranges. The smaller carbs, and the advanced camshaft timing, do bring the power band down and do give great throttle response for around-town driving. If this is what you're after, this engine would make you happy.

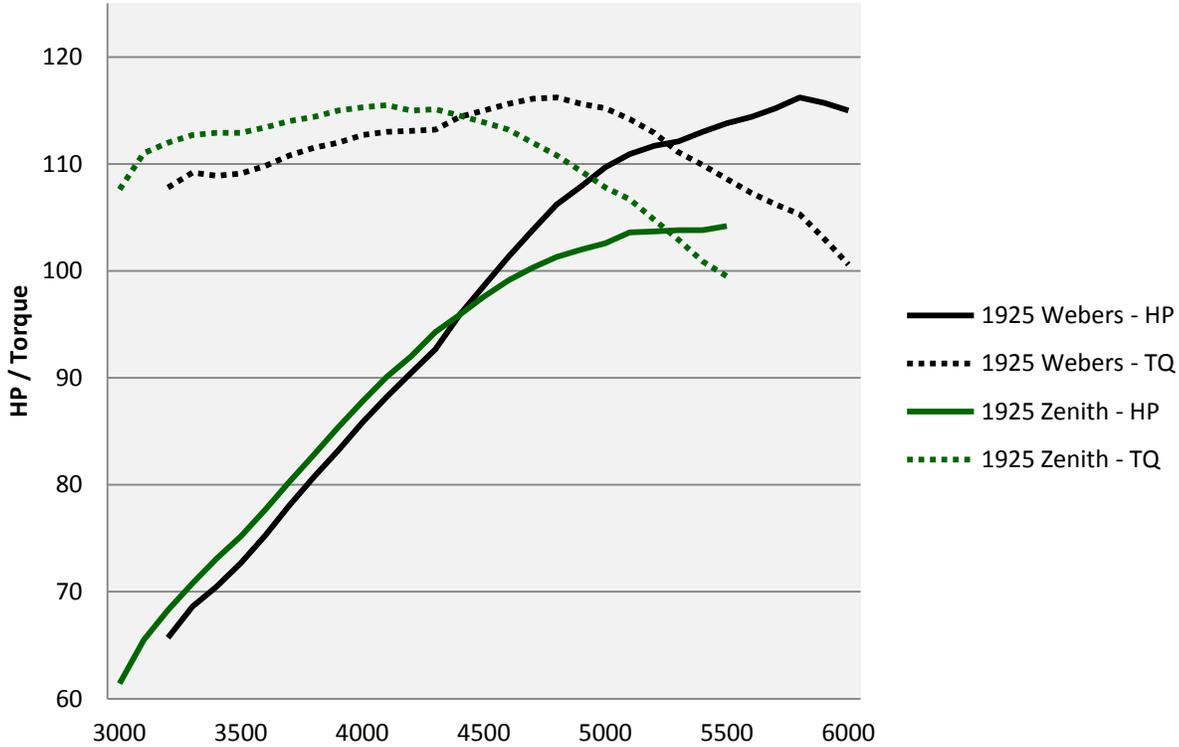
1925 Zeniths vs. 1925cc Single Plug (Webers)

This graph shows how the 1925cc engine can benefit from improved breathing.

116hp@5800 / 116ftlbs@4800

104hp@5500 / 115ftlbs@3900-4300

1925 Zenith vs. 1925 Single Plug (Webers)

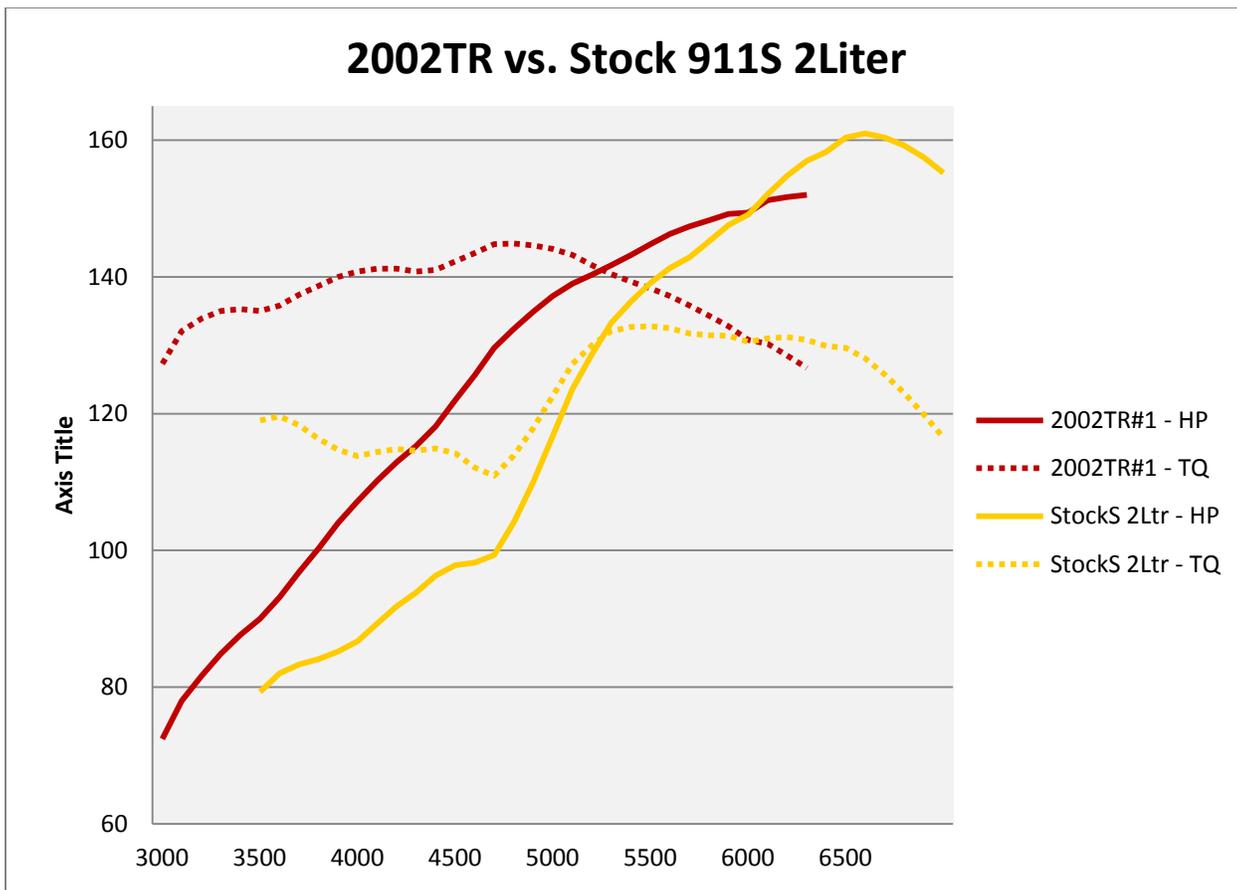


2002TR#1 vs. Stock 2 Liter 911S

This graph compares a completely stock 2 liter 911S engine, with stock muffler and air cleaners, to the first test of the 2002TR with stock muffler. *The first 2002TR engine test specs are shown in the Engine Development PDF file.*

151hp@6200rpm / 146ftlbs@4900rpm

161hp@6600rpm / 133ftlbs@5500rpm



The 2Ltr 911S has the advantage of a bigger cam, higher RPM, and the added cylinder filling of 6 cylinders, but can't match the power of the 4 cylinder 2002TR until 6K. It will be interesting to compare a 2002TR with a hotter camshaft and free flow exhaust.

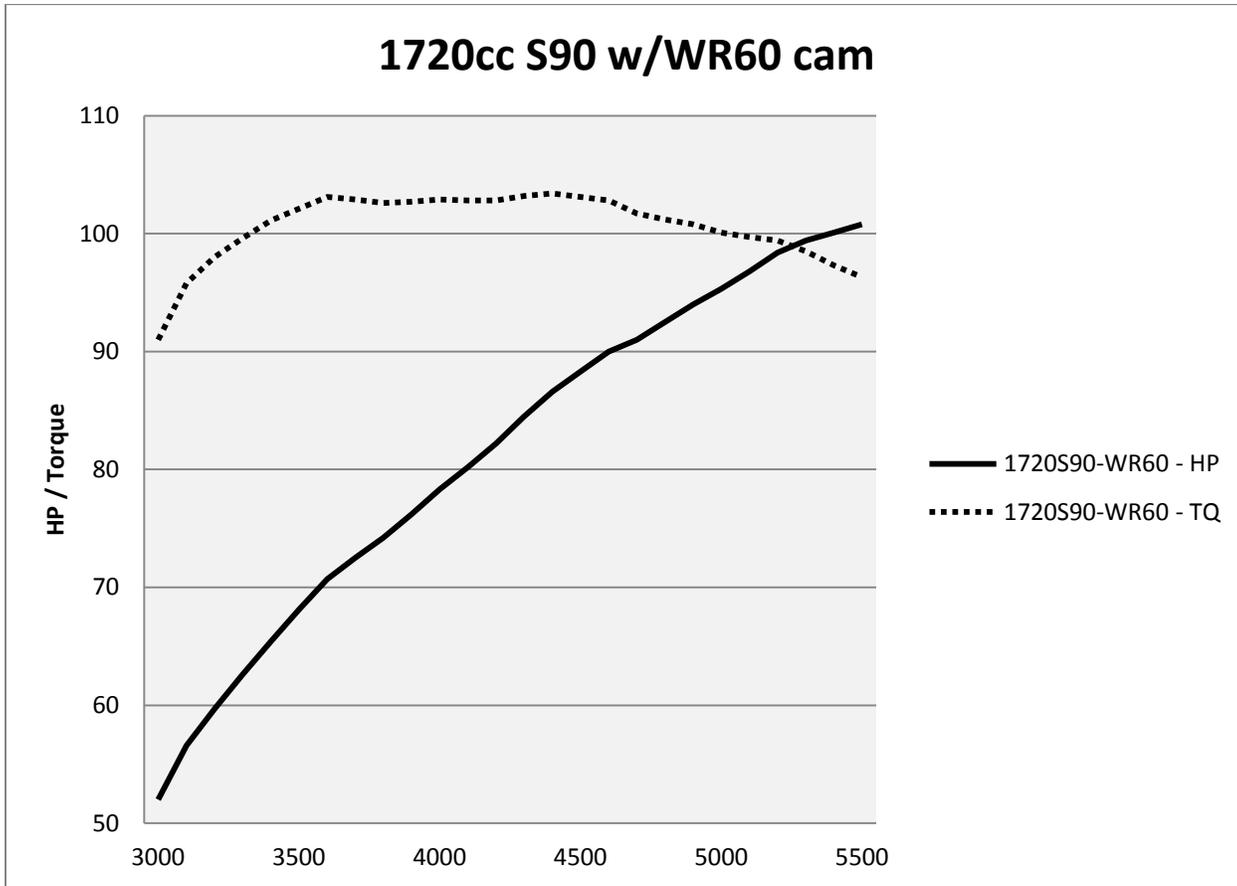
1720cc S90 with WR60 camshaft

This is the first test of the 1720cc engine with the WR60 camshaft. The duration of the WR60 is 242 degrees on the intake with .365" of lift. The exhaust has a stock Super profile of 234 degrees with approx .325" of lift. Lobe separation is 108 degrees. The production WR60 cam is advanced 3 degrees when ground to provide lobe centers of 105 degees on the intake and 111 degrees on the exhaust. It provides excellent low end performance and is an improvement over the stock cam and the popular Elgin 7008 as shown in the following tests. This engine was assembled completely stock with the exception of:

WR60 camshaft 242 degree, .366" lift Intake / 234 degree, .325" lift Exhaust (advanced 3 degrees).
86mm cast iron cylinders with JE forged pistons, 9:1 CR.

Test RPM was limited to 5500.

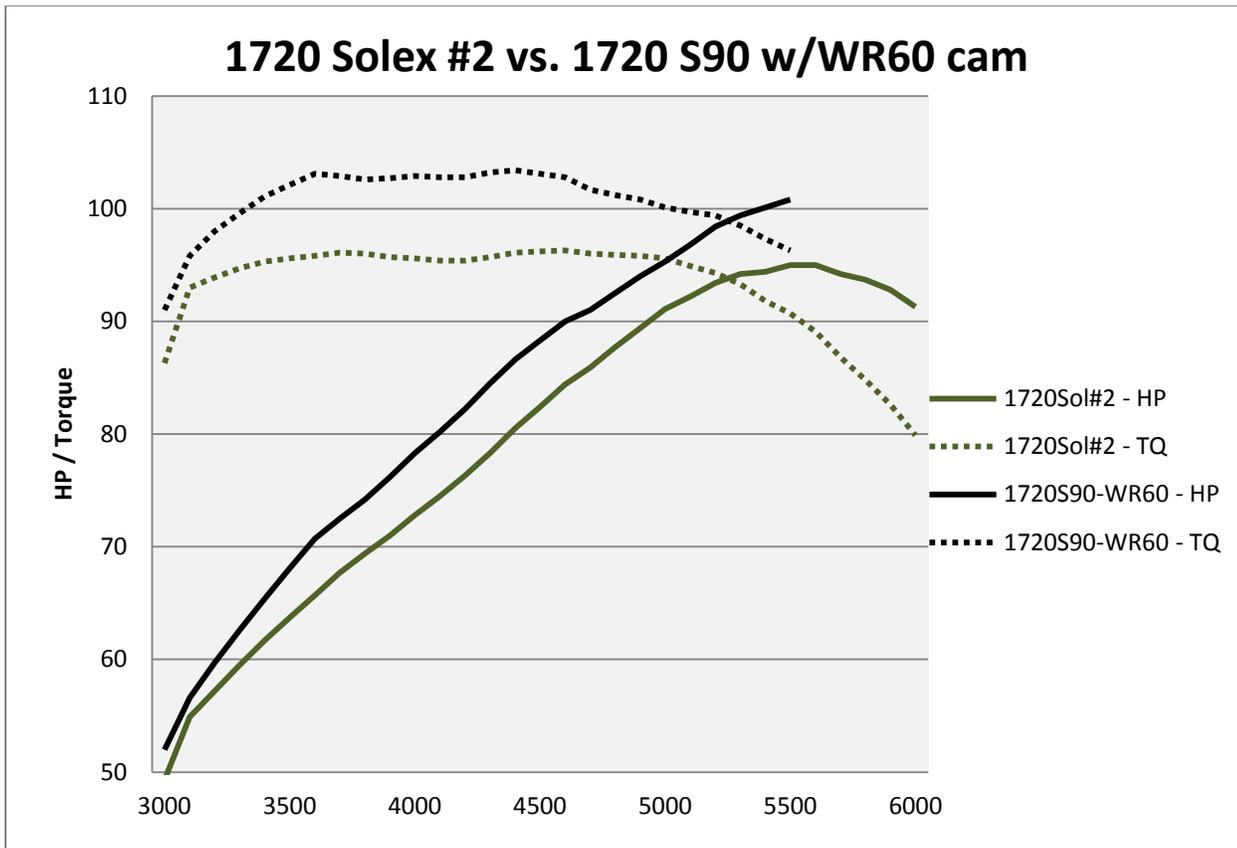
101hp@5500rpm / 103ftlbs@3600-4400rpm



The next graph compares a basically stock 1720cc SC Solex#2 and the 1720cc S90 with WR60 camshaft. The larger exhaust valves don't seem to help the SC.

101hp@5500 / 103ftlbs@3600-4400

95hp@5600 / 96ftlbs@4600

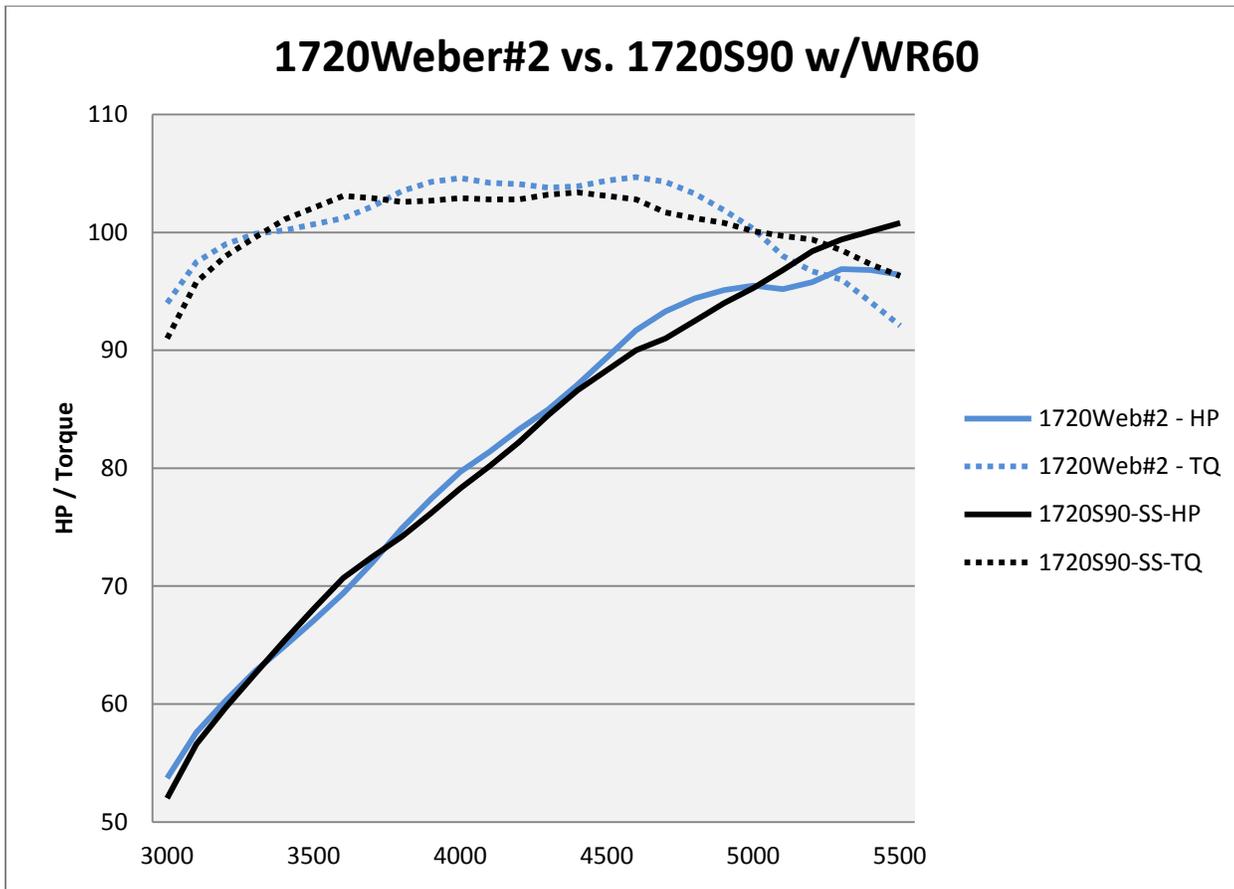


Since the Solex #2 engine wasn't assembled at WR, it's difficult to determine the exact differences in the specifications between the two engines. The WR60 S90 definitely has the edge.

The next graph compares the 1720cc Weber #2 to the 1720S90 with the WR60 camshaft. Both of these engines have 31mm exhaust valves. The S90 has the stock 40mm intakes the Weber engine has 38mm intakes.

101hp@5500 / 103ftlbs@3600-4400

97hp@5300 / 105ftlbs 4600



This comparison shows two things, the boosted mid range available with the Weber air horns, and the boosted top end performance available with the WR60 camshaft.

In Search of Low and Mid-Range Torque

Hotrod engines for a performance minded customer who is willing to put up with the modified look, the required shifting, and the lower rpm performance loss, can be a lot of fun. However, many 356 owners want an increase in power without modifying the power curve or the looks of the engine (twin plug, etc). A quick check of most 356 owners driving habits will show that most shift between 3800 and 4500, and few rarely rev over 5500. After building a number of very powerful engines with extended redlines in the 7K rpm range, I decided to approach the “performance” 356 engine in a different way: by designing an engine with a 6K redline and stock power curve (peak torque around 4200 and peak hp around 5500) but with an improvement in power throughout the entire rpm range.

Obviously, the larger the engine, the more power it will produce, but this brings up the question of dependability and overheating of the engine. The WR 77mm crank and Carrillo rods are bullet proof, and with the use of the LN Engineering cylinders, piston-squirters, and the aluminum fan-shroud oil cooler, engine temps are not difficult to control...in either the 1925cc or 2002cc. A stock full-weight flywheel, or even a slightly lightened one, are fine for damping the resonance of the longer 77mm crankshaft, especially when the revs are kept under 6K, but to realize improvements from the increased engine displacement the breathing needs to be better. This is achieved by more cylinder head flow, either by increasing valve and port size, or adding more camshaft lift and duration. The problem with increasing camshaft lift and duration is that it puts more stress on the valve gear, and the increased valve overlap affects the very low rpm power and throttle response. The valve gear stress is not a major concern if the revs are kept under 6K, but maintaining excellent low rpm power and throttle response is important.

For the next engine, I decided that a stock Super cam profile was the maximum I would use in order to keep the power curve stock. The heads were modified with regular steel (not stainless) 42mm intake valves (with 8mm stems) and the chambers modified to provide the best flow with the 91mm cylinders. The exhaust valves were standard SC/912 sodium filled with stock 10mm stems. Head flow with identical intake and exhaust cam profiles was at 75%, exhaust to intake, exactly what I wanted.

For this engine, the camshaft is a new design, the WR50, with 112 degree lobe separation. The wider lobe separation gives less valve overlap and more intake vacuum. The engine specs and results of the dyno test are listed below.

1925cc SC w/WR50 camshaft

WR50 camshaft 234 degree, .325" lift, 4 degrees advanced.

91mm LN Eng, Nikasil coated aluminum cylinders and JE pistons with 9.0:1 CR.

WR aluminum pushrods.

Stock SC crank and rods.

Modified late heads with 42I/34E valves.

Solex 40P11s with stock 32mm venturis. New Euro Alu. aircleaners with 2" air stacks.

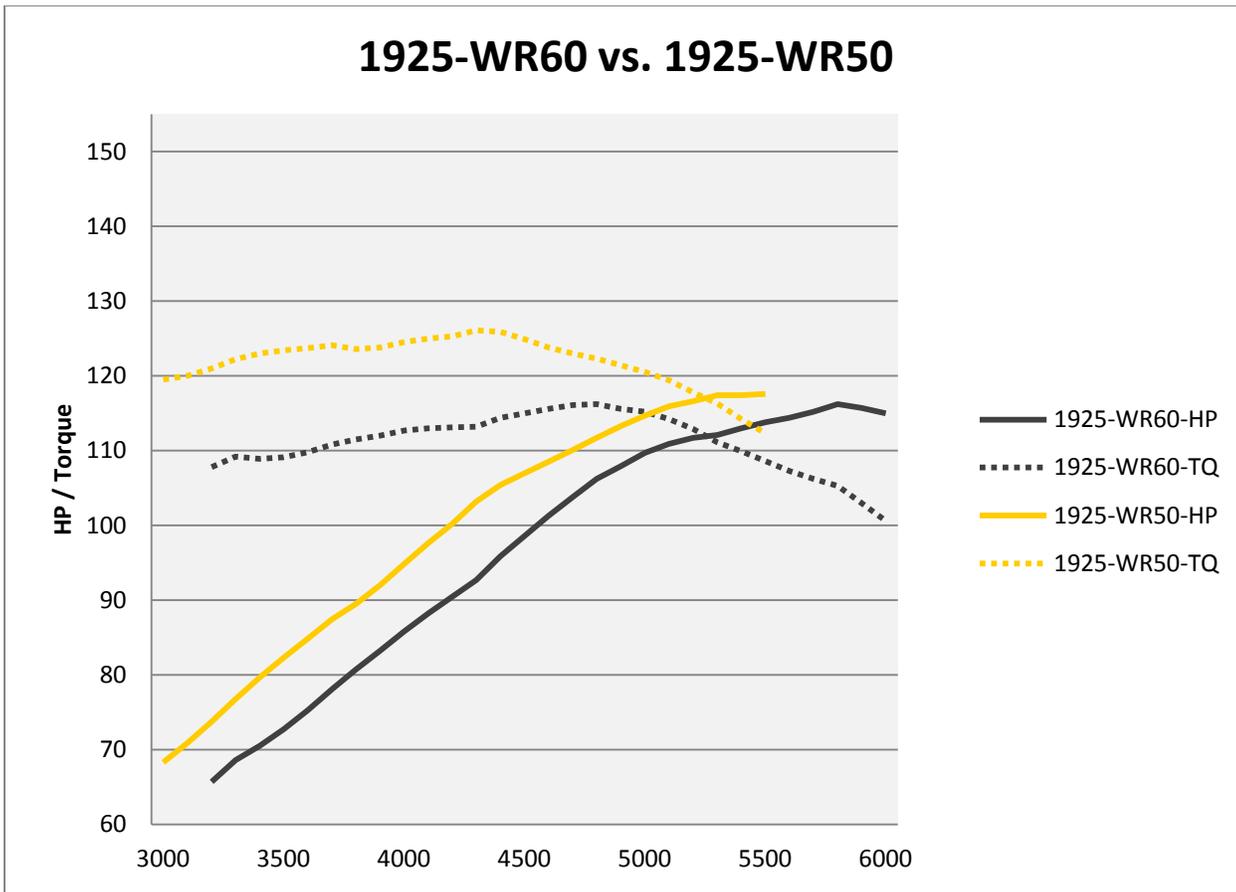
Stock exhaust.

WR CDI ignition.

117hp@5300 / 126ftlbs@4300.

The engine is charted with the 1925 single plug with Webers and WR 60 camshaft.

1925-WR60 vs. 1925-WR50



You can see from the chart that the new camshaft provided a real boost to the bottom end and mid range. We limited testing rpm to 5500 and the engine would easily load with full throttle at 2500, which is usually a problem for most 356 engines. It would also easily rev past the 6000rpm redline which was set with the WR CDI ignition. The car was a blast to drive. The torque was completely flat and any type of driving was effortless.

THE NEW WR50 CAMSHAFT...the perfect street cam.

There is really one thing that will directly improve throttle response – vacuum. All of the other changes such as smaller valves, smaller carbs and venturis, more ignition advance, are ultimately trying to achieve the same goal, just from a different direction. Simply advancing the camshaft will increase vacuum, mostly by advancing the intake valve closing position. This change alone will increase the dynamic compression ratio but will also move the power curve down in RPM (you'll make peak power at a lower RPM). Increasing the lobe separation reduces the overlap, which also has the same effect, but simply increasing the lobe separation moves the intake event so that lower cylinder pressures are achieved and the power curve is moved upwards in rpm. A combination of the two is the answer.

The newest camshaft, the **WR50**, takes advantage of widened lobe centers (more lobe separation) and an overall advancing of the camshaft. The result is better vacuum at idle providing an overall better idle, better low rpm throttle response, and better fuel economy. *The WR50 has been designed for use with 42mm intake*

valves and 34mm exhaust valves. No testing has been done on smaller valve sizes but the cam should work well in those applications as well.

THE WR50 CAMSHAFT INSTALLATION SPECS

<u>Camshaft</u>	<u>Lobe</u>	<u>Lobe Center</u>	<u>Duration@.050</u> "	<u>Open</u>	<u>Close</u>	<u>Lobe Sep</u>
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WR50 - Setup for Solex 40P11 or Webers advanced 4 deg.

INTAKE	108	234	9	45	112
EXHAUST	116	234	53	1	

WR50 - Setup for Zenith or early Solex carbs advanced 6 deg.

INTAKE	106	234	11	43	112
EXHAUST	118	234	55	-1	

LIFT .325"

The WR50 cam is ground straight up and must be advanced during installation. This can be accomplished by using the WR Adjustable Cam Gear Kit and following the "Degreeing the Camshaft" instructions. To simplify the indexing procedure, you can just set the intake-closing event (ABDC) at the degrees marked in **blue**. Generally, a variation of + or - 1 degree is not a problem.

1720cc 356C with WR50 camshaft

This is the first smaller 1720cc engine tested with the WR50 camshaft and 356C cylinder heads modified with WR stainless intake and exhaust valves.

WR50 camshaft 234 degree, .325" lift, 6 degrees advanced.

86mm LN Eng, Nikasil coated aluminum cylinders and JE pistons with 9.5:1 CR.

WR aluminum pushrods.

Stock C crank and rods.

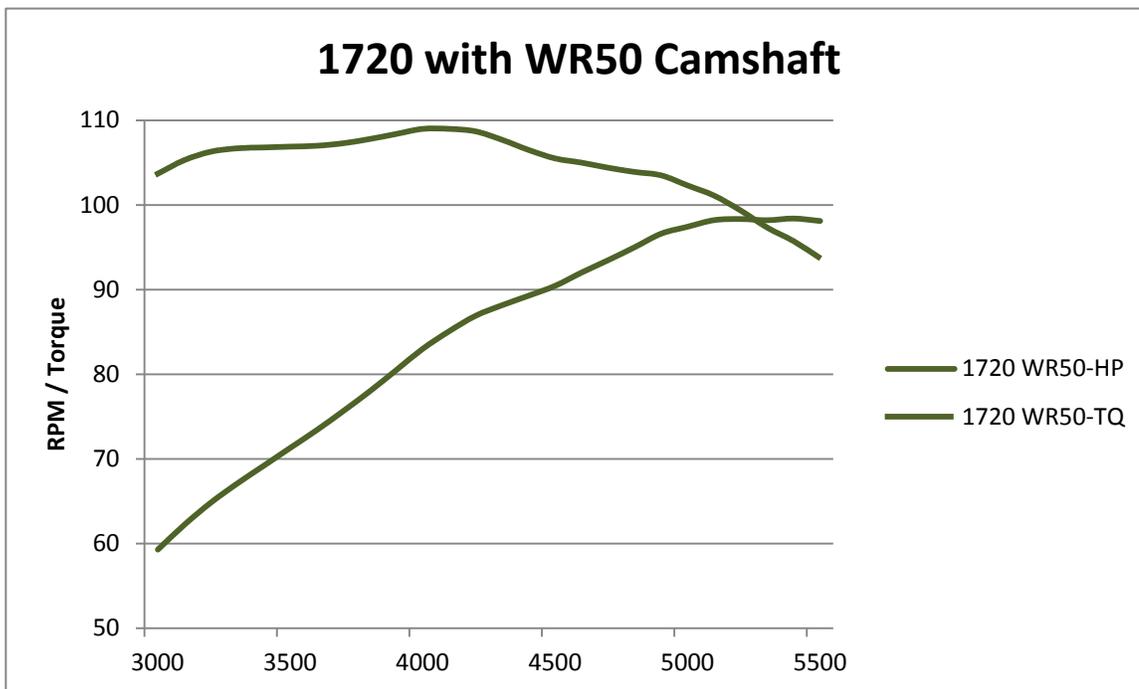
Late heads with 42I/34E valves.

Stock 32NDIX Zenith carbs with 28mm venturis and stock mesh aircleaners.

Stock exhaust.

WR CDI ignition.

98hp@5100-5500 / 109ftlbs@4100

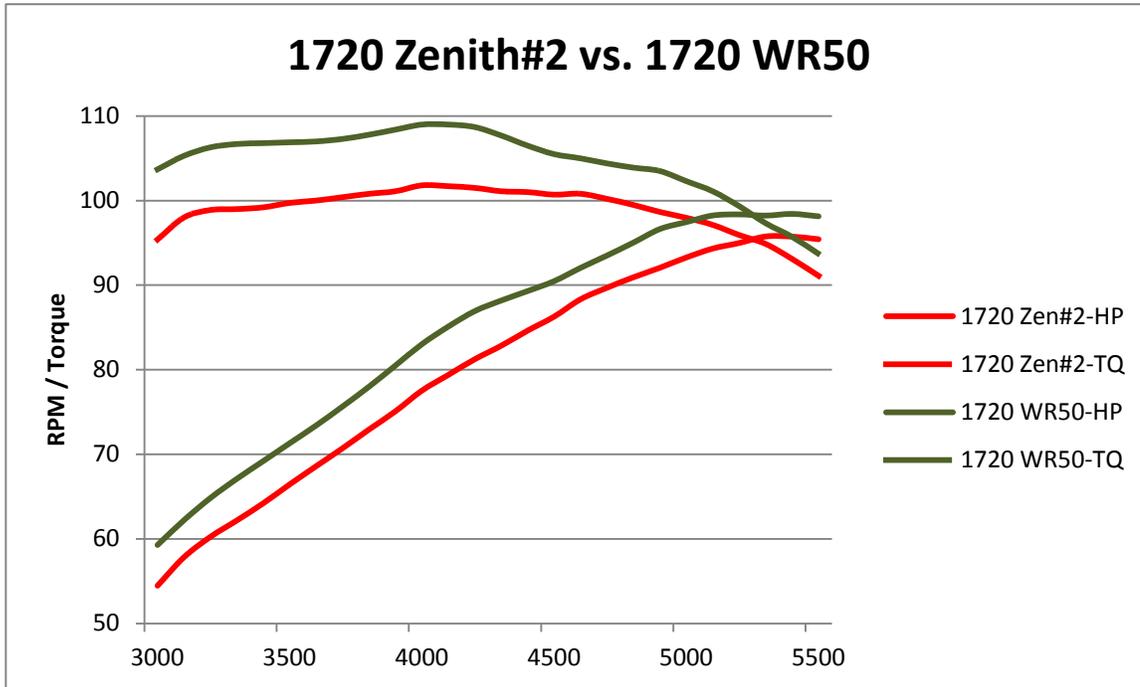


The 356C engine was stock except for the larger 42mm intake valves and the WR50 camshaft. The engine performed very well in the car. It was noticeably stronger all the way through the RPM range compared to a stock 1720cc C engine, and because of the excellent vacuum, the engine would easily idle at 600-700 rpm.

Below is a comparison to a previously dynoed 1720cc 356C engine with an Elgin 7008 camshaft and stock heads (**1720 Zenith #2**).

96hp@5400 / 102ftlbs@4000

98hp@5100-5500 / 109ftlbs@4100



The chart shows the dramatic improvement in power throughout the rpm range with the combination of the WR50 cam and larger intake valves. This test shows that cylinder head work, including larger intake valves and better flow in the combustion chamber, **is not only an advantage with big carbs and more displacement.** Remember, more camshaft duration produces peak power at a higher rpm but with the smaller Zenith carbs that is not the best combination.

WR-DELTA Cylinder Heads



The stock 356 cylinder head has always suffered from poor flame travel, especially when the chambers are opened up for better flow. The larger chamber then requires a taller and heavier dome on the piston, which not only adds weight to the piston, but further inhibits flame travel across the top of the piston dome. Twin spark plugs solve this problem, but not everyone wants the non-original look of twin-plug ignition, and the added expense that comes along with it.

When I first started to increase power in the 356 I found (and substantiated on the dyno) that more intake flow was needed (please see the Engine Development article). This required larger and less shrouded intake valves, and as mentioned above, the chambers and piston domes grew larger. A solution to the problem was needed, but it would require redesigning the chamber and a special 3 dimensional machining of the piston dome to correctly match the new chamber.

Several test heads were welded up, machine and hand shaped, several intake valve sizes tried, and all were flow tested to determine the combustion chamber shape that would provide a good compromise between flow and size. The first prototype head is pictured above, with the matching piston. As you can see, the sides of the chambers have been completely welded up to the surface, providing a true squish area around the combustion chamber. An added advantage of this design is that a 10mm- $\frac{3}{4}$ " reach spark plug can be used. This pushes the plug further out into the center of the chamber, providing much better flame travel, and the 10mm size provides a much larger area of metal between the plug and the valve seats. The large unshrouded chamber of the 91mm twin plug heads were typically 73cc in volume, and had excellent flow. The new head has a chamber that is only 65cc in volume and the flow is only slightly less at close to full lift. At lower lifts the flow has actually improved slightly.

The prototype head pictured, and the matching piston, is the one used on the first test engine. The first test of the heads was not done with performance in mind. The main goal was to test the new chamber design in

regards to timing and fuel quality. If the results were positive, the next step would obviously be with a high performance engine.

The test engine was very similar to the 1720cc with the WR50 camshaft. The difference was that this engine used smaller 40mm intake valves, smaller Normal intake ports, and a lower compression ratio of 9.0:1. These changes were made because I wanted to directly test the difference between the intake valves and port size on a Zenith carbureted engine, and with the lower compression ratio, the possibility of running Normal fuel rather than premium with the new heads. The performance of the new heads, and specifically the timing advance necessary to achieve the best performance, would tell me what I needed to know about the new chamber design.

The engine was dyno tested with the following specs:

WR50 camshaft 234 degree, .325, 6 degrees advanced.

86mm LN Eng, Nikasil coated aluminum cylinders and JE pistons with **9.0:1 CR.**

WR aluminum pushrods.

Stock C crank and rods.

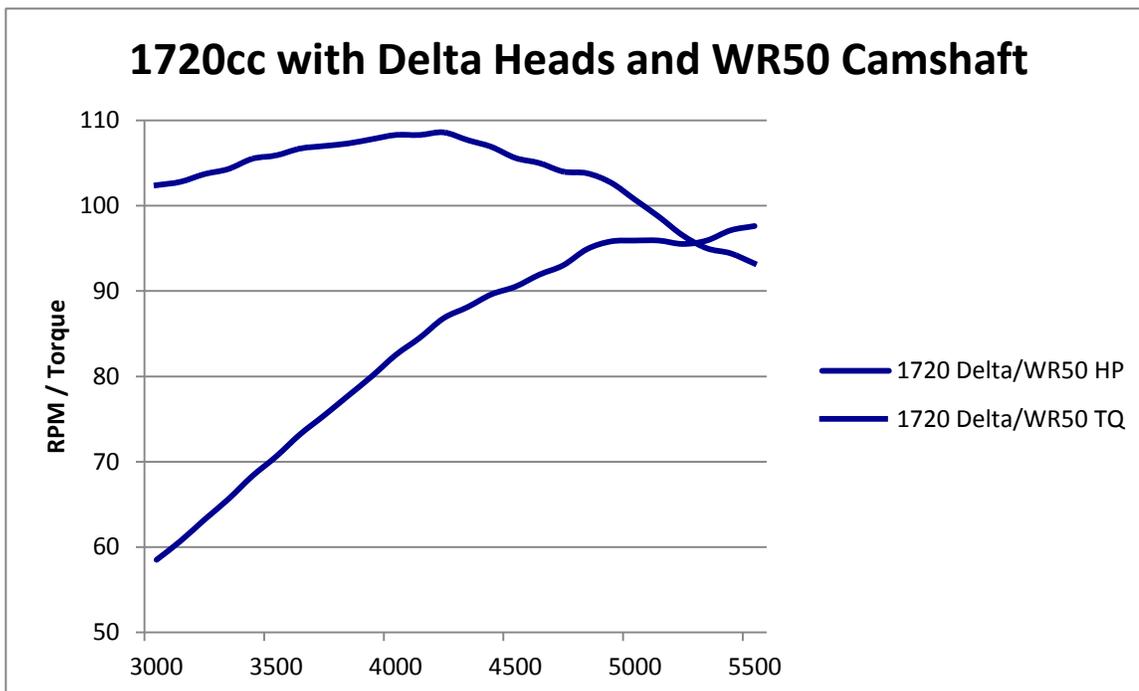
WR Delta Heads with 40I/34E valves and smaller Normal intake ports.

Stock 32NDIX Zenith carbs with 28mm venturis and round can type air cleaners.

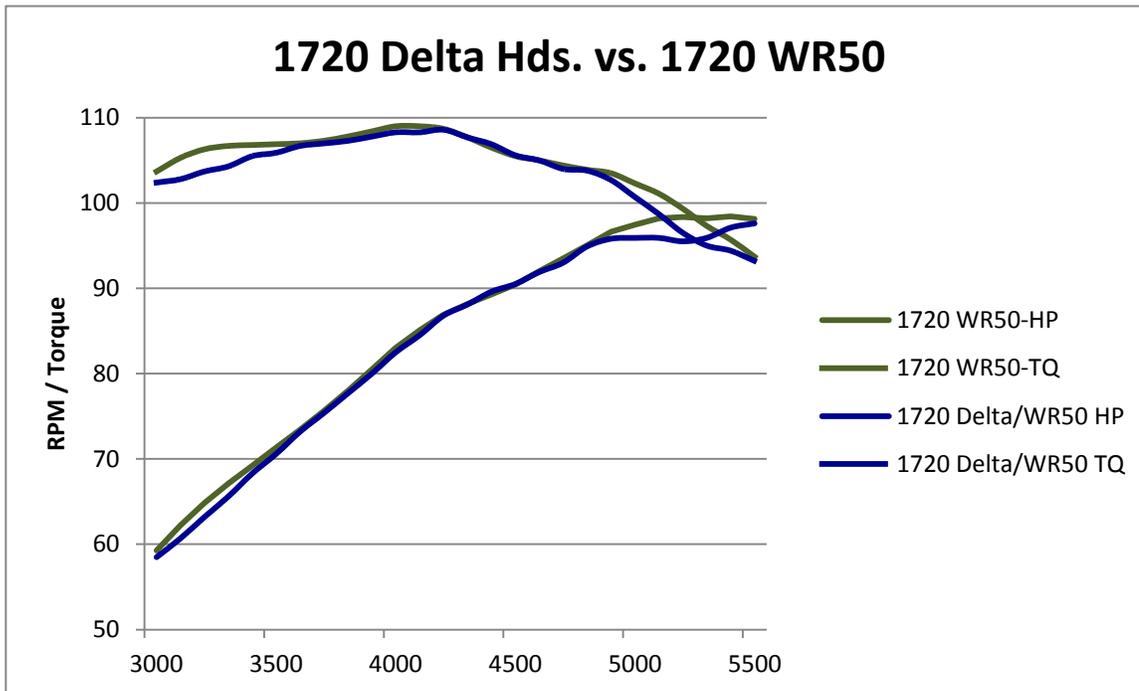
Stock exhaust.

WR CDI ignition.

98hp@5500 / 109ftlbs@4200



Below is a comparison of the Delta Head engine vs. the 1720 Zenith WR50 without the Delta Heads.



The drop off in performance above 4900 RPM shows that the larger Super ports, and 42mm intake valves, of the 1720-WR50 engine helped the upper rpm flow. The lower rpm gain can be contributed to the higher compression ratio, but since the engine was able to perform well on Normal fuel, this was an acceptable and expected trade off.

As far as the WR Delta Heads are concerned, some amazing results were realized. The best power was achieved with a maximum timing advance of only 30 degrees vs. the typical 36 degrees (28 degrees is the typical advance limit used in the twin plug engines). This is the best indication that the new chamber is more efficient and that the new spark plug location provides much better flame travel. Also, this power was achieved with a one-half point lower compression ratio, and on regular fuel! Up until now, even Normal engines have required Premium fuel.

The obvious next step is a performance engine with the new WR Delta Heads. Since it's obvious that more compression with less timing advance is possible, I'm convinced that any engine will benefit from these heads. But before I build a performance single plug, I want to test twin plug and single plug ignitions side by side in the new heads. This will be the final word on whether twin plug is still necessary in high-performance 356 engines.

The idea of a completely stock looking engine producing twin plug power is exciting. STAY TUNED!

WHY DO WE WANT LESS OVERALL ADVANCE?

The most obvious indication of the efficiency of a combustion chamber is the amount of timing advance needed to completely burn the mixture. Timing is usually pushed right to the limit of detonation in order to achieve the most complete burning of the mixture, the highest cylinder pressure, and the most power. The “perfect” timing is the point where the engine makes the best power without detonating, and with a good dyno, this is easily determined (when timing is advanced too far, power will begin to fall off). A more efficient chamber usually has a softer transition into detonation. For this reason, a better, more efficient chamber is an advantage with any engine.

WHAT’S WRONG WITH THE 356 CHAMBER?

We have to consider the roots of the 356 engine. Since the base engine for the first 356 was a VW, the most obvious way to increase performance was to increase cylinder head flow and rpm. Porsche designers used the basic VW design and moved the position and angle of the exhaust valve to allow the valves to be made much larger with the same bore size. This increased the flow dramatically, but also substantially enlarged the combustion chamber. Since Porsche was already on its way to designing the four cam and later 911 engines, a major change to the 356 head was never undertaken (some subtle changes were made for the 356C: unshrouding of the intake valves and steepening the chamber bevel cut to improve flow, and an increase in the exhaust valve size). The large chamber of the 356 typically requires 36 degrees of timing advance to achieve complete combustion. This is also the case with other large, single plug combustion chambers, and larger domes for higher compression almost always require twin plugging to achieve maximum power (the 4 cam and early 911 engines are good examples). Twin plugging looks “cool” but is a solution to a design problem that has been solved in newer engines with 4-valve chambers and centrally located plugs. Engine designers will usually agree that one good flame front will make more power than two colliding flame fronts, providing the burn is complete. We’ve already proven that twin plugging with the stock chamber and high compression improve performance in the 356, but what about the new WR Delta heads?

“Throwing down the gauntlet “ TWIN PLUG vs. SINGLE PLUG!

About a year ago one of the first 1925cc twin plug engines suffered a minor engine failure. The intake valve guide on the number 4 cylinder came loose and was sucked into and damaged by the valve, resulting in a small piece of the guide being sucked into the chamber and damaging the top ring land of the piston. Amazingly, the stainless valve and Nikasil cylinder were not damaged, but the chamber was beat up badly by the small piece of silicon-bronze guide material. Up to this point, I had no special guides for the 356 heads that used 8mm stemmed valves, and the cylinder head shop that I had been using was making them from blank 8mm oversized guides. Stock 356 guides are simply pressed into the head with approximately .005-.008” of interference fit and generally are not a problem. That wasn’t good enough, and so I designed a guide that would eliminate the potential problem. The new WR Guide is of silicon-bronze material and has a tapered tip for the intake and a flat tip for the exhaust. It’s machined for a standard 8mm intake stem seal and has a ring

just below the spring perch that is counter-bored into the head. On top of this ring sits a special WR Spring Pad that locks the guide into place, and also has an inner support for the new WR Dual Spring. Should the guide ever become loose it cannot move because it is locked in place by the spring seat and counter-bored head. The springs are perfectly matched to the 356 engine and can accommodate lifts up to .500" with the seal and spring seat in place.



You're probably asking what this has to do with twin plug vs. single plug engines? Well, when the owner experienced the failure, I had the car transported to the shop and pulled the cylinder heads. Since the engine's performance had been well documented on the dyno, and by hundreds of miles of driving at WR and also by the owner, the performance and character of this engine were known. And since I was in the middle of testing the first set of WR Delta heads, this engine presented the perfect opportunity to do a back-to-back test of the potential changes, performance increase/decrease, and twin plug vs. single plug using the new heads. Of course, this was done at no cost to the customer and he was thrilled to have his engine updated to the new design.

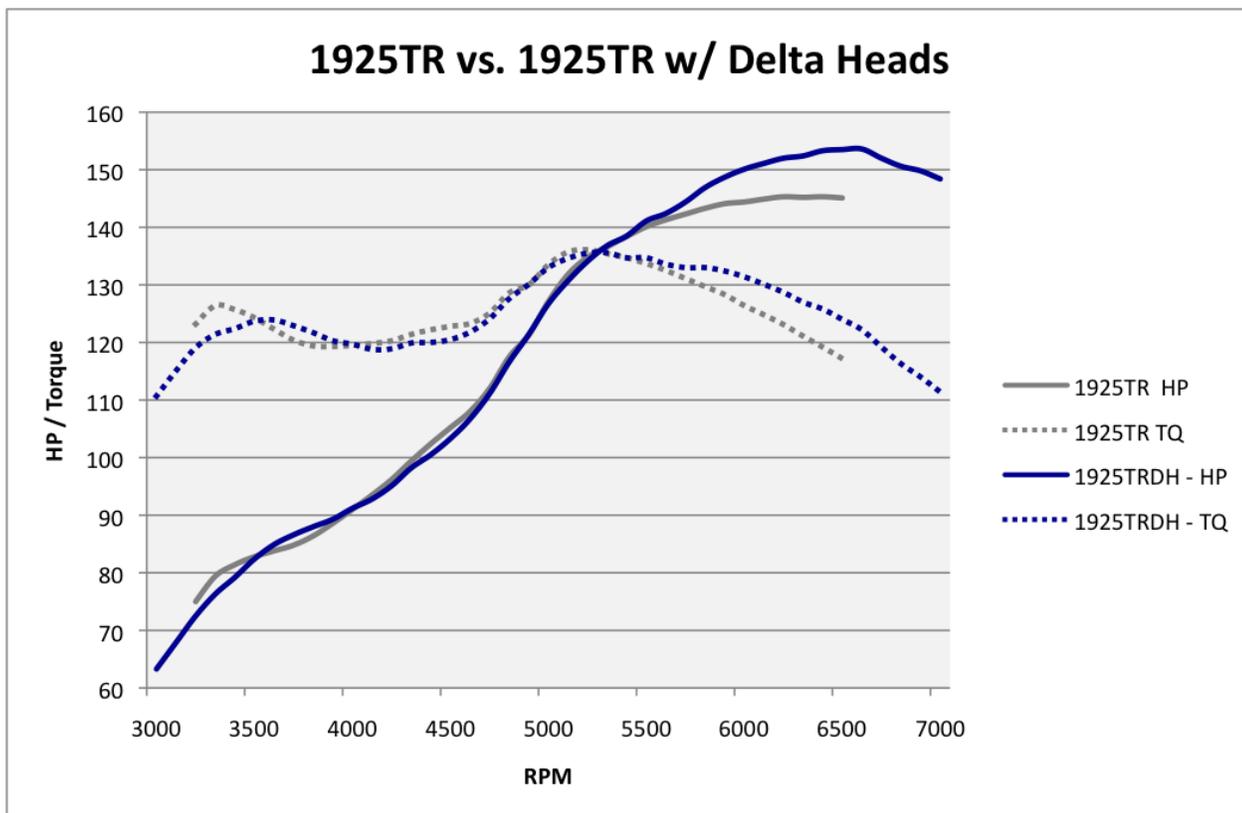
The customer's heads were disassembled, and the extensive welding and machine work were performed to convert the chambers to the new WR Delta head design with the second (lower) plug in place. The main plug was changed to the 10mm 3/4" reach, and the lower plugs remained the 10mm 1/2" reach type since their location wasn't changed. New pistons also had to be made and JE had to make a special 3D program for the one-off twin plug design. The compression ratio was not changed and remained at 10.5:1. Everything else on the engine remained the same...the only changes were to the cylinder head chambers and the pistons. The first testing was done on the DTS engine dyno at Head's Up Performance in Fullerton, CA. A special switch was installed so that the engine could be easily changed from twin plug to single plug ignition.

The first dyno chart below shows the performance as tested with the new Delta Heads vs. the original dyno tests with the old style WR heads. Both these curves are with twin plug ignition turned on. As you can see, the Delta head design added 9 HP to the performance...with no other changes! *This was an improvement that was not expected.*

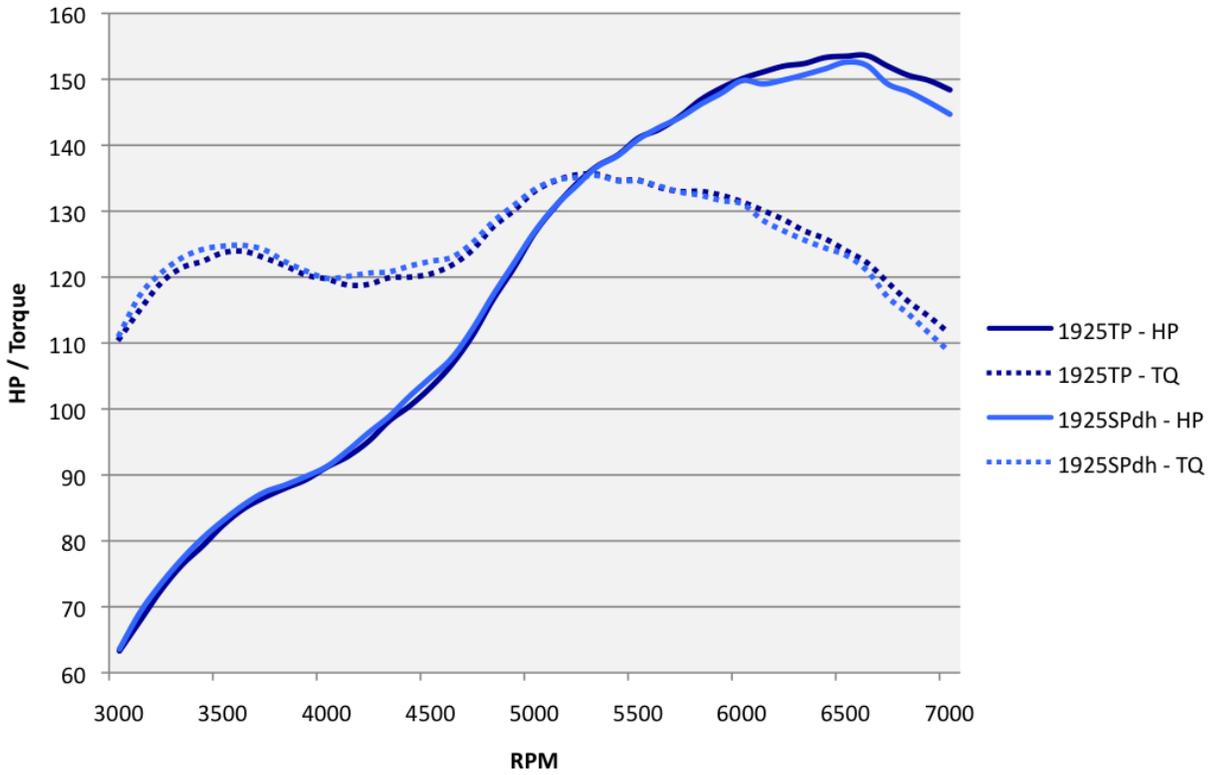
The second chart shows the latest engine test with twin plug turned on vs. single plug (with only the upper plug firing). With twin plug the best power was achieved at 28 degrees maximum advance; with single plug the best power was achieved with 34 degrees advance. There is a slight increase above 6K but not enough to warrant the expense of twin plug.

The results of testing on this engine have definitely given a “thumbs up” to the WR Delta head design. Of course, further testing will be done, and six engines with different applications are currently under construction. The most exciting news is that it’s possible to achieve twin plug performance on a basically stock looking engine!

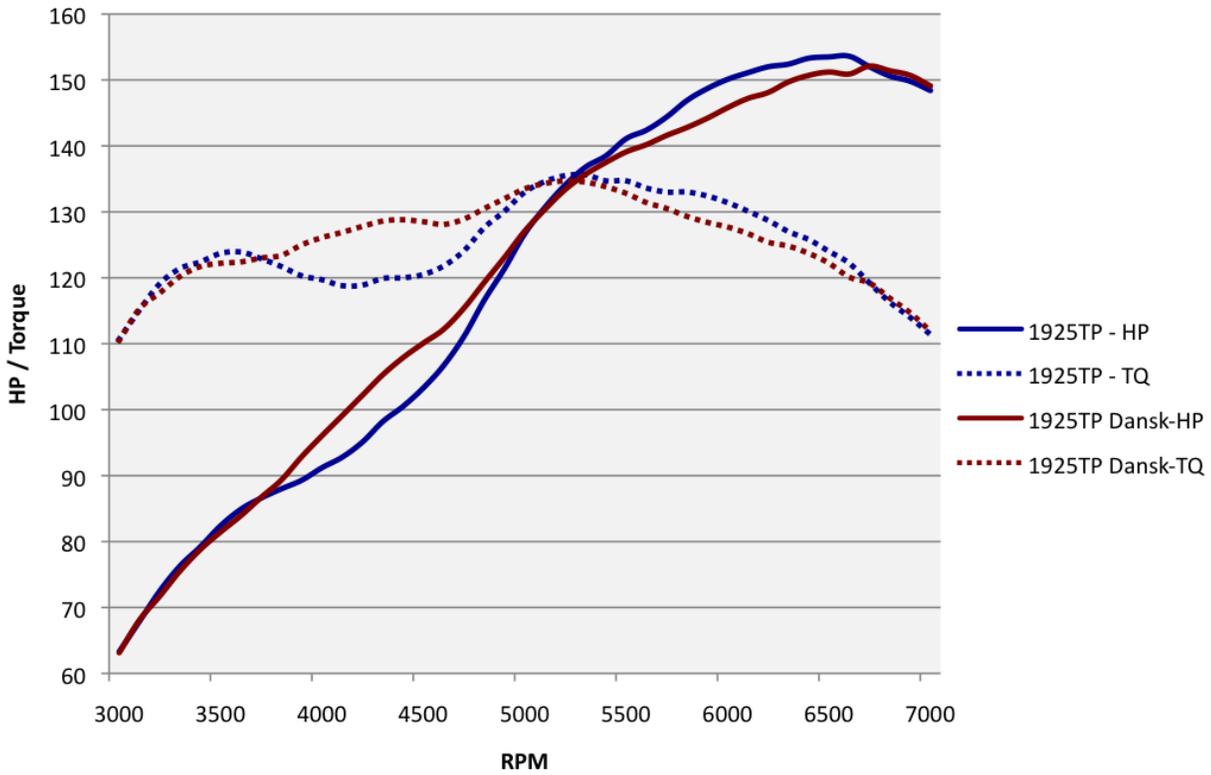
Two more charts show the comparison of the WR Sport Exhaust vs. the stock Dansk exhaust, and also the comparison of the WR Sport Exhaust to a 1.5” diameter 4:1 header. These charts show the dramatic affect that exhaust can have on an engine with a performance cam that has a lot of overlap (camshaft selection is discussed in the [Building a Performance Engine](#) article).



1925 Twin Plug vs. Single Plug DH

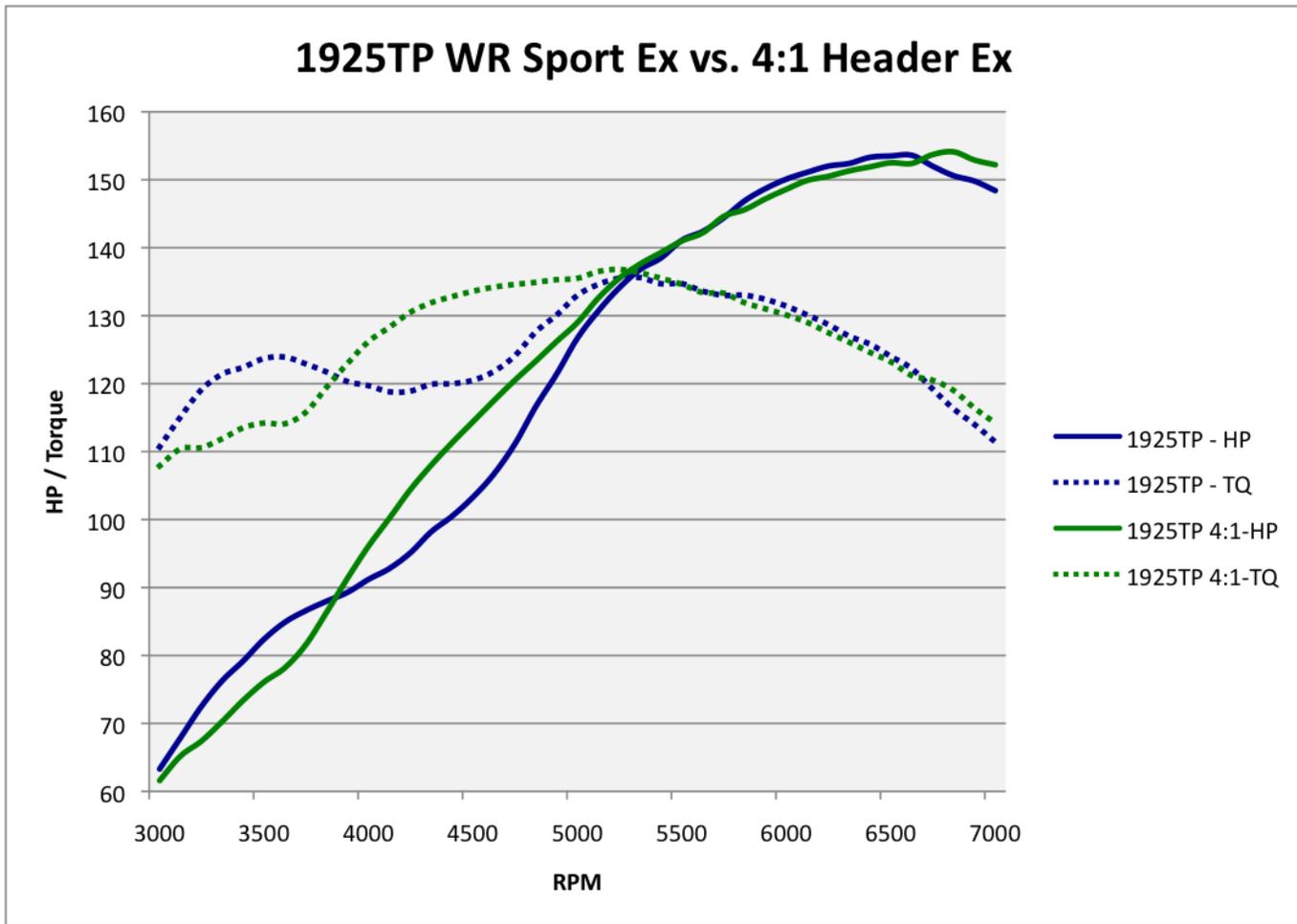


1925TP WR Sport Ex vs. Stock Dansk Ex



In the above graph you can see the improvement to the mid-range from the baffles and backpressure of the stock Dansk muffler, but the added backpressure also reduces the power above 5250rpm.

Most stock mufflers are designed to reduce a phenomenon known as reversion. A simple explanation is that when the normal pressure wave of the exhaust goes back up the pipe towards the cylinder head, it can have the affect of pushing some intake charge that is on its way into the combustion chamber back into the carburetor where it will be again sucked down as intake charge (big cams with a lot of overlap make this problem worse). This double carburetion creates an overly rich mixture in the specific RPM range that the reversion occurs, and that's why you always see a flat area in the power curve of big cam engines. This is covered in more detail in the Building a Performance Engine article.



The equal length 4:1 header is tuned for the RPM range between 3800 and 5500. The tuning affect limits the performance slightly between 5800 and 6800 and then improves the overall peak power. This was a header with no megaphone and no muffler. The megaphone, especially a reverse cone megaphone, of the correct length would boost the upper end power, and adding a muffler such as a glass-pack after the collector would add back pressure and reduce the top end power.

A proper 4:1 equal length header can tune the power for a specific RPM range...perfect for a race engine using a narrow powerband. The problem with the 356 engine is that the shortest primary length possible is about 36

inches, which is too long for high rpm power. Racers try and compensate for this by using larger diameter pipes, but this reduces the mid-range power.

As you can see, exhaust is always a trade off.

Coming next: The perfect 356 Street Engine