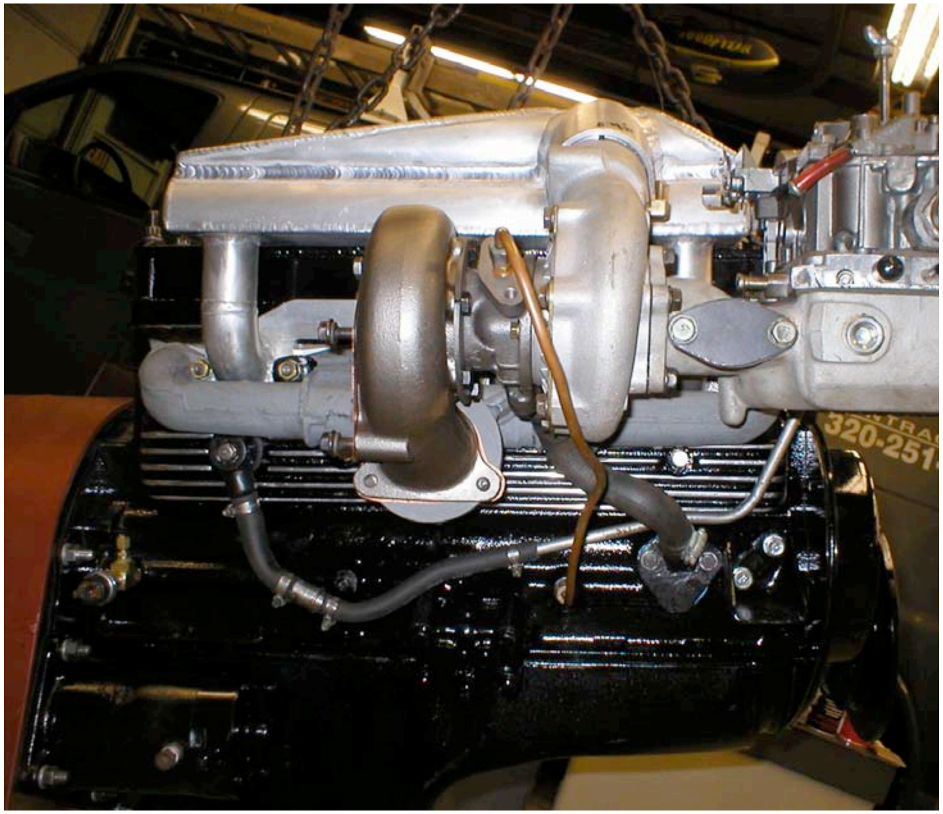


Salt2Salt engine in final form

Turbocharging the Champ flathead six

by Greg Meyers

I don't propose to know everything about the Champ flathead six, however, I do count myself as one of the few who have raced one that I built and set records at Bonneville: http://salt2salt.com . I have been modifying these motors for about 7 years now and have some comments for anyone who wishes to hear them. The long-time guru is Bill Cathcart, and you would do well to check out his website at: http://www.cathcartsstudebaker.com/ . I have relied heavily on discussions with Dick Datson and his various publications http://www.gatorsuperchargers.net/

The Champ flathead six remained minimally changed throughout it's entire production run, from introduction in 1939 until it was replaced by the overhead valve version (still basically the same on the bottom) in the early 60's. The engine had a bore of 3.00" and stroke of 4"(4.375" on the 185") which gave a displacement of 169 cubic inches. The cylinders were oriented to give a shorter, lighter block. There were three shared intake runners and four exhaust runners. End cylinders (numbers 1 and 6) each had its own exhaust with cylinders 1 and 2, 3 and 4, 5 and 6 "siamesed" together, oriented with less cylinder wall (and no water jacket) between them. There was still a substantial amount of meat between the cylinders, and some intrepid souls have hogged them out 0.125".


Note spacing between pistons

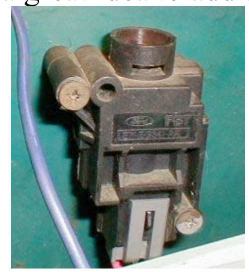
The crank was heat treated drop-forged steel and had 4 mains which, in the late fifty's were over 3" in diameter. It was only 1" longer than a Chevy v-8 crank, had significant overlap and was very hard. Rod bearing area was greater than the larger Chevy six. The rods were long at 6.375" with a light but strong I-beam configuration. This combination is ideal for supercharging or turbocharging. Remember, that the disadvantage of the flathead as opposed to the overhead was breathing, and with boost, that is not going to be a problem……

Ideally, most people want an engine which is not fussy about what rpm it is running. Torque should be available from the get-go. Most drivers don't run their cars long at 5000-6000 rpm unless they are obligated to in an effort to keep up with traffic. This is a consequence of the power band of the engine, and the overall ability to match it with the gearing available. Blowing (for this discussion, turbocharging or supercharging) a Champ engine is very logical once the elements are brought together. It has an indestructible bottom end. Cranks in these engines don't break. The rods are forged and can be made somewhat lighter. The longer stroke, according to Smokey Yunick, is a true asset in terms of torque thru 5000 rpm on anything but a full race motor. The cam timing for blown engines (turbos in particular) can be essentially stock. Valve timing is much less crucial in longer stroke engines. If you are able to make power between, say 2000 and 5000 rpm, and keep the gearing on task, then you should have a successful result.

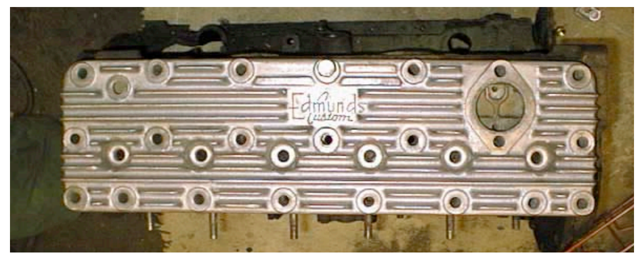
What needs to be corrected? Well, technology has indeed progressed since 1939, and with some really straight-forward modifications, an indestructible engine can result. The Champ engines had some oiling issues. Oil was distributed to the lifters, and on higher mileage engines, as the lifter bores wore, the clearances which resulted would translate into lower oil pressure. Few other engines with similar design had lifter oiling, and it has been common practice to eliminate this in Stude sixes. If you are squeamish about this, than start hunting for oversized lifters. The Stude overhead valve 6 oil pump can be bolted on in place of the Champ, IF you use the gear from the Champ which meshes with the cam. This is absolutely necessary though the gears look alike. With these mods, our Bonneville racer consistently was able to show 60-80 pounds under load. In racing situations, an oil filter was unnecessary, though a magnetic drain was helpful. In a daily driver, there are ways that a resourceful gearhead could modify the stock partial flow system to accept modern "outboard" aftermarket oil filters. By a little rerouting, the stock or modified oil pump can be made into a full flow system. On the TurboStude (http://turbostude.com)


Double oil pumps. Note nipples for inlet and outlet to turbo.

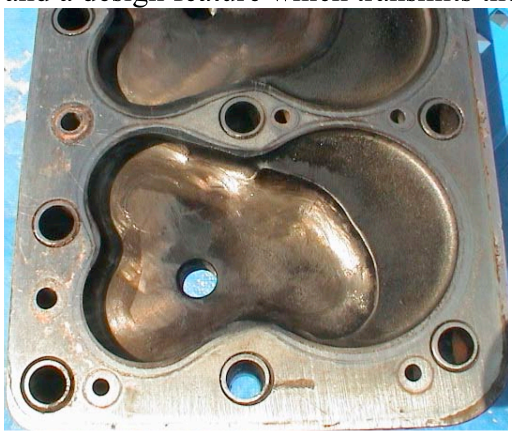
I piggy-backed two stock oil pumps with the second supplying oil to the turbo and an oil filter. That oil filter was located in such a way as to allow me to prelube the pumps and the turbo. In any event, make real sure that you prime the pump and get oil pressure before starting the motor for the first time. An oil pressure switch is easy to add in one of the numerous plugs along the oil galley on the passenger side. This is really a good idea whenever a turbo or electric fuel pump is added. When wiring, it would also be a great idea to add an impact switch in series with the oil pressure switch.


Ford impact switch

These are easy to get (if you know where to look) in wrecked Fords (behind a panel in the trunk) and are just about free for the asking. They are also a great "secret" ignition disabling switch to prevent your beauty from getting hot-wired….. Fashioning a lifter box suction system might be a good idea. The vent to the atmosphere can be modified to accept a pcv valve which returns to the intake as in modern vehicles.


Edmunds head 9.5:1 C.R.

What else needs some help? Well the stock head should be scrutinized. Though the low compression ratio is nice for a boosted engine, the design has a rather flimsy base plate (the bottom part with the combustion chambers cast/machined in). The combustion chamber designs used by Stude engineers were really progressive, and when compared to designs used by the Ford V-8 guys (Edelbrock, Meyer, etc) were right there! The problem will come when you try to keep them on top of the engine at medium or higher boost. If a stock head is to be used, get it cleaned, magnafluxed, and if still in the running, see if someone will do a cryo treatment on it. This super-freezing will align the molecules and decrease the likelihood of cracks. In the Bonneville racer, I had the entire block, the cam and the rods treated in this manner. The stock head has 14mm plug holes with 0.75" reach. The typically recommended plugs don't reach the chamber! You may want to think about this as you pick your head, as the recess, while good for fouling engines, won't do much for performance (though some think it may control the flame front a bit with less detonation…). The plugs you are able to use will be a function of the reach of the plug, thickness of the head gasket and plug gasket, the range, the projection of the plug, the height of the chamber, the pop-up of the piston and, depending on the location of the plug hole, the lift of the valves. Aftermarket aluminum heads are available from Ben Ordas and Bill Cathcart. Many believe that in a racer situation, with many on-off sequences to replace the head gasket, check displacement, etc. the aluminum heads take a beating. It's your call here… I built a very special head for our racer out of steel. It has twice the water capacity, three water outlets, a much thicker baseplate, modified Harley KR chamber design, and a design feature which transmits the "squeeze" thru to the base-plate.


chamber design on Salt2Salt 8.5:1 C.R.

How you attach the head is important. Head-bolts are inferior and unpredictable. The little Stude motor has 22 of them. That's typically one more row of fasteners holding the head on compared to many other engines! Go with ARP studs,washers and nuts if you are serious though a stock head will take Chevy V-8 studs. Chafe out the threads in the block and put a bit of no-seize in each. Hand tighten the studs and make sure that when the head is fastened down, the threads are lubricated. No thread-locker. Torque will be a function of the type of head you pick. The head gasket used will not likely be a problem if the head is right and the deck of the block is prepared correctly. The compression ratio of stock heads is just right, but many aftermarket heads are a bit aggressive for most blown applications, if you want more than a few pounds boost. If you are ordering a new head, you may be able to get it made with less compression. Other alternatives are to have a thicker copper head-gasket made, hog out the chambers or go with a modified piston. If you do hog out the already thin chambers, it would be wise to find an extra, unuseable head with similar chambers and have someone with a band-saw slice it up to see where you can remove some meat….. I used Coppercoat on both sides of standard Felpro composite head-gaskets and followed with some Alumaseal in the cooling system. For high boost, given the siamesed cylinders, I decided to go with stroke rather than bore to increase displacement, worried about leaks at the head gasket between the closer cylinders.

Though it has not been a huge issue on many hot-rodded Stude sixes, I believe that we will see trouble at the next weakest link if higher engine outputs are likely. The fiber timing gear is not going to be as strong as the rest of the engine, and an aluminum gear can be obtained from a V-8 which could be modified by a competent machinist. A spacer shim will also be necessary. Check with Phil Harris at Fairborn Studebaker parts for this gear. Ignition on higher boost engines will require a little extra encouragement, and going a bit higher tech with a Champ distributor modified using Mopar parts (Dave Thiebault) may be appealing. It is, however not necessary. The stock distributor doesn't care if it is working with 6 or 12 volts, and can be run without the vacuum advance if appropriate. I have even modified one to give boost retard/vacuum advance.


The clutch can have heavier springs added to it with good effect, as the increased torque and a modern rear-end may put more strain on that part of the driveline.

Any engine which will be boosted will generate more heat. One can almost watch the heat gauge increase along with the boost gauge unless it is dealt with efficiently. Stude engines always seem to have all sorts of things left in the water jackets. Anything one can do to clean these out will help. A modern radiator and auxiliary electric fan controlled by a relay and temp sensor is a great idea. Oil can be cooled as well, and the outboard oil filter set-up mentioned above allows a number of possibilities here. Your goal is to maintain about 200 degrees Fahrenheit as an operating temp. (More on cooling in the discussion on tuning).

Turbocharging a Stude can be done in two ways. Fuel can be mixed with air either before, or after the turbo. I will limit my discussion to carburetors, as they are straight-forward, plentiful, and I understand them. Draw-thru design is when the air and fuel enter the carb and then proceed to the turbo. The advantage of this approach is its simplicity. Tuning the carb is a little easier, and the carb doesn't require any special preparation to live under pressure. Disadvantages include more difficult cold weather starting, air/fuel mixture going thru the turbo is a little harder on it, and all pressure control is through the wastegate. Intercoolers are not commonly used on these. With more of the intake exposed to both air and fuel, there is a greater chance for "drop-out" of fuel. The dynamics are more like fluid than gas and therefore harder to predict and model. Intake designs Can be quite straight-forward in either case, and can incorporate the cast flanges from the stock manifold. These weld nicely to mild steel.

TurboStude intake

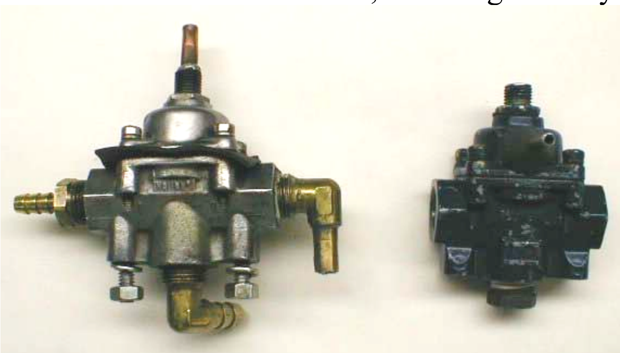
Salt2Salt intake Mk II

The other configuration, "Blow-thru" requires changes be made to the carburetor since it will be pressurized. Typically, the carb must be sealed. This entails tight gaskets around the accelerator pump shaft, some type of O-rings on the throttle shafts and plugs on any other vents open to the atmosphere.

Seal on accelerator pump of AFB

ThermoQuad floats don't collapse like anAFB…..

The carb floats must be able to stand high pressures (foam filled). Some carbs are more easily modified than others. The carbs for both types (esp. blow-thru) are generally bigger than you would expect. Consider any engine as a pump. A boosted engine running at two atmospheres will flow almost twice as much as normally aspirated at one atmosphere, and thus may require twice the CFM. It is also important to run a bit rich to help prevent detonation. Remember that it will take an atmosphere plus about 6 more pounds to get fuel to go into a boosted carb environment, and therefore you will probably need an electric fuel pump capable of giving 14 pounds plus whatever boost pressure you plan on attaining. For example, an engine with a planned 10 pounds of boost must have a fuel pump which can put out 24 pounds. There are ways of fooling a mechanical pump into higher output by sealing the vent "across the diaphragm" from the outside, and plumbing a hose in to this side from the output of the turbo. This worked on the Avanti, which never got over about 6 psi boost in a stock R-2. A fuel regulator, also with a rising rate (plumbed to the output of the turbo) will be a good way to guarantee that enough fuel is available. This should optimally be a return type regulator which shunts fuel to the carb, returning a steady flow back to the gas tank.



Holley regulator mod for rising rate and fuel return

This may seem like a lot of extra work (draw thru doesn't require special fuel pumps or fancy regulators), but blowthru allows an intercooler and is more tractable (if not safer) in cold weather.

The inlet tract for either design is not overly complicated for the serious back-yard mechanic with a little welding experience. Some flex hose, clamps and a trip to the exhaust shop can usually result in a useable set-up. Books have been written on turbo installations, and it would be good to scan thru a few before starting out.

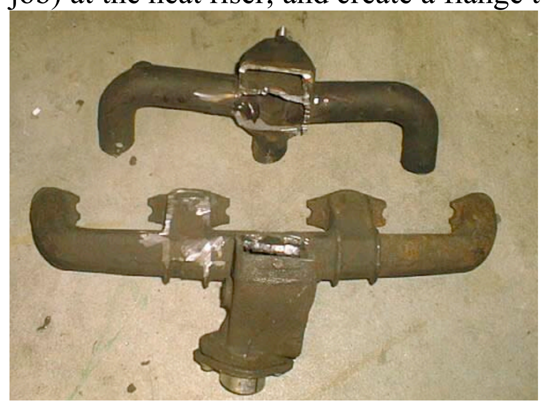
The Champ motor in its 169" configuration is just about perfectly matched with the Chrysler 2.2 liter TO-3 turbo. These are available in many wrecking yards. If you can, get any fittings attached to the turbo (exhaust pipe flanges, etc.) to at least use as patterns for your build. This turbo should not cost more than $100. A rebuild kit costs $110 if necessary. If possible, try to wiggle the shaft side to side. It shouldn't. up and down a little is ok. Look for oil on the vanes, and black soot inside the center section. Try to find one with a water cooling jacket if you intend to run it on the street. The TO-3 will start to spool up at about 2500-3000 rpm, perfect for the street, but run out of capacity by 5500 rpm. For the bigger 185" engine, the larger TO-4 turbo super 60 turbo like the one used on the Buick turbo-Regal would be better, especially if lag is not an issue. There are some exciting ways of getting rid of lag, but that's another story. I expect you will be quite happy with the performance as it is….

The oil inlet is typically brake line sized, the outlet being more like ½" ID plumbed into the oil pan above the oil level. If you have dispensed with the mechanical fuel pump, the block-off plate can be the destination of the outlet oil.

The exhaust system should be about 2 ½" ID coming off the turbo, and because the turbine side of the turbo muffles the exhaust noise, a muffler may not be necessary. One must remember when building a turbo set-up that it will become quite hot. Some allowance for expansion is necessary (see the many books on this). The more isolated from heat the intake can be made, the better. Cold air is denser, and thus increases the efficiency of the pump. It will also help against detonation. Remember that if the engine/pump is to be running at twice the non-aspirated CFM, it will require twice the air filtration capability as well.

The exhaust manifold itself is a good grade of cast iron, and can be welded with MIG. Time with a grinder is all that is necessary to convert these.

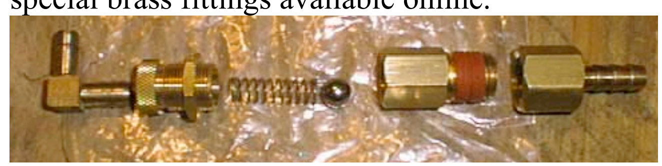
Cut away the intake tract from a stock intake/exhaust (a messy arduous job) at the heat riser, and create a flange to hold the turbo out of ½" steel.



Dismembered champ intake/exhaust

TurboStude exhaust with flange for TO-3

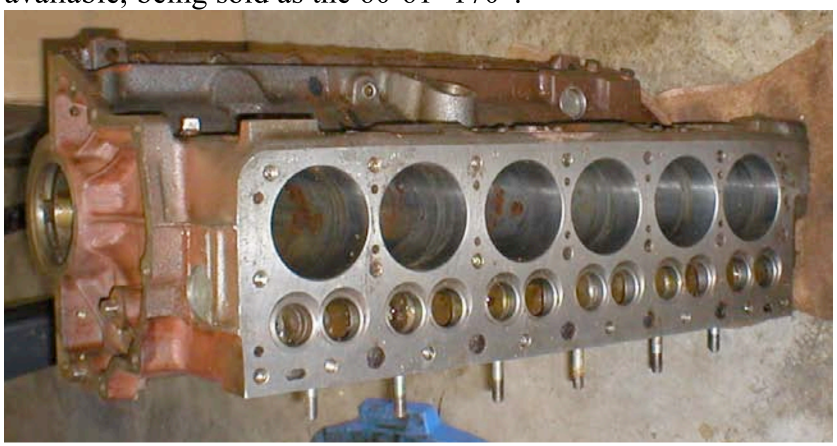
Some type of system will be necessary for boost control. In many cases, the integral wastegate is just fine, and can be modified with different preload or boost signal control gadgets to allow fine tuning of the boost. This can be done very inexpensively with existing parts and perhaps a few special brass fittings available online.



Exploded parts for boost control

Pistons should be the typical configuration with three ring grooves. I am a strong believer in forged pistons if you expect to aim at boost over 10 pounds. If you can specify, go for Total-Seal rings and ask that the “carbon” groove typical on Stude pistons not be added.
Studebaker rods are not bulky in appearance, but, in my experience and in discussions with others, are quite trustworthy. They should, of course, be treated like any rods being replaced in a high performance motor. The rod length is essentially the same on all the Champion motors. At the top, the system of holding the wrist pin is by a clamp. If one wishes a slightly lighter reciprocating mass, then dispense with the bolt for this clamp and change it to a floating wrist pin, held in by circlips.

One could argue that the smaller 169” motor with smaller main-bearings (but not the babbitted engines) might be able to spin up quicker and with a shorter throw than the 185”, achieve a higher rpm. This might be important when matching turbos. The later 170” motors were made using the “ big diameter main” crank , the same rods, and pistons which set the wrist pins further from the crown. Some new-old-stock blocks are still available, being sold as the 60-61’ 170”.



New old stock

The only difference in these blocks from the 185” was some notching at the bottom of the cylinders to allow the rods to pass by.

Once you have cobbled something together, there will most likely be a number of places where even small leaks can thwart your efforts to achieve psi. Placement of “pressure sensor” tubes for your regulator distributor and maybe your modified mechanical fuel pump can affect how the engine will perform. Some of this is trial and error. Some is discussed

I have decided that for a trouble free build, minimal boring be done, and no relieving of the deck. The valve seat area should be tampered with as little as possible. Good valves from a high performance VW or Chrysler turbo can be made to work. Again, remember that the volumetric efficiency of this engine will come from the turbo, so wild valve changes are not necessary. Some detailing of the intake and exhaust tracts is ok, but avoid wholesale hogging! It will be important to match the ports to the manifolds however, and some time spent here can be good for 3-5 CFM.

in various texts. It will vary depending on your carb location and final intake plumbing. At this point, you should have a CO_2 fire extinguisher within easy reach. Hot manifolds, gas leaks under pressure and no way to put out a fire is a bad combo!

Tuning this kind of set-up is a stepwise process involving changes in the timing, air/fuel ratio, fuel pressure and various temperatures. If you have gotten this far, you will need to acquire or borrow some measuring tools. First off, you need to have a fuel pressure gauge mounted on the hood (not inside the car, but visible while driving). You should have something to sense the Air to Fuel ratio. This could be as simple as an O_2 sensor (mounted about 10” from the turbo outlet in the exhaust pipe) connected to a digital voltmeter. After it heats up, it will record a voltage between zero and one volt. On boost, your goal is to keep it at about 0.9 volts. There are a number of aftermarket devices with LED displays which probably do a much more accurate job. You will need to hook up at least one boost gauge, capable of measuring up to 30 pounds. These can be obtained quite cheaply thru industrial surplus stores. Knowing what the boost pressure going in to the carb, and after the carb, will be very informative and a second gauge temporarily in the setup will help size the carb. A significant difference in psi might lead one to going to a bigger CFM carb, or perhaps lead to wiring the secondarys shut in a four-barrel….
You need an oil pressure gauge, probably a turbo oil pressure gauge, a water temperature gauge, and if you can get one, a “temperature gun”. This gadget senses temps wherever you point it. A little laser indicates where it is aimed. It would be best to get a version capable of sensing up to 2000 degrees with some accuracy down to about 150 degrees.

Your goal in tuning is to proceed from no boost to high boost a little at a time, watching your engine values. Remember that this engine was originally designed to run about 180 degrees and make 85 horsepower. Depending on your build, you may be tripling that number. This causes more heat. With more heat and pressure comes a greater chance that the engine will detonate. This will end the party real quick if not addressed. The game is to keep making little changes without causing detonation anywhere along the rpm band. Detonation is sensed by ear, by reading plugs (probably too late) or by doing something with electronics. For most of recorded history, the ear was used, with pretty good results. A fancier way would be to pirate a detonation sensor (basically a contact microphone like on some guitars) and attach it to a little computer taken from a Saab or Volvo. It could be attached to a device called a SafeGuard made by J&S Electronics which will actually retard timing on individual cylinders. To prevent detonation, one could cool the charge, decrease ignition advance, decrease compression ratio or decrease boost. Since you want to INCREASE the boost, you will have to first decide what boost you want to achieve, and then adjust the other factors a bit at a time. Changing the compression ratio is something you can't do so easily, so you will need to think about this before bolting on the head…..You are best off not going higher than about 8.5:1 unless you've done this before. In any event, a lower ratio will be compensated for by the final boost. You should determine what fuel you will be using at this time. TurboStude was set up with 7.5:1 C.R. to run on street gas of 87 octane. Salt2Salt was set to run on race fuel with 118 octane rating. Holding C.R induction tract configuration and fuel type constant, that leaves A/F ratio and timing. The A/F ratio needs to be rich enough at all times to be the appropriate stoichiometric mix for efficient burning AND probably richer to help cool the compressed intake charge down. For this to occur, the primary and secondary carb circuits will need to be adjusting with the rising boost. On boost, as previously noted, one needs to see about 0.9 volts on an O2 sensor. One needs to see the fuel pressure keeping up with the carb's requirements. If the fuel is not adequately provided, the ratio will lean out right when you don't want it to happen. Sometimes a pressure sensing switch (Hobbs switch) can turn on a water injector or a fuel injector just before detonation has been occurring. Advancing the timing will cause detonation which is dependant on the boost pressure. Distributors can be set up to advance timing when a vacuum is sensed, and retard it when boost comes along. Generally, timing is rather conservative on turbocharged engines. Static on a Champ should be about 15 degrees BTDC for a start. Don't assume normal numbers. Be happy with less advance than in normal aspirated engines. Watch the timing/richness as you slowly allow the boost to rise by adjusting a boost control (wastegate preload or "leak" from the sensor tube). Watch the temps along the head and the intake and exhaust manifolds for even heating. This may indicate trouble spots. Watch the plug temps. Use a plug that is one to two heat ranges cooler than stock. Look for even burning, comparing plugs from one to six. The 169" has shown over 15 pounds boost with a TO-3, and the 185" has shown more than 17 pounds boost with the TO-4 without detonation. Calculations indicate that an intercooler will only decrease efficiency below 15 pounds boost on this engine, so I'd recommend other means of preventing detonation.

I would expect that one can routinely double horsepower with a turbo on this engine without doing it harm. The Salt2Salt engine was on an engine dyno before final revisions were made in the cooling system and induction tract. At 17.1 pounds of boost (above atmosphere) it put out 233 hp and 289 foot pounds of torque at about 4200 rpm. Compare that to engines from Detroit built last year! G.M.