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## Ultimate SOHC engine.

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Location:

Western Australia

### Fiat SOHC Performance Tuning.

#### 1. Introduction.

Despite having very humble origins as a power-plant for the 1969 front drive revolution Fiat 128, in my opinion the SOHC is quite a spectacular engine and Aurelio Lampredi's finest mass produced work. Notwithstanding it's 'inferior' design non cross-flow cylinder head the SOHC engine can be made to top the magical 100hp/l figure, which is certainly a benchmark for engines of this era. Aurelio was a very clever man and he intimately understood the relationship between the moving piston and the column of air that follows it, he did after all design some of Ferrari's finest Formula 1 engines of the 50's and 60's, and he used all the lessons learned from that time with Ferrari when he joined Fiat and designed the gem we know as the SOHC (**Single OverHead Cam**)

During the early '70's the SOHC became the engine of choice for many of Italy's finest tuning houses and some managed to develop quite extraordinary power in the engines 8 valve form, topping 100hp/l with mechanical fuel injection. Many tuners also developed cross flow DOHC 16 valve cylinder heads to fit atop the standard block for various racing classes and Hp went even higher. However, this sort of engine build is well beyond the scope of this discussion as I'm not writing about a multi valve, dry sump, mechanical fuel injected, 12000rpm, \$30,000 engine that everyone drools over but no one is ever going to build. I figure what people want to know about is what 'works' when you mix and match some of the standard components. Most home tuners want a few tips on how to do the fairly basic task of assembling an engine and while they're at it, improve a few things and get a bit more power out of it in the process. I'm certainly not reinventing the wheel with any of this, achieving a good result is possible by always choosing best practice, understanding some basic tuning theory and following

Aurelio's lead.

In standard form the SOHC eclipses it's 'big brother' the Fiat twin cam. When you consider that around the same time the 125 special was making 100hp from 1608c, (approx. 62.5hp/litre) with much larger inlet ports / valves and far higher valve area / displacement ratio, the 'inferior' SOHC with it's non cross flow design holds it's own to produce a healthy 75Hp in stock trim from 1290cc's. (58.125hp/litre) The SOHC was also massively over-engineered in it's bottom end, it uses the very same con-rod bolt hardware as it's 1608 counterpart as well as the same sized main and big-end journals. The sohc engine in a form that is true to it's original 1116cc's was still a current production engine in Eastern Europe as late as 2009, albeit with only Euro 1 emissions compliance, that's a production run of over 40 years. Not many mass produced engines can boast that, certainly not Fiat's twin cam. It only lasted through to the mid 1980's before it underwent major design changes (reverse flow) and then ceased to be produced altogether before that decade ended, a lifespan of just 25 years when it was completely redesigned as the 16 valve engine.

So what does all of this have to do with building a performance SOHC engine, well not much and also lots. I'm hoping it gives some of the uninitiated readers a glimpse into my love of Lampredi's work, and also my reasons to build heavily modified engines based on a 40+ year old design, that some would term ancient and obsolete. I think it's far from that. These engines are amazingly strong and capable of a reliable 8000rpm in the longer stroke options and up to 10,000rpm for the short stroke options.

'Ultimate' SOHC.

What is the 'ultimate' SOHC engine, using a mix and match of stock components is a question I'm asked very often. The trouble is ultimate can mean different things to different people. Some may want or need to stay with one of the smaller capacity options for licensing, or racing rules, or for the sake of originality. Which capacity combination of the SOHC is the ultimate? Are we purists or are we racers? Maybe the majority of us are somewhere in-between, so where do we take this discussion?

I think all X1/9 owners would agree, that the first thing they would want from their X1/9 is a bit more power! It certainly would be nice to match the cars excellent road holding capabilities with a similar level of performance. Being Fiat X1/9 owners would mean having a tight budget and needing to keep a ceiling on the overall cost. It also means retaining the original engine configuration so we can retain the original transmission and drive train. We don't want to re-engineer the car, why would we want to change anything about

it. The chassis and the balance is just about perfect from the factory, we all just want a bit more power.

As you have a budget it means you can only afford to spend money once to do, or have the job done, properly the first time. If your prepared to put in some effort, a well built "street" SOHC can make an X1/9 quite a quick car. There is no need for engine conversions, no need for 16 valves, no need for a turbocharger if you only need 90 to 100 hp/l at the crank. Any X1/9 owner heading down this path has actually come to their first crossroad. It's the first choice you need to make in our journey along the road to your personal ultimate SOHC, and that's choosing to stick with Lampredi's finest. I'm certainly glad you have as I think too many people consider power-train swaps without really knowing the true potential of this little gem. To me the SOHC engine is the heart and soul of the X1/9 and replacing it - especially for anything non Lampredi - is almost sacrilegious.

What is the goal? This is what you need to answer and be realistic about it. An achievable target for your budget, your requirements and expectations, and your level of skill. Any performance improvements to the engine would be expected to achieve OE reliability, provide a measurable improvement and be cost effective. Transmissions don't like hard launches with the sort of power level we can get with carburettors or fuel injection, and turbocharging can double that. A forced induction option would need some thought and money spent in this direction to maintain the OE reliability factor.

X1/9 owners are an eclectic mix and you can find a wide variety of different builds across the world by owners with vastly different goals. Collectively we would have covered just about every combination of mix and match including turbocharged variants of the SOHC. I'm going to try to break down and collate information into what I think are some of the achievable levels or stages of improvement. Starting from some bolt on cost effective options that have a measurable effect, up to what I would consider the most reliable way to assemble a 'mix and match motor' using components sourced almost exclusively from the Fiat parts bin. At the end some discussion about engines and output with aftermarket components. Turbo options exist and will be discussed but limited to stock factory components using OE manifolding.

Simply getting outright power isn't the goal of this book, it's a cost vs benefit analysis of the components that can be used. To be informative it's going to need to offer some advice on component selection, have some current OE part numbers to help locate useful parts, include some of the aftermarket options and measure their relative cost effectiveness and performance potential compared to the standard components. It also includes some tips on choosing a combination of components that will perform to expectations. To help decide

what those expectations are, you need a grounding in some of the basic and slightly more advanced aspects of performance tuning this particular engine type and this is where we are going to start.

Disclaimer.

For the sake of keeping all the information in one thread, it's going to mean quite a bit of duplication of things I've already posted here on Xweb, and on other forums ... and I'm also going to have to ask everyone to allow me the indulgence of having this thread to myself. If anyone feels this thread deserves another to discuss any possible content inclusion or problems, then please go ahead and start one. It's simply to allow me to edit this and keep it concise, please comment somewhere else. Please remember that this is a live on-line work in progress. This is a first draft, and will be available as a pdf. file when complete. I'm also going to quote other members of this forum directly in this thread, so if you've said or done something and I think it's a good turn of phrase or very clever, I'm going to use it and quote you as a reference. When I use pictures, most of the pictures will be mine that I have taken, but some will have been lifted from around the web. If you see a picture and it's yours and I haven't quoted you as a reference and you would like me to reference you or not use it, PM and it's not a problem.

Last edited: Nov 29, 2016

i cavalli mai abbastanza, ed il peso sempre troppo.

Nothing is as simple as it looks. Its always twice as expensive and takes twice as long as you originally thought!

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## 2.Tuning Theory

### The OTTO cycle revisted.

Anyone who has played with a four stroke engine will have heard of the OTTO cycle, intake/compression/ignition/exhaust describing the four 'strokes' of the four stroke engine. This may have been enough to describe Nikolaus Otto's engine in 1864, but the modern high speed petrol engine is quite different in many ways.

For a high speed / high performance petrol engine, it makes more sense to break the engines function into a few more sections, combining the

movement of the piston with the movement of the valves, as it is these parts that control the movement of air into and out of the engine. I like to think of the engines cycling as links in a chain, and when it comes to improving the output of an engine, it has to be remembered that a change to one link of the chain can (and often does) affect other links further down the cycle, just like the old adage, "a chain is only as strong as it's weakest link"

Starting at TDC, we have the period of,

'(1) Valve Overlap'. At this phase we have both the exhaust valve (just closing) and the intake valve (just opening) off their respective seats and the piston at TDC. This is a very important phase as it establishes (hopefully) a pressure in the cylinder that is below atmospheric (due to exhaust scavenging) which initiates the flow of air from atmosphere into the cylinder while the piston is dwelling at TDC.

'(2) Intake pumping' describes the period which the piston is travelling downwards creating a low pressure in the cylinder which draws in air from the atmosphere until the piston reaches BDC.

'(3) Intake ramming' describes the period from when the piston passes BDC and has begun travelling upwards until the intake valve closes. Intake flow past the valve will continue due to the air column's inertia.

'(4) Compression' describes the period from when the intake valve closes, to when the piston is just before TDC, and a spark is initiated.

'(5) Fuel burning and expansion' describes the period from ignition to when the exhaust valve opens.

'(6) Exhaust blowdown' describes the period from the exhaust valve opening until the piston reaches BDC.

'(7) Exhaust pumping' describes the period from BDC to TDC while the exhaust valve is open.

**2a.) Compression Ratio.** (calculating it and improving on what you have.)

A short primer on making static compression ratio estimation calculations and some of the measurements that need to be taken to determine it. You could take a few measurements of your original piston so as to determine what your actual compression ratio was for the exercise, but what we are really interested in is the CR you'll end up with. You can make an educated guess, ask the parts

vendors to supply a few measurements from the parts they are selling or refer to the manufacturers catalogue (usually the most accurate) and use this to decide which piston is best for your needs.

To get a ball park figure for compression ratio changes with different piston crown configurations, we can do a little math before handing over the cash. For a Fiat twin cam piston the dome shape is called a conical frustum. Take some basic measurements and use [this formula](#) to find the volume.

You should also determine the valve flycut depth and if possible the radius or diameter of the circular cut used, and again some math will give us an idea of the flycut volume. This is an angled truncation of a cylinder, sometimes called a [cylindrical wedge](#) or a [cylindrical hoof](#). We know the angle (valve angle in relation to the bore axis) so depth and diameter (or radius) is what we need to measure.

Next measurement is the compression height of all the pistons in question. Compression height is the distance from the gudgeon pin centreline to the top of the piston crown EXCLUDING any dome or dish. To measure this accurately, fit a pin into the piston and measure from the bottom of the pin and the piston crown, subtract half the gudgeon pin diameter (11mm) and you've got this measurement. If the caliper is used between the top of the gudgeon pin bore and the piston crown (add 11mm) some inaccuracy will come from the caliper tip not quite sitting flat against the inside curve of the pin's bore.

And lastly you need to determine where your pistons sat in relation to the cylinder block deck when the crank is at TDC. This is the 'Deck' measurement of the piston. The piston crown down the bore a little is 'Minus Deck', the piston crown level with the top of the block is 'Zero Deck', and if the piston crown was to protrude past the cylinder blocks surface this would be known as 'Plus Deck'

The piston's deck measurement is set by the pistons compression height, the con rods centre to centre length and the engine blocks overall height. These measurements can all vary by small amounts known as 'production tolerance' and this is the reason you can't rely 100% on any published figures, including anything I write here! If each measurement was towards the bottom end or top end of any production variance and all the variables 'stacked up', the resultant CR figures could be very different to those come to by simple calculation. When the piston arrives and the bore has been prepared, final calculation simply NEEDS to be done by direct measurement. A piston must be mounted on a rod, a crank fitted and the measurements made, there is simply no other way.

The block deck surface can be machined by very small amounts to get the piston crown exactly where you want it. There are lots of good reasons why it's

better to keep the piston at zero deck rather than anywhere else, but a little pop-up is a good thing sometimes. I use it myself, but never more than 0.5 or 0.6mm and never at the expense of deck height. I only ever give a light skim the block deck surface, to get a fine finish for head gasket retention and guarantee Straight and True. Removing excessive block deck height is another "compromise" way of getting to an end result as it compromises deck strength, alters the camshaft to crankshaft phase and it alters the timing belt tension. If you want the piston crown to pop up, then find a piston with the appropriate CH or find a longer con-rod.

The pistons deck measurement and the head gasket compressed thickness determine the engines Squish / Quench (SQ) clearance. SQ is different to Piston to Head clearance. In a SOHC a large SQ area is presented at the far side (away from the plug and hence the ignition point) of the combustion space. If the SQ is kept tight, this can be used to promote good pre-combustion swirl. Its called SQ because as the piston rises it 'squishes' the remaining air / fuel mixture in this area towards the ignition point. Whatever fuel /air is left in this small space at TDC is then 'quenched' and cooled by the large surface area to volume presented.

The combustion chamber volume needs to be measured by direct measurement. Approximately 33.5cc in the combustion chamber is a 'nominal' figure. The actual combustion chamber volume will change depending on variables like valve seat height and valve manufacturer so the only way to calculate it properly is to measure accurately for your particular head. Actual chamber volume for a 78 euro 1300 head is around 33cc + - about 0,5cc and the extra CC or so is to allow for the piston top ring land volume, which is something many standard calculations fail to mention. The piston is a smaller diameter above the top ring, and this gap has a volume which contributes to the chamber volume at TDC. When the piston is sitting at zero deck, I usually figure this in at around 0.75cc for an 87.0 bore SOHC. This also affects any volume figure you might get for a 'pop up' of the piston above the deck surface, most times it also has a chamfer or rounded edge which further alters the volume figure.

You need all this info so you can make an educated decision on the pistons and other components you should buy and so you can come up with a plan for your build.

A basic compression ratio calculation might look like this:

Volume at BDC is (swept volume - pop up volume )+ flycut and ring land clearance volume + gasket volume + chamber volume.

Volume at TDC is (volume in gasket - pop up) + flycut and ring land clearance

volume + chamber volume.

Volume of BDC over Volume at TDC is expressed as a ratio to one (xx:1)

## 2c.) Increasing the Static CR.

What compression ratio do I need, is another favorite question. The answer depends what your expectations are. The best answer will depend on what you will be doing to improve the engines VE at the same time and what other components you intend to combine into the engine build. The answer to this question determines so many aspects of any SOHC build. Compromises here and realistically at every single 'cross-roads' in the decision making process have a knock on effect. For a performance build there are three basic ways to go about increasing the static CR.

### 1.) Increase the swept volume.

This is pretty obvious. Over-boring or stroking will increase the swept volume in the bore at BDC, and with no other changes to the piston crown or combustion chamber the static CR will increase as your compressing this greater total volume at BDC into the same volume at TDC

### 2.) Reduce the volume in the combustion chamber.

a) First up would be getting rid of the full circular recess, a euro spec head doesn't have this so all else being equal you will get at least 9.2:1. You can machine the recess away, but that creates other issues with cam timing, cam belt tension, and if you should ever need to surface plane the cylinder head again, there simply isn't any material left. Fiat recommend a specific combustion chamber depth as a minimum, by removing 1.5mm (or more) to remove the circular decompression recess, you actually exceed Fiats minimum specifications for head thickness... personally I think the designers know best, and I feel planing the head by this amount weakens the head deck surface.

b) Use a head from a smaller engine capacity. The 1116cc version of the sohc has a smaller combustion chamber. It was designed to suit an 80mm bore size and the combustion chamber only has a width of approx 80mm to suit. This unfortunately shrouds the inlet valve and limits the flow potential of the head. The inlet ports are among the smallest available in the range of engines. The inlet valve seat throat is also smaller than 1300 / 1500 variants at approx 29mm. Using an '1100' head will certainly raise the static CR, and this will give the engine very good 'punch' up to the point where the flow losses outweigh the compression ratio increase, which is up around 5500rpm give or take 500rpm.



This option is very much a "one step forward and two steps back" approach. It comes back to the physics - the higher you cycle a four stroke engine and maintain VE you will produce more power- and the 1100 cylinder head's compromises will greatly lower the VE above 5500rpm unless it is optimised. The same early /late combustion chamber styles apply to these heads, the later combustion chamber is far better from a performance perspective. The Yugo 1100 head is a late combustion chamber shape and would be an available option in the U.S. for anyone going down this route.

c.) Use a 'Euro spec' cylinder head. IMO this is simply the best option, as it is as the factory intended the engine to be in the first place. Be aware that there are also two distinct combustion chamber shapes for all SOHC engines regardless of capacity or intended market. The post 1975ish style head is definitely the better of the two, it's easy to spot the differences when you see the heads side by side. In the US the go to item would be a 1300 Yugo cylinder head as it will have the late combustion chamber shape you want for best results and no decompression recess. A 1500 style 'euro' head will give you the added benefit of larger port sizes and also the larger 31mm valve seat throat as well as a larger exhaust valve. The 'tipo' style head is effectively a factory performance item, it comes fitted with larger intake valves (in 37.5 and 39.5 mm options) with even larger valve seat throats again. More details and pictures in the 'Cylinder Heads 101'

3.) Change the piston crown shape or the piston compression height.

a) Using a piston with a raised dome is one way to increase the static CR especially in the smaller capacities where options are more limited. Available options exist in both cast and forged pistons. A very tall 'wedge style' dome is not ideal from several perspectives. It tends to divide the combustion chamber (when the piston is at TDC) into several small pockets and restricts the progression of the flame front after ignition. It's obvious when you look at the ignition advance requirements of engines that run these sort of pistons. Tall wedge style pistons can be made to work well, but it requires a lot of attention to combustion chamber shaping and in many cases re-shaping the dome. CH is still important even with a wedge style dome, as SQ clearance at 1.0 - 1.2mm is still desirable.

b.) Use pistons with a taller compression height (CH). Lots of options exist for these engines in both forged and cast. With the 'euro' style combustion chamber a flat top piston works very well. This helps prevent pre-ignition and the possibility of a secondary ignition due to the large SQ area presented. IMO a flat top piston in a 1500 /1600 to get to 10.5:1 wins over a similar capacity /similar static CR and a big wedge dome, all day - every day.

c.) Use pistons with a different flycut volume. The 1500 USA piston has a large cast in flycut, volume approx 4.8 - 5.0cc's. By comparison a small flycut piston has a flycut volume of about 0.6 to 0.8cc's. Big difference that's easy to see.



Many more details and pictures of production and aftermarket piston options in 'Pistons 101'

## 2d.) Limited compression and other compromises.

If your engine is compression compromised, you will be "behind the eight ball" in building Mechanical Efficiency (ME) into the bottom end. The only thing you can do with a compression compromised engine is to try and increase the volumetric efficiency (VE) as much as possible. This in effect is the only way you can boost the engines dynamic CR. Performance engine build improvements will build ME and VE, and bump dynamic CR. If your compression compromised, it restricts your choice of camshaft, because you need to attempt to still keep some sort of realistic DYNAMIC compression ratio. In all these theoretical examples, the ME, VE and dynamic CR are considered for a specific amount of engine revs. The VE %age can change considerably at different rates of engine cycling, which is why an engine can drop power at one point of the rev range, and gain somewhere else after any modifications...

Engine example A) Increase the static CR (an improvement in ME) and retain the same cam timing and other engine parameters, your going to see a bump in the Dynamic CR, and a bump in HP.

Engine example B) Retain the static CR, increase the valve open cycle in duration, keep other engine parameters the same, and generally your going to see a drop in the Dynamic CR, and a drop in HP

Engine example C) Retain the static CR, Increase the valve open duration cycle, change other engine parameters which affect the VE (like add twin carbs or free flow exhaust), and with some luck you might have altered the balance back favourably in Dynamic CR (by getting a greater mass of fuel / air in over the same cycle speed) and your likely going to see a bump in HP

But this can "stretch" out into the engine many end up with...

Engine example D) Retain the static CR, increase the valve open duration considerably (big cam) slow the port air speed at low revs considerably (big carbs) the engine described will rev to 8500rpm but it probably won't feel very lively, it won't "pull strongly" and it won't be any fun below 4500rpm. This is hardly the best engineered solution to the presented problem is it, but it does lead to the natural progression of the next idea.

Engine example E) Retain the static CR, retain the standard euro valve open duration (no drop in Dynamic CR) increase the available flow thru the head and the increase the valve lift and improve the exhaust flow (so we are talking BIG improvements in VE)

The aim in performance engine building is to increase the Volumetric Efficiency, that's what porting and polishing does, and what fitting twin carbs does as well by allowing the engine to breathe in and out easier. The higher the VE, the lower the required static compression ratio, the lower the required CR, the smaller the required piston dome, the smaller the required piston dome the easier the flame front will propagate in the combustion space and that improves horsepower. It's an interconnected relationship. It's also a fact of physics, the higher you cycle a four stroke engine and maintain VE you will produce more Hp.

## **2e.) How much compression is too much.**

Too much static CR is when you have exceeded the "knock limit" for the octane rating of the fuel you are using. If the engine is to run on low octane fuels then the tall wedge dome style hi compression pistons are not really what you want. A tall wedge dome will interfere with the combustion process which in turn makes the engine very sensitive to ignition timing variations. If your at the 'knock limit' of the fuel you have available they wouldn't be the best choice.

A flat top piston is less sensitive to ignition requirements. It allows good propagation of the flame front as it keeps the space free from obstruction. Any swirl created by the SQ area will be effective and also not obstructed by the dome, good swirl promotes an homogeneous fuel /air mixture right before the moment of ignition. A tight SQ also draws heat out of the small volume of fuel

/air mix left furthest from the spark plug and may prevent it from pre-igniting.

The word 'octane' (octo being eight in Latin) comes from the following facts. When you take crude oil and "crack" it in a refinery, you end up getting hydrocarbon chains of different lengths. These different chain lengths can then be separated from each other through refractive distillation, as they all evaporate at differing temperatures. These different hydrocarbon chains are then blended to form different fuels. You have probably heard of methane, propane and butane, all three of them are hydrocarbons. Methane has just a single carbon atom. Propane has three carbon atoms chained together. Butane has four carbon atoms chained together. Pentane has five, hexane has six, heptane has seven and octane has eight carbons chained together.

It turns out that heptane handles compression very poorly. Compress it just a little and it ignites spontaneously. Octane handles compression very well, you can compress it a lot and nothing happens. Eighty-seven-octane fuel is fuel that contains 87-percent octane and 13-percent heptane (or some other combination of fuels that has the same compression limit of the 87/13 combination of octane/heptane). It spontaneously ignites at a given compression level (for a given temperature) and can only be used in engines that do not exceed that compression level. This is what I mean when I talk about exceeding the 'knock limit' of the fuel being used, simply going above the level of compression at which the fuel will spontaneously combust.

Octane ratings of 100 (or more) are commonly used in piston airplane engines. In the case of AvGas, 100 is the fuels performance rating, not the percentage of actual octane in the fuel. It has some tetra ethyl lead (TEL) in it still (which is why it's illegal for road use) which is an 'anti-knock' additive, so it can handle much higher pressure values before it reaches its knock limit. (the point of spontaneous combustion)

Straight up high static compression isn't the only possible culprit in an engine with 'pinging' issues. If, for example, the static CR has been bumped and a short duration cam is used, the dynamic CR may be exceeding the knock limit of the fuel. This can explain why an engine will 'ping' or 'knock' at differing throttle openings as the VE is affected by throttle position, and the change in VE in turn affects dynamic CR. Intake air temperature can have a big effect on an engine that is close to the knock limit as the point of spontaneous combustion is affected by temperature. If your experiencing a "pinging" under load you have a few options, raise the octane rating of the fuel your using, lower the static/dynamic compression values to where they are below the knock limit of the fuel your using and make sure your intake temps are as low as possible. 'Pinging' may not be the noise of pre-ignition but the first sounds of detonation at WOT, and detonation kills engines.

The other down side of too much compression is that it's a diminishing return. Raising the static CR from a lowly 8.5 up to 9.5:1 equates to an approx 10% bump in power, going from 10.5 to 11.5:1 gives about a quarter of this gain... the reason why is pumping losses. It's a fancy name for a parasitic power loss, simply because it takes more effort (energy or Hp) to compress the incoming fuel / air mix and also to expend the spent gas, than what is gained in recoverable power by the increased static CR. Just because a bump to 10:1 static CR is a great move doesn't mean that 11:1 is going to be better.

### "Someone told me the SOHC engine was based on an Abarth design"

AlConsentino said:

*(from FAZA Abarth Fiat Lancia 'bible' by Al Consentino): "Beginning of the Fiat 128-X1 /9 engine actually began back in 1962 when Carlo Abarth unveiled his first all Abarth DOHC engine designed by their chief engine man, Luciano Focchi. The photo here with the Bosch distributor mounted on the chain drive cover and the twin ignition, Marelli distributor mounted on the rear of the exhaust cam is one of the Abarth DOHC engines in the 1300cc category, (1288.3cc). The engine number 230-S has a*

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I'm afraid I think Al's ramblings on this subject are just that...ramblings. To claim that Lampredi's SOHC is derived from an Abarth DOHC engine just because it has the same bore /stroke and same number of crank bearings is perhaps stretching the truth!!

Lampredi's SOHC was according to Fiat literature at the time "all new". It shares some internal dimensions with the 124OHV and early variants of the DOHC engines, which is understandable when you consider mass production techniques that Fiat chose to machine their "new" SOHC engine with the same crank journal sizes as the already (at the time) in production OHV and DOHC units.

The original SOHC, toothed belt drive camshaft, non crossflow 1116cc engine was completely new in its general layout when introduced. When "redesigned" several years later for an increased bore size of 86mm, the block was changed considerably (non siamesed bores, different water jacket layout) but the bore spacing/crank journal sizing/head bolt pattern etc remained constant ... so it's only in the SOHC's second form that it bears any (dimensional) resemblance to the Abarth #237 DOHC 1300 which Al references...

Bore spacing, head bolt layout, rod ratio, bore/stroke ratio, etc etc are just a few of the parameters that an engine designer needs to consider ... To say

Lampredi's SOHC was a copy of Focchi's work without a very detailed comparison is a very big claim.

A good compilation of engine related formula can be found here...

<http://www.macdizzy.com/formulas.htm>

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i cavalli mai abbastanza, ed il peso sempre troppo.

Nothing is as simple as it looks. Its always twice as expensive and takes twice as long as you originally thought!

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### 3. Pistons 101

#### 3a.) Piston selection

At the risk of stating the obvious, pistons are not all the same. Some of the standard pistons have slots in the oil ring groove for oil drainback. Higher quality and stronger pistons have oil holes drilled for the oil return. Same with lots of other differences in construction like a steel reinforcing band inserted in the casting or not. The same manufacturer with different styles of piston to suit engines of the same size, with one coming from the "sports" or "rally" model that has the piston made a little differently sometimes with less material and an overall lighter weight. Then there are differences in the materials used, obvious when you see a few pistons side by side as I have over the years.

If you want to do a nice job, quality parts is a given. From bottom of the range to top of the range cast pistons there can be a difference of almost 100% in the wholesale price. Luckily there were so many of these engines made, OEM supply of quality pistons should continue for some time, certainly the more common crown configurations. Shop early, and you'll avoid paying the "I need it now" premium for both parts and postage.

This is a budget build and budget means only doing it once, and doing it properly. The pistons are a large portion of funds needed for an engine build. First choice would be real KS marked Kolben Schmidt pistons. Second choice would be German Mahle manufactured pistons. Mahle also package other peoples pistons in their boxes, so sometimes you'll get Mondial or Borgo pistons packed in a Mahle box. In a rough sort of scale of quality Mondial / Borgo would

be a very close tie for third. Each piston type is good up to a particular level of static compression and revs. There are plenty of parts imported from eastern European countries where they have a lot of these engines, but usually the absolute base models with low output and they locally manufacture pattern parts. I think the Germans and Italians make some high quality replacement car parts and these are what I prefer to use.

Having established there are differences in pistons, next is different ring sets. You can get a choice of cast ring /chrome ring /molybdenum faced ring and even thinner factory rings. The 1580 SOHC standard ring pack is a nice option as it uses thinner rings at 1.5/1.75/3 (whereas standard is 1.5/2/4) and even a molybdenum coated options from the factory 16v engines that have the same bore size. Total seal is an aftermarket option but their ring sets come at 86.5, 87.0 and 87.5 sizes, so only 87.0 bore size ties in nicely here with factory oversizes.

I stick with parts I know, I have pushed these particular part numbers and brands in previous builds and have a good idea which brands and construction types tend to fail and where /why. So what does the last 500 words boil down to, basically don't shop for parts for a "performance" build with the cost being the primary consideration.

To sum up with six famous words... "Fast, Cheap and Reliable. Pick Two."

### **3b.) Production Piston crown types.**

The Fiat SOHC 8v came with seven different piston crown designs across production. A picture is worth a thousand words, so here are a pictures of all known production crown types.

Type 1. Machined in large valve flycut.





Type 2. Cast in Large valve flycut.



Type 3. Machined in small flycut.





Type 4. Machined in small flycut with 0.6mm central dome.

Type 5. Cast dish and machined flycuts.

Type 6. Machined dish and valve flycuts.

type 7. 1.6 dome and machined flycuts.

Type 8. Uno Turbo series 1 - this is only for 80.5 standard bore, but included for further discussion.

Crown shape isn't the only difference, quite a few of these designs are available in several different compression heights. Compression Height (CH) is the term

for the measurement from the gudgeon pin centre line, to the crown of the piston (excluding any dome or dish)

### 3c.) Production Compression Height and Dimensions.

#### MAHLE Pistons.

P/N 0078000, CH of 34.7mm with flycuts 2.6mm deep, dome height 0.6mm, crown shape type 4, overall length 77.3mm. Standard size 86.0mm, oversizes 0.2,0.4,0.6,0.8 and 1.0mm.



P/N 0087000, CH of 34.15mm, flat top piston, crown shape type 2, overall length 73.65mm. Standard size 86.4mm, oversizes 0.2,0.4 and 0.6mm.



P/N 0087100, CH of 34.45 with flycuts 2.8mm deep, flat top piston, crown shape type 3, overall length 73.95mm. Standard size 86.4mm, oversizes 0.2,0.4 and 0.6mm.

P/N 0087200, CH of 34.15mm with flycuts 2.7mm deep, flat top piston, crown shape type 3, overall length 73.65mm. Standard size 86.4mm, oversizes 0.2,0.4 and 0.6mm.



P/N 0087300, CH of 34.9mm, with flycuts 2.76mm deep, 0.5mm dished top piston out to a diameter of 72mm, crown shape 6, overall length 74.4mm.

Standard size 86.4mm, oversizes 0.2,0.4 and 0.6mm.

P/N 0087400, CH of 34.9mm, with flycuts 2.7mm deep, flat top piston, crown shape type 3, overall length 74.4mm.

Standard size 86.4mm, oversizes 0.2,0.4 and 0.6mm.





P/N 0087500, CH of 33.3mm, with flycuts 2.3mm deep, dished top piston, crown shape type 5, overall length 72.8mm. Standard size 86.4mm, oversizes 0.2, 0.4 and 0.6mm.

























































































KOLBEN SCHMIDT Pistons.

93 449 600 (86.0mm) and oversizes 620 (86.6mm) and 640 (87.0mm)  
(the KS version of a Mahle 0780)

[illegible]

90 699 600 (86.4mm) and oversizes 620 (86.8mm) and 630 (87.0mm)  
(the KS version of a Mahle 0873)



FIAT / IVECO							
1	2	3	4	5	6	7	8
          	          	          	          	          	          	          	          

93 302 600 (86.4mm) and oversize 620 (86.8mm)  
(the KS version of a Mahle 0087100)

[illegible]

92 317 700 and oversizes 710 (86.6mm) , 720 (86.8mm) and 730 (87.0mm)  
33.3CH 1581cc type piston (type 5) crown shape  
(the KS version of a Mahle 0875)

[illegible]

93 301 600 and oversizes 610 (86.6mm) , 620 (86.8mm) and 630 (87.0mm)  
(The KS version of a Mahle 0872)



92 448 600 (86.0mm) and oversizes 620 (86.6mm) and 630 (86.8mm)  
Fcccd piston, 34.7CH with 7.5mm dome wedge (11:1 for 1300)





### MONDIAL Pistons.

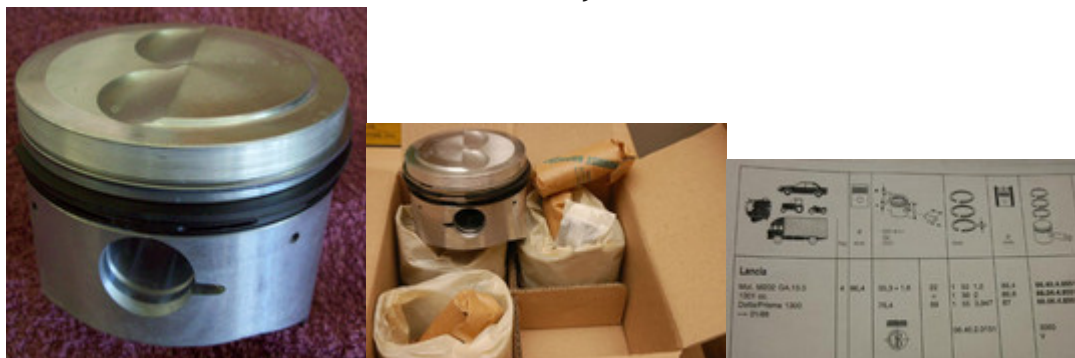
Mondial 8289 34.45 CH smallflycut



Mondial 7417 34.7CH with 0.6 dome (pimple) small flycut



Mondial 8551 35.30CH 1.6 dome small flycut



Mondial 9748 33.3CH dished top (-2.3mm) 1580cc engine



### BccO Pistons.

66.7543.0 34.9CH small flycut, crown type 3.



66.6298.0 34.7CH with 0.6mm dome, type 4 crown.



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### FIAT Genuine Pistons.

OE 86.8 piston, flycut volume approx 0.7cc, CH unknown, Fiat p/n 7642421



### 3d.) Aftermarket Pistons and Crown shapes.

Vick's auto offer 'wedge style' high compression forged pistons, so this is an available option but how anyone is supposed to decide if they will suit their requirements, I have no idea?? There is no CH or dome dimensions listed at all. Not a budget item at \$600US for four, plus non standard rings (and I think gudgeon pins too) on top of that. The Venolia pistons of this style that I've seen took a fair bit of "finishing" on the crown before I would use them. The machining between the fly-cuts leaves a raised strip, and the whole crown is covered with sharp edges. I wouldn't use them without finishing and smoothing, YMMV.

Venolia, Wiseco, Arias, to name a few of the bigger ones. they are all high quality US based piston manufacturers who will make you whatever you want. In a minimum quantity and long lead times (in some cases) and always at a price. I doubt anyone could pick any technical differences between the pistons they manufacture and the methods and materials they use. I have a few design drawings that I'll scan and share.

KS, Mahle, and ASSO are also other brands of Forged 'wedge style' dome pistons I've used over the years. High priced, High quality, can handle high revs.

Matt at Midwest sells increased CH (35.2mm) pistons with a flat top, these are an available option. Also available with a 2.4mm flat half dome. Not what I would call a budget item at around \$725US for a set of four but they are a forged custom designed item complete with rings and pins...You can click the link to see lots of clear pictures and all the appropriate dimensions that you'll need to decide if these will suit your build.

### 3e.) Designing your own piston.

If your particular configuration doesn't have a 'production' piston available, I don't think we should simply rule it out of this discussion. The option of using a non production piston (and by production I mean sitting on a shelf that you could get the cash out and own) needs to be included, as does the option of designing one yourself. Choose your own manufacturer, that's not what I'm talking about. I mean designing something to suit your bore / stroke / crank / rod configuration. The piston people will need a whole bunch of numbers from you, and they will make them exactly as you ask, so there are a few simple rules to follow. If you make a mess of the dimensions you could end up with a set of useless pistons, at very best it will compromise your build.

Bore clearances. That's a manufacturers recommendation as this depends on material and construction technique, they will know what works for their



methods.

Ring choice. This is certainly the first thing you decide on (not the crown shape) Are we going to use production piston rings? Aftermarket rings? Ring widths? ring groove depths and widths? ring construction? ring coatings? (choices here will determine the required bore finish) How are we going to package the ring set into the available space?

Compression height.

Gudgeon pin.\*This is somewhere you can save a lot of weight from a stock piston assembly. The aftermarket manufacturers can make a much lighter gudgeon pin for you, this alone can make going for an aftermarket piston worthwhile there can be such a difference. Pins and pistons come as a matched / honed pair in a lot of pistons. Some even come directionally marked i.e. a paint dot on piston and one end of the supplied pin. Wiseco make gudgeon pins they sell separately, S566 is almost the right size and weighs just 90 grams, unfortunately they are a little too short for a SOHC as they are only 63.5mm long (2.5 inch) and a SOHC pin is 68/69 mm

Retainer clips.

and lots more that I'll get to...

### **3f.) Standard Production engines. Some approximate CR figures.**

**For the engine tuner as all these production pistons have the same basic standard diameter of 86.4 mm and most are interchangeable, it gives good scope for mixing and matching across differing capacities and achieving different static compression ratio with a simple piston change when rebuilding. To make an informed decision we need to have some idea of the standard production static compression ratio for differing markets and capacities and how this is achieved.**

The European X19 1300 has a 9.2:1 static CR, as do most SOHC European spec 1300 engines. Some unusual models of 1300 SOHC like the 'energy saving' Uno and the Lancia Delta 1301 came stock with 9.35 to 9.5:1 static CR due to a piston crown changes.

For a standard 1975 on European spec X1/9 1300

(86.0 bore x 55.5 stroke =1290cc)

Cylinder volume = 322.52cc

Head gasket volume = 4.76cc (0.8mm crushed 87 internal diameter)

Volume in head = 33.5cc (nominal)

Volume of valve relief = 1cc (machined valve relief less small dome)

Total at BDC = 361.78cc

Total at TDC = 39.26cc

Compression ratio = 9.21:1

European 1500 X19 was also 9.2:1 static compression, and shares the same basic piston crown shape and CH values as the USA specification engine.

Unfortunately with the 1.5mm full circular decompression recess that the US spec engines have this drops to just 8.5:1.

For a standard Euro spec 1500 X19 (1498cc)

(86.4mm bore and 63.9mm stroke)

swept volume = 374.8 cc per cylinder

Head gasket volume = 7.44cc (approx 1.5mm thick crushed) 1.65mm new ASTADUR type\*

Volume in head = 33.5cc (nominal)

Volume in valve reliefs = 4.75cc (cast relief-nominal)

Total at BDC = 420.49cc

Total at TDC = 45.69cc

Compression ratio = 9.20:1

The main reason the US spec engines have considerably less output than the European versions is their lower static CR of just 8.5:1. Some non USA based 1500 engines use different piston crown variations again, and despite using more restrictive carburettion and valve timing, still put out similar hp and torque values due to a slightly higher factory static (9.4:1) compression ratio due to a piston crown change. European 1580cc displacement engines also use a basic static compression ratio of 9.2:1. It uses pistons that have a dished head to maintain this. The volume of the dish is approx 5cc.

So logically, for the home tuner looking to achieve a bit more power the next question would be, how much compression can I achieve?

### **How to work out YOUR static compression ratio.**

Some real world examples.

This is a 1300 engine with 8551 Mondial pistons and a euro late model combustion chamber head

Assume bore is 87.00

These Pistons are 86.50 above the top ring land and the top ring groove is 9mm down from the crown.

The Valve Flycut volume is approx 1.0cc

The Piston sits at approx 0.3mm plus deck

The dome is 1.6mm high, has a diameter of 70mm, and is 35mm wide (half a circle)

The Nominal Combustion Chamber volume is 33cc (euro 1500 carb)

Your head gasket is going to be 1.2mm compressed and has an inside fire ring diameter of 87.2mm and will give a SQ clearance of 0.9mm

So let's do some math...

Swept Volume of the cylinder.

$\pi \times R^2 \times \text{Stroke}$

$3.14285 \times (43.5 \times 43.5) \times 55.5$

$3.14285 \times 1892.25 \times 55.5$

330cc

Volume of the piston 'pop up'

$3.14285 \times (43.25 \times 43.25) \times 0.3$

$3.14285 \times 1870.5625 \times 0.3$

1.765cc

Volume of the dome.

$[3.14285 \times (35 \times 35) \times 1.6] / 2$

$[3.14285 \times 1225 \times 1.6] / 2$

3.08cc

Volume of the head gasket.

$3.14285 \times (43.6 \times 43.6) \times 1.2$

$3.14285 \times 1900.96 \times 1.2$

7.17cc

Volume of the ring land clearance.

$[3.14285 \times (43.5 \times 43.5) \times 9] - [3.14285 \times (43.25 \times 43.25) \times 9]$

$[3.14285 \times 1892.25 \times 9] - [3.14285 \times 1870.5625 \times 9]$

53.62cc - 52.91cc

0.71cc

and then put these numbers into the equation,

Volume at BDC =  $(330 - 1.765 - 3.08) + 1 + 0.71 + 7.17 + 33$

= 367.035

Volume at TDC =  $(7.17 - 1.765 - 3.08) + 1 + 0.71 + 33$

= 36.955

V at BDC / V at TDC = 9.9:1

This is a 1500 engine with Mondial 8551 pistons (35.3CH and 1.6 half dome) with a nominal combustion chamber volume of 33cc.

Assume bore is 87.00

These Pistons are 86.50 above the top ring land and the top ring groove is 9mm down from the crown.

The Valve Flycut volume is approx 1.0cc

The Piston sits at approx 0.3mm plus deck

The dome is 1.6mm high, has a diameter of 70mm, and is 35mm wide (half a circle)

The Nominal Combustion Chamber volume is 33cc (euro 1500 carb)

Your head gasket is going to be 1.5mm compressed and has an inside fire ring diameter of 87.2mm (Fel-pro) and will give a SQ clearance of 1.2mm

So let's do some math...

Swept Volume of the cylinder.

$\text{Pi} \times R^2 \times \text{Stroke}$

$3.14285 \times (43.5 \times 43.5) \times 63.9$

$3.14285 \times 1892.25 \times 63.9$

380.017cc

Volume of the piston 'pop up'

$3.14285 \times (43.25 \times 43.25) \times 0.3$

$3.14285 \times 1870.5625 \times 0.3$

1.765cc

Volume of the dome.

$[3.14285 \times (35 \times 35) \times 1.6] / 2$

$[3.14285 \times 1225 \times 1.6] / 2$

3.08cc

Volume of the head gasket.

$3.14285 \times (43.6 \times 43.6) \times 1.5$

$3.14285 \times 1900.96 \times 1.5$

8.96cc

Volume of the ring land clearance.

$[3.14285 \times (43.5 \times 43.5) \times 9] - [3.14285 \times (43.25 \times 43.25) \times 9]$

$[3.14285 \times 1892.25 \times 9] - [3.14285 \times 1870.5625 \times 9]$

53.62cc - 52.91cc

0.71cc

and then put these numbers into the equation,

$$\begin{aligned}\text{Volume at BDC} &= (380.017 - 1.765 - 3.08) + 1 + 0.71 + 8.96 + 33 \\ &= 418.995\end{aligned}$$

$$\begin{aligned}\text{Volume at TDC} &= (8.96 - 1.765 - 3.08) + 1 + 0.71 + 33 \\ &= 38.825\end{aligned}$$

$$V \text{ at BDC} / V \text{ at TDC} = 10.8:1 \text{ (10.79)}$$

If fitted to a North American Spec engine with the 1.5mm full circular decompression recess in the head, we substitute the 33cc chamber volume for 38cc, so simply add 5 cc to the BDC/TDC volumes

423.995 / 43.825 = 9.67:1 with absolutely no changes to the cylinder head, up from the standard 8.5:1.

Even higher if you substitute a thinner head gasket (1.2 crushed = 1.79cc less volume)

This is a 1603 stroker build using Mahle 0872 pistons (34.15CH - with enlarged shallow inlet flycut) Combustion chamber volume was determined by measurement to be 31.5cc.

Bore is 87.

Pistons are 86.50 above the top ring land and the top ring groove is 6.5mm down from the crown.

Valve flycut measured volume is 1.5cc

Piston sits at 0.65mm plus deck

Combustion Chamber measured volume is 31.5cc

The Head gasket is going to be 1.5mm compressed and has an inside fire ring diameter of 87.2mm (assuming a Felpro 21195-PT2)

So lets do some math...

Swept Volume of the cylinder.

Pi x R squared x Stroke

$$3.14285 \times (43.5 \times 43.5) \times 67.4$$

$$3.14285 \times 1892.25 \times 67.4$$

$$400.831\text{cc}$$

Volume of the piston 'pop up'

$$3.14285 \times (43.25 \times 43.25) \times 0.65$$

$$3.14285 \times 1870.5625 \times 0.65$$

3.821cc

Volume of the head gasket.

$$3.14285 \times (43.6 \times 43.6) \times 1.50$$

$$3.14285 \times 1900.96 \times 1.50$$

8.961cc

Volume of the ring land clearance.

$$[3.14285 \times (43.5 \times 43.5) \times 6.50] - [3.14285 \times (43.25 \times 43.25) \times 6.50]$$

$$[3.14285 \times 1892.25 \times 6.50] - [3.14285 \times 1870.5625 \times 6.50]$$

$$38.655\text{cc} - 38.212\text{cc}$$

0.443cc

and then put these numbers into the equation,

$$\begin{aligned} \text{Volume at BDC} &= (400.831 - 3.821) + 1.5 + 0.443 + 8.961 + 31.5 \\ &= 439.414 \end{aligned}$$

$$\begin{aligned} \text{Volume at TDC} &= (8.961 - 3.821) + 1.5 + 0.443 + 31.5 \\ &= 38.583 \end{aligned}$$

$$V \text{ at BDC} / V \text{ at TDC} = 11.4:1 \text{ (11.389)}$$

If you add just 2cc to the chamber volume you get 10.9:1

If you add just 3cc to the chamber volume you get 10.6:1

If you need more chamber volume, do a little deshrouting on the plug side wall and around the inlet valve, or scoop a little out of the inlet valve head. (which has the added bonus of dropping some weight out of the larger heavier inlet valve. The SQ at 0.9mm is good anywhere in the range of 1.0mm (+-0.2mm) works well

(provided you have adequate V to P clearance)

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Last edited by a moderator: Today at 3:49 PM

i cavalli mai abbastanza, ed il peso sempre troppo.

Nothing is as simple as it looks. Its always twice as expensive and takes twice as long as you originally thought!

Ultimate SOHC thread [here](#)

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Steve Cecchele

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#### 4. Cylinder Heads 101.

##### 4a. Different combustion chambers.

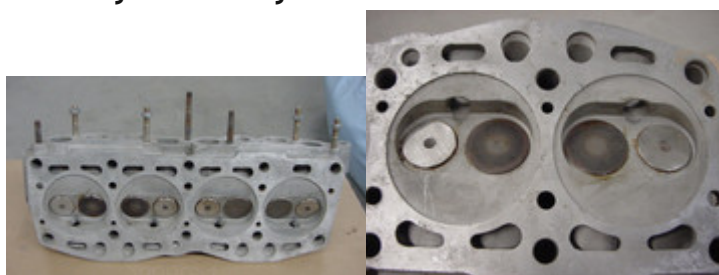
This diagram from Fiat literature shows the change of combustion chamber shape made around 1975 for the European market. I believe the USA had the early style combustion chamber right through until 1978! (probably something to do with emissions) Basically Fiat dropped the full circular recess that had been used on 1300 engines up till then. Fiat enlarged the width of the chamber, altered the plug side wall angle, and improved the VE when they did so, gaining 3hp.



An early 1116cc cylinder head combustion chamber.



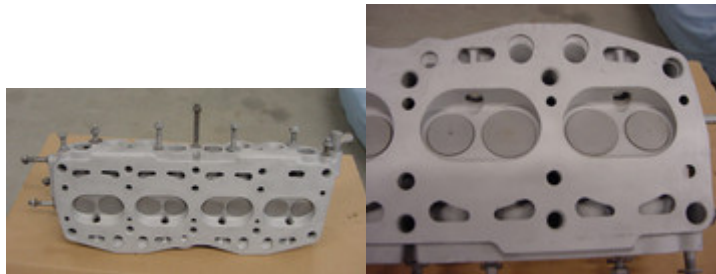
An early 1290cc cylinder head combustion chamber.



Here is a late model 1300 Euro spec head. Notice the chamber width as the machining goes out to approx 86mm across, also note the bridged water jacket (above the chamber) and the shape of the chamber wall with the plug. This is the later design combustion chamber and the one you want to use for best performance. 1300 and 1500 combustion chambers are identical, except for the addition of the larger exhaust valve.



The late 1116 head looks just like this except the chamber width is only 80mm (same as the bore size) basically the chamber wall is 3mm closer to the valves periphery, this limits flow above about 5500rpm when used on an 86mm bore. Note how far the combustion chamber is in from the fire ring (someone has retro fitted this to an engine with 86mm bore) as well as the differences in the spark plug face of the chamber (not laid back anywhere near as far)



1st choice would always be a 1500 euro head as the port sizes are a little larger, the intake throat size is a little larger, and the exhaust valve is a little larger, so it flows best of the standard X19 heads. Fiat did a good job on the ports so they need little work, more benefit can be had from reworking the bowls and the bend.

Second choice would be a post 75 1300 euro head and add the larger exhaust valve, and throat out the seats, and tidy up the ports effectively turning it into a 1500 head. (after extra work) The USA equivalent of this would be a Yugo 1300 head.

Third choice would be a post 75 1100cc euro head, and a deshroud on the



milling machine to bring the combustion chamber out to bore size, throating out the seats, and then fit the larger exhaust valve, once again bringing it to 1500 euro spec (after even more work) The USA equivalent of this would be an 1100 Yugo head.

Last choice would be any head that had the full circular decompression recess at bore size as this would need to be milled away to improve the quench/squish and raise the CR, which weakens the head deck and alters the cam timing.

Of all the options the 1500 cylinder head (Euro or USA) is preferable for a couple of reasons. It has a superior combustion chamber shape which shrouds the inlet valve far less than other designs. The ports are the best for flow and it has the larger exhaust valve and larger inlet valve seat throat. The 1100 combustion chamber is smaller in volume and this is what gives the compression boost, but it is also its biggest drawback. Re-working the combustion chamber to deshroud the inlet enlarges the chamber anyway, so this negates the advantage.

The biggest single difference to flow with all these standard heads would be the inlet valve seat throat. The early heads have a seat throat of around 29mm, later heads use a throat of approx 31mm. For a simple increase in flow this can be taken out to 32mm. It may not sound like a lot, but if you work out the cross sectional area, it starts to make sense.

$3.14285 \times 16.0 \text{ squared} = 804\text{mm sq}$  for a 32mm throat

$3.14285 \times 15.5 \text{ squared} = 755\text{mm sq}$  for the stock 1500 throat (approx 31mm)

$3.14285 \times 14.5 \text{ squared} = 660\text{mm sq}$  for the stock 1300 throat (approx 29mm)

#### 4b. Valve train upgrades.

##### Valve upgrades.

A common valve upgrade (back in the 70's) was to use inlet / exhaust valves from a Lancia Fulvia 1600cc engine. This requires using the collets and retainers from this engine as well, then to seating the valves at appropriate depths to ensure correct valve lash clearances could be achieved with standard thickness shims. Nice thing about this modification is the 7mm valve stem, the Fulvia retainers are nice and light, and in a round about way these come from the Fiat parts bin.

Exhaust valve = 34mm head dia , 7mm stem dia , 107,5mm stem length.

**Inlet valve = 38mm head dia, 7mm stem dia, 108mm stem length.**

**These days there are a few more options available;**

**30.5 / 31mm x 8 x 108.5 Fiat P/N 46531591 (1100/1300 cc standard exhaust valve)**

**33mm x 8 x 108.5 Fiat P/N 5973129 (1500 cc standard exhaust valve)**

**36mm X 8 X 108,5 Fiat P/N 5999660 (standard inlet valve 1100/1300/1500)**

**37,5mm X 8 X 108,5 Fiat P/N 46531590 (1581 cc stock intake valve Tipo SX)**

**39,6 X 8 X 108,5 Fiat P/N 46531591 (largest stock sized inlet valve used by Fiat in these SOHC engines)**

**If you don't mind doing some modifications to the valves then these are also possibilities.**

**For 7mm stemmed valves for sohc then Renault Clio (and also used on other Renault models)**

**exhaust valves ( 33.6 x 7 x 107.8 ) these are chrome stemmed and stellite faced**

**intake valves ( 37.5mm x 7 x 107.8 ) with a 30 degree taper on the head.**

**Another oversized intake / exhaust valve for Fiat SOHC use intake / exhaust valve from Peugeot / Citroen / Fiat scudo, ulyse 1584cc (diesel) engine.**

**intake ( 41.6 x 8 x 108.8 )**

**exhaust ( 34.5 x 8 x 108.37 ) chrome faced and stellite head.**

**Lightening the valves.**

**Lightening the valves is quite common practice in high performance engine build ups. It can cut down the valves weight considerably which in turn allows the valve springs to control the valve better and keep it firmly on its seat when its supposed to be. As far as I can ascertain it doesn't affect the valves seat/seal life adversely. I have had lightened valves in my 128 (sohc 1300) for nearly 100,000kms and I haven't encountered any problems. It could actually increase the life of the valve and the seat at high revs as if the valve doesn't bounce on its seat, the sealing face won't suffer an extreme (temporary) overload at the seat face when the valve spring loses control.**

I use the valve refacing machine in a way it was probably never intended to be used, using the grindstone to slowly grind the head of the valve concave. This can be achieved by mounting the valve in the rotating chuck, and positioning the spindle so that the grindstone contacts the heads centre. I do it very slowly using the coarse grindstone I have for my valve refacer, all the time allowing cool water to pass over the valve head to minimise any thermal problems.

The downsides to removing metal from the valve head are:

A. it will decrease the compression ratio, as the combustion chamber volume increases by the volume of material removed, and\*

B.the thermal gradient across the valve head increases, as there is less material in the head to dissipate the absorbed heat (in the valve heads centre)

A 'theoretical' benefit is that the valve should maintain a better seal under combustion pressures, as the concave face presents more surface area and is pressed into the seat tighter by the high pressures in the chamber.

The biggest benefit will be that the spring being able to control the valve better, due to it's lighter weight. This will raise the available rpm of the engine before valve bounce occurs.



Valve guides.

Valve guides lengths are common amongst all the sohc. After about 1974, they went to a 14mm nominal OD guide, prior to this they were a 15mm nominal OD guide. Guides are usually around 14.02 standard, and come in 14.05 and 14.08 and 14.10 oversizes. I like to buy slight oversizes and just fractionally emery them down to ensure a tight fit.\*

A trick is to use a 15mm OD guide for a 14guide head, and machine it with a step so it presses in to a specific depth(can't drop or move) and the step is the positive stop. It means you need 15mm spring shims and spring steps. I bought a box full of 15mm OD AlSi bronze guides and use these with a step in performance head builds. Once upon a time guides came fitted with

retainers and steps to achieve the same thing, so it's just another one of those cost cutting things that has been dropped with modern production techniques, but it was a good idea all the same.

Sometimes the standard head will come with one oversize guide, so be aware of this when you strip a cylinder head. It will be marked under the spring seat shim, in very small numbers like 0.05 or 0.10. If they mess up on the assembly line they don't throw the head out, they oversize that one guide... I've been caught a couple of times going to drop a guide in and it literally drops right thru!! so look carefully when you dis-assemble the head.

### Oversize Inlet Valves.

Fiat intake valves come in three basic sizes. 36mm , 37.5mm and 39.5mm. Unfortunately you can't just put a bigger valve straight into the head onto the existing valve seat as the OD is too small. To install larger valves require the installation of a larger outside diameter valve seat insert. A good machine shop can do this, but this sort of work doesn't come cheap because of the skills and machinery required, the new inserts can cost a few lire too as some are made from very fancy steel alloys. Larger intake valves and a larger valve seat throat can make a lot of difference to performance. The enlarged seat throat is what makes the real difference, simply having a bigger valve head isn't the reason for more flow.

If done right it's one of those modifications that doesn't have a downside (apart from the added expense) so I feel it would pay to invest in this modification and work this into your budget. Not only does it improve breathing in the upper rev ranges, it will give you more torque down low as well. It will improve the VE of the engine by allowing it to breathe easier as some restriction to the air flow into the engine is reduced. I've seen examples of head modifications (and done them myself in the past) that can get a 36mm valve and throated seat up to 120cfm, but I believe that's at the expense of port velocity. A more realistic flow figure for an optimised 36mm valve and port that maintained good port air speed would be around 110cfm. I know that a 37.5mm valve can be made to flow around 120 to 125cfm and still maintain good port velocity. I know that a 39.5mm valve and well prepared port can flow up to 160cfm. at very high port velocities. Absolute flow limits absolute HP, sure, but port velocity affects torque throughout the rev range. (\*figures at 28" H2O depression.)

### Inlet Valves larger than 40mm.

a) As valve head diameter increases the valve starts to get too close to the cylinder wall and the combustion chamber wall, shrouding the flow

considerably at low to moderate lift. The cone formation is more important than total area available (also known as the valve curtain).\*

b) Another thing that you have to watch is total port volume and cross sectional area. Whenever the cross sectional area is increased or reduced the velocity, temperature and pressure of the flow will be affected. Major changes in the cross sectional area will upset the flow, so it is important to avoid major section changes.

c) Even though you can grind and modify some areas of the port to increase the cross sectional area, there will always be some point that simply cannot be opened up any larger, due to water jackets and other mechanical limitations. This effectively becomes your port choke, and no matter what you do in other areas of the port, flow will be restricted by the choke. This area, wherever it may be, will determine the absolute maximum flow limit of the port.

d) Maintaining air speed and swirl (the vortex) in the port is more important than absolute port size.

e) The aspect of the port (ie the included angle between the valve and the port centreline) plays a big role in total flow as well and can be diminished by taking the ports out to their theoretical maximum size.

A smaller efficient port is certainly preferable to a large lazy one. Keeping the port air speed high is one of the big factors in getting these little engines to work well at all revs. I think most of the time a larger valve is simply used to mask the ports flow inadequacies, a far better result will come from a smaller valve and a more efficient port.

The exhaust valve.

According to PBS in their very old SOHC literature "the engine was basically insensitive to exhaust valves and ports," but I disagree. The exhaust valve and port is easy to overwork and then exhaust flow can exceed inlet flow (for a 36 inlet valve) which is not a great thing for a NA engine, but this is different IMO to "insensitive"

I have used 1500 type heads (with 33mm exhaust valve) on 1300's and noted an improvement in output, intake valve size stayed the same, compression ratio stayed the same, and exhaust/intake manifolding was the same, the improvement (in volumetric efficiency) came from better exhaust flow only.\*

I have also manufactured exhaust systems for X19's using the std twin outlet manifold (similar to what USA readers refer to as a '74 manifold) A high performance system using 2.25 inch tubing and mufflers and noted an improvement in output, once again the gains (in volumetric efficiency) came from the exhaust side only.\*

Same can be said for headers/ extractors over the standard manifold. A measureable increase was recorded all due to an improvement on the exhaust side only.

Exhaust valve seat inserts are more difficult to keep in the head due to the greater temperature differentials on this side of the engine compared to the intake, perhaps this is why they (PBS) chose to leave the exhaust seats alone. There is also the greater cost for the seat inserts as the material is generally of a higher grade than an intake seat, so maybe it was an economic decision to keep the cost of their BVH down. You've got to remember that the main focus of their sales would also have been people putting one of their heads onto an otherwise unimproved bottom end, so effectively a low compression engine. The higher you raise the static CR the greater the pumping losses from exhaust restrictions becomes.

So the engine IS sensitive to exhaust restrictions as good improvements in output can be had from modifications to this side of the engine, especially if your above 10:1 static CR.

Valve seat preparation.

This is one of the basics to improving the flow through the cylinder head. A top quality 3 angle valve job will make significant flow improvements at all engine speeds and valve lifts. Try and save money here and you may as well forget doing the job as the results will not meet your expectations. On top of the regular 3 angles, an additional 90 degree straight plunge cut to enlarge the throat of the valve seat will show significant flow gains. It is definitely worthwhile to have this straight plunge cut extend into the alloy head inside the valve bowl to make the straight run into the back of the valve as long as possible.

While cutting the seats consideration also needs to be given to seat height, as this affects the valve spring tension. Relative seat height between the inlet and exhaust valves also needs looking at. Sinking the exhaust valve slightly lower than the inlet will improve flow around overlap and reduce the amount of inlet charge that is drawn out through the open exhaust valve, commonly known as 'draw through.'

In addition to the seat work, you also need to carefully prepare the valve heads. A 30 degree back cut to both the intake and exhaust valves will improve flow, after the valve is lapped and a clear seating matte grey area is seen, bring the 30 degree back cut right up to within 0.5mm of this sealing line. Careful attention to valve margins and a top cut on the intake valve to reduce flow reversion at overlap are worthwhile steps in a performance head build. You need to find a competent machinist who is prepared to work to a fine tolerance and pay them well for their efforts, otherwise your simply wasting your time.

### Valve Springs

Using the correct valve springs help prevent both valve float and valve bounce. Valve float is an adverse condition which can occur at high engine speeds when the valve does not properly follow the closure phase of the cam lobe. This reduces engine efficiency and performance, and represents a significant risk of severe engine damage due to valve spring damage or pistons contacting the valves. They also negate valve bounce which is a related condition where the valve does not stay seated due to the combined effects of the valve's inertia and resonance of metallic valve springs that reduce the closing force, and allow the valve to re-open partially.

### The PBS Big Valve Head (BVH)

#### The PBS BVH

PBS literature is very very old. Things have moved on since the dark ages of no internet and no eBay. PBS used a Nissan valve for their BVH conversion, the 40mm valve had its collet groove recut to the Fiat style. The valve used was also longer overall, which required trimming for length. PBS often left the overall valve stem length longer than standard (approx 108.5 mm is stock valve length overall) to compensate for the reduced base circle cams they sold. Another way to compensate for reduced stem length or a reduced base circle camshaft would be to machine the cambox to maintain correct valve lash specs.

How does a PBS BVH compare to a Tipo style 'factory' BVH? Well I can't say, as I have never seen reliable flow figures for a PBS modified head, or a head modified in the PBS method. There would also be a difference between different porters methods and abilities. What I can, and will quantify are components that I have tested. Stock head, modified 36 valve and 37.5 valve stock head, standard factory big port head and one that I've tested and optimised. I now work in CFM on a flow bench. A few years ago I was always criticised for having no hard data, people wanted flow numbers and some would poo-poo what I had to say. Have I changed the way that I port a sohc,

no. I've always been an advocate of smaller port sizes and an efficient port and I still do it the same way I have for the last 20 years plus. These days I just get to verify my results on a flow bench and prove what I've known all along... and as a bonus I can get to find those last few CFM, the hard ones to find.

A 37.5 valved tipo head is around 110cfm. A 39.5 valved chinese tipo head is over 120cfm, one that's been optimised is over 160cfm, so that's the potential of the tipo head, they are known facts. Having done a few heads in my time I can assure you that trading flow against speed is always an issue. High port air speed is essential to get good ram effect (and get above the magical 100%VE in certain conditions) A slow large port may flow more in gross numbers, but the dyno results show that the power curve suffers until the revs get really high. Will a PBS BVH get this sort of flow and have the same sort of airspeed? NFI. Someone else needs to come up with that data so we can all compare.

There are many ways to go about a certain task, but it's safe to say there are always "good ways" and "not so good ways" to get the job done. I can only advocate best practice in every case, so if you want to get the best possible result why would you compromise your chances of getting there by making a 'compromised' choice. Why would you use a modified nissan valve? (which to do now would be at far greater expense over an OEM item) Why would you start at a point that compromises everything that you do from then on. Well it simply was what they (the guys at PBS) had available and it had the capability of making them the most money. They could regrind the bunch of standard emissions grind cams they had, and the longer stem worked out. If you had the \$\$ you could buy one off the shelf so 'in the day' was a solution ...is it the 'best' possible solution to the problem, well no because it definitely as some engineering compromises built in, but it worked.

The 33 exhaust valve makes a good improvement, don't listen to PBS engineering's ancient and obsolete advice on this. They were "telling what they were selling" at a time when a stock 33mm valve for the exhaust wasn't available, alternate valves were probably hard to source and exhaust valves are more expensive due to the materials and construction /production methods used. It will make a difference to output, no if's or but's, if due to nothing else it will lower pumping losses. If you do a nice job on the intake side you can get 150cfm without too much effort and a 39.5valve/36 throat. If you leave the exhaust at 31valve /27 throat flow maxes out at about 100cfm. Flowing 150inlet / 100 exh. has the exhaust at just 66% I/E ratio, personally I like about 75-80% I/E and changing to a 33 valve/29 throat will easily give 110cfm with minimal bowl work and without removing any material from the port, so we see an exhaust port speed increase and the I/E



ratio comes up...do a really nice job on the intake and the flow will be closer to 160cfm, and the 31 valve just wont keep up. (not without dropping port speed)

In today's day and age, you can buy a better head, better valve and a better cam ( for lift / duration than any of their regrinds PBS sold) off the shelf from Fiat. If you apply best practice to this pile of parts then from both an engineering and performance perspective, you end up with something far better than the famed PBS BVH, simple.

### Cylinder head casting numbers database

I'm going to try and build a database of all (!! ) available sohc cylinder heads, arranged by cast in factory number, noting valve sizes, port size, combustion chamber type and application where possible. I'll try and get a picture of the cast in number, the casting year date stamp and one of the head face to show the valves and combustion chamber.

If you have suitable pictures of cylinder heads that are not on this list, please message me.

128A000 4195125



128A 4302158



128A 4321562



**128A 4322399**



**128A 4343497**



**128A 4312399**



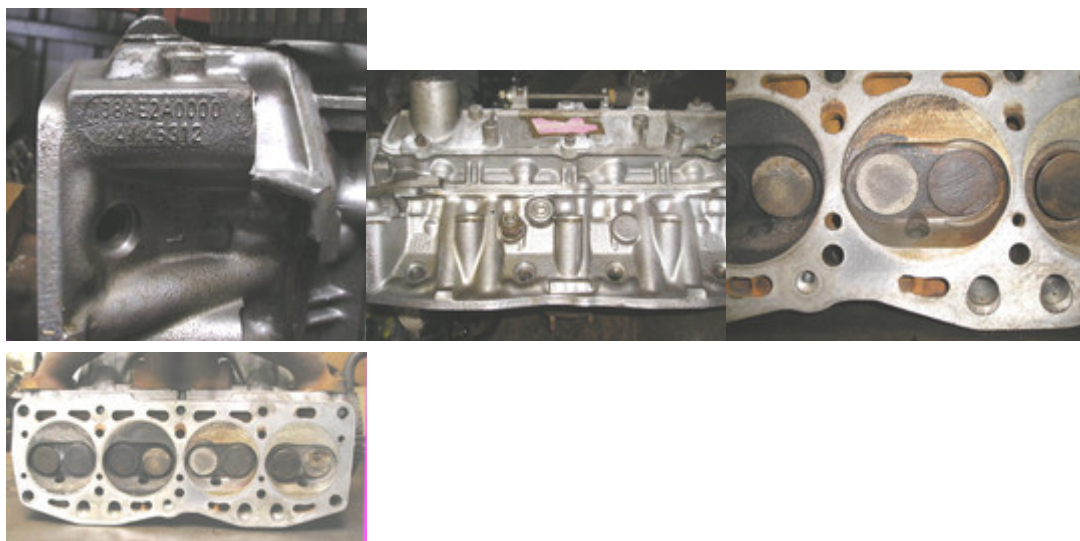
**128A 4469750**



**128A part number 5882141**

**128AR 4322847****128A1 4444407****128BCOCO 4372444****138AE2 AO 4407542 (Late 1500 euro Ritmo)****138AE2A000 4445312 (Late 1500 euro/Aust X19 1980)**





**M202DA.11.0 5984624 (1100cc late UNO 1984 production)**



**M202DA.13.0 5960060 (1300cc late UNO)**



**7575664 (1500cc late 14 bolt SPI Regata 1987)**



**7579454 (1500 late euro carb X19)**



### **Head gasket choice and correct installation procedure.**

So many people have head gasket issues, which I find quite amazing as the SOHC Fiat is NOT a head gasket eater even at high power levels. IMO it comes down to two factors why people have problems, gasket choice and installation technique

### **Torquing and re-torquing... why's, hows, do's and don'ts.**

Before installation make sure bolt holes and threads are clean. Oil and drain bolt threads. Apply a small dab of antisieze compound under the nut/bolt head between it and the thick flat washer, this reduces the friction involved to a minimum and helps achieve the maximum clamping force without taking the fastener into the 'plastic (deformation stage) and keeping things in the 'elastic' range where the fastener will return to it's original dimensions when load is released.

If the threads in the block are not clean or lubed this can give you a false torque reading. Chase out the threads well, you can buy specific tools for

this rather than using a thread tap which can remove metal from the threads, which you don't want, something a bit like this,



The M12 bolt / stud combination is always a retorque style engine, and uses a retorque style head gasket. It absolutely needs a retorque after a heat cycle and again after several hundred Km. Failing to do so will lead to a head gasket failure.

First torque on assembly. multiple stages, the more the better so the head clamps down evenly, 15/30/45/60 or 20/40/60 and then finally 69 lb/ft. This is going thru all the bolts /nut one at a time in torque sequence to each value, then stepping up the wrench to the next value, and repeating for the other nine fasteners... it takes a little while, but certainly pays dividends by only having to do the head overhaul / gasket replacement once.

First re-torque after one heat cycle... run car, fan cycles on / off maybe three times, shut her down. Let it completely cool, overnight is best, retorque in the morning when the ambient temp is coolest. A second re-torque, I usually do after maybe 100 miles (160km) again completely stone cold.

For retorques the procedure I follow is...In torque sequence order, one bolt/nut at a time, loosen the bolt/nut around 1/4 to 1/2 a turn with a breaker bar, retighten back the same amount. (I use a paint marker on the bolt nut to get it back to pretty close to its original position) Then swap the breaker bar for the torque wrench and using steady slow and even pressure on the torque wrench, take it straight up to the final torque value (9.5kg/m) Then go on and do the other nine head fasteners in precisely the same sequence, loosen/nip up/retorque.

Engines with M10 head fastening hardware, things are a little different. There has been much discussion about the 'Torque and Angle' (TAA) system used by Fiat during later production, and also the use and reuse of the 'Torque to Yield' (TTY) style of bolts used. Many servicing and instruction

manuals imply that following a TAA system will negate the need to re-torque after heat cycling. But, it must be remembered that the non retorquer system relies on the use of a compatible head gasket.

Goetze in conjunction with Fiat developed a Polymer composite construction gasket, which rather than settling and compressing under heat cycling (like a regular composite gasket does) it contains a special polymer which is heat activated and actually hardens. This style of gasket is known as 'Astadur' and when used with the correct bolts and tightening system, is the ONLY system which will not require retorquing after assembly and heat cycling. It's not the type of bolts, not the tightening method used, not the gasket alone, but a complete system that all works together to provide this non-retorque ability.

With EVERY other type of gasket, even when following the TAA system of tightening, the head fastening hardware MUST be re-torqued to ensure that the gasket doesn't fail.

Fiat service letters and manufacturers torque instructions confirm this, as it's likely they were receiving warranty claims from people following a non-retorque method when using a NON-Astadur style head gasket. Below is the torque specifications supplied with Victor-Reinz gaskets which clearly shows the use of TAA system for initial tightening, and the need to retorquer after 1000km. Also a picture showing the torque specifications supplied with Elring brand head bolts and gaskets.

[View attachment 87](#) [View attachment 88](#)

If you wish to source the correct Astadur head gasket the correct Fiat part numbers are;

5951682 is the 1.65mm Astadur (polymer construction) gasket for the TEN bolt M10 engines (up to 10/85) supersedes to 7588550

7580221 is the 1.65mm Astadur (polymer construction) gasket for the 14 bolt M10 engines (11/85 on) which supersedes to 7637103

7604404 is the 1.65 Astadur (polymer construction) head gasket for the Tipo 14 bolt engine (supersedes to 7666858)

So with M10 fastening hardware you have a choice. If your using a straight torque system, then you need to torque on build, retorquer after one heat cycle, and then retorquer again after a couple of hundred Km's ... that's the right way to do it.

Torque should be 61.5lb/ft for straight torque, at least three stages on initial torque too, so 20/40/60/61.5 lb/ft. For a proper Retorque you should back each bolt off 1/2 a turn, one at a time in retorque order, and then retorque it straight to 61.5 lb/ft and then move onto the next fastener in the head torque sequence and follow the same steps until all ten are done.

If you use torque and angle system, then 40Nm, and two x 90 degrees, one bolt at a time in torque pattern order at the initial torque value (40Nm) and then one bolt at a time to 90 degrees, and then through the whole sequence again with another 90 degrees.

Unless your using a genuine Fiat (Goetze type) Astadur polymer composite construction gasket then this initial torque should be followed by an additional 90 degrees after several 100 km's and this retorque is done without first backing the bolt off, it's simply one bolt at a time in torque sequence a further 90 degrees, with most systems recommending doing this in two stages 60 degrees followed by 30 degrees for a total of an additional 90 degrees.

follow these steps and you will have success.

added thought... it also pays to check the manifold to head stud/nuts at the re-torque stages... and also the exhaust flange nuts (if your running a twin front pipe) as these will also come down another 1/8 of a turn usually. after 100 miles I usually check the cambox bolt tension too, and run a feeler gauge thru the gaps to confirm the lash hasn't altered beyond spec.

Last edited by a moderator: Today at 3:54 PM

i cavalli mai abbastanza, ed il peso sempre troppo.

Nothing is as simple as it looks. Its always twice as expensive and takes twice as long as you originally thought!

Ultimate SOHC thread [here](#)

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## 5. SOHC flow modifications.

### 5a. Port Velocity.



**fiatfactory**

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Location:

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Most discussions about porting, talk almost exclusively about achieving greater values for airflow. If simply having larger values for airflow were the key to maximum horsepower then we could expect the “bigger is better” theory to hold true, which it doesn’t. The keys to producing the best airflow for an engine lie in port velocity and flow efficiency. If a port is modified to produce good flow with a minimal amount of material removed, then since it is flowing more air through much the same sized port, the velocity (air speed) must have also increased.

Though too much port velocity can limit top end power, low velocity can reduce power throughout the whole power curve. On a carburetted engine, a smaller port volume will improve throttle response as it has less damping effect on the induction pulse. Less damping will enhance the atomisation of fuel from the auxiliary (or second) venturi, which in turn aids both fuel distribution and burning efficiency. Higher port velocities also support atomised fuel better with less chance of fuel falling out of suspension or forming into large droplets.

A small volume - hence high velocity - port will also enhance cylinder ramming at the end of the intake stroke and this will increase volumetric efficiency. This can be coupled with attention to entry direction through the valve which can promote better cylinder swirl and aiding combustion efficiency, which all leads to what we want to achieve - more power being produced.

The exhaust port velocity is also important. A slow exhaust port can cause an engine to have little low-end power before coming “on the cam” abruptly. As the intake valve opens it’s the exhaust flow that provides the energy to initiate flow past the valve, well before the piston begins to move down the bore. If the exhaust velocity is low, effective scavenging of the combustion chamber is lost during the overlap period.

For both intake and exhaust the key to making an efficient port, is to manoeuvre air around any corners as effectively as possible. Though light, air has sufficient mass to be affected by momentum as it moves through the port, and requires little velocity to exhibit a tendency to go straight ahead rather than around a bend. Air arriving at too sharp a turn in the port will not negotiate the turn at the tight radius, it will simply hug the turn at the wall of the larger radius. This can make the port flow considerably less, and can be seen by the air as a very real constriction.

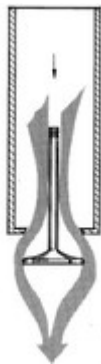
The key to getting air to negotiate corners efficiently comes down to two main factors.

1. Making the corner as large a radius as possible.
2. Increasing the port cross sectional area enough to slow the air, hence enhance its ability to negotiate the turn.

### 5b. The Flow Cone

This next part is a very important part of the porting / understanding flow paths concept - the Flow Cone. I talk quite a bit about how "shrouding" will reduce the total flow through the port considerably, well here is why. Understanding the dynamics of airflow around an obstruction is crucial to achieving good flow through a port. It is vital to remember that the valve head is the greatest restriction to the flow path, as it sits right in the middle of the airstream and all flow must move around the valve head before it enters the combustion chamber. This is one of the reasons I honestly can't see any value in bare port flow numbers... how often is an engine going to be running like this?

Smoke or water flowing thru a clear tube shows how the airflow forms a typical cone shaped path above and below the valve head. An interesting fact is that when flow through the port becomes better and the velocity of the flow increases, these cones become shorter. Another fact is that if anything happens to break into the area formed by these Flow Cones on either side of the valve head- like tight cylinder wall shrouding or dropping the short side radius - then the total flow through the port is severely reduced. To achieve maximum flow through any port these Flow Cones must not be disturbed in any way. Serious engine builders spend quite a bit of time ensuring that the angles and widths, particularly of the valve face, margin and leading edge (upper for intake, lower for exhaust) are as they want them. This is because these factors have a strong positive influence on this Flow Cone formation.



Some factors that can have a negative influence on the Flow Cone formation, and hence drop the total flow through the port are.

#### a) Shrouding from the cylinder wall / combustion chamber walls

b) Shrouding by the valve cutout pockets / piston dome

c) Dropping the short side radius of the intake port

In the Fiat sohc cam engine the greatest factor of these three is the effect of shrouding by the combustion chamber walls. To get good flow on an 86/87mm bore sohc engine, you really need to relieve the combustion chamber and deshroud the inlet valves.

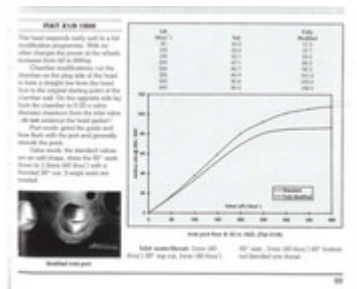
Some people when fitting larger valves or porting cylinder heads have a tendency to drop the port floor (reducing the short side radius) in an effort to bring the flow into the backside of the valve at an oblique angle. This is just totally wrong. If you try and bend the flow right at the edge of the valve, the cone doesn't form around the edge of the valve and total flow drops off considerably. To get a uniform cone formation around the entire circumference of the valve, we want to turn the flow well above the valve head, and let the flow come straight into the back of the valve. There are always restrictions to what is possible, but one thing is absolutely certain, that you should try and get the sides of the intake port dead straight and perpendicular to the valve for as long a distance as possible.

Total flow past the primary obstruction (the valve head) can also be increased if the Flow Cone becomes more of a Vortex. Think back to Primary School science lessons. Remember getting two bottles of water and inverting them to let the contents empty, and giving one of the bottles a little swirl as you were inverting it.

The bottle that has the extra energy imparted to it forms a "whirlpool" or vortex at the mouth, and empties considerably quicker than the tumbling flow of the "non-swirled" bottle. Precisely this same effect can be applied to an inlet port, and Fiat have already done it for us with the Port Bias that is found in the standard production ports. The offset bias, and the transitions formed by this bias, angles the low flow (the lower portion of the port) towards the far side of the valve, directing the airflow in such a way that a swirl effect is imparted, and total flow increased. If this offset bias is ignored (think of these like the little "winglets" you see all over a contemporary F1 car which angle the airflow around obstructions) then the vortex effect is completely lost, and total flow is reduced.

5c. SOHC head flow data and comparisons.

Taken from "How to Build, Modify and Power Tune Cylinder heads"  
by Peter Burgess / David Gollan - B Eng Hons.- Veloce publishing ISBN 1-903706-76-9



This data relates to a X19 1500 (UK spec) standard 62 rear wheel HP. (rated \* 85 crank HP) (9.2:1 CR 24/68 64/28 9.9 mm inlet lift cam, 34DMTR carb, twin out exhaust manifold, no cat conv.) By comparing the same vehicle, on the same dyno, with only the modifications to the cylinder head - and still using standard valve sizes - (ie valve mods, chamber mods, valve seat mods, very light smooth out of ports) results in a noticeable increase of 22 rear wheel HP to 84 rear wheel HP. Max. flow increased from 86.5 cfm to 108.5 cfm at 400thou lift. (measured at 25in. H2O) The flow at 250thou increased from 80.7cfm stock to 92.3 cfm when modified, so the modified head flows more at 250thou lift than the completely stock head had at 400thou of valve lift! These results mirror my own findings and flow testing, which are based over 30 years of Fiat SOHC experience.

If you couple a cylinder head prepared as above, with an increased compression ratio (for example by using 1300 small valve relief pistons in a 1500) a longer duration and higher lifting cam, a free flowing exhaust system (but still using the stock intake and exhaust manifold) with a 34dmtr carburettor and 2.25 inch muffler and pipes, a well built 1500 overbore can net close to 100RWHP. I have had this in my own 1500 X19 at 99RWHP and have built several customers cars to the same / similar spec, they all gave similar results. 100 rear wheel Hp is certainly achievable from a naturally aspirated 1500cc sohc. It requires more port flow and a higher static CR than standard specifications, but with a balanced mix and match of the other "good" bits and pieces this sort of result is possible. By working mainly the valve bowls and seats we maintain a high port velocity (as the port size does not get increased significantly) and this results in very good low and mid range response, in fact much better than the standard engine due to the increased port efficiency, and the increased mechanical efficiency provided by the higher CR.

### Comparing flow data from different sources

To compare flow measurements when different pressure drops are used for testing is quite straightforward, as flow follows a "square" law of pressure versus flow. To calculate a "correction factor" use the following formula.

Flow at new pressure drop = square root of (NPD/OPD) x flow at original pressure drop

Conversion from 25" H2O to 10" H2O would be;

Flow at NPD = Square root of (10/25) x Flow at OPD  
= a correction factor of 0.6324

Conversion from 10" H2O to 25" H2O would be;

Flow \* NPD = Square root of (25/10) x Flow \* OPD  
= a correction factor of 1.5811

Figures corrected to 10" H2O for a standard 1500 X19 cylinder head.

50thou = 10.3 cfm  
100thou = 21.19 cfm  
150thou = 32.95 cfm  
200thou = 43.7 cfm  
250thou = 51 cfm  
300thou = 53.7 cfm  
350thou = 54.25 cfm  
400thou = 54.70 cfm

What is significant for these numbers is that the %age increase in flow rate above 250thou of valve lift drops off considerably, so the the curve "flattens off" noticeably.

Figures corrected to 10" H2O with modified port/seat/throat/36 mm valve

50thou = 10.95 cfm (6.31% gain over stock)  
100thou = 23.84 cfm (12.5% gain over stock)  
150thou = 37.44 cfm (13.65% gain over stock)  
200thou = 50.6 cfm (15.8% gain over stock)  
250thou = 58.37 cfm (14.45% gain over stock)  
300thou = 64 cfm (19.18% gain over stock)  
350thou = 66.78 cfm (23% gain over stock)  
400thou = 68.62 cfm (25.5% gain over stock)

Here flow test data on a standard port flow of the tipo head with 37.2mm valve fitted, seats 3 angle cut but port and OE valve totally standard. Test was done at 10" of H2O, but lift shown on a metric scale. I've done my best to read off the graphed figures accurately at the commonly used lift measurements at 100 thou intervals.

50thou = approx 12cfm (\* approx 1.25mm lift)  
100thou = approx 23cfm (\* approx 2.5mm lift)  
150thou = approx 33cfm (\* approx 3.8mm lift)  
200thou = approx 42cfm (\* approx 5mm lift)  
250thou = approx 52cfm (\* approx 6.35mm lift)  
300thou = approx 57cfm (\* approx 7.6mm lift)  
350thou = approx 63cfm (\* approx 8.9mm lift)  
400thou = approx 65cfm (\*approx 10.15mm lift)

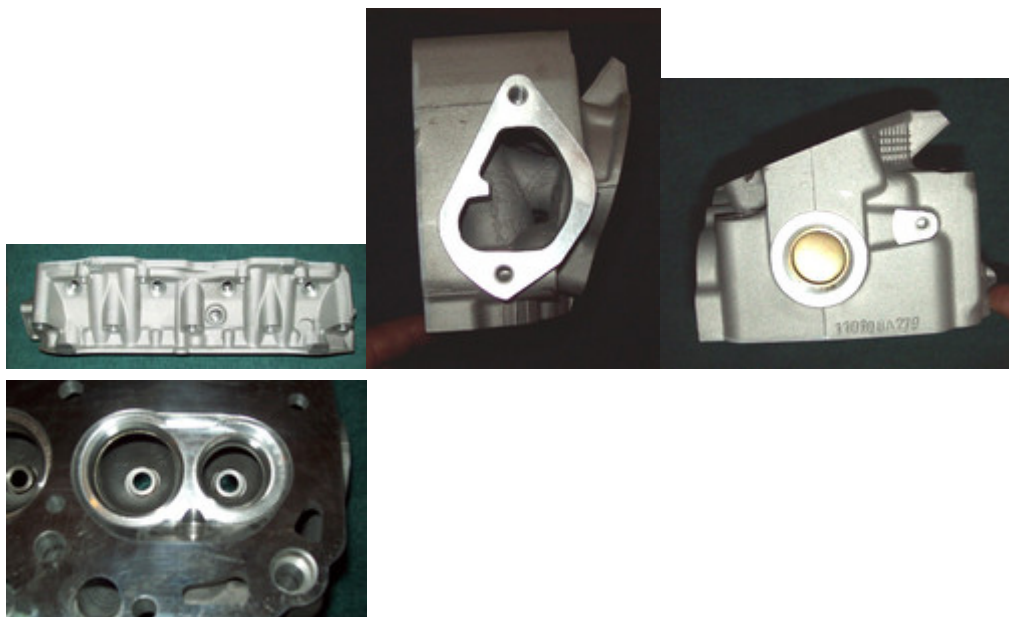
Never having tested a stock tipo sohc 37.2mm intake valve cylinder head I have no raw data of my own to compare, but these numbers look about right. What I do have is data on a X19 1500 cylinder head with modified throats / seats / valves / chamber and fitted with a 37.5mm intake valve, again no significant increase in port size.

50thou = 12.3cfm (up from 10.95cfm - approx 12% over a 36mm valve in a similarly prepared head)  
100thou = 25.6cfm (up from 23.84cfm - approx 7.5% over a 36mm valve in a similarly prepared head)  
150thou = 43.6cfm (up from 37.44cfm - approx 16% over a 36mm valve in a similarly prepared head)  
200thou = 54.6cfm (up from 50.6cfm - approx 8% over a 36mm valve in a similarly prepared head)  
250thou = 65.5cfm (up from 58.37cfm - approx 12% over a 36mm valve in a similarly prepared head)  
300thou = 69cfm (up from 64cfm - approx 8% over a 36mm valve in a similarly prepared head)  
350thou = 72cfm (up from 66.78cfm - approx 7.8% over a 36mm valve in a similarly prepared head)  
400thou = 75cfm (up from 68.62cfm - approx 10% over a 36mm valve in a similarly prepared head)

so on average a change from a 36mm valve head to a 37.5mm valve head will net approx 10% in flow across the board on a prepared head

5d. Tipo style head - 14 bolt. aka "The Chinese Head"





I'm quite impressed with the quality. Don't let the "Made in China" tag fool you, there are certainly some good manufacturers over there, with modern machinery and factories, so there are some companies who make quality aftermarket parts. This is an aftermarket Tipo style head 14 bolt, already fitted with LPG compatible valve seat inserts and cast iron guides. 39.5mm inlet valve size, 35.5mm seat throat size. 31.0mm exhaust valve head size, 27.0mm exhaust seat throat size. Inlet port size 28.5/29.0 and exhaust port size 27.5mm.

I've flow tested this head on my bench (which uses a depression of 28" of water for testing) and the results were pretty good for a straight out of the box head. Figures are still at 28" of H<sub>2</sub>O, corrected for temp/humidity etc

#### Inlet

0.050 30.4cfm  
 0.100 60.6cfm  
 0.150 77.8cfm  
 0.200 95.7cfm  
 0.250 106.6cfm  
 0.300 118.8cfm  
 0.350 121.9cfm  
 0.400 124.0cfm

#### Exhaust

0.050 25.8cfm  
 0.100 41.2cfm  
 0.150 56.0cfm  
 0.200 70.6cfm  
 0.250 82.3cfm

0.300 86.1cfm

0.350 87.8cfm

0.400 88.1cfm

Port air speed numbers were good as well. I only took measurements at 200thou and 400thou, my machine plots a port speed profile across 9 points (8 points around the circumference and one right in the centre) using a pitot tube. At 200thou the 9 points range between 249 and 261 feet/sec, at 400thou the range is between 317 and 335 feet/sec, which is very good for an untouched port in both total and %age variation across the port. Now these numbers are with "as supplied" seat cuts, nothing fancy. Some improvement could be had simply by altering the seat cut to a narrower sealing face, at the moment they're almost 3mm wide. Same with the valves used, straight out of the box TRW replacement valves, no backcut or profiling, so these are totally raw figures and my baseline for these heads.

I retested the "Chinese" Tipo test head after I spent a bit of time fettling one of the intake ports to increase the flow capability. I also had larger exhaust valve seats fitted (to suit the 1500 type exhaust valves) and mildly worked one exhaust port as well. The results are very promising. Measured at 28" of H2O and corrected for temp/humidity etc (39.5mm inlet / 33.4 exhaust)

#### Inlet

0.050lift 32.7cfm (std Tipo 30.4cfm) (stock X19 1500 head 16.3cfm)

0.100lift 61.4cfm (std Tipo 60.6cfm) (stock x19 1500 head 33.5cfm)

0.150lift 83.5cfm (std Tipo 77.8cfm) (stock x19 1500 head 52.1cfm)

0.200lift 102.3cfm (std Tipo 95.7cfm) (stock x19 1500 head 69.1cfm)

0.250lift 118.9cfm (std Tipo 106.6cfm) (stock x19 1500 head 80.7cfm)

0.300lift 128.1cfm (std Tipo 118.8cfm) (stock x19 1500 head 84.9cfm)

0.350lift 136.1cfm (std Tipo 121.9cfm) (stock x19 1500 head 85.8cfm)

0.400lift 143.2cfm (std Tipo 124.0cfm) (stock x19 1500 head 86.5cfm)

#### Exhaust

0.050 34.0cfm (stock Tipo 31mm valve 25.8cfm)

0.100 53.6cfm (stock Tipo 31mm valve 41.2cfm)

0.150 68.3cfm (stock Tipo 31mm valve 56.0cfm)

0.200 83.6cfm (stock Tipo 31mm valve 70.6cfm)

0.250 95.1cfm (stock Tipo 31mm valve 82.3cfm)

0.300 102.3cfm (stock Tipo 31mm valve 86.1cfm)

0.350 105.2cfm (stock Tipo 31mm valve 87.8cfm)

0.400 107.4cfm (stock Tipo 31mm valve 88.1cfm)

Port air speed has also increased, by an average of around 2%...to the range of 323 to 346 ft/sec



I think there is more flow to be had, as again this was with "as supplied" seat and valve profiles, but as it stands the port shape should flow enough air for around the 140hp (crank) mark on a 1500

This is not a Fiat produced cylinder head, and I've never had a Fiat produced Tipo head to directly compare it to (and flow test with my bench for a direct comparison) Though going from other flow figures found on the web, it does flow a couple of more than the stock tipo head with a 39.5mm intake valve. The port sizes are close to 1500 x19, but slightly larger. Biggest difference is probably at the short side radius, maybe port height.

Stock 1500 x19 heads (best figure for untouched port) that I've had is 88cfm at 400thou lift, these Chinese made Tipo style heads flow 124cfm (same lift and depression) out of the box, a significant difference - and the port air speed is considerably higher too!

I currently (Sept 2013) have modified inlet ports/seats/valves that exceed 160cfm, some with more than 350fps air speed. Should be good for 160+hp on a 1600 engine and dyno sheets will come. New heads should be ready for some CNC treatment early in the new year, and then they will be available to the public. Not really what I would call a "street" head unless your prepared to build the rest of the engine to match. If you need to ask what they will be worth fully dressed, you probably can't afford one.

5e.1500 14 bolt intake 37.5 valve / 34 throat , exhaust 33 valve

New seats fitted, throats 34mm.



Chamber and port untouched, you can see how much material is coming out of the throat.



Bowl rough out.



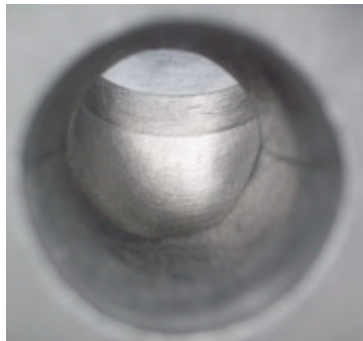
**Rough bowl shape compared to untouched**



**Bowl rough out finished**



**Port rough finished.**



**37.5 /33 valves back cut prep**



**Finished port**



Finished chambers



This head has had no significant increase in port size. Stock ports measure 28.5mm and this heads ports have barely been enlarged and are 29.0mm. The stock 1500 head has a seat throat of 31.1mm, this head is 34.0mm. Stock valve size is 36mm, this head is 37.5mm. I've corrected these following flow figures from 28" back to 10" of water so they can be compared with other numbers floating around on the web...

100 thou lift (stock 21.2cfm) modified 29.6cfm  
 150 thou lift (stock 33cfm) modified 43.3cfm  
 200 thou lift (stock 43.7cfm) modified 56.6cfm  
 250 thou lift (stock 51cfm) modified 64.6cfm  
 300 thou lift (stock 53.7cfm) modified 69.0cfm  
 350 thou lift (stock 54.3cfm) modified 70.8cfm  
 400 thou lift (stock 54.7cfm) modified 66cfm

Not a bad result, and as is would still be a nice head capable of around 110hp at the crank... if I can push the 350 to 400 thou flow a little higher and get it up to around 75cfm \* 10"/ 125cfm \* 28" at 400 thou and also drop some of the port turbulence it could be 120hp at the crank. The main focus is on a strong mid rang more than concentrating on outright Hp. More work around the port roof area and a different seat cut yielded good results. The major aim was getting the port to maintain flow after 300 thou, and right now it barely drops away at 350 (120.5) and 400 thou (119.5) and at the same time port speed has remained very high, so I think we've achieved this. The high port velocity is a key with this head, for a street driven car this will make the most difference and will certainly help the engine make more torque.

100thou (start 122f/sec) final 129.3 feet/sec  
 150thou (start 186f/sec) final 195.2 feet/sec  
 200thou (start 240f/sec) final 244.9 feet/sec

250thou (start 272f/sec) final 276.8 feet/sec  
300thou (start 278f/sec) final 299.9 feet/sec  
350thou (start 277f/sec) final 295.5 feet/sec  
400thou (start 273f/sec) final 294.0 feet/sec

Here are some flow figures (corrected to 10" of water) for comparison with other figures on the web

100 thou lift (stock 21.2cfm) modified 29.6cfm, final 33.8cfm (gain 54%)  
150 thou lift (stock 33cfm) modified 43.3cfm, final 49.9cfm (gain 50%)  
200 thou lift (stock 43.7cfm) modified 56.6cfm, final 62.7cfm (gain 42%)  
250 thou lift (stock 51cfm) modified 64.6cfm, final 69.7cfm (gain 36%)  
300 thou lift (stock 53.7cfm) modified 69.0cfm, final 72.3cfm (gain 34%)  
350 thou lift (stock 54.3cfm) modified 70.8cfm, final 72.0cfm (gain 33%)  
400 thou lift (stock 54.7cfm) modified 66cfm, final 71.1cfm (gain 31%)

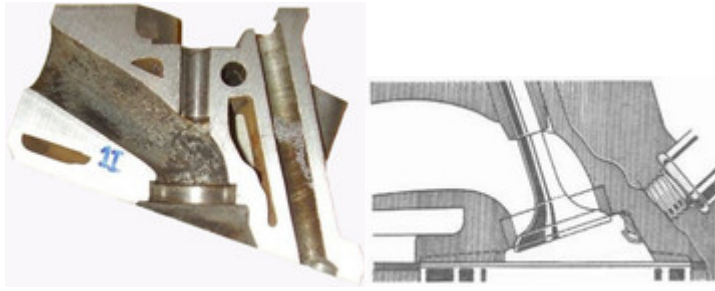
I tested the exhaust flow at four data points (every 100 thou) but the results are very good, so any pumping losses in this engine will be minimal. Flow at 28" of H2O

100 thou 43.9cfm  
200 thou 80.5cfm  
300 thou 103.6cfm  
400 thou 109.8cfm

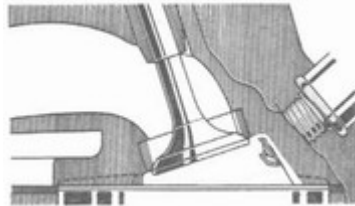
5f. Basic modifications for more port flow.

I thought a sort of slideshow of cross section pictures will show the areas that require metal removal. It's not a lot of metal that needs to be removed, and it's hard to faithfully represent something 3 dimensional in a 2 dimensional format. I'm showing a line of material removed from the port roof, but in reality this is only showing the thickest area of metal removal. Material is removed from the entire top half of the port down to zero material removal at the ports waistline. This is starting with a 1500 euro head.

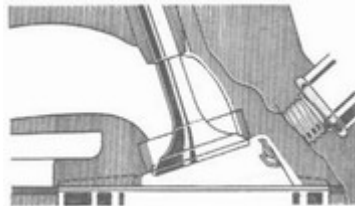
This first picture shows the stock late model combustion chamber in cross section, no modifications.



This second picture shows the combustion chamber modification on the inlet valve plug side, as well as the seat being throated. The chamber modification straight lines the lower corner of the chamber and removing up to 2mm (or more if the valve is larger in head size than 37mm) from the upper edge of the chamber (plug side). The throating of the valve seat shows how much more of the valve head is now directly exposed to the flow in the port.



This third picture shows the blending of the long side radius from the throating cut (or plunge cut) into the port as well as a back cut on the left hand side of the inlet valve to blend the flow into the seat contact face. (see how different it is to the stock valve seat a couple of pictures above)



The fourth picture shows the blending of the port roof into the cut back valve guide. Very little of the guide is removed, so it makes no difference to valve seat or guide life to trim this little of the guide away, but it does make a difference in flow thru this hi flow area. This picture also shows the chamber blending on the non spark plug side of the chamber, basically blending the sharp edges.



Chamber modifications again are hard to show in a picture (especially with

shiny fresh metal everywhere) so in this representation the areas to remove metal are shown in red. Again this is a blend from areas that have a couple of mm of metal depth removed, down to zero where it blends in smoothly without any step. As much material as possible should be removed from all around the inlet valve out to bore size, but DO NOT undercut the fire ring of the cylinder head gasket. If the fire ring edge gets exposed it just doesn't last and head gasket problems will follow. Standard head gaskets the fire ring is around 87.0 to 87.2 mm ID. Special head gaskets are made for large bore sizes up to about 88mm internal. The radius where the chamber floor and wall meet should be maintained, a sharp edge here is no good. This shows the area on the plug side of the inlet valve that requires attention. Again it is just "straight - lining" the lower corner of the combustion chamber with an new top corner about 2mm out from the original top corner... it removes the area of the chamber wall that breaks into the flow cone. When it breaks the cone it also drags raw fuel droplets across the "edge" that is part of the original plug side chamber wall where the vertical and angled milling cuts meet, creating the "washed" area. (pics to follow)



A pair of finished combustion chambers, the scribe line is the inside of the fire ring. Second picture is of the same chambers completely unmodified



Finally the last picture shows the important areas again, but on an actual cutaway cylinderhead, positioned at 18 degrees incline (like a 128) so the valve is vertical.





Do these modifications, get a good three angle valve seat cut, back cut the inlet valves, and this is getting up around 105cfm of flow at 28" depression with a 36mm valve / 32mm seat throat. Approx 25% improvement over standard.

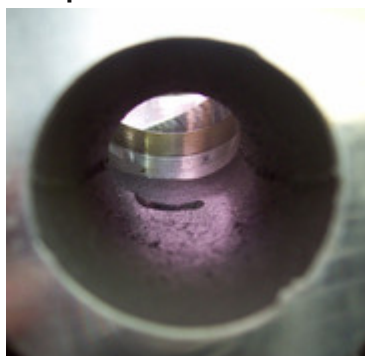
#### 5f) Porting: A step by step guide.

A bit of a step by step walk thru porting a SOHC (Tipo head)

Most first time porters make the mistake of beginning the task at the manifold face of the head, in my opinion this is the wrong place to start. I begin the job around the valve guide area, as the depth of material removed here affects the overall port height and also the bowl depth. I also like to divide the port into several sections, and work my way back and forth to keep the port round and roughly blended. The port has two definite sides, the 'chamber wall side' and the 'exhaust port side'. The port also has a 'roof' and a 'floor'. Lengthwise the port is also divided into sections. The port mouth at the manifold face, the port bowl which is the area below the valve seat, and the valve guide area.

Here a a few pictures and a brief description on each. For now we are focusing on the inlet port.

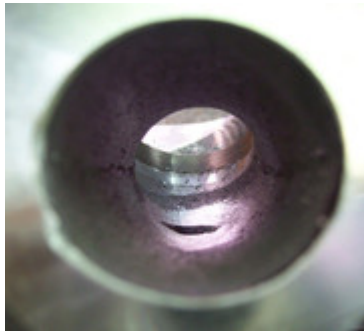
Standard port, note the big lump around and leading up to the guide area. When the INLET guides are reinstalled they will be trimmed back flush with the port roof.



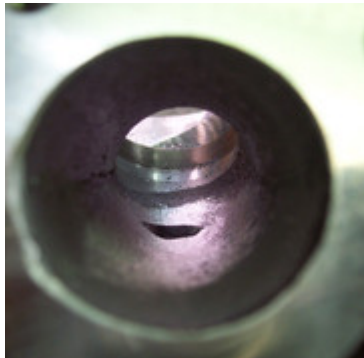
Beginning to remove material from around the valve guide area



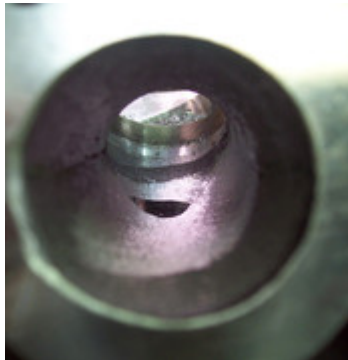
**More removal and blending back and around the guide area to maintain even material removal.**



**More blending back.**



**Working around the chamber wall side of the valve guide area. In this picture you can just see the machined step that exists around the valve guide. This isn't the valve guide bore proper, it's larger in diameter and you can just make out the step where it drops back to 14mm.**

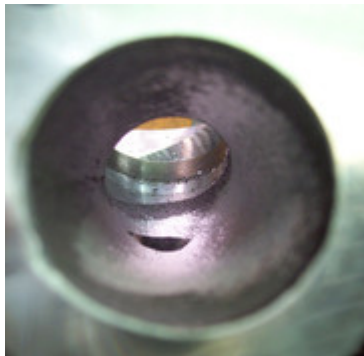




Working back along the port roof, the step in the guide bore is obvious now, I use this as an indicator of bowl depth and port roof height and use a simple depth gauge to measure the valve guide bore depth from the cam side. This sets the port roof height and to some degree the ports diameter.



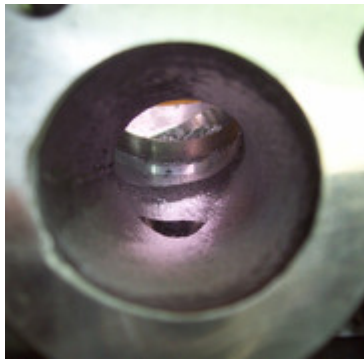
Beginning to take material from the 'chamber wall' side of the port. You can see how I sweep the burr around the port to keep the section round. Don't hold the burr in one place and try to grind away material quickly, all you'll do is end up with lumps and divets all over.



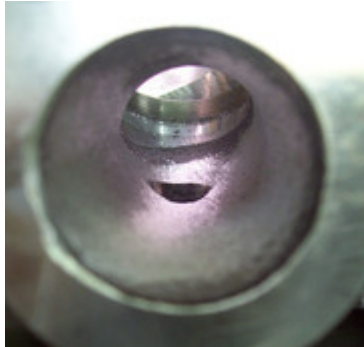
Material removal from several mm in depth around the valve guide, reducing to zero at the other end of the burrs sweep at the port floor.



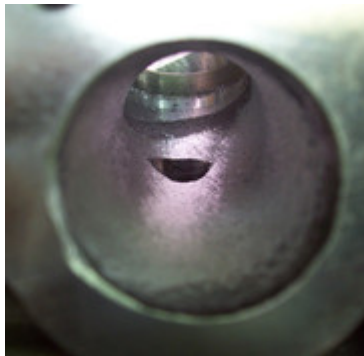
Blending out towards the port mouth.



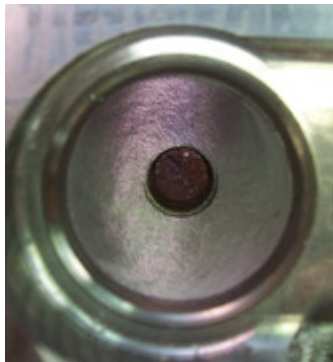
Working the exhaust port side and maintaining a rounded port shape. Most material is removed from the roof and the chamber wall side.



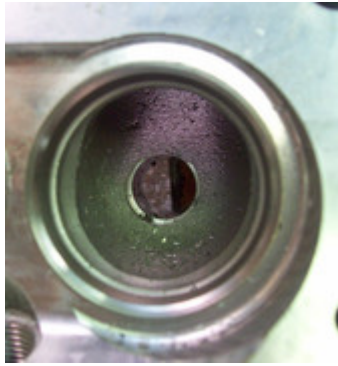
Further blending.



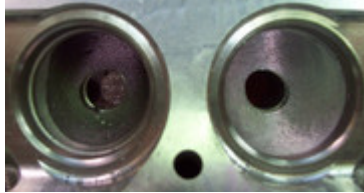
Working the valve bowl area. This port has the seat throat cut at 36.5mm



An untouched bowl for comparison, you can see the milling cut that opened the seat throat out.



Side by side comparison.



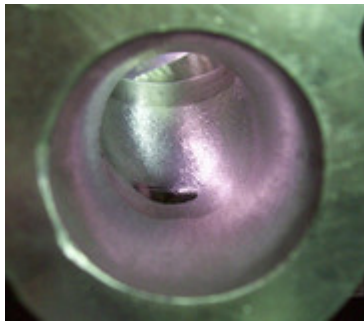
Port view with the bowl partially blended, notice the area on the chamber wall side is the 'wider' side of the valve guide, this is the ports offset bias.



More blending. Notice how the guide bore step is getting much smaller as the bowl gets deeper and the port approaches the shape and size desired.



Basic porting done. The finish is all burr finish, no smoothing or sanding has been done in the bowl yet, the port length has had a round file run over it to blend in and straighten the roof and chamber wall side. This port is still waiting on manifold matching so the port mouth is still not really opened out.



Finished bowl, note the valve guide bore step is just about gone. next step is smoothing everything with 80 grit by hand.



Port moulds of this exact port once it reached this stage. Throughout my flow testing program of the Tipo head, one trend stood out more than any other. The port roof height (and hence the port diameter) and the 'fullness' of the valve bowl have a definite relationship, and valve bowl depth plays a big part in maintaining good flow rates at and above 350 thou of lift, regardless of the valve seat throat or port diameter chosen. The 'fullness' of the bowl refers to the bowl depth (or height when you look at these 3D's) notice how straight the long side edge running into the valve seat area is.

Top view.



'Chamber wall' side view.



'Exhaust side' of port view.



Underside view.



Comparison to an untouched Tipo port.



The next step is port matching to the inlet manifold. To do this well I again make a silicone mould of the entire flow path. This gives a good visual

of the mismatch to work from.



Last edited by a moderator: Today at 3:57 PM

i cavalli mai abbastanza, ed il peso sempre troppo.

Nothing is as simple as it looks. Its always twice as expensive and takes twice as long as you originally thought!

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Location:  
Western Australia

## 6. Induction

Let's start at the basics. The induction system consists of three parts, the air filter, the intake manifold and the carburettor. Flow through the system is not a smooth and even flow, but rather a series of pulses or pressure waves as each inlet valve opens. The manifold can be designed to make use of these pressure waves to enhance cylinder filling, and the theory and some practical applications can be found in the section on inlet manifold design. Most engine tuners will use an off the shelf manifold so this is what we will concentrate on. For maximum efficiency the manifold should provide an equal distribution of fuel/air mixture to all cylinders. It is important to maintain the fuel in small droplets in an homogeneous mixture, and many factors can influence this. The standard manifolding uses a water jacket to heat the manifold and maintain the fuel in a vapourised form. This is at the expense of some outright power, as it also heats the air and makes it entire mixture less dense. However in the majority of cases for the sake of smooth running and rapid warm ups, it still provides a benefit. The fuel / air mix is always going to be exposed to the heat from the cylinder head as it travels through the inlet port, so the power gains from a non heated manifold would be negligible.

## 6a. Carburettors.

The carburettor to use can be broken down into three basic choices, those that fit onto the standard manifold, those that will fit on the standard manifold with minimal modification and those that need aftermarket manifolds.

### 1) Carburettors that fit on the standard manifold.

The standard 32 DMTR / DATR / DATRA carburettor has a base pattern of 85mm x 45mm (approx). These carburettors have a 32mm throttle plate and are progressive carburettors. A primary throat opens initially, then when the primary is approx 2/3 open, a linkage mechanism begins to open the secondary throat progressively until both throats reach full throttle simultaneously. The measurement that interests you is the venturi size. For a standard 1300 engine this is sized at 22mm on both the primary and secondary throats. This size is the limiting factor from a performance perspective, as it meters maximum amount of AIR the carburettor can flow. This is important, as many people think that the carburettors job is to meter the amount of fuel that enters the engine - this is wrong - the carburettor meters the amount of AIR the engine can inhale, and mixes a predetermined amount of fuel with that air (via the main, idle and pump jets) for the engine to burn.

DMTR / DATR/ DATRA carburettors are basically all the same, the main differences being how they actuate the choke mechanism, which is a strangler flap to reduce the amount of air available when the intake is restricted. The carburettor tops from various models are interchangeable (with slight differences) so manual / water operated choke operation is purely personal preference, and what is available. There are also slight differences between models to handle local emissions requirements for the intended market.

DMTR/DATR/DATRA carburettors are available in 32/32, 32/34 and 34/34 butterfly sizes, depending on the engine they were fitted to as standard. The same butterfly size on two different carburettor models can have different VENTURI sizes and this will make more difference than the additional butterfly size. (ie from 32 to 34mm) The 34DMTR/DATRA found on the Euro/UK versions of the 1500 use 23/26 venturi size. Some 34DMTR carbs (as found on 2litre Lancia Beta's) have much larger venturi sizes up to 25/27. This can provide a major improvement in available air flow when compared to the 22/22 venturi size found on the standard carburettor. It may not sound like much, but compare the difference in cross sectional area between two 22mm venturis and the cross section of 25/27 venturis. The venturi sizes in all DMTR/DATR/DATRA carburettors are fixed as they are cast

into the alloy body, and without removing metal can not be changed.

### Sizing the carburettor to your engines requirements.

Even for the stock 1300 venturi sizing of 22/22 is conservative, the engines can handle more carb in euro trim, no problem. But it's easy to put too large a carburettor on a motor and would be the most common mistake made by DIY tuners. Sizing a two barrel progressive carburettor comes down to a cross section sizing that suits your airflow requirements. For example a 22mm venturi has about 380mm square in cross section, and a 27mm venturi is 572mm square. that's a jump of just over 50% increase in cross section of the secondary by going just 5mm larger.

There is a 34DMTR from something like an A112 Abarth is 23/25 from memory, that's on a zippy 1050cc engine that makes 70hp, and suits a lightly warmed over 1300 nicely. It can flow enough for around 85hp max.

34DMTR with 23/26 feeds a euro 1500 x19 at 85hp, and is again a nice step up. This flows enough to make around 90hp max

There are 32/34 variants from Regata / Ritmo, sized to suit engines of around 100Hp, enough flow for about 110Hp max.

And a 34DMTR/21 with 25/27 feeds a 2 litre engine in a Lancia Beta, which again is a conservative carburettor for the engine, but still makes almost 120hp, and flows enough for about 125Hp max.

That's a great selection and one to suit just about every requirement. There is a carburettor from the Fiat parts bin that will mount on the standard manifold to produce max power levels around the numbers stated.

### 34DMTR jetting

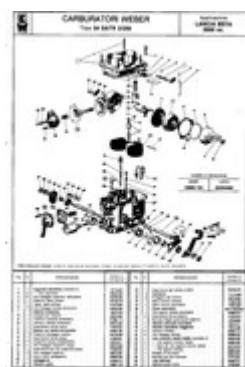
These are the listed standard settings for a 34DATR2/250. According to my Weber bible, the 34DATR 2/250 is standard fitment to a Lancia Beta 2000. (beta 1600 is a 34datr 1/250)

primary venturi 25mm  
secondary venturi 27mm  
diffuser 4.00  
primary main 1.20  
secondary main 1.50  
primary idle 0.50  
secondary idle 0.80



primary air corrector 1.70  
 secondary air corrector 2.40  
 emulsion tube F30  
 pump jet 0.50  
 needle/seat 1.75

Here is a scan the page from my book if you need more info like part numbers, but it's in Italian.



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A couple of scans from 34DMTR21 carburettor specs, another great carburettor to use on a mildly tuned 1500.



Rules of thumb with carb setup....

A larger air corrector weakens the mixture more at higher than lower RPM.

As a rule of thumb, 3 progressions of air corrector (say 1.50 down to 1.35... so 3 x 0.5mm jumps) equals (roughly) one step up in main jet size (say from 1.50 to 1.55)

Increasing the main jet orifice size enriches the mixture uniformly at high and low engine speeds.

Both these metered parts are linear in their numbering... so a bigger suffix = a larger orifice... however when it comes to emulsion tubes, this goes out the window and you need to consult reference tables to decide what is richer/ leaner... as E tubes doesn't follow a numerical progression... just to make life interesting...

if you want a copy of the E tube table, I can scan it and post with cross reference to general applications and changes

Emulsion tubes have more influence at small throttle angles and during accelerations, significant factors that influence it's operation are the outside and inside diameters of the E-tube, which alters the amount of fuel that is displaced in the jet well, generally a thinner tube is richer as it will leave more fuel in the jet well for the engine to draw on.

The location, size and numbers of holes that it has along its length control how the fuel is emulsified as the fuel is drawn from the jet well thru the primary venturi.

idle jet size on the secondary will affect how the carb comes onto the transition phase between the idle circuit and the main....that's when the throttle blade is about 1/4 of the way opened.... and the idle jets also spill fuel at WOT.

Look in your Haynes manual on page 56 and 57, these are pics from the OE specifications manual. The three pics on the top of page 57 show idle on the idle mixture screw, primary transition and secondary transition respectively. The fuel to the secondary transition ports is metered by the secondary idle jet.

#### Idle theory

<So the secondary idle jet only comes into play at secondary transition? If so, it has nothing to do with my long-standing idle issue. Correct?>  
Yes that's correct.

<When idling, fuel is delivered via the idle passage (item 37 on Haynes page 57). Amount is controlled by idle mixture screw.>

Again, spot on correct. Prim idle passage is also notated as 35, before the idle jet where fuel is draw from the main jet well. Not really shown on the

idle mixture screw (39) is an O ring, this is VITAL for correct idle mixture, otherwise air is drawn down the idle mixture screw threads. The idle mixture screw should also have a very fine point, when they are overtightened, the fine tip can bend / be flattened out, which will affect the idle mixture control. Once the throttle blades move past the primary throat progression ports, fuel flow is controlled by the primary idle jet

<The idle speed adjustment opens/closes the primary butterfly, correct? At idle, should the primary butterfly be completely closed? (if so, what's the point of the idle speed adjustment screw?).>

Correct, the idle speed screw is shown on page 58, notated as item 19, it has a spring to hold it in tension so it can't back itself out. At idle the butterfly is almost completely closed, the purpose of the idle speed screw is actually more of a throttle stop, to prevent the butterfly bashing the sides of the carb, instead it comes to rest on this stopper. The idle stop screw should JUST be holding the prim throttle blade off its absolute stop.

<I'm beginning to convince myself that I have a blockage somewhere in the idle passage. I can set the idle to 1000 rpm using the idle speed screw. Go for a drive and it idles at 1800. Return home and I can completely close the idle mixture screw and it still idles at 1800. Reopen mixture screw 1.5 turns, back out speed screw until 1000 rpm, all seems fine, turn your back and she stumbles and slowly dies.>

Classic symptoms of blocked (or partially blocked) idle fuel circuit, or an air leak into the idle circuit (which will not let the fuel be lifted from the main jet well into the idle circuit), or too small an idle jet on the primary (but this would be if you had a long duration cam and low manifold vacuum)

I would be stripping the carb, and really concentrating on passages 35 and 37, there are some excellent spray throttle body cleaners available these days, try some of this and then blow out with compressed air, concentrate on the prim idle circuit.

Other thing to check would be vacuum leaks at the manifold fittings. Our 78 x19's have a takeoff for the fast idle check device, this can leak air and upset the idle metering too. That's the fitting on top of the manifold, on the runner to number 4. The fast idle actuation device (not shown in the haynes manual) attaches to the "rear" of the carb just below the gasket line, and when vacuum is supplied to its diaphragm, actuates a lever to raise the idle up to around 1800 revs ... I prefer to cap these off myself, all this circuit does is provide a fast idle for CO check (and who does those in Australia!) it contributes nothing to the operation of the carb.

### Common problems with DMTR/DATR/DATRA carburettors.

Problems with DMTR/DATR/DATRA carbs can usually be grouped into three categories, vacuum leaks, idle passage issues, heavy float.

**Vacuum leaks.** Most common is a bent base plate, caused by over-tightening the mounting nuts. The only sure fire way to check this is carb removal, and put a straight edge across the base, straight and diagonally. Fix is relatively simple, remove all linkage assemblies and face the base on a sheet of glass with fine sandpaper and plenty of water flowing over it moving the carb in a figure 8 fashion. Main thing to watch for is not to touch the throttle blades on the sandpaper.

The carbs also tend to wear on the primary throttle shaft, repair of this is a little more involved, as it requires removal of the primary shaft, and replacement of the teflon bushes and seals at each end of the shaft. While your at it, usually you do the one bush/seal on the secondary as well. The basic aftermarket kits don't come with these vital parts however, so you need to source a genuine Weber or Fiat/Lancia (extended) kit and these have the bush/seals. The bush is actually a strip with diagonal cut ends. When these are fitted the sometimes need to be reamed in situ. Shaft seals just prise out and push in.

Check for primary shaft wear is grasp the linkage end of the primary, and try to move it. There will always be some movement, but if the idle speed varies when the shaft is being moved (radially) then it's definitely time to strip the carb.

**Idle passage issues** can be either a blockage or an air leak. Blockage is straightforward, remove all the idle parts/jets, clean with solvent and blow thru all passages with compressed air. The idle circuit has the smallest passages in the carb, so any dirt ingress tends to find its way into the idle passages and stay there. If the carb has idle passage issues, usually this can be diagnosed by looking down the primary with a flashlight while the engine is running, if fuel can be seen dripping onto the throttle plate from the primary diffuser (the part the fuel should issue from at revs) then a blockage is almost certain. Most likely places are the idle jet and idle mixture screw passage.

**Idle circuit issues** can also involve air leaks. If there is an ingress of air where there shouldn't be, then vacuum will not be able to draw fuel into the idle circuit from the jet well. Usually this is the O ring on the idle mixture screw. If this is damaged / missing then air is draw down the screw threads

rather than the vacuum being used to pull fuel into the passage. Other points for the ingress of air are several core plugs, fitted at the factory to block drilling holes at manufacture. These can be brass cup type plugs or simple lead shot balls hammered into the end of the passage. Diagnosing these is a little more tricky, but tell-tale fuel stains are the best way. Replugging them or simply using a proprietary mixture like JB weld/ Devcon to cover the offending plug usually works well.

Float issues are also quite common in this series of carburettor. The float is made from a material called "Spansil" and over time this can become porous to the fuel it is immersed in. Check is quite simple, remove it and weigh it, from memory it should be 12.5grams. If the float is fuel soaked then it will weigh a bit more (usually around 14 grams), making it sit too low in the bowl, therefore displacing too much fuel and making the fuel level too high in the well. (same symptoms as too high a float level) Simple check for float soak with no weighing device is try to dig your thumbnail into the float material.... if you can see a damp spot around the mark you thumbnail has made, then the float is most likely fuel impregnated and requires replacement.

#### OE carburettor intakes.

Euro /UK / Australian Specification X19 1500 (1980 casting) 4425193 128BS.2C.0, this manifold has runners that are 28mm at the face and are 28.5mm just inside. This is the manifold number Al Consetino mentions in his book, in a dyno / engine build sheet as being the "preferred" stock manifold.



Australian Specification X19 1300 (1978) manifold 4269347 128ASOC0025, this manifold has runners that are 26mm at the face, but just in they are 27mm



US spec 1300 (1974) manifold is Fiat part number 4320518, which is basically the same dimensions as the Australian spec 1300 manifold, but Australian spec ones have a vacuum takeoff point to power a fast idle device (goes where a brake booster hose would fit on something like a 128)

US spec 1300 (75-78) is part number 4401817

US spec 1500 (79 -80) is part number 4409482 (which looks just like the 1300 Australian spec manifold with the vacuum takeoff fitting but I've never

had one in the flesh to measure or flow test)

### 2) Carburettors that fit onto the std manifold with minimal mods.

This would take in DCNF/DCNVA carburettors (36 or 40mm) whose base pattern is approx 83mm x 51mm. These are twin throat simultaneous carburettors. Both throttle blades are affixed to a common shaft and they open together. The studs from the original DMTR/DATRA footprint need to be removed, the holes welded then redrilled and tapped at the appropriate centres to suit the DCNF/DCNVA. The biggest advantage of using a DCNF style carburettor is the removeable venturis so the size can be easily altered to suit the application. Downside of this particular setup is the orientation of the fuel bowl and the butterflys themselves. The fuel bowl axis will sit along the car centreline when fitted to the original manifold, technically not correct, but I can tell you from experience that it works. Butterfly position in this orientation is also less than ideal, the butterflys affecting fuel distribution to the cylinders at part throttle. Throttle hook up is less than ideal as well. For some classes of racing in the US, this is a legal carburettor upgrade when used with a spacer adaptor.



A second option exists for a single DCNF/DCNVA type carburettor on a modified factory manifold. With a bit of mill machine time and some talent with a TIG welder, a manifold can be made to mount the carburettor with the fuel bowl facing forwards. This places the butterfly axis more favorably for air flow and fuel distribution. This orientation also allows for a far easier throttle connection to the OE linkage.



### 3) Carburettors that mount on different manifolds.

This would take in single DCNF, IDF, DCOE and DCD applications, twin DCNF, twin IDF and twin DCOE applications. These are all twin throat simultaneous carburettors. With the exception of the DCD, all these carburettors have both throttle blades are affixed to a common shaft and they open together. The DCD carburettor uses two shafts with the throttles geared together to open simultaneously.

Aftermarket manifolds for DCNF (as both single and dual) IDF and DCOE type carburettors are quite commonly available. Single DCNF manifolds are probably the least common (which is why I've gone to the effort to modify standard manifolds) but can offer a good compromise of performance and economy with less outlay and lower tuning costs (only need two jets instead of four as with duals for example) Sprint made a good example that is X1/9 specific. Alquati made similar manifolds but only to suit the 128 engine tilt in both DCNF and DCD stud configurations, these can be modified for use on

the X1/9.

To fully develop its potential in horsepower and torque the SOHC engine needs the benefit of separated inlet runners. There is a significant amount of cylinder filling late in the inlet cycle (when the piston has already gone past BDC) due to the "ramming effect" which is afforded by the inertia contained in the rapidly moving air contained in the port. A waste of time unless you have cam and compression to justify the carbs though, as the returns from fitting just twin carbs to an otherwise standard motor will be minimal versus the costs involved.

One thing to note is that while manifolds for a 128 and x19 may look similar, they are different. The engines incline at different angles (11 for the X19 and 18 degrees for the 128) so the intake manifold is specific for each application. DCNF's (all downdrafts in fact) should be run perfectly vertical and that is straight from Mr Eduardo Weber himself , not me. I think the guy who designed the carbs should know and in Webers own published 'Tuning manual' it states "Make sure that when fitted on inclined engines the down draft carburettors keep their barrels vertical"

Braden's book on Weber's doesn't mention it at all...in text. But there is one illustration and the caption says "this is how Weber recommends mounting downdrafts"...and it shows the carbs vertical in all directions.

Tomilson's book on Weber carburettors (which is far more detailed) says this..."Weber also advises that the installation of down draft carburettors on inclined engines, requires that the barrels be kept vertical...Other Weber installation tips are listed as "preferred" and suggested as methods to extract the best possible performance from a carburettor. The carburettor should be installed in such a manner that the float chamber faces the front of the vehicle. This is to help prevent the float bowl from emptying during heavy acceleration and while climbing steep hills. A forward facing bowl will also prevent flooding when the brakes are applied. The orientation of the float fulcrum axis should be towards the front end of the vehicle and parallel to the wheels rolling axis. Again this is preferred and not always possible. On engines where one carburettor feeds two or more cylinders, the main throttle spindles should normally be parallel to the crankshaft axis to avoid uneven distribution of the mixture to the cylinders. Engine inclination can result in uneven distribution of fuel to the cylinders. Every attempt must be made to install down draft carburettors in a vertical position"

Now PBS made an inlet manifold to suit the SOHC, but instead of making two distinctly different manifolds (like Alquati, Sprint and many others) PBS cut another corner when they made one manifold to suit both inclinations...

Quite simply it was an economic (for them) decision, not one based on sound engineering and they chose to 'split the difference' and have the carburettors inclined for both applications.

That said manifolds can be altered you can weld the carb side stud holes, remachine the carb mount face to the correct included angle, then redrill and retap the holes. Easily done on a mill, and I've done this many times as 128 setups are far easier (and usually cheaper) to source than X19 ones.

#### Single carburettor upgrades.

DCNF single. One of my personal favorites, giving good tuneability from the everything metered adjustability of Weber carburettors, and not having the cost or tuning issues related to twin carb setups. Alquati, Sprint made manifolds like this, and these still come to market from time to time. Be aware of the 128 manifold for this upgrade that looks similar and is also available in a DCD carb base stud pattern. The one problem with the single DCNF manifold is that originally the setup was designed to use a 36DCD. With the DCD carb the throttle blades are not on a single shaft like the DCNF. The DCD has two shafts and the butterflies tip towards each other, whereas the DCNF having a single shaft the throttle butterflies tip forwards. With the DCNF this creates a mixture distribution problem at partial throttle, the centre two cylinders being richer than the outside two. Not a big problem at WOT as the individual mixtures tend to sort themselves out. Running a carburettor spacer works well on these manifolds, and can be helpful in evening up part throttle mixture distribution.

Sprint manifold suit a single 40DCNF for X1/9



Single DCD for 128/Ritmo/Uno



IDF single. I've never seen one of these that is X19 specific, but one to suit 128/Ritmo/Uno is available ex South America.



DCOE single. I've never seen one in the flesh, and this could be a standard manifold that was modified. LYNX makes an adaptor to fit DCOE to various stud patterns, so perhaps this is one of those adaptors welded to a stock manifold. Flow path is less than ideal.



#### Twin carburettor upgrades.



DCNF duals, IMO the best twin setup giving fitment without cutting sheetmetal and great throttle response. Nice straight and equal length inlet manifold runners.



Alquati manifold to suit 2 x DCNF to 128/Ritmo/Uno.



Abarth manifold to suit 128/Ritmo/Uno



Hormann tuning manifold and airbox to suit 128/Ritmo/Uno.



IDF duals. Have issues with float bowl orientation but they can work, although at extreme grip levels fuel starvation in turns will result due to this. Most people would never get their X to show it up. IDF manifolds tend to twist the ports too as the throttle bore centres are quite wide, much wider than the port spacings on the SOHC engine, and this affects available manifold flow. As the carburettors are wider they also need to be offset away from the top engine stay bar. This is a Fiatorque (Australia) manifold to suit 2 x IDF for X1/9.



DCOE duals, will need sheetmetal removal to allow fitment, they won't fit without cutting the bodywork.



## 6b. Carburettor spacers

Another method to tune the carburettor to the engine is with a spacer to provide an increased plenum volume. In a single carburettor application there is a basic relationship between the volume of the manifold plenum (including the volume in the spacer) and the size of the carburetor that can be applied with confidence: the smaller the carburettor, the larger the plenum.

The reason for this is that, when the engine is under carbed for capacity or revs, the pressure differential (vacuum) between the inlet manifold plenum and atmospheric is very high. Air rushes thru the venturis with great velocity and then has difficulty turning the corner into the manifold runner. Fuel droplets, which have their own inertia, sometimes don't make the turn at all, but instead hit the floor of the manifold. Raising the carburetor with a

spacer provides more time for the fast-moving mixture of fuel and air (which has been sped up by the action of the venturis) to lose some of its velocity and lets it make the turn into the manifold and runners.

By increasing the volume of the original plenum (I have used up to 2 inch spacers), the engine is 'tricked' into performing as though the carburetor were larger than it actually is. There is a larger reservoir of fuel/air mixture for the cylinders to draw from, and the pulses which occur as the intake valves open in succession are dampened. It's common to increase the jet sizes slightly when a spacer is first installed, since the vacuum signal to the primary diffuser is diminished as the carburettor throats are moved further away from the manifold runner entrances. Also the increased size of the plenum often requires a larger shot of fuel from the accelerator pump to keep the throttle crisp.

I've also used spacers in twin carburettor setups and seen improvements on the dyno. I think the benefits have something to do with the "cone" formation of the airflow around any restrictions, like the diffuser and the throttle blades. Raising the carburettor allows more complete formation and less restriction (shrouding) from the curve in the manifold that is IMMEDIATELY below the butterflies. If the carburettor is raised with a spacer the manifold is straighter after the exit of the carburettor and the formation of the flow cone is not disturbed, and net flow is increased.

Remember its not just the QUANTITY of fuel that's delivered, its also the QUALITY, and by this I mean well atomised. Use of a spacer will help maintain the fuel particle in suspension, if the fuel/air mix makes it into the cylinder well atomised, much more power will be available than if the same quantity of raw fuel found its way in there.

#### 6c. Inlet manifold design.

Both side-draft and down-draft carbs (dcnf vs dcoe) operate the same way, and neither type is capable of making more horsepower than the other. Both dcnf and dcoe simply meter the amount of air supplied to the engine through the venturi size we fit and the throttle blade angle, and mix the amount of fuel we decide to give the engine with this air. What makes the difference is the manifolding, this is simple physics.

What can make considerable difference, is the manifolding they are attached to.

Taking the case of a single inlet valve ducted to one carburettor venturi the system can be considered using the stopped ccan pipe principle, because it

relies on the movement of sound waves. In this case the wave is started at the opening of the inlet valve by a reduction in pressure, as the pressure in the cylinder at this moment is below atmospheric. The pulse then travels to the open end of the air intake is thus one of negative pressure, and on reaching the atmosphere and emerging, it is replaced by a reflected positive pulse which travels back to the valve. It is this reflection that is made use of in ramming the charge and its influence depends on the time taken to travel twice the length of the pipe.

So it is this reflected wave of rarefaction (of the opposite sign) that instantaneously enters the open end and travels to the valve that is going to do the additional 'work' for us. Any calculation for length must take into account the speed of the wave in the gas, and the time for that wave to travel to the end of the pipe and back.

So let us take  $V$  as the velocity of sound in the gaseous medium,  $L$  is the length of pipe in inches,  $T$  is the time for the pulse to travel from closed to open end and back in seconds.

$$T = \frac{L}{V}$$

to express  $T$  in terms of crankshaft degrees this becomes,

$$T = \frac{(\text{rpm} \times L)}{V}$$

Now the speed of sound is difficult to measure as this varies with temperature, but for this example a good starting point would be about 1100 feet per second. (at average pressure and temp of the induction system) Obviously with any increase or decrease in engine speed,  $T$  becomes shorter or longer respectively, so a fundamental flaw in this principle is seen by the fact that the rpm could be increased till there was no pipe length left at all. Another discrepancy is added by the fact that when the valve is open the cylinder is in effect included in the pipe length and as the piston is moving, so the resonant length of  $L$  is also varying.

While manifold length can be designed to give maximum ram at peak revolutions this may not always be desirable, best results are obtained if we calculate the length so that the torque is as high as possible over that percentage of the power curve most likely to be used.

So, if we picked some theoretical numbers, and say that max torque (ramming effect) is required at 5000rpm, taking  $V$  as 1100 ft/sec and  $T$  as 90

degrees of crank rotation.

(In the rod ratio discussion we will get into where in the cycle the piston speed is greatest and how this is affected by rod ratio, and how all this affects the ram effect )

we then obtain using the formula for inlet length,

$L = \frac{(\text{degrees crank rotation} \times \text{speed of sound in gaseous medium})}{(\text{revs})}$

$$L = \frac{90 \times 1100}{5000}$$

$$= 19.8 \text{ inches}$$

This considerable length shows the difficulty of accommodating ramming effect into the system, though the carb and the dimensions of the port through the head are included in this length.

Another example of formula to calculate this is found in Chrysler's patent specifications for their cross ram manifolding from back in the 70's.

$$L = \frac{72C}{N} (+ \text{ or } - 3)$$

Where L is duct length in inches to back of intake valve, N is the rpm where max torque is required, C is the velocity of sound (ft/sec) at expected temperature and pressure.

$$L = \frac{72 \times 1100}{5000} (+ \text{ or } - 3)$$

$$L = \text{nearly } 16 \text{ inches } (+ \text{ or } - 3)$$

You can do the math to figure this length out for the engine you want to build. I'm sure that's what SteveH did for his championship winning autocross car. (will find pictures and insert here) He used 1.25ID custom bent alloy tube, nearly 18 inches long to get max benefit of the 'ramming' effect at the SOHC's natural torque peak at around 4 to 5000rpm, this is what is probably the 'ultimate' induction setup for a SOHC with this manifold and his custom slide throttle plate

As the total length of the inlet tract includes the length of any air intakes

fitted to the carburettors, the possibility of fitting extensions of a graded length is often mooted. If this were the whole answer, experimentation would be easy. The carburettors could be placed right up near the head, and plain pipes attached as necessary.

However, as these are sound waves, a free passage is essential for the full effect and this is obstructed by the carburettor throttle blades, chokes and diffusers. A slide throttle setup like SteveH's does away with all obstructions, allowing the sound waves free passage at WOT. Thus the manifold itself has a greater effect on the ramming issue than any "ram" tubes attached to the carbs.

'Ram' tube is actually a bit of a misnomer, the reason they are used is to provide a bell mouth at the entrance to the carb, this allows air into the carb easier with the proper swirling motion needed for maximum flow and is another physics lesson in itself.

#### 6d. Air horns and Air boxes.

Often overlooked in the quest for more power is attention to air entry to the carburettors, and provision of sufficient filtration. We want to do all we can to encourage the formation of a vortex to allow air to enter the air horn mouth as smoothly and effectively as possible, it's not a gimmick or trick, just simple physics. More rollback on the air horn lips makes them work even better, here's a picture of a genuine Weber 40DCNF air horn on the left, and a TWM brand (Now Borla Induction) air horn on the right, the TWM is worth a few % more flow. The engine will "see" extra length either above or below the carburettor slightly differently as a spacer affects port volume and length whereas a bellmouth affects only overall inlet tract length.



Here's a good example of a airbox designed and built by Brad Garska and his comments.

"I started out with the standard single filter elements and found that the car just ran out of breath on the top end. Played with it for awhile and suspected that it did not get enough air. So I built an air box. The one shown is the second of 2 I built. It made a world of difference no more problems at all it will now keep pulling well beyond the tach's limit. A nice side effect is the sound is still there but not as loud. Sounds real nice without being annoying after awhile."



## Downdrafts Vs Sidedrafts

An argument that has been around for as long as the sohc, which "works" best on this engine, downdrafts or sidedrafts. Lets first up make the assumption we are talking Weber carburettors (or essentially copies like a Dellorto) and further in the discussion we will touch on "bike" carb conversions... but for now twin carbs that allow for an individual runner setup on "production" aftermarket manifolds not something that is custom made or "bespoke" and a one off. Downdrafts would then fall into two types, DCNF carb based and IDF carb based. Sidedrafts would be a Weber DCOE.

To keep this simple we will assume that by downdraft we are only talking DCNF style carbs. As alluded to in the previous section the IDF manifolding requires the offsetting of the carbs to clear the top engine stay bar, and this puts a considerable (and uneven across cylinders) twist to the ports. Quite simply this induces far too many compromises for outright performance and for that reason we will exclude this setup from this discussion.

First thing that must be noted is that DCNF's and manifolding will fit the sohc in both an x1/9 and 128 bodies with no modifications to the bodywork (X1/9) or heater box (128). DCOE's however, will definitely need bodywork / sheetmetal alterations to fit an X1/9, and will require the removal/modification of the heater box in a 128. Unless considerable bodywork is removed from an X19, removing the top cover to adjust the floats or replace the needle and seat on DCOE's will require removal of the carbs from the manifold to perform this routine adjustment/replacement. If the requirement of chopping into the bodywork of your X1/9 isn't enough to dissuade you from going the DCOE route, perhaps you should read on.

Most people when arguing for one style or the other rely on mythical and anecdotal evidence to justify their arguments, that's not what I'm about. If it doesn't have basis in FACT and can be proven, repeatably, by the scientific method I'm just not interested in listening.

*I wondered if the DCNFs suffer because the air/fuel has to change direction compared with a DCOE?*

*A straight shot using DCOE's will certainly have a somewhat better hp gain if all else is the same.*

*I would have thought that the DCOE was the carby of choice for most professional race teams on straight 4 & 6 engines for several decades would be pretty good evidence*

And these are precisely the myths I'm talking about.

A big part of the myth seems to stem from PBS literature from the 1970's that states something like " for maximum HP from a sohc use DCOE's" with simply no evidence to back this statement up. DCOE's may be the carb of choice in the case of some other engines, but right now we are specifically talking Fiat sohc.

DCOE throttle bore spacing is considerably wider than the SOHC's port pattern and this fact will require the manifolding to turn left / right to compensate for this width difference. It just so happens to be that DCNF's throttle bore spacing is almost exactly correct to suit the SOHC's port spacing, so due to this fact the DCNF manifolding actually offers a straighter shot into the engine.

With DCOE manifolding the air is forced left/right and then down into the cylinder, there are at **least** three changes of direction. The manifolding also needs to flatten off so the carburetors can be mounted at near horizontal, with most DCOE manifolds this happens quite abruptly at the manifold to head interface. If you study the cross sections of the sohc head layout you can clearly see that the sohc port is very updraft inclined, it certainly doesn't travel in a horizontal fashion at all.

Air as it enters the carb mouth isn't moving in a linear fashion, if flow is best, the air actually spirals in a vortex into the carb mouth. That's why we have full rollbacks on our bellmouths etc, to assist the air in spiralling inwards thru the bellmouths as this increases the flow rate. Because of this spiralling motion, I like to think of the air column in a way replicating the movements of a spinning tailshaft. The smoothest running tailshafts (that lose the least energy while running) have precisely the same angles imposed at both universal joints, and I can assure you that three universal joints just does not work. I believe this is a direct analogy for what is happening in the inlet tract of an individual runner system in the real world.

So what does the dcoe "tailshaft" look like... it's absolutely wrong with multiple changes of direction and uneven angles, which draws energy from the spiralling air column.

Now consider the dcnf setup. Air enters the carb, past the throttle blades and bends forward, along the port and then bends pretty much precisely the same angle downwards into the cylinder... just like a tailshaft with two universals that have the same running angle.





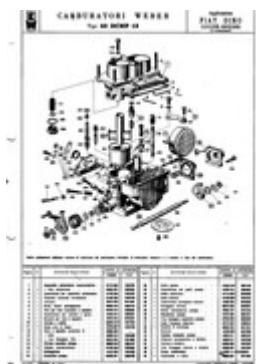
Above are port moulds of a well developed sohc port with DCNF manifolding. I cast these up in silicone so I can get exact port to manifold matching when porting these heads, this one is prior to any port matching and the clear step at the manifold / head interface is still there. It clearly shows the even bends that the air column has to negotiate. After looking at these, could someone please enlighten me to where this "poor change of direction" that you get with DCNF's is?

*DCOE's flow more than a DCNF..*

This is another of the commonly accepted 'myths' about these two types of carburettors. If you actually compare the insides of a 40 DCOE and a 40 DCNF and you will be surprised at how restrictive the DCOE is, especially in the area of the primary diffuser. The 40 DCOE has a full circular ring that contains the primary diffuser that reduces the cross section considerably, which DCNF's don't. 45's DCOE's are made differently in the primary diffuser area. This is one BIG fact that everyone just seems to forget about when the dcnf / dcoe argument comes up... the 40dcoe's restrictive primary diffuser.(also known as an 'auxiliary venturi')

Here are some pictures that show what I'm talking about. The dcoe is definitely more restrictive in its internal design, there are just no if's or but's on this one.





Now in theory the 40 DCOE's will accept a 36mm choke, but **the 40 DCOE's primary diffuser is just 37mm ID.** With a 36mm choke there's not going to be a lot of venturi action happening with just 1mm difference between them, so more likely is maybe a 34mm venturi maximum (IMO even that would be tenuous) so a maximum choke size of just 32mm would be more effective.

A 40DCNF will definitely accept a venturi with 36mm dimensions and work, as it does not have the same restrictive style of primary diffuser.

Now we all know that only back to back flow test of a dcoe and a dcnf (lets talk 40's) bare mounted to a flow bench will give a definitive answer with a number to compare, but don't wait for me to do it as I already know the answer. It's plainly obvious when one compares the two styles of carburettor side by side, so the anecdotal "evidence" that DCOE's will flow more is a myth.

SteveC

Last edited by a moderator: Today at 4:32 PM

i cavalli mai abbastanza, ed il peso sempre troppo.

Nothing is as simple as it looks. Its always twice as expensive and takes twice as long as you originally thought!

Ultimate SOHC thread [here](#)

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**fiatfactory**  
Steve Cecchele

## 7. Camshafts 101.

More than any other single factor, overall engine performance is determined by the timing of the valve events. This is usually described by measuring the points during the engines rotation where the intake and exhaust valves are opened and closed. The location of these events and the amount of lift achieved is a convenient way to compare one camshaft to another, but simply knowing (and comparing) the start / finish and the total lift of two cams is not a scientific (or

Location:  
Western Australia

good engineering) method. Many other factors contribute to how well a cam works in an engine. The total duration and lift are valuable guides, but really, the rate of lift and the lobe separation angle are just as vital.

Only considering the angular positioning where the valve is stated to open or shut is largely meaningless in practical terms. Literally, it means that the valve is raised or lowered in no time at all. Conversely, the view that the first or last few degrees have little or no effect because the lift may be quite minute won't stand up to close investigation either. Optimum valve timing is dependent on the pressure conditions in the inlet tract, exhaust tract, and the combustion chamber at the precise moment each valve is opened or closed, and many factors can influence this.

In a general sense, anything that affects the efficiency of the induction system (carburettor, manifold, ports, valves/seats) or the exhaust system (valves/seats, ports, headers, pipes) will have some influence on these conditions. In addition, the length of stroke and the length of the connecting rod will determine the acceleration rates and instantaneous speed of the moving piston, which will also affect these pressure conditions and the efficiency of the intake / exhaust strokes as volumetric efficiency is directly related to piston velocity. Any significant change that increases the efficiency of an engine will require different optimum valve timing requirements, but more than anything else, valve timing is affected by engine speed. Unfortunately due to mechanical limitations, the conventional valve train does not allow the valve timing to be altered as engine speed increases, so the engine output can only be optimised within a relatively narrow engine speed range.

At low rpm, the elapsed time between valve events is relatively long. As the cycling rate increases, the available time for each cycle becomes smaller and the relative time between events becomes less. If the cycling rate continued to increase, the period between the events will become so brief that the engine's efficiency is seriously impaired. The only way to counteract this is to increase the duration between valve events, therefore, in a high rpm engine, it is common to extend the valve open duration and decrease the lobe separation angle. Lengthening the valve-open timing does several things to overall engine operation. Firstly increasing duration raises the effective engine speed range. If there is greater mechanical duration between the valve events, there is more relative timing between these events at higher cycling speeds, and the total rate can go higher before the available timing between events becomes too restrictive.

This is not helpful by itself, but because of the increased cycling speed, there may be more HP available, as it is a fact of physics that in a four-stroke engine, if the cycling rate is increased, provided the efficiency (VE) of the

intake/exhaust can be maintained.... IT WILL PRODUCE MORE POWER.

When you consider the differences that occur when a change in cam/crank timing is made using the same cam, the changes are relatively small, the total lift isn't changing, the area "under the line" in the graph of lift versus crank degrees is still the same, so what happens?

Most differences between different timings of the same cam happen in the time around TDC ...at overlap... when the gaps between the valves and the seats are pretty small. Thus any statement that these initial movements have negligible effect must be taken with great reserve, particularly since practical experience tends to prove the reverse. I came to the realisation that improvements in flow (intake and exhaust) must be most effective at overlap tdc, that is, and in that case these flow improvements must also be taking place thru these minute gaps.

Lets consider typical emission Fiat timing of 15/55 (for simplicity)...

We are in the overlap period and the piston is rising as the inlet valve opens. With the 15/55 timing, the inlet valve is hardly open at tdc, so low speed running will be good, but high speed filling will be ordinary to say the least. If the inlet valve is opened too early it could well send a positive pressure wave in the opposite direction, i.e. out to atmosphere and the air intake (reversion), once again manifold design will have a great influence here, as does the efficiency of the exhaust system. If the pressure in the cylinder at this point is above atmospheric, a reverse wave will start, if the pressure is below atmospheric and negative wave will travel out to atmosphere, and be replaced with a reflected wave of the opposite sign (positive), which can be shown to contribute to ramming the charge

If the exhaust valve closing is delayed too long, (on the other side of tdc) fresh intake charge can be drawn straight out the exhaust valve (BSFC\* brake specific fuel consumption..goes up... hp goes down) This is often known as intake draw through, this can also happen when the overlap is very long. It happens towards the end of the overlap period, when the pressure in the inlet exceeds the pressure in the exhaust. At this point intake mixture flowing into the cylinder will be drawn into the exhaust tract with the remnants of the spent gasses, when the intake valve is opened very early, the effect of draw through increases

Consider next what happens at (and around) bdc, which is two phases... bdc inlet and bdc exhaust

The exhaust kicks off its seat at 55 bbdc so at bdc the valve is about half open.

With the high cylinder pressure when the valve opens, such an opening would mean that plenty of spent gas would be cleared at the bdc point. If the valve opens earlier it means the power stroke finished earlier, this implies a reduction in the mean working pressure and the power produced. What actually happens is that the earlier opening exhaust valve will tend to do the opposite, i.e. increase power. The earlier the valve is opened the greater the pressure and thus the bigger "kick" given to the initial discharge of gas. (This is sometimes referred to as the exhaust "blowdown" effect) In addition the valve is more fully open at bdc and reaches full lift early on the following upstroke, when the angularity of the crank and connecting rod is such that the piston is travelling at high speed. A wide-open valve at this point will ensure less restriction to pumping out the spent gas that remains.

The advantages accruing from an earlier opening exhaust valve... early gas release, valve well open at bdc and the valve fully open when the piston is accelerating on the exhaust up stroke - may more than compensate for the mild shortening of the power stroke. After the first 100 to 120 degrees of crank movement the working pressure falls very rapidly anyway, the piston is also slowing down and the crank angle is becoming progressively less effective in terms of favourable mechanical advantage to apply shaft rotation. Therefore, although at first the idea of shortening the working stroke might be a strange way to obtain more engine power, there is, as always, an explanation supplied by physics. It is simply that more is gained from the reduction in exhaust pumping work than is lost by allowing a little of the power impulse to escape. Optimum placement of exhaust opening is determined primarily by the mechanical efficiency of the engine and the required operating speed. Generally, if the engine has a relatively long stroke and the primary speed range is relatively low, the exhaust opening should be delayed to extend the power stroke and gain maximum low speed torque. If the engine has a relatively short stroke and the primary operating speed is in the upper range, the exhaust may be opened earlier to extend the length of the exhaust phase at high revs. It turns out that as the speed increases, an engine generally will become less sensitive to the placement of the exhaust opening event, however if the engine concerned has inefficient exhaust characteristics, it's sometimes helpful to open the exhaust early and lessen the exhaust pumping losses.

The next phase is the most important, as placement of the intake valve closing is critical in high-speed engine operation. Remember it is important to extend intake timing so the engine has more time to breathe at high cycling rates

In our standard timing example, at bdc the inlet valve is also about 50% open, and does not close for another 55 degrees, into the upwards compression stroke. This is made possible by the general refusal of the gas to reverse its direction simultaneously with the pistons reversal at bdc. It continues its

direction of flow in opposition to the rising piston, but if the valve closure is delayed too long, the flow will be reversed and the gas pushed back into the inlet manifold. The point at which this can be expected to occur depends a great extent on induction system design, of course the longer the valve can be kept open AND the flow continued in the right direction, the greater the cylinder fill, and hence more torque and (probably) hp.

The drawback is that with continually varying throttle openings, the inertia of the gas cannot remain constant and thus the tendency or otherwise for reverse flow to occur is dependent on gas flow speed, which again depends on throttle opening and engine speed....

Therefore, if inlet valve closing is delayed for the sake of good power at high rpm, slow running may be poor due to pressure waves in the inlet manifold causing uneven mixture distribution. On single carburettor applications with a small plenum, this reverse pulsing can reach the carburettor venturis and upset fuel metering. Here again manifold design dictates the point where too much is no good, individual runners almost invariably allows the use of a longer delay in inlet valve closure.

Now it has often been found that valve timings aimed at max power at peak rpm undesirably reduce the lower speed torque. This is not strictly a result of lobe duration. It is a product of lobe duration and lobe phasing. I have found if emphasis is concentrated on really good medium speed performance, that same configuration will make good gains at the upper end too, so I think the two ideals (power vs. torque) are by no means irreconcilable, but the components all need to be matched to the individual requirements. Generally poor low speed torque and indifferent idling are mainly caused by some defect in the charge being exploded, quite often due to residual contamination of the charge, this is often called intake dilution. (Sohc are bad for this) This generally occurs during the early portion of the overlap period.

When the overlap is relatively long, the intake valve is opened quite some time before the exhaust phase has finished. If during this period the pressure in the inlet tract is lower than the pressure in the exhaust, a portion of the spent gasses may change direction and be drawn into the intake. This lowers intake efficiency in extreme cases and in long duration camshafts is often the cause of poor low speed running and response. Once again, this is speed related. I.e. Pressure decreases as speed increases, hence the manifold vacuum drops when revs rise and this is less likely to happen at high rpm.

**Lobe centreline angles** in essence the definition of lobe centreline is quite self explanatory, it is the midpoint between the valves opening and closing events. If we use an example of a 30/70 camshafts intake lobe, then we can calculate

the total duration in crankshaft degrees ( $30 + 180 + 70 = 280$ ) and halve it (140)... the lobe centreline angle is 140 crankshaft degrees after the camshafts opening point ( $140 - 30 = 110$  after top dead centre or 110 ATDC) ...pretty straight forward.

The exhaust lobes total duration in this example ( $70 + 180 + 30 = 280$ ) and halve it (140) then the exhaust lobes centreline is 140 degrees after the exhaust valve begins to open, so 70 degrees after BDC. As we reference the engines timing relative to TDC, we refer to this as 110 degrees BTDC, again pretty straight forward.

**Lobe separation angle** is the term used to define the angle in CAM DEGREES (as opposed to crank degrees) between the centreline of the intake lobe and the centreline of the exhaust lobe.

Once again if we use a 30/70 70/30 cam as an example (which has been ground at split overlap) then the exhaust lobes centreline is 110 crank degrees BTDC, the intakes lobes centreline is 110 crank degrees ATDC.

As we want to reference LSA in CAM DEGREES, we halve these values (cam rotates at half crank speed) so 55BTDC and 55ATDC, and the LSA has an included angle of 110 CAMSHAFT degrees.

With what has been covered so far, we can use these two figures to determine the camshafts advance, as by subtracting the angle to full lift (Lobe centreline) from the LSA ( $110 - 110 = 0$ ) we can determine the cam is timed at 0 degrees.

In a twin cam engine the LSA can be altered by advancing one cam in relation to the other, unfortunately with our sohc engine, this angle can only be altered by grinding another camshaft, with one set of lobes advanced or retarded in relation to the other.

Now it may sound like semantics, but this can be used to alter the overlap period, which even though the amount the valves are open during this period are usually quite small, has a significant effect on HOW the engine responds...

**Valve overlap** is a valve event that combines intake and exhaust openings, it is the period where both valves are open together, the exhaust valve is closing at the end of the exhaust stroke, and the intake valve is beginning to open prior to the intake stroke occurring. It carries with it a bunch of compromises, get it right and the payoff is BIG, get it wrong and the engine just does not perform adequately.

Commencing the intake valve opening prior to commencing the intake stroke



gives the valve a head start on the flow the engine needs, bearing in mind that even with a 40mm intake valve and 160cfm of flow it appears the head is incapable of satisfying the flow requirements of higher output engines (like a really hot 1600 or a milder 1900 stroker for example) so the higher the valve is lifted at any point of the induction stroke the better.

So for an induction limited engine like our SOHC's, the most important part of the induction stroke is the first 90 degrees after TDC. If we manage to achieve a high density /high speed air column flowing into the cylinder at this point, we know this is going to pay dividends in the later part of the intake stroke, by introducing an inertial ramming effect, where VE's of above 100% can be achieved... and this is the crux of getting these engines to perform, and why they CAN get figures of 100hp/l and more with no fancy variable valve timing and electronics, this is the positive side of early intake opening, but there can be negatives as well.

To close the exhaust valve at TDC is impractical as the tail end of the exhaust stroke won't have sufficient valve curtain area to freely pass the spent gasses out. The answer is a delayed closing of the exhaust valve, and as a consequence the exhaust valve is still open during the intake stroke cycle. Using our 30/70 example, typically (with a billet cam) the exhaust valve would be maybe 2mm off it's seat and the intake valve maybe 5mm off it's seat at TDC, and this poses the question "what's stopping the exhaust flowing out the intake valve..." the answer is that at low engine cycling speeds is absolutely nothing.... therein lies the penalty of large overlap values.

### **7a. Standard Production Camshafts**

Fiat 128 1116cc Type 128A.000

12/52 52/12 (checked at 0.50mm)

9.1mm gross lift

Running clearance 0.30 inlet 0.40mm exhaust

Nett lift 8.8mm inlet 8.7mm exhaust

"Specifications and Features" July 1969

128 Coupe 1116cc Type 128AC5.000

12/52 52/12 (checked at 0.50mm)

9.75mm gross lift

Running clearance 0.30mm inlet 0.40mm exhaust

Nett lift 9.45mm inlet 9.35mm exhaust

"Specifications and Features" Nov 1971

128 Coupe 1290cc Type 128AC.000  
24/68 64/28 (checked at 0.50mm)  
9.75mm gross lift  
Running clearance 0.40mm inlet 0.45mm exhaust  
Nett Lift 9.35mm inlet 9.30mm exhaust  
"Specifications and Features" Nov 1971

128 Rally 1290cc Type 128AR.000  
24/68 64/28 (checked at 0.50mm)  
9.75mm gross lift  
Running clearance 0.40mm inlet 0.45mm exhaust  
Nett Lift 9.35mm inlet 9.30mm exhaust  
"Specifications and Features" Jan 1972

X19 1300 Type 128AS.000 (Euro spec)  
12/52 52/12 (checked at 0.60mm inlet / 0.65mm exhaust)  
9.75mm gross lift  
Running clearance 0.40mm inlet 0.50mm exhaust  
Nett lift 9.35mm inlet 9.20mm exhaust  
"Specifications and Features" June 1973

X19 1290cc USA 1975 spec  
Type 128AS.031.5 (leaded)  
Type 128AS.031.6 (unleaded CC)  
10/54 54/10 (checked at 0.50mm)  
9.1mm gross lift  
Running clearance 0.30mm inlet 0.40mm exhaust  
Nett lift 8.8mm inlet 8.7mm exhaust  
"Specifications and Features" Nov 1975

X19 1500 Australian Spec Type 138AS.023  
10/54 54/10 (checked at 0.50mm)  
9.1mm gross lift  
running clearance 0.30mm inlet 0.40mm exhaust  
Nett lift 8.8mm inlet 8.7mm exhaust  
"Specifications and Features" June 1979

That's all the OE Specs I have to hand....pictures of the cam timing diagrams to follow.\*

Recently added X19 1500 UK "specifications and features" and 1985 Regata "specification and features" to my technical library, so info from them to follow also

These also from the Haynes X19 manual (scattered around the manual, but

Haynes have been known to get it wrong on occasion)

X19 1290cc Type 128AS.040.5

12/52 52/12 (checked at 0.50mm)

9.75mm Gross lift

Running clearance 0.40mm inlet 0.50mm exhaust

Nett lift 9.35mm inlet 9.25mm exhaust

X19 1500 Type 138AS.000

12/52 52/12 (checked at 0.50mm)

Gross lift 9.90mm inlet 9.85mm exhaust

Running clearance 0.45mm inlet 0.60mm exhaust

Nett lift 9.45mm inlet 9.25mm exhaust

X19 1500 Type 138A2.000

12/52 52/12 (checked at 0.50mm)

Cam lift 9.20mm inlet 9.25mm exhaust

X19 1500 USA

Type 138AS.040

Type 138AS.031 (california)

gross lift 9.20mm inlet 9.25mm exhaust

I would guess that the X19 1300 128AS.000 cam would be the same as the 128 coupe / rally (24/68 64/28 9.75mm) but it's duration is listed differently due to the different check clearance specified (0.60/0.65mm compared to 0.50mm)

From the official service manual - from Fiat USA - covering '79-'82 X1/9 models.  
(Courtesy rx1900)

Engine type: with carb with air pump 138AS.031

66 HP SAE net at 5250 rpm

76 ft.lbs. at 2500 rpm

with carb w/out air pump 138AS.040

67 HP SAE net at 5250 rpm

77 ft.lbs. at 2500 rpm

with fuel injection 138BS.040

75 HP SAE net at 5500 rpm

80 ft.lbs. at 3000 rpm

Camshaft for all engines. 12/52/52/12

Lift 9.2 mm inlet

**9.25 mm exhaust**

Valve timing check clearance 0.60mm inlet 0.65mm exhaust.

Valve running clearance 0.28-0.35 mm Inlet, 0.38-0.46 mm exhaust

Camshaft Fiat # 4331831.

In all these engine specifications it's the SUFFIX code which gives you an idea which market or emissions standard the engine was built to.

.000 is euro spec

.023 is Australia and Switzerland

.031 is catalytic (?)

.040 is US spec

**More production camshaft information**

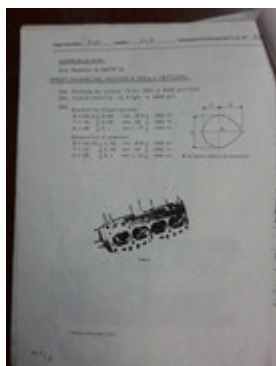
128 coupe / X1/9 1300 (75hp) 24/68 64/28 lift at the valve (no play) 9.75mm for intake / exhaust (Fiat part number 4331512)



X1/9 1500 carburettor (85cv) 24/68 64 28 lift at the valve (no play) 9.85 inlet 9.90 exhaust (Fiat part number 4333059)



and just to be thorough, the specs for the later euro 1300 (73hp) which is a 12/52 9.2 cam (Fiat part number 4358713)



now the two interesting things to note are,

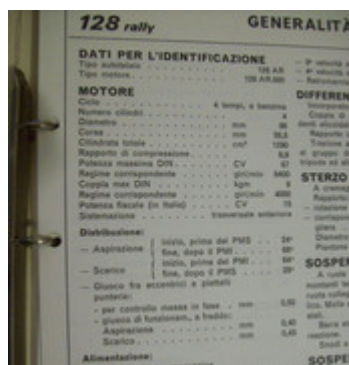
1. all these cams have a 28mm base circle, but the two 24/68 cams total lift can't be measured by putting a caliper across the base and then across the nose... as the cams lift ramp begins before the mid way point (spec U) as this is already 28.35mm ... (so 0.175mm of lift at this point) ... unlike the 12/52 cam where the base circle true value can be measure (U is 28.00mm)

2. the euro 1500 cam is 9.85mm lift on the intake, and 9.90mm lift on the exhaust... recently I acquired a copy of the factory specs and features manual for the 1500 euro carb 5 speed X19 and that concurs with the FIA documents.

1500 euro x19 five speed cam specs page from 'data and characteristics 9/78'

[illegible]

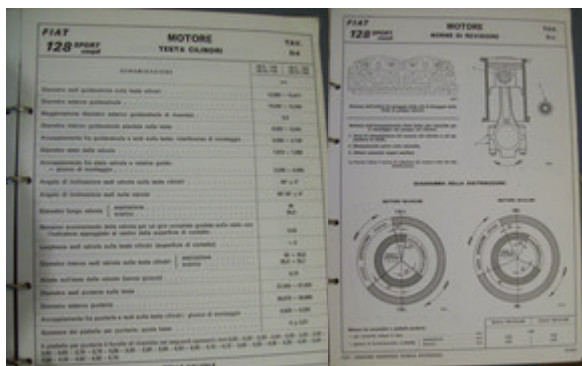
128 rally cam specs 'caratteristiche e dati 1/72'



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128 sport coupe cam specs ' caratteristiche e data 11/71'

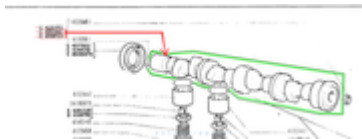


here's a scan of the Fiat part numbers you DONT want...these are the part numbers and supercessions for the basic run of the mill 128 1116cc sedan. (12/52 and 9.1 and later 9.2mm of valve lift)

4221372 is the original part number for a 128 1116cc sedan, 12/52 9.1mm.

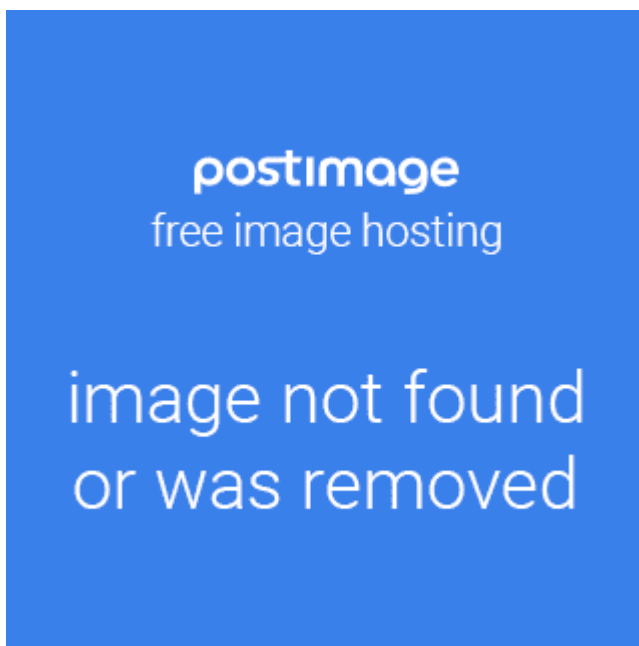
it superceeds to a 4332961, which is 9.2mm lift and the same duration.

this the superceeds to a 4358713 which is the same... there are ebay sellers who are trying to pass off this part number as a 'euro x19 cam' as it was in the 1975/78 euro 1300, but it's a 12/52 9.2mm cam, not a 24/68 64/28 9.75mm intake (1300) or 9.85mm intake (1500) X19 cam, so 'buyer beware'



The 128 Sport coupe 1100 (just to confuse the issue) uses a cam with 9.75 lift, but is 12/52 duration... I don't have that part numbers to hand but basically caveat emptor if you shop for a cam based on lift alone.

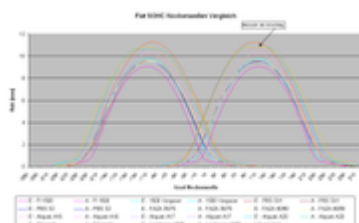
And finally, a quick visual comparison between a standard emissions X19 cam (12/52) and an X19 1500 euro camshaft (24/68) This is not how you should shop for one, but the two compared side by side it's pretty obvious which one is which...



if you can't figure it out the euro cam is on the left.

## 7b. Camshaft Comparison

This detail provided by Ulix, he measured some of the available cams and mapped them for a good visual comparison. (I have a larger and clearer copy from him, just need to load it to imageshack)



I've got a lot more cam details, and plenty of discussion about cams and selection to follow.



### 7c.Camshaft selection.

Performance cam with fuel injection.

The long duration cam on an EFI motor dilemma is common to all engines that use a single air flap and a common plenum. At idle and low throttle openings the relative manifold vacuum is very high and it will always be the case that when one inlet valve begins to open, there will be another that is on it's way to closing. Using a longer than standard duration cam will compound this problem as one valve will open even earlier, and the closing valve will be open for longer as well, as the overlap period is longer. Air will always flow via the easiest path (just like water or electrons) and it is easier for the opening cylinder to draw from the one that is closing, rather than past the partially closed throttle blade and it's this that upsets the metering of the EFI with loss of air flow through the AFM and the confusing pressure waves present...it's as simple as that... an individual runner EFI setup wouldn't have the same problem as the cylinders are not connected on the inlet side and will tolerate a lot more cam duration and overlap.

The Euro 1500 24/68 won't have sufficient overlap to cause huge issues, but the idle speed will need raising to around 950 rpm up from 850 to give acceptable smoothness. An even better solution would be a custom made cam with slightly less or similar overlap, but with a higher gross lift. This would mean faster opening and closing ramps and a more rounded cam "nose" to allow the valve to be held a full lift for a longer period. For the best result we could design a cam profile and have a cam reground to suit the engine specs based on nett port flow, certainly not beyond the capabilities of a talented cam grinder.

#### 7d. Aftermarket camshafts.

[illegible]

Alquati cams were made by Pittatore. Alquati was mostly just a reseller of parts, they manufactured very little. Most times these cams can be identified by the material and a number / letter combination stamped onto the cam's rear, which is Pittatore's grind number. All Pittatore cams are

computer ground,so have incredible accuracy in both lift and phasing between lobes, and are IMO the best cams for a Fiat performance engine because of the materials used and accuracy of the grind.

Pittatore performance cams are nitrided steel and made from billets, so have a standard base circle diameter (in almost all cases) Pittatore also made OE cams for many Italian manufacturers, Fiat included, from cast iron. In the 1990's I imported a bunch of Pittatore cams to Australia and in amongst these I got them to put non standard grinds onto these cast iron blanks. To maintain the stock base circle value the profiles chosen had to have less total lift than the max value found on a production camshaft (9.85mm)... A B22 Pittatore cam is a 24/68 64/28 9.75 lift 128 coupe cam grind. A B22/12B would then be a 12B grind on one of these cast iron cams.

### Regrinds

Here's an interesting example... of how inaccurate the usual hand ground cam is.

Listed on ebay as...

The cams are regrinds from a leading camshaft supplier and have been correctly heat treated after machining.

Because these cams are regrinds, they have a smaller-than-stock base circles so you will need to use larger than stock shims or mill the cam box to take up the difference.

NOTE: all specs shown are at .050 lift; not the often overstated ramp-to-ramp spec.

### Critical Specifications:

Duration: 245 degrees \* .050 lift

Lift: 10.16mm

Lobe centre: 108.2deg

Base circle: 24.55mm (+.775 mm nominal clearance)

Now checkout the cam doctor specs... almost a whole degree difference in the duration in what are supposed to be the same cam (a16 delta) and differences in lift all over the place...and that's between the two lobes that they checked (one on each cam most likely) the scatter is almost certainly typical of the scatter across the four lobes on the same cam.

[illegible]

**It's no wonder people get luck lustre performance from these regrinds...**

## 7e. NITRIDING

**Gas nitriding is a surface heat treatment which leaves a hard case on the surface of the cam. This hard case is typically twice the hardness of the core material up to .25mm deep.**

This process is accomplished by placing the cam into a sealed chamber that is heated to approximately 950 degrees F and filled with ammonia gas. At this temperature a chemical reaction occurs between the ammonia and the cam metal to form ferrous nitride on the surface of the cam.

During this reaction, diffusion of the ferrous-nitride into the cam occurs which leads to the approximate .25mm case depth. The ferrous-nitride is a ceramic compound which accounts for its hardness. It also has some lubricity when sliding against other parts. The nitriding process raises and lowers the chamber temperature slowly so that the cam is not thermally shocked. Because of its low heat treat temperature no loss of core hardness is seen.

Gas nitriding was originally conceived where sliding motion between two parts takes place repeatedly so is therefore directly applicable to solving camshaft wear problems.

**Different materials used for camshafts plus more scans and info to come...**

## SteveC

Last edited by a moderator: Today at 4:03 PM

i cavalli mai abbastanza, ed il peso sempre troppo.

Nothing is as simple as it looks. Its always twice as expensive and takes twice as long as you originally thought!

Ultimate SOHC thread [here](#)

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## 8. Exhaust

### 8a. OE Exhaust manifolds.

"I've heard that a 4 into 2 cast manifold is a lot better than the normal 4 into one manifold, approaching the performance level of a fabricated steel 4-2-1 tuned manifold"

Well the 4/2 manifold is certainly a huge improvement over the 4/1 manifold and to prove it all we need to do is look at a few Fiat published numbers. 128 Rally 1300 (1971 euro) and 128 coupe 1300 (1972 euro) specifications and features list all aspects (cam/carb/comp ratio/port&valve size) of the engines as being identical, except for the power output, 67hp vs 75hp. The only difference in the two engines is the exhaust manifold, the 128 rally uses the single front pipe whereas the coupe uses the twin and has 8hp more.

So a twin outlet front pipe definitely makes a nice improvement in the order of 10% over the single outlet item. Some aftermarket header manufacturers quote figures for %age increase over standard, but that is comparing their product to the 4 into 1 manifold. The figures would be nowhere as impressive if compared to a 4 into 2 manifold, so caveat emptor.

Here in Australia the 128 coupe manifold is a good choice, even better is the 1500 x19 manifold as the ports are a little larger, then there is the regata 1500 85s manifold that can work well but it has a threaded hole to blank off (or use for an O2 or A/F sensor). The Yugo 4 into 2 manifold is similar to this with a threaded fitting cast into it. Similar to these would be the 1974 X19 manifold. The most easily and current twin out manifold suits Fiat Punto , Tipo 1.6 litre variants, this has the largest port size and noticeably larger holes at the manifold outlet. These are all very similar but the offset between the head and the outlet is a little different, though if your fabricating your own front pipe this isn't a big deal.

Definitely poor mans headers, that will last longer and work as well or better than most shop bought headers/extractors.

74 X19 USA exhaust manifold (4310369)



**128 coupe twin out exhaust manifold and front pipe (4252518)**







**Tipo, Punto 1.6 exhaust manifold (7691880)**



Yugo exhaust manifold and front pipe







**Stock X19 1500 /1300 style euro twin pipe exhaust system**



### 8b. Twin out manifold retrofit

sparks said:

#### *1974 Exhaust Manifold System*

*I finally have my new exhaust system done. After installing one of Matt's hi-po heads this summer, I was impressed with the performance increase. However, it soon became obvious that the stock exhaust system was a real performance limiter. A catalytic test pipe helped, but the rest was still a problem. Several members suggested that the 1974 4 into 2 exhaust manifold*

[Click to expand...](#)

### 8c. 2.25" system.

The steel strap extension with two holes bolts directly to the lower engine mount (late type lower mount with the extension arm for muffler mount) and on the side of the muffler you will notice a flat plate welded on, this has two captive nuts welded to it's underside and is used to attach the original gearbox exhaust mount. The entire system is sprung with the engine/trans. The muffler setup shown is for a left side rear outlet X19 (here in Australia we had exits on left or right depending on year model) tailpipe is removed in this picture. Muffler used is also 2.25 internals, quite a few mufflers that are 2.25 inlet/outlet nipple shrink down to 2.0 or 1.75 internal pipes, so be aware of this when choosing a muffler. I like the larger pipe size as I believe the total volume of the collector and pipe before the muffler acts like an expansion box. The 1500's I install this system onto are usually around 10 to

10.5: CR and you can stand several metres back and still feel a very strong tailpipe pulse. Several have dynoed at near 100hp at the rear wheels, so I know this works and works well.



8d. twin front pipe. to stock muffler.

The EFI muffler and the carb muffler (for N.A.with cat convs) are pretty much the same, except the inlet pipe to the muffler of the carb version is quite a lot shorter, and commences much closer to the LHS of the car. if you have the option to use a carb style muffler it will give you more room to get a nice collector and decent length in the secondaries.

I take the ball and socket assembly off the 4-1 manifold, the socket part will bolt up to the mufflers inlet flange, with the long studs facing to the right side of the car. I cut the ball off the original front pipe and leave a short stub of metal attached to it.

Using a stock front pipe from a 128 coupe or any Fiat FWD model that uses a twin frontpipe, I use this as the basis for the front section. The Regata 85s we get her in Australia has generously sized secondary pipes, and the bend that routes the pipes to the rear of the car is in more or less the right place.

From here I get a 2.25 section of pipe with a single 90 degree bend, I have often used the front pipe from a lancia beta. It's large sized and quite heavy gauge and the bend is a large radius mandrel bend with no crimping or section reduction. Cut the secondaries at a suitable place so when the collector and bend is applied everything lines up nice and square. Heat and hammer the end of the 2.25 pipe so it flares out a little and the two secondaries will fit inside it without getting squashed up. Tack weld the secondaries where they touch together so this section seals.



Then offer up the 2.25, it should fit snugly over the secondaries. The short ball and pipe stub simply pushes into the muffler end of the collector pipe, don't worry about the small step down in size it was going to do that anyway when it gets to the mufflers entry pipe and bend. make sure you slip the circular (or is it triangular? it's been a while since I did this job) flange onto the collector pipe before you push the stub in and weld it up or else it's not going on!!

Fit up the flange onto the long studs with it's tension springs and over length nuts. When everything looks neat, tack it all in place.

Remove the new front pipe section complete, weld it up on the bench. Where the down pipes run into the collector, simply heat it a little with an oxy-acetylene torch and hammer down so the collector looks neat and the welds can be nice and flat (look at my pics of the 2.25 system and you'll get the idea, you can see the heating and hammer marks)

Its really that simple, no math involved, no length and volume calculations, but I can assure you it's going to be the simplest performance upgrade you've ever done and it gets rid of that awful contraption of a front pipe and ball /socket from the engine bay, which constantly comes loose, leaks and is a PITA to work around.

The twin pipes pass under the rear transverse chassis cross member, between the rh suspension point and the jacking point on the engine support cross member. The collector basically sits where the cat delete pipe is for the Australian market, and the muffler is still stock and supported by the stock mounting springs.

Another way people have gone is to use a piece of flex join pipe to take up engine /muffler movement ... pretty simple and effective also... nearly the performance of aftermarket headers and exhaust at a tiny fraction of the cost.



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## 9. Connecting Rods.

### A little about Rod Ratio

The rod ratio is the connecting rod length divided by the crankshaft stroke. A longer rod and a shorter crankshaft stroke results in a higher rod ratio and the higher this ratio, the better. The shorter the rod the greater the angularity of the rod as it operates inside the engine and this results in higher forces acting against rotation. These are what are known as first order forces. The greater the rod angularity, the greater the force component that will focus on the piston skirt and consequently greater friction between the skirt and cylinder, this results in greater friction losses.

There are also what are known as second-order forces and these cause unbalance and vibration and will make the engine lose torque output due to unbalance. The second-order forces are totally dependent on the ratio of crank radius / rod length and twice the angle of the crankshaft. Therefore the higher the rod ratio the lower the forces that counteract the torque gain and decrease engine performance.

The most important reason though for considering rod ratio is that it affects how long the piston dwells at TDC before moving downwards. The longer the rod, the longer the piston dwells at TDC, so the combustion process can build pressure before the piston begins to travel downwards, higher pressures equal more torque. A longer rod also increases the maximum speed the piston reaches as it travels down the bore, this in turn affects the speed of air in the ports and higher port air speed also builds more torque. For all these reasons it is important to use a rod as long as possible.

Using the 1290cc engine as an example, at 8000rpm we have a mean piston speed of 14.84M/s, but due to the very high rod ratio we have a peak piston speed of 23.86M/s at 78 degrees ATDC - an increase of over 60% over the mean piston speed - and between 64 and 93 degrees ATDC the piston speed is above 23M/s, thats nearly 30 degrees of crank rotation. This imparts a lot of velocity (energy) to the column of air moving through the inlet port, which inturn allows the flow through the port to continue at high velocity throughout the remainder of the inlet valve event. So despite its relatively small inlet valve size of 36mm

compared to its large 86mm bore, and very modest inlet port size of just 26mm, it's this high airspeed that allows the little 1290cc engine to produce a healthy 75Hp in stock trim, which is around 58.125hp/litre.

The 1495cc and 1581cc versions behave in a similar fashion.

1495cc (63.9 x 86.4) has a rod ratio of 2.007:1 (128.25 CtoC rod and a 63.9mm stroke) which will give a mean piston speed of 17.087M/sec at 8000rpm, but the peak piston speed is 27.583M/sec at 77 ATDC, it has a piston speed of over 27m/sec from 67 ATDC through to 88 ATDC.

1581cc (67.4 x 86.4) has a rod ratio of 1.906:1 (128.25 CtoC rod and a 67.4mm stroke) which will give a mean piston speed of 18.022 M/sec at 8000rpm, but the peak piston speed is 29.190M/sec at 77 degrees after TDC, it has a piston speed of over 28M/sec from 62 ATDC through to 92 ATDC.

The 1300 conrod is quite short at 120mm, and it is cast. The 1500/1600 conrod is 128.5mm and is forged.

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## 10. Crankshafts, flywheels and fasteners

### Bearing failure.

"Spinning a big end" bearing is a bit of a misnomer in that the bearing doesn't get destroyed because it isn't clamped into the con-rod properly and actually spins. Big end bearing failures, unless caused by oil starvation/oil excessive temperature, are generally caused by the engine detonating.

The location of the oil delivery holes in the crankshaft are "timed" so that as the journal turns pressurised oil is spread across the bearing, supplying the all

important wedge between the bearing and the journal just before the major load is transferred to the journal by the connecting rod. When combustion is uncontrolled and the piston is forced down at the wrong time, this wedge of oil isn't timed to the force being applied.

What happens next is interesting. If the engine is operated for long under detonation conditions the pounding will make the bearings squeeze inwards at the parting line. This forces the parting line edges of the bearing to start scraping oil off the journal, the temperature at the interface goes up until the bearing melts and bang, game over.

This is also why bearings are generally a little thinner at the parting line than in the middle, to prevent the edge from becoming a scraper.

If you want to try this at home you'll see what I mean. Take a half round bearing shell and place it on a hard surface, like a steel plate, with the centre resting on the plate and the ends pointing upwards. Take a ball pein hammer and begin lightly tapping the centre of the shell, before long the ends will begin to move inwards, detonation in the cylinder does just this.

### **bearing dimensions**

conrod and main bearing dimensions 1372 /1581 engines

Brand Name	Qty	Housing Diameter	Bearing width	Material	Wall thickness	Shaft Diameter
------------	-----	------------------	---------------	----------	----------------	----------------

Main Bearing	4	54.507 mm - 54.52	20.25	M157	1.85 mm	50.78 mm - 50.8 mm
MAHLE Original						
007 HL 20624	200					

MAHLE Original	1	54.507 mm - 54.52	22.75	M157	1.85 mm	50.78 mm - 50.8 mm
007 HL 20625	200					

Brand Name	Qty	Housing Diameter	Bearing width	Material	Wall thickness	Shaft Diameter
------------	-----	------------------	---------------	----------	----------------	----------------

Connecting Rod Bearing	4	48.629 mm - 48.646	18.95 - 19.2	M157	1.534 mm - 1.542 mm	45.508 mm - 45.528 mm
MAHLE Original						
007 PL 20347	200					

### **Engine ancillaries**



## Flywheels.

Uno Turbo -122 tooth count

1300 X1/9 (4 speed) -120 tooth count

1500 X1/9 (5 speed)-124 tooth count

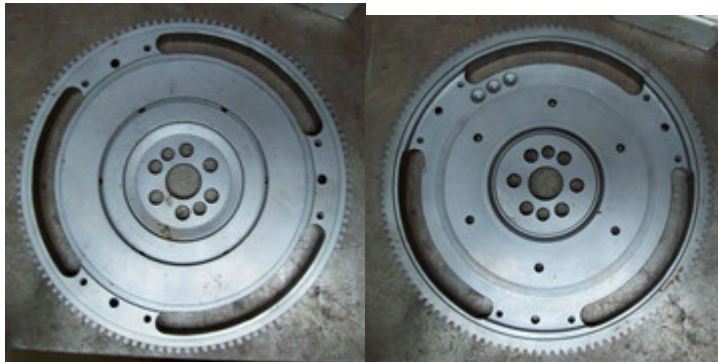
Flywheel weight. Weight is only half the story, what matters more is the items moment of inertia (MOI). MOI is a quantity expressing a body's tendency to resist angular acceleration, which is the sum of the products of the mass of each particle in the body with the square of its distance from the axis of rotation. What we are concerned with is the mass moment.

So if mass is removed from the flywheels periphery, it affects the MOI by a much greater degree than removing it from close to the central axis.

Alloy flywheel for four speed transmission, weight 2.9kg (6.4 Lbs)



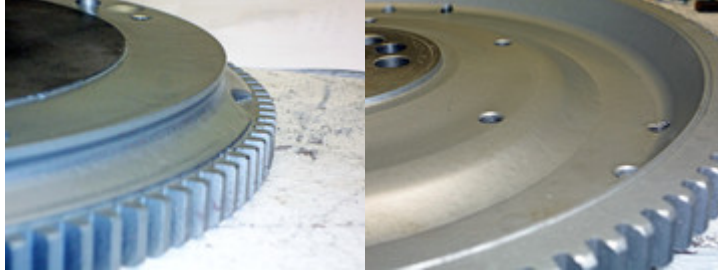
Lightweight 4340 CrMo flywheel 4.150kg (9.15 lbs)



lightened OE 1300 4 speed flywheel from MWB



Detail of weight removal 1300 4 speed OE flywheel



## Nuts and bolts 101

Nuts and Bolts.

Standard Fiat hardware works just fine and depending on your level of build can be more than adequate. Options do exist for aftermarket replacements.

OEM Head bolts.

Long M10 x 1.25 (102mm) M12 shank up to 1980. OE part number 4469756

Short M10 x 1.25 (88mm) M12 shank up to 1980. OE part number 4469757

Short M12 x 1.25 (88mm) up to 1979. OE part number 4223901

OEM head studs.

(M12x1.25) OE part number. 13529330

OEM M12 nut. OE part number 16101521

OEM head bolt/stud washer.

OE part number 4286034 or 4190030 (M12)

OE part number.....(M10)

Note: 1300 block engines all use M12 head mounting hardware (5 studs and 5 bolts) Early 1500 block engines also use the same M12 hardware.

1980 on 1500 use M10 hardware (10 x M10 bolts)

Later production 1500 use M10 hardware and additional M6 x 4 (14 bolt)

M12 hardware uses 19mm heads

M10 hardware uses 17mm heads

very late M10 hardware uses 15mm heads, and these are all torque to yeild with integral head bolt washer. (Uno Turbo)

OEM Rod bolts and nuts.

Rod bolt (M9 x 1.0) OE part number 4150297

Rod nut OE part number 12555020

OEM flywheel bolts.

OE part number 14348670

OEM flywheel spring plate.

OE part number 4179090

OEM main bolts.

OE part number 4263780

OEM head dowels.

1300 OE part number 4305665 (13 x 15 x 10)

1500 OE part number 4440099 (13 x 15 x 14)

OEM cambox

stud lengths (early sohc used studs to mount the cambox)  
bolt lengths

OEM oil pump drive gear bushing.

OE part number 4129982

Aftermarket fasteners.

ARP 209-2801- flywheel bolts

ARP 203-5403 - Main stud kit

ARP M12 head studs.

ARP 207-4201 - M12 head stud kit, haven't used these myself but dimensionally they look about right, still in research and development.

ARP 207-4701 - M12 head stud kit, similar to above but with the short stud 'undercut' to provide more even clamping force between the two differing lengths. Still in reasearch and development

**ARP M10 head studs.**

LONG: ARP AM4.500-1LB stud. 4.500" overall length, M10 x 1.25 threads at both ends, hex at nut end for installation, engaged length approx 0.900", nut thread length approx 1.000"

SHORT: ARP AM4.250-1LB stud. 4.250" overall length, M10 x 1.25 thread at both ends, hex at nut end for installation, engaged length approx 0.900", nut thread approx 1.000"

Use with:

NUTS: ARP 301-8352 M10 x 1.25 12 point (16mm wrench) (pack10)

WASHERS: ARP 200-8592 hardened washer M10 (pack 10)

BUSHES: ARP 200-8598 Stepped insert bush (pk10)

**Correct method for stud installation.**

1. Clean the threaded holes in the block with a M10/M12 x 1.25 tap (or preferably a thread chaser) and rinse them clean with A GOOD SOLVENT, I use Isopropyl alcohol. (this makes fantastic engine final assembly cleaner) Isopropyl alcohol dries 100% RESIDUE FREE so will not affect the bond strength of the Loctite. (Solvents like brake cleaner, petrol and even acetone will leave a residue that does.)
2. Clean the threaded end of the stud going into the block with isopropyl.
3. Test fit the stud into the internal threads of the block. They must fit and rotate smoothly with uniform friction during this test fit.
4. Remove the stud from the internal threaded block hole.
5. Apply Red Loctite (# 262 or #271) on the threaded end of the stud.
6. Assemble the threaded stud into the block.. hand tighten, not more than 4 INCH POUNDS.
7. Apply some nickel (or silver) based anti-seize sparingly on the entire length of the UN-threaded area of the stud. This will help reduce the corrosion between the cylinder head and stud.
8. Apply the same anti-size or assembly lube on the remaining threaded end of the stud where the cylinder head nut goes. Different lubricants or no lubricant has a very significant effect on the clamp load produced with a given torque

setting.

\*The Loctite-ing the studs into the block prevents the studs from coming loose. What should never be done is over tightening the studs into the internally threaded holes in the block. This will cause the junction between the threaded and non-threaded area of the stud to crash into the entrance of the internally threaded hole, resulting in a threaded joint failure or at the least damaged threads.

9. Fit the cylinder head with a cheap disposable head gasket (I have a guarnitauto gasket that I use over and over again for this, I would never use this brand for final assembly) and torque the nuts in sequence to about 40lb/ft. Let sit for a few hours so the Loctite can set. This step ensures the newly fitted studs are completely square to the head surfaces while the Loctite sets.

10. Remove the head again and remove the gasket and hang it up for next time... the studs should now be firmly in place and sitting exactly perpendicular to the block face.

11. go about with final assembly when the time is right.

This same method would also be used to set main cap studs into the block.

ARP also recommends applying tension / release several times before final torquing, for all studs / bolts (including their rod bolts when tightened with a torque wrench), The 'friction factor' changes from one cycle to the next. That is, friction is at its highest value when the fastener is first tightened. Each subsequent time the fastener is torqued and loosened, the amount of friction lessens. Eventually the friction levels out and becomes fairly consistent for all following repetitions. This phenomenon is known as preload scatter or preload error. This is basically the difference between the amount of preload achieved on the first installation of the fastener and the amount of preload achieved on subsequent torque/loosen/re-torque cycles.

Rod bolts as fitted to the SCAT rod option are also supposed to be final torqued by the "stretch" method. This involves accurately measuring the un-torqued bolts length, progressively torquing them and each time measuring the bolts stretch until a specified amount of bolt stretch is achieved. To do this you need an accurate micrometer and it needs to be one with pointy ends - not flat faces - as the bolts have machined dimples in their ends for the micrometer to fit into. ARP provide a small chart to track these measurements, as when you re-use the rod bolts you can be confident that they will not fail if they still maintain the same amount of stretch ...if they grow in length beyond specs

from the original length, you replace them ...which is why measuring them before you start is important.

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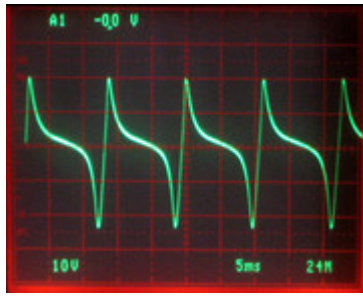
## 11. Ignition

### Electronic ignition systems.

Both the usual Bosch and Marelli electronic ignition systems are Variable Reluctor (VR) systems. The VR sensor is an induction type sensor, it is "passive", i.e. it does not require a power source, and has a small magnet built in.

The sensor uses a magnetic pickup to produce a signal. A core of steel is wrapped with hundreds of turns of fine wire at one end. A small magnet is attached to the other end, and this assembly is mounted in the distributor facing the distributor shaft. When a pin or pole on the distributor shaft (the reluctor) moves past the sensor (Stator) it causes a change in the magnetic flux field around the sensor. As the pole of the reluctor approaches the coil (stator) assembly, the flux from the magnet is pulled in close to the bar. The sudden field change induces an electrical current in the coil. As the teeth move away, the flux springs back outward, inducing a voltage in the pickup coil. This induced current has reversed direction as the magnetic field returns to normal. The result is an alternating current (AC) voltage that reverses polarity and crosses zero as the pin aligns with the sensor.

The output voltage of this sensor varies with the speed of the engine. At idle the peak output is approximately 0.6 volts, at mid-RPM it is around 3 volts, and at very high RPM it might go as high as ~50 volts. This type of sensor produces an alternating current (AC) wave output. The pulse is positive when the reluctor is approaching the stator, and negative leaving (if you have the right polarity)



(pic by Bernice Loui)

This primary voltage is managed by the control module to supply a regulated current to the primary winding of the ignition coil, to prevent damage to the ignition coil. When the control module is triggered by the distributor impulse, this interrupts the coil primary circuit. Each time the coil primary circuit is broken, this induces a high voltage in the coils secondary winding, which is in turn distributed to the spark plugs through the conventional means of the distributor cap and rotor.

The variable reluctor sensor has been the most widely used in automotive electronic ignitions. It has been used by virtually every auto manufacturer for many years and is still widely used. It is a rugged, reliable system that holds up well in a high temperature, high vibration environment. Because it generates a signal without requiring external power, it is very easy to implement. The magnetic variable reluctor sensor is gradually being phased out in more modern automobiles, however, because it has limited ability to sense teeth that are very close together, which is necessary to gain the positional accuracy required by modern engine management systems.

### Ignition Fault finding

#### Bosch inductive discharge system.

Bosch coil number: 0221 122 012

primary winding resistance at 20 degrees C (68F) 1.2 - 1.6 Ohms

secondary winding resistance at 20degrees C (68F) 6.0- 10 kilohms

resistor value at 20 degrees C (68F) 0.85 - 0.95 Ohms

#### test procedures;

A) Resistor: ignition off, disconnect resistor at both ends, measure. If resistance is higher or lower than specified values, replace resistor.

B) Primary: Disconnect wires from ignition coil. Ohm meter on terminals 1(-) and 15 (+) of coil. If measurement above or below values, replace coil.

C) Secondary: Disconnect wires from ignition coil. Ohm meter on 1 (-) and 4 (output) If measurement above or below values, replace coil.

D) Coil Voltage: Volt meter lead to terminal 15 (+) and other lead to vehicle

ground. Ignition on. Minimum reading should be 5 volts. If reading is lower, check wires and connections at resistor, control module and ignition switch.

E) If coil voltage is good, connect the voltmeter to the control module terminal 15 and vehicle ground. Ignition on. Voltage should equal battery voltage. If less check wiring and connections between ignition switch and control module.

F) If voltage at module is adequate, next connect the voltmeter between coil terminal 1(-) and vehicle ground. Ignition on. Maximum reading 2.0 volts. If reading higher replace control module.

### **Marelli Plex ignition.**

Non ballast type system. Same ignition coil across all plex units.

Coil: Marelli BAE 207A

Primary winding: resistance at 20 degrees C (68F) = 0.75 - 0.81 Ohms

Secondary winding: resistance at 20 degrees C (68F) = 9500- 11500 Ohms

Resistance in the lead (Distributor to ICM) at 20 degrees C (68F) = 680 -780 Ohms

Reluctor air gap 0.3 - 0.4mm

SteveC

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### **Planning your engine - The Paper Build.**

Before you start building an engine you should have an idea of what you want as a finished product, then develop a plan of action for the engine that will get you there. I didn't coin the phrase, but I like to call this - The Paper Build.

In my opinion, most people go about building an engine the wrong way, they simply don't look at the entire engine as a system. Instead, they either over cam, over port or over carb the engine and end up with less than the sum of its parts. If you don't stray too far from Aurelio's original design parameters and keep the cam choice sensible and the ports relatively small and very efficient,



then your engine will have good low down and mid range pull. As I said before lots of people over cam, over port and over carb... then the engine doesn't wake up until after 5 or 6k revs... that's mostly due to poor air speed in the ports at lower revs. For good engine response, air speed is the key, and balancing all the components flow capabilities makes the engine more than just the sum of the individual parts... and this is the 'trick' to building a strong engine... balance.

I prefer to match the components carefully, if not more conservatively and spend more time on tuning the finished product. This will result in a much more crisp running engine with more useful power and a stronger flatter torque curve.

So your choices fall into these broad categories.

- (1) Capacity. 1300, 1500 or 1600 (or larger)
- (2) Cylinder head choice and planned modifications.
- (3) Piston choice (and planned static compression ratio)
- (4) Camshaft choice (to match the available head flow and chosen C/R)
- (5) Induction
- (6) Exhaust
- (7) Ancillaries (lightweight flywheel etc)

come up with a plan, and stick to it!

The Fiat SOHC engine was produced in many different bore and stroke combinations but maintained a standard bore-spacing. Technically speaking there are four distinctly different engine blocks. The first generation (128A) of engines used a stroke of 55.5mm and a bore of 80mm to produce a displacement of 1116 cc. For the second generation (128A1 and later 138A) the cylinder block was redesigned to allow the bore to be increased to 86mm to give a displacement of 1290 cc for many 128 variants and the X1/9. The third generation (138A2) of SOHC used a taller engine block. It was available in bores of either 80.5mm or 86.4mm and a stroke of 63.9mm. The fourth generation (146) of engines the block was altered yet again to have an 'open face' design. This series standardised on a longer 67.4mm stroke with either an 80.5mm or 86.4mm bore.

This discussion should include the 1116 block and the differences between the 1290 and 1116 blocks. I've included a subsection for 55.5 crank in a 1500 block, effectively a long rod 1300. More for a theoretical discussion than something I would build, but it would have its place in the right circumstances. There is also no subsection for "1500 block with longer stroke crank options" as the internal dimensions of the crankcase preclude the use of longer stroke cranks

without significant machining, and IMO a loss of OE reliability. The crankcase configuration between the 1500 (3rd series) and 1600 block (4th series) is a little different and this leads to a couple of issues for some bore stroke configurations.

The primary reason the 1300 builds revs so quickly is the nature of its over square design. For those that don't know, a 'square' engine design is one where the bore and stroke are equal. 'Over square' is an engine who's stroke length is greater than the bore diameter. An 'under square' engine is one where the stroke length is shorter than the bore diameter.

It is the nature of an over square engine to build revs very quickly compare to an under square engine. Each engine design has its unique characteristics: the nature of an over square engine is to make more peak HP, higher up in the rpm range than an equal displacement under square design. Also, the under square design will make more torque (and have a broader curve) at lower rpm than the over square design.

This is why you see truck engines with long strokes and small bores which turn comparatively low rpm. While performance engines tend to have shorter strokes and make more HP at higher rpm.

The characteristics are due to the piston speed for a given rpm, the length of time the piston spends moving vertically in the bore and the valve area/displacement ratio. Over square engines have to build rpm to generate port velocity, so they don't make good torque. But they have more valve area for a given displacement so they can move a lot of air once they build that rpm.

The under square engines can't turn as much rpm because of the higher piston speeds for a given displacement. They can't build rpm as quickly either because the piston acceleration required is far greater. The torque comes from the long induction stroke and the comparatively small valve size resulting in a higher intake velocity. There is also additional time for the expanding gasses to push down on the piston which is translated directly into torque.

### **1300 engine options**

86.0 x 55.5 is 1290cc

86.4 x 55.5 is 1301cc

86.6 x 55.5 is 1307cc

86.8 x 55.5 is 1313cc

87.0 x 55.5 is 1320cc

87.2 x 55.5 is 1326cc

87.4 x 55.5 is 1331cc

Oversize pistons are available up to 87.4 from most manufacturers, The standard head gasket comes with a fire ring inside diameter of 87.2 or 87.4 mm depending on manufacturer, so choose your head gasket carefully if your considering a maximum overbore engine.

Aftermarket racing head gaskets often come with 88mm fire ring inside diameter, and specialist forged pistons are available up to 88mm, but in the end it's just 1350cc... so a lot of extra expense for 30cc over an 87mm bore and about 8.5cc of swept volume per cylinder... that's not going to make a great deal of difference. You also start having to spend extra money to ensure the cylinder wall isn't too thin (by sonic checking)

Maybe if you were racing and wanting to get that last 1% from your regulated engine, but just not worth it for a street car engine.

### **1500 engine options.**

As with all builds, you need to come up with a plan. In the 1500 block (2nd series engine) your choices boil down to 4 basic options.

1) Stay 1500 and rebuild, retain existing head with a freshen up. Your at the cross roads and get to choose, to some degree, your static compression. You get to set your quench clearance, and you get to position the piston where you want to.

1a) Stay 1500 and rebuild. The option exists to get a Tipo based head and fit it to your engine, 39.5 /31 or 37.5/33 factory combinations, a sort of factory big valve head (without all the compromises that PBS built into theirs) Static compression, SQ clearance and piston position as above

2) Stroke it to 67.4 mm. Retain current head. Static compression, SQ clearance and piston position as above

2a) Stroke to 67.4 mm. Tipo based factory BVH. Static compression, SQ clearance and piston position as above.

IMO the 1603 (87.0 x 67.4) hits the sweet spot when you consider bore / stroke and rod ratios, valve to bore (capacity) sizing, and potential in Hp/l.

1500 / 1600 use the same rod, forged std, 128.5 mm long. To reuse std rod would be fine, and when stroking to 67.4mm they will fit the stock crankcase with very minor work to the crankcase oil gallery. I like to check stuff before I use it (and push it hard) so my rebuild would include crack testing the rods,

rebushing them and resizing them after fitting new std rod bolts and nuts. All this adds up to more than you get a set of aftermarket SCAT conrod's for, so it's a bit of a no brainer these days to go the SCAT option if you intend to push the engine hard.

These combinations are what I feel are the best options for a performance "street" engine out of everything presented in this discussion, simply due to the availability of factory crank and piston options, the availability of "off the shelf" aftermarket conrods, and the availability of factory BVH options. I would rate the tuning potential of these options quite high, at least 9 /10.

**"should I use 1500 instead of a 1300 as a base"**

It's far easier to build compression in a 1500 by using a flat top (and readily available) small flycut cast piston, up to around the 10 - 10.5:1 mark with relative ease (certainly when compared to the 1300) and reasonable costs.

The second advantage would be it opens up a whole range of cylinder heads (that will only suit bores of 86 mm or more) including the 14 bolt Tipo based options which are effectively a factory BVH (without all the PBS engineering compromises built in to them) These will fit on a 10 bolt block with minor modifications, but the option exists for a 14 bolt 1500.

The third advantage would be con-rods and con-rod choices. 1500 forged rods are way stronger than the cast units of the 1300. Aftermarket options in 128.5 mm CtoC rods are relatively cheap and available, but you can't say the same about the 120 mm CtoC rod for a 1300.

And the fourth advantage would be the availability of a factory crank to stroke the engine easily to 67.4mm and 1600cc.

You miss out on all this if you stay with the 1300 engine.

I've included a subsection for 55.5 crank in a 1500 block, effectively a long rod 1300. More for a theoretical discussion than something I would build, but it would have it's place in the right circumstances. There is also no subsection for "1500 block with longer stroke crank options" as the internal dimensions of the crankcase preclude the use of longer stroke cranks without significant machining, and IMO a loss of OE reliability.

**1600 engine options.**

Using a late model Open deck Tipo /Punto style block. Longer crank options are available using this block due to the repositioning of the main oil feed gallery in

the crankcase, which allows for increased stroke length cranks. There are factory crankshaft options of 67.4mm and 78.4mm, as well as a host of aftermarket crankshafts.

### Engine component weight reduction

Reducing the weight of internal and ancillary components is always a good thing. It can reduce the loads imposed on other components and reduce power losses due to first and second order forces. I've borrowed a few pictures from other threads (for now) so thanks peteX19 and lookforjoe.

#### 63.9mm crankshaft (22.2 lbs.)



#### 67.4mm Fiat crankshaft (20.2 lbs.)



#### Fiat 1500 fcced con-rod (629 grams)



#### Scat H beam con-rod (548 grams)



**Stock 1500 large cast flycut 86.4mm piston and rod assembly (rings removed)  
1173 grams)**



**Stock 1500 large cast flycut 86.4 pistons & rods (complete) 1180.5 grams**



**Scat rod and 86.8 Mondial small flycut 34.45CH piston (1151 grams)**



**Scat rod and 87.0 34.15CH small flycut KS piston (1119.5 grams)**



**Stock 1500 flywheel (16.4 lbs)**



**PBS lightened flywheel (12.2 lbs)****Fiat pressed steel Camshaft timing gear (1500)****Fiat sintered steel Timing gear (1500)****Fiat cast iron timing gear (1300)****Fiat single row front crank 'V' pulley (1300 type)**



Fiat single row front crank 'V' pulley (1500 type)



For more pictures and weights of various engine components go [here](#)

SteveC

Last edited by a moderator: Today at 4:09 PM

i cavalli mai abbastanza, ed il peso sempre troppo.

Nothing is as simple as it looks. Its always twice as expensive and takes twice as long as you originally thought!

Ultimate SOHC thread [here](#)

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**fiatfactory**  
Steve Cecchele

Location:  
Western Australia

## 1300 engine options

### 'Best of the best' 1300

If you want to choose the 'best' standard engine parts available to mix and match into the strongest 1300 you can get, then the recipe is quite simple, I like to call it the 'best of the best 1300'

The basis is a 1500 euro cylinder head, as stock this flows the best of all the standard heads. But that's still only around 87/88 CFM at 10mm of valve lift



at 28" of water depression. To reach the magic 100hp at the crank number you need around 100/105 cfm of flow at the same lift/depression. This can be done with a stock 36mm valve but requires a skilled head porter and lots of attention to detail. If the 36mm inlet valve is substituted for a 37.5/37.7mm valve, then flow can get up around 125cfm, with only a very very minor increase in port size (only about 0.5mm) but lots of attention to detail at the port 'bowl'... for your build this is what I would recommend. In my head porting 101 section of my online book draft, I describe a head precisely like this

You could go for a 39.6mm valve, but for a 1300 this would mean some loss of airspeed at lower revs... and loss of driveability at lower revs... it would however continue to flow more air at higher lifts and coupled with a higher lift camshaft would make a higher HP number for sure... IMO the 39.6 valve is much better suited to the larger 1500/1600 capacities (or a 1300 that's built more for track use).

Once you have the head flow sorted then the rest is actually quite straight forward...and the other components can be chosen and matched to suit.

Unless you have an open cheque book, then the 8551 Mondial pistons are a good choice, and will give a static CR with a euro 1300/1500 head combustion chamber at right on 9.9 / 10:1. Their one disadvantage is their overall weight... so coupled with them I would recommend using the lightweight gudgeon pins available from Ross pistons, as this saves approx 30 grams per pin, and brings the total piston weight down to standard again.

Camshaft I would use a euro 1500 24/68 cam... a great cam with good balance of driveability and performance... and in the scheme of things well priced too. To achieve the best combination of power and torque an adjustable cam gear would be a great investment.

A lightweight flywheel helps the engine respond faster and cuts down parasitic losses. lots of choices here.

The exhaust ... well IMO the stock 4/2 manifold performs as well as / or better than almost every header out there on the market, so that is what I would use. Small benefit can be had by using a manifold from the larger engines... these are available new in europe at a reasonable price ... you could also use a stock USA spec 74 manifold as the difference is very slight. What makes more difference is what comes after the manifold. If you have a good exhaust guy that will use mandrel bends with butt joins and TIG welds... then there is a lot to be gained over the stock 74 exhaust system. I would be using a very generous pipe size for the collector and muffler

(2.25inch) and a 2" tail pipe. The twin downpipes you can adapt something from a larger engine FWD Fiat if you don't want to start from scratch.

The carb and manifold... well as I said before a single DCNF style carb will fulfill your criteria... sure it may not have the visual or aural appeal of dual carbs... but honestly will give better low down response and at the top end around 90% of the HP / torque of twins. I've even had customers adapt their original air cleaner to suit so that at first glance the engine bay looks totally stock! All these mods in fact won't change how the engine looks... and maybe that appeals and fits well into your build ideals.

Ignition... lots of choices here. Non vacuum advance distributor as used by euro 1300 is an s135 (Marelli) Lumenition or Pertronic make optical trigger kits to suit

So there you have it... actually pretty basic stuff... the rest of the build spend are things to ensure longevity ... water pump /oil pump / core plugs / bearing shells / gaskets / fasteners ... shop for quality and you won't have problem.

If you want to get up around 100hp, that's not too hard with the right combination of parts, and some cylinder head modifications, The stock euro 1300 is 75hp, so your talking a 33% improvement over that. Increased static compression, more head flow, an improved induction system - which doesn't need to be twin carbs - a single 36DCNF style carb will do, and a decent exhaust system ... basically improving the mechanical and volumetric efficiency of the engine.

IAVA 1300TV 70hp, 82hp, 100hp and 102hp engines from the factory in Argentina.

From 1971 to 1983 the Fiat 128 in Argentina had sports versions made by ARTIs (Industria Argentina Advanced Vehicle) which mostly had improved upholstery, steering wheels, wheels and tyres and sporty stripes. But the highlight of this production run was a list of mechanical improvements, which included a new intake manifold using a Solex dual throat simultaneous opening carburettor, an improved cam and exhaust changes. The first 128 ARTIs was called the 1100TV, for Tourism Veloz. It developed 70hp with a dual throat Solex.

In 1974 the 1300TV was launched, it produced 90 HP SAE or 82 DIN hp at 6,750 rpm /9.8kg/m at 4500 rpm ,had an 8.9: compression ratio and was equipped with a Solex 34/34 two barrel simultaneous opening carburettor. It achieved a top speed of 165km / h, quite sporty for the time and it's small

engine capacity.

In 1977 came the 1300TV/90. Equipped with a Solex C34 EIES carburettor (26 mm chokes) 9.5:1 compression ratio and a 24/68 64/28 camshaft. It made 88hp (DIN) at 7000rpm / 10.24kg/m at 4500rpm, and was able to reach 170km / h.

Next came the 1300/100. Equipped with a Solex C34 EIES carburettor (27mm chokes) an improved camshaft (39/65 71/29) larger valve sizes (38mm inlet and 35mm exhaust) for 100hp (DIN) at 7500rpm

Finally, at the top of the range what would be the most powerful version of the 128 ever made, the ARTIs 102hp version, it reached 180km / h and accelerates from 0 to 100 in less than 10 seconds. The final production of the model saw them come equipped with a 5 speed gear box and air conditioning.



CARACTERÍSTICAS		1300 TV
<b>MOTOR</b>		
Motor: motor de 4 cilindros, 1300 cc		
Relación y número de las válvulas	9.5:1	
Velocidad máxima	170 km/h	
Consumo a 90 km/h	6.5 l/100 km	
Motor: motor de 4 cilindros, 1300 cc		
Relación y número de las válvulas	9.5:1	
Velocidad máxima	170 km/h	
Consumo a 90 km/h	6.5 l/100 km	
<b>DISTRIBUCIÓN</b>		
Orden de los cilindros	1-3-4-2	
Velocidad máxima	170 km/h	
Consumo a 90 km/h	6.5 l/100 km	
<b>TRANSMISIÓN</b>		
Velocidad máxima	170 km/h	
Consumo a 90 km/h	6.5 l/100 km	
<b>ALIMENTACIÓN</b>		
Velocidad máxima	170 km/h	
Consumo a 90 km/h	6.5 l/100 km	
<b>VERIFICACIÓN</b>		
Velocidad máxima	170 km/h	
Consumo a 90 km/h	6.5 l/100 km	



"Bottom end is std pistons and stock deck height. I'd like it to run on 93 octane, so about a 10:1."

This is the most common "set" of bottom end parameters and would be the most common "perceived upgrade" that people consider. The stock 1300 bottom end, and the owner wanting to get more pep from it by just doing work to the top end. The engine is compression limited. In this scenario it's not likely that the engine owner is going strip the bottom end and machine the block surface to achieve a different piston position.

This is a "compression (height) compromised 1300." No matter which head or head gasket choice you make your Squish /quench clearance is limited (compromised) to the minimum of the head gasket thickness you find PLUS whatever distance you have the piston still down the bore. SQ of 1,0mm for a street engine is ideal, any wider than that and your giving away ME and VE, which is worth real HP. The SQ will be even wider if you use a head with any sort of machined (decompression) recess. If your compression limited you will be "behind the eight ball" in building Mechanical Efficiency (ME) into the bottom end. Performance engine build improvements will build ME and VE, and bump dynamic CR. If your compression limited, it restricts your choice of camshaft, because you need to attempt to still keep some sort of realistic DYNAMIC compression ratio.

The only thing you can do with a compression limited engine is to try and increase the volumetric efficiency as much as possible... this in effect is the only way you can boost the engines dynamic CR.

"Can a 1300 with a polish/ported head, 1500 carb, 1500 intake and 1500 cam be close to 100hp (at the crank)?"

I don't think you will get that...but you could come close.

As your 1300 is going to be standard CR, and standard duration camshaft (even though you have a tiny bit more lift) these will be your limiting factors. There is little point in installing a cam with any longer duration than the standard euro spec unless you raise the static CR, the reason for this becomes clear when you consider the DYNAMIC CR of the end result. If a longer duration cam is used, then the valve is still open while the piston has travelled further up the bore during the compression stroke. At the point the inlet valve closes, there will be less volume in the space above the piston (than there would have been with the shorter duration cam) and the result of this is a lower dynamic compression ratio. This is why a longer duration cam in a standard compression ratio engine will generally deliver

lack luster performance, and in many cases will actually drop the HP output.

I have an excel spreadsheet somewhere that calculates the piston height in the bore at increments of crank rotation (for rod ratio comparisons but useful for dynamic CR calcs as well) and I can post links and examples here.

So 100 crank HP from a 1300 with some minor mods and standard CR.... probably not. If you raised the static CR you would come close, but in a 1300 there is a limit (unless you want to spend on hi compression pistons) to the CR that can be achieved with standard parts. Over boring the cylinders will give you a greater swept volume. Skimming the block will get the piston right to the top of the bore. Using a very thin head gasket will reduce the amount this component adds to the chamber volume. Skimming the cylinder head will reduce the chamber volume. A combination of all the above will be the top limit of static CR with standard parts... but all of them are going to add to the cost of your build.

So the bottom line...

- 1.) If your engine needs a rebuild, then over boring and choosing a piston with a taller CH than stock will help. A light skim of the block to get the piston at zero deck height or slightly proud... the skinniest head gasket you can find while still ensuring the piston to head clearance (squish clearance) is 1.0mm and no greater than 1.25mm. This will get your static CR up a little, maybe as high as 9.5:1, you need to check this by direct measurement and ensure ALL the chamber volumes are the same.
- 2.) Port the cylinder head as per my recommendations, install 37.5mm tipo inlet valves on a larger valve seat, get the seat throat out to 34mm, deshroud the inlet valve.
- 3.) Use the inlet manifold (1500) and 34DMTR carb, install a carb spacer of around 50mm tall to blend the flow from the two circular carb throats into the oval manifold mouth. Use a better aircleaner assembly (that has more internal volume than the stock item) and route some cold air to it.
- 4.) Try and pick up a 1500 sohc twin out exhaust manifold (the internal ports are bigger than the equivalent 1300 item) build or have built a freeflowing exhaust system (at least 51mm pipe size)
- 5.) Try and find a marelli plex ignition setup from a regata/uno etc (that has no vacuum advance)
- 6.) Use a lightened flywheel

Do all this and you will get there, do some of it and you'll get part of the way.

"Will using a yugo 1100 head to raise the compression"

The upsides on using a Yugo head:

1. They do not have a recessed compression reduction area like a North American head has, and can be used unmilled, yielding 10:1 or higher with a bigger bore and minor deck work.
2. Even if using a regind cam with a -.040 cambox, and decking the block, timing belt tension can still be set using stock components if an "unmilled" head like the Yugo head is used. Milling a North American head flat plus a -.040 cambox is enough to prevent correct tensioning on a 1300, and there's no simple "go-to" tensioner solution to take up the slack.
3. Uses standard valves and valve train components so costs are contained.
4. They all have the unshrouded intake valve pockets and laid-back plug face like the 1500cc head which promotes good flame front propagation. Actual 1300cc Fiat heads up to 1978 are really poor in their combustion chamber design.

The downsides:

1. Relatively small intake ports that can stand to be opened up a bit. It's a little fussing but something you can do in your garage with some patience. At a minimum, just port match 1" inward to allow correct alignment with the intake manifold. In the plusses/minus column, it is less problematic to use a head with ports too small than it is to use ports that are too big.
2. 31mm exhaust valves instead of 33mm, but we've proven that the exhaust on these motors is over-scavenged to begin with, so the effect of 31mm exhausts are negligible.

"what other things can I do - cheaply"

If you were going to be prepping a set of 120mm CtoC stock rods the option exists to extend the CtoC length, by just a little. The 1116 and 1290 share the same conrod and it is the same casting. The one difference is the addition of a bronze bush at the small end of the conrod for the 1290's full

floating gudgeon pin (the 1116 is a press in fit). You can start with an 1116 rod, have the small end machined out to have a bush fitted and then offset bore the bush to effectively increase the rods CtoC length. I've seen a few NOS 1116 rods floating around on Ebay pretty cheap too, as there's not a big demand. I've done this mod... long ago and not for anything to do with rod ratios... but simply to push the piston a little higher in the bore, and get more static CR. Back when I first started playing with the SOHC some of the OE piston taller CH options just didn't exist, as these came later in the engines production and evolution. This was one way of going from 0.5 minus deck to 0.5 plus deck with what was available.

Prepping rods and having them machined isn't cheap, but I like to check stuff before I use it (and push it hard) so my rebuild would include crack testing the rods, rebushing them and resizing them after fitting new std rod bolts and nuts. If you were to start with a NOS 1116 rod there's no need for resizing the big end, a dye check would suffice to ensure your starting with a rod that has no production flaws, and the bolts would also be new. So this would make economic sense if the NOS 1116 rods were cheap enough ...the 1116 engine is still current production..

#### **63.9 mm stroke crank options. (in a 1300 block)**

The 63.9 stroke crank will fit the 1300 block, no problems, if you overbore to 86.4mm you get a normal 1500, well 1498 cc. If you want to use a 63.9 mm stroke crank in a 1300 block, the piston will effectively travel 1/2 of the extra stroke upwards (aka the "throw" -  $8.4\text{mm} / 2 = 4.2\text{mm}$ ) and past the top of the block so there are two choices, make the rod and /or the piston shorter by this total measurement.

Now the stock 1300 piston has a compression height of around 34.7mm, take 4.2mm from this and you now have a CH of 30.5 mm, unfortunately there are no factory pistons from the Fiat range that have the dimensions we want, so you need special pistons made.

Same with the conrods, there is nothing that is a straight swap out fit, a 115.8mm (120 - 4.2mm) conrod is also a special manufacture. Again as noted earlier the rod ratio is heading in the wrong direction ( $115.8/63.9 = 1.81$ ) and it's the SOHC's high rod ratio that is part of what makes the engines what they are.

#### **67.4 mm stroke crank options (in a 1300 block)**

The 67.4mm stroke crank can be made to fit the block with a little bit of grinding here and there to make clearance. You could get up around 1600 c in a



"1300 Block" engine, and this was the basis for aftermarket manufacturers like PBS and Alquati who offered these kits before the "1500 / 1600 block" options even existed. They made very fancy fully counter weighted crankshafts to do this application. These kits have been known to change hands for serious \$\$\$. The PBS 68 mm stroke crank is known to have a habit of developing cracks, so if purchasing one of these as a used unit crack testing is advised.

The trouble with going 1600 is the 1300 block is three-fold.

If the rod is kept standard then the rod ratio (the ratio of rod length to stroke length) drops considerably. Stock 1300 had a rod ratio of 120mm / 55.5mm, which is about 2.16:1. If the same length rod is used and the stroke length increases to 67.4, the rod ratio tumbles to 1.78:1, that's more than a 20% change.

A lower rod ratio means that the rod presents at a much higher angle to the cylinder direction when the piston travels up and down the bore, a higher rod ratio allows the rod to stand more vertically for the entire range of travel. The greater the rod angle the more side loading the piston experiences, and this greater side loading creates more friction. Extra friction is more heat and less power.

The second reason is how the piston speed changes due to the rod length. Mean or average piston speed is simply the stroke and revs over a minute, which gives you a mean piston speed of feet per second. It gets more complicated because as the crank rotates the rod is seldom vertical, due to this angularity it means that when the crank is half way through it's rotation, the piston is actually sitting more than halfway down the bore. This means the piston has an instantaneous speed that varies throughout the cranks rotation. A longer rod will give a higher instantaneous piston speed at some point of the cranks rotation, and this higher piston speed creates a larger draw on the column of air that is following it down the bore as it moves. The faster we can get the column of air moving, the more energy it holds and the longer it takes to slow down. This allows the air to keep flowing into the cylinder at a higher speed even when the piston reaches bottom dead centre and reverses it travel and begins to rise back up. Air although light has it's own inertia, and getting the air column to have a higher speed gives it greater inertia. This is one of the key points of performance engine building. So a longer rod and a higher rod ratio is absolutely beneficial from this standpoint... and one of the key reasons the SOHC engine behaves as it does.

Fitting a longer rod and a longer stroke just isn't feasible... there just isn't enough height in the block to allow a longer rod and a suitable piston to be packaged into the available space... as it is even with the standard length rod

the piston need to be very short, and there is only a finite minimum amount of space the rings will fit into above the gudgeon pin, the PBS pistons actually have the lower ring unsupported around the lower edge as the gudgeon pin sits above the lower ring lands lower edge.

The third issue with these "stroker" options is the conrod choice. The Stock 1300 is a 120mm cast conrod and this will become the Achillies heel of the engine and limit it's rev potential and longevity. It also means custom pistons (this configuration requires a CH of 28.6mm with a 120 C to C rod) and/or having to remachine alternate rods that meet length and construction criteria, or have rods custom made. This is simply lots of extra expense to get where you could be with stock parts in a "1500 block"

It was a solution back in the day, but as soon as the taller block 1500 became available, it sort of became obsolete ...1600cc in a 1500 block is a much better 'fit'.

For all these reasons I would rate these "stroker mix and match" of parts quite low on a scale for tuning potential...maybe 5/10... mostly because of the high cost vs the returns, when it could be done cheaper and better in a 1500 block. So your basically limited to around 1320cc with a 1300 block, unless you want to spend up big.

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i cavalli mai abbastanza, ed il peso sempre troppo.

Nothing is as simple as it looks. Its always twice as expensive and takes twice as long as you originally thought!

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**fiatfactory**  
Steve Cecchele

Location:  
Western Australia

### 1500 engine options.

This would be the most popular base for a performance engine build. The 1500 is available in both carburetted and fuel injected versions. The cylinder blocks come in three types;

M12 head fasteners  
M10 fasteners (10 bolt)  
M10 fasteners(14 bolt)

## USA to UK /Euro /Aust spec differences

There are quite a few minor differences that make the 1500cc 85hp carburetted (138A.000) engine different to others.

1.)The cylinder head is different as it does not have the full circular machined recess that the US spec engines do. All the heads are made flat and then the recess is machined in afterwards. I have seen heads with the same casting number with both flat and recessed faces, so the chamber SHAPE is the same but the US spec head gets a 1.5mm circular plunge cut on the milling machine. This decompression recess isn't flat on the base either, it has a dome type of shape to it.

There are also quite a few different versions of the head available. For example some with air injection port and some without, in Australia X19 heads have the air injection port there cast in, but it isn't used. This doesn't alter the flow potential of the cylinder head as the injection port is in the exhaust port

2.)The inlet manifold is different, the ports through the 1500 carb euro/Uk and Australian spec cars have larger ports. 4425193 is the cast in part number on this one.

3.)The exhaust manifold is different. The manifold the US 1500 cars and all FI versions was a single outlet design whereas all carb X19's in Europe/UK use a dual outlet design. (similar to the US spec 74 manifold) The 1500 manifold has larger ports the part number cast into this manifold is 4392487. The 128 rally/coupe/x19 1300 euro use a similar manifold but it has smaller ports, the part number cast into this manifold is 4252518.

Interesting Note: The exhaust manifold and front pipe actually has the most benefit (HP wise) of any of these differences. A superb example of how much difference would be to compare euro spec 128 rally and 128 coupe engines. same head design, same CR, same inlet manifold and carb, same cam specs. the 128 rally used a single outlet design manifold (67hp) the 128 coupe used a dual outlet design (75hp)

4.)The carburettor used in the UK is a 34DATRA. Here in Australia we still had a 32DATRA (precisely the same carb as our 1300 spec cars strangely enough) and our cars (combined with a different camshaft to the UK/Euro spec cars) were only rated to 80hp.

5.)The camshaft. Euro and UK X19 1500 spec cam is 24/68 64/28 with 9.9mm lift (same duration as the 128 rally/coupeX19 1300 euro spec cams, but the 1300 ran 9.75mm lift)

## Step by step raising the static CR

The stock 1500 USA spec pistons have the large cast in flycut and a CH of 34.45 so the piston when it's at the top of the bore is still about 0.55mm down from zero. Add to this the stock heads 1.5mm full circular recess and that's 8.5:1 static CR. If you use a Euro (flat - no circular recess head) and retain the stock large flycut pistons your at 9.2:1, which is the standard euro spec for a 1500 carb.

The euro spec 128 / X19 1300 uses a piston that has a 34.7mm compression height, and it has a 0.6mm dome (it's really more like a pimple) and have the small valve flycuts. With no skimming of the block / head, with these pistons your up around 9.6:1 in a 1500 (depending on gasket thickness , chamber volume etc etc as this all varies with production tolerances) and the piston is still around 0.25mm down from zero.

If you use pistons from an Uno 70 (this is a 1301cc engine which stock has a CR or 9.35:1) these have again the small flycuts, are flat on top, small flycut and a 34.9mm CH. They are just 0.1mm down from zero deck.

So with 34.9CH pistons in a 1500 using a thin re-torque type h/gasket (1.2mm crushed) bored to 87.00 mm with the std stroke and 0.1mm block skim to set the pistons at zero

swept volume = 380.00cc  
head gasket volume = 5.95cc  
volume of reliefs = 0.70cc  
volume in cylinder head = 33.5cc  
total \* BDC = 420.15cc  
total \* TDC = 40.15cc

Static CR = 10.46:1

And this is without using any sort of dome piston and having all the advantages of a flat top piston (better flame propagation and faster burn, able to use less total ignition advance, high squish / quench etc etc) and not removing any block or head deck thickness.

## Mix and matching the differences to your advantage - 1500 EFI

### Cylinder head and camshaft retrofit

dcioccarelli said: ↑

*My take on the ultimate SOHC engine ... in my case I not only wanted to remain 100% Fiat but also 100% X1/9. My goal was to only use stock Fiat parts but to mix and match US and Euro parts.*

*I have had a long-standing ambition to create the X1/9 that I feel Fiat should have created. The premise of the idea is that, having owned 3 X1/9s (1300 Australians spec, 1500 - carb Euro spec and a*

[Click to expand...](#)

A good example of mixing and matching to get a positive result. Bumping the static from 8.5 to 9.2:1 with a head change would be worth in the region of 4 - 5% increase in Hp /torque. Fitting the higher lift and longer duration cam from the carb version would nett a similar improvement, so he's definitely bumped his engine to around the 80/85Hp, 85lb/ft mark of the euro carb version. Add in the port /valve seat improvements that were performed (should lift the flow rate to around 95/100cfm) and Dom is likely to be up around 95Hp.

Unfortunately Dom wasn't able to take advantage of the twin outlet exhaust manifold. His local emissions regulations require fitment of the catalytic convertor, so he's still looking for a solution to that. He has a suitable manifold and front pipe from an uno/strada, but needs to adapt the front pipe to the existing cat exhaust system, so it's just a "packaging" issue. When he fits this it should release another 7 to 8 useful Hp and make another noticeable gain.

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**fiatfactory**  
Steve Cecchele

Location:  
Western Australia

## 1600 engine options

1600 swap over.

Differences between 1600 (tipo) and 1300 sohc (128 specific but applies mostly to X1/9)

The Tipo head has only two bolts that hold the thermostat assembly onto the head, so unless you make an adaptor plate the 128 thermostat will not fit straight onto the tipo head. If you want to connect the heater, this adaptor will also need to incorporate a heater hose fitting, as the tipo head does not have a heater hose fitting at the cam drive end..

You could use the tipo thermostat assembly (which are cheap and plentiful) as this has the heater fitting, but the tipo doesn't use a bypass thermostat system, so you would need to modify your bottom radiator hose or make some sort of joiner to have something to connect the bottom hose to.

front water jacket plate. Tipo is a different shape. to fit the 128 / x19 style engine mounting a 1500 sohc front water jacket plate is needed. One of the holes that would go thru to water needs to be welded and ground flat. Only when the 1500 sohc front water jacket plate is fitted can the front "snail" mount be fitted to the block.

Timing belt tooth pitch. Not really an issue, but obviously you need to use all three gears and a belt to suit. Rounded tooth belt is a more modern design.

Timing belt tensioner, tipo uses a different method of tensioning. 128 / X19 type spring tensioner can be used, but needs to be a 1500 tensioner mount and a 1500 bearing... the 1300 bearing and mount are different to 1500, so in your case if you go the 128 / x19 tensioner route you will need to source these.

Auxiliary shaft and oil pump drive gear. A real trap from young players this one! Tipo aux shaft skew gear and the oil pump drive gear it meshes with are not a 1:1 drive ratio. 1100/1300/1500 type aux shaft and oil pump drive gear must be used if the distributor is to be block mounted.

Camshaft. Tipo cam, apart from being pretty crap from a performance perspective, also has the distributor (computer controlled so it has no "guts" it simply distributes) driven from its end... this precludes the fitment of the top engine mount. You need to fit the 1300/1500 cambox /top mount bracket, and while you're at it use the 128 coupe camshaft

1300 and 1500/1600 steel backing plate is different, the tinware that goes between the block and transmission... you need to use a 1300 one that suits your four speed transmission.

Auxiliary drive. 1100/1300/1500 sohc uses a regular trapezoidal section "V" belt, the Tipo 1600 uses a multi ribbed serpentine belt setup... if you want to retain things like your standard alternator, you need to convert the tipo to the V belt pulley

front timing belt pulley, tipo front pulley is really heavy and it incorporates a toothed pulley for engine timing / crank angle sensors. Fitting the 1300 front pulley will work..BUT... then your timing marks won't line up with any available timing marker, so you would need to remark your front pulley at least. In some

cases to mount the timing marker, (if you wanted to use the regular 1500 x19/strada/ritmo etc timing pointer and bracket) you may need to source and fit an appropriate front seal carrier plate, as this incorporates the threaded bosses to mount said timing marker and bracket.

Yellow timing Belt cover. Tipo wont fit, 1300 cover is too short, you need to source a 1500 timing belt cover and backing steel plate. referring to problem of timing markers above... If you are really really lucky, a 1500 belt cover from some models of ritmo/strada has the three cast in timing marks to suit the regular 1300 front V pulley standard marking and comes as a one piece item. Most 1500 yellow belt covers are two piece and do not have these three cast in marks for ignition timing which is why these engines use a bolted on bracket and pointer...which uses a different front seal carrier than the one your 1300 has.

water pump and pulley... offset and pulley is different to suit the multi ribbed belt. I'm pretty sure the tipo multi ribbed water pump pulley will foul the chassis rail in both 128 and X19 chassis.

Rear water pump housing and steel water return pipe. Tipo housing does not incorporate a fitting for the heater hose, it uses a heater hose nipple on the steel return pipe instead. 128 rear pump housing has the correct fitting for the stock heater hose to join to.

flywheel, 1600 tipo uses the larger 190mm clutch (most some are 200mm), 1300 128 is 180mm diameter. You can use either flywheel or clutch BUT you must fit a 1300 ring gear to the tipo flywheel if you go this route. Whichever flywheel you use, make sure it is fitted with the timing dimple positioned correctly, so you don't become a member of the "180 club"

starter motor ring gear. 1500/1600 and 1300 are different tooth counts, you need to have the 1300 ring gear to use the 1300 starter motor if you retain the stock four speed gearbox.

I'm really not sure if there are any sump differences between a 128 and a tipo/tempra/dedra, but I'm guessing there probably will be some. I would be tending towards swapping the 128 sump over just to be sure, unless you can see there is no difference.

automatic crank difference... make sure the tipo engine came from a manual transmission, there is a difference at the flywheel end of the crank (same with strada / ritmo) which is easy enough to machine in a lathe, but the crank needs to be out of the motor to do this.



there are probably a few other small things that I'll think of as the day progresses... so expect the list to grow

Anyway, bottom line is, if you do this, you will basically be stripping the engine back to the head and block assembly. i.e. removing the flywheel, front pulley, water pump, aux shaft etc etc and swapping in a lot of 128 or X19 parts.... not too difficult, but not actually a straight bolt in fit by any means.

### 1600 stroker options

1500 block height (from the crank centerline to the deck face) is 195.7mm (+ - production tolerance approx 0.1mm) If we have a crank throw of 67.4mm (so half is 33.7mm) and a rod length of 128.5mm then the max piston compression height we can have to achieve a "zero" deck height is 33.5mm. ( $33.7 + 128.5 + 33.5 = 195.7$ )

The stock 1580 pistons have a compression height of 33.3mm but a dished head that will make the CR just 9.2:1. The stock 1500 big flycut pistons are 34.45 to 34.65 in CH and will poke out the top by around 1mm. X19 1300 pistons are 34.7CH and have a 0.6mm pimple but some uno 1300's use a piston with 34.9CH and smallflycuts. The Mahle / KS pistons known as 0872, have a 34.15CH and smallflycuts that are 2.7mm deep

With these 0872 pistons a "pop up" of 0.65mm will be achieved at TDC with a stroker crank. If used in conjunction with a felpro head gasket (which is approx 1.5mm thick when crushed) this will give a piston to head clearance of 0.85mm, about as tight as you want to get.

Working out some rough CR figures.

87mm x 67.4mm gives 1602cc, so thats 400.5cc per cylinder

Euro cylinder head chamber volume is approx 33.5cc

the head gasket is about 87mm ID and 1.5mm thick when crushed, so it has a volume of approx 7.5cc

"pop up" volume is approx 2.87cc

Flycut and ring land clearance volume is approx 2.2cc

Volume at BDC is (swept volume - pop up volume) + flycut and ring land clearance volume + gasket volume + chamber volume.

Volume at TDC is (volume in gasket - pop up) + flycut and ringland clearance volume + chamber volume.

$$V * BDC = (400.5 - 2.87) + 2.2 + 7.5 + 33.5 = 440.83cc$$

$$V * TDC = (7.5 - 2.87) + 2.2 + 33.5 = 40.33cc$$

$$440.83 / 40.33 = 10.93:1 \text{ static compression ratio}$$

That's all in theory as to use these pistons with a larger intake valve and higher valve lift, the valve flycuts need enlarging which is going to drop the CR. Any good machinist with a piston roll-over vice for his milling machine will be able to do the job. It's simply a case of removing the rings (as the piston vice will use the ring grooves to hold and steady the piston) setting the vice up for the 18 degree tilt that the pockets are cut at, setting his cutting tool at the desired radius and making a cut down to the original flycut depth, but only on ONE valve pocket per piston. This means two pistons get the right pocket machined, and two get the left done. Trickiest part for the machinist is getting a nice radius at the bottom of the cut, you don't want a sharp edge here. The original flycuts are approx 19/20 mm in radius, 2.7mm at the deepest point. Recut to a 22mm radius as you need approx 2mm min clearance around the 39.5 valves. Last time I had this done it was \$125 for the four pistons. The flycut does deepen the pocket a little, at the deep end of the cut by about another mm in depth, which works well for cams with a high LATDC too.

### 1599 sohc build

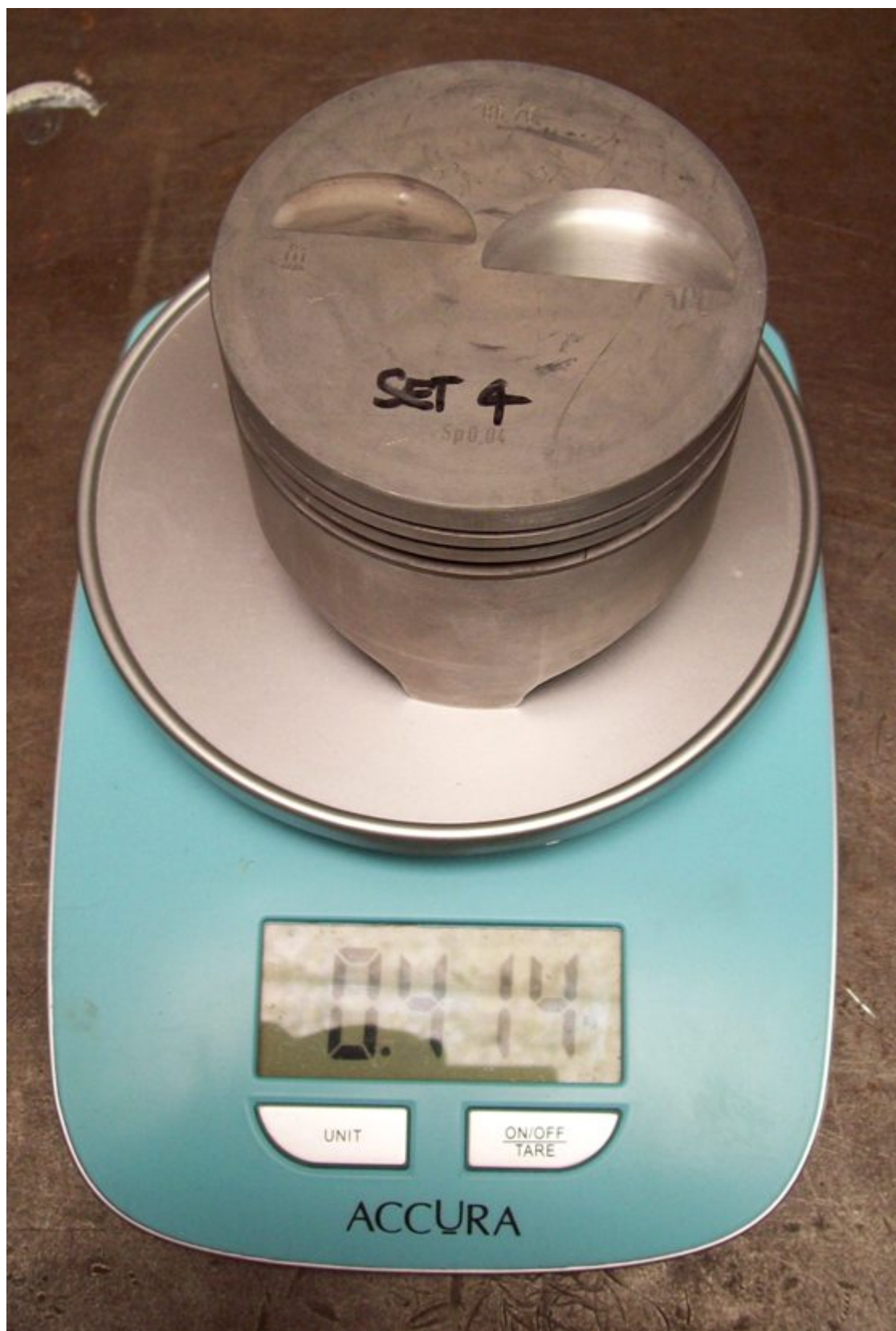
I have a 1599 build underway...

(86.8 x 67.4) 14 bolt block, new (chinese) 14 bolt Tipo head, 39.6/33.4 valves, 36.5/28.5 seat throat (160cfm inlet/120cfm exh), 0872 Mahle (Kolben Schmidt) pistons with inlet flycuts enlarged, aiming for 11:1ish Static CR, TRW valves (intakes lightened), TRW valve springs, Scat rods, ARP fastners, alloy toothed alt/w/pump drive, Kent vernier cam gear, under bucket lash adjustment, Tipo (10 tooth) oil pump, marelli Plex ignition. Pittatore steel 42/82 12.2mm cam, Alquati DCNF intake, twin 44dcnf, custom extractors, lightened and polished crank, windage tray, 4340 CrMo flywheel.

Quite a lot of focus is going into reducing reciprocating weight and the associated parasitic losses.

Mahle 0872 pistons with inlet flycut enlarged, bare weight 414 grams





the stock mahle rings weigh 38 grams per piston, for comparison a set of rings on the mondial pistons that are often used are 42grams.



the lightweight Ross gudgeon pins at 103 grams each, p/n 866-01-27





for comparison the stock Mahle (122g) or Mondial (135g) pins depending on the wall thickness used.





even the pin retaining clips come in different wire thicknesses, and therefore different weights. A set of 8 Mahle clips weighs in at just 6 grams, the Mondial clips weigh in at 12 grams for the set of 8.

I have three sets of Scat rods available (the exchange rate was good so I stocked up) and the lightest set (there is around a 5 gram per rod variance across the three sets I have) weighs in at 545 grams each. SCAT p/n 2-5050-1915-1000-866. FIAT, Punto H-Beam con rod set.





That makes the weight of each rod/piston/ring/pin and clips assembly just 1101.5 grams ( $545 + 414 + 38 + 103 + 1.5$ ) which is pretty close to my target weight of 1100 grams per assembly, and this is 79 grams per piston/rod group lighter than the original parts.

the lightweight crankshaft that I'm working on for the 1599 build, I haven't weighed it yet as it's not finished, but my goal weight is around 8kg (17.6lbs)



and a comparison to a stock 67.4 crank





Lightweight 4340 CrMo flywheel 4.150kg (9.15 lbs)







Miller's Mule alloy auxiliary shaft pulley



Alquati toothed belt accessory drive crank gear



Shimless valve buckets (used with valve stem lash caps)





The inlet manifold I'm running, with 44DCNF's on top. It's an original Alquati 128 manifold I had welded and remachined for the correct engine inclination for an X19. I also had the water jacket welded up and machined so the manifold can be pinned to the head for positive location once it's match ported. Standard it's about 31mm port size at the head face and approx 37mm at the carburettor end.



I've also had these manifold spacers made up, they are 38mm thick with a 44mm hole at one end tapering to just under 37mm at the other. This will give me some material to blend into the manifold, and give a straight run for the air after the carburettor instead of hitting a bend straight away.

With a 6mm phenolic spacer at either end will give me an additional 50mm of manifold /port length which is about 175mm at the moment. I want extra manifold length and volume and I'm aiming for 225mm to the base of my 44dcnf's. The carbs are 85mm and the full rollback bell mouths add another 50mm, so I'm looking at 360mm from the back of the valve to atmosphere.



lots more pics of the parts and the engine assembly as I get the time.

SteveC

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DanielForest likes this.



**fiatfactory**

Steve Cecchele

Location:

Western Australia

## Long stroke crank options.

### 1800cc-1900cc Builds

If you have the funds, and the inclination, the 3rd series (Tipo/Punto Open deck) block lends itself to some large capacity options. There are "factory" cranks available that takes the engine to almost 1900cc!! There are also quite a few manufacturers that offer speciality stroker cranks, even pistons to suit these long stroke options. AFAIK there are no factory OE pistons to suit these crank selections. Does not fall into what I would call "budget" in any sense of the word except for - blowing it!

A couple of particular long stroke crank completed engines come to mind. Both were well executed, well photographed, and dyno proven with excellent results so I've compiled them and the results in a subsection of it's own.

### Komar 1806

All I really know are some basic specs and what is shown in pictures and a you tube link. 1600 block, Tipo style 14 bolt. Head Tipo style 14 bolt. Valve sizes 39.5mm intake, 33.5mm exhaust. 87.0mm bore. 76mm stroke custom 8 counter weight crankshaft. 1806cc

Built by David Komar for abarth2litre who is a member of this forum.

Nice result.





### Fiat X1/9 1800cc Dyno2



[ame=""]Fiat X1/9 1800cc Dyno2 - YouTube[/ame]

### Fiat x1/9 1800cc Dyno



[ame=""]Fiat x1/9 1800cc Dyno - YouTube[/ame]

### 1807 with custom injection from Italy

In the shadow of mount Etna in Sicily lives a man called Salvatore. He's not a mechanic, for him this is a hobby. He has done some wonderful work on his X19 engine, I'm very impressed by the results and his work. I've exchanged a few emails with him and have his permission to tell his story and use his pictures.

This 1807 puts out enormous torque and Hp with just 8 valves from good solid engineering and clever head development.



Rev limiter set to 8600 rpm

Maximum torque of 24 kg/m (173.5 lb/ft) at 6000 and 151Hp

Torque stays at 24 kg/m at 7000 rpm and 176Hp

21 kg/m (151lb/ft) at 8500 rpm and 187Hp

The completed engine.





Some pictures of the engine internals:

76mm stroke, 8 counterweight crankshaft. Crank weight 11kg.



Conrods. H beam, 130.5mm length, weight 452 grams.





Pistons. Manufactured by CPS in Italy, 87mm bore, 27mm compression height, weight including rings and gudgeon pin 360 grams.



Pistons mounted to rods.



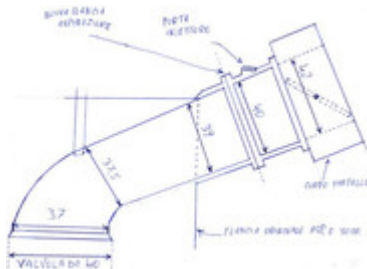
Camshaft and valve train. Camshaft nitrided steel billet 304 degrees duration (44/80 80/44) 12.25mm total lift, 4.00 lift at TDC inlet, lash clearance 0.30.



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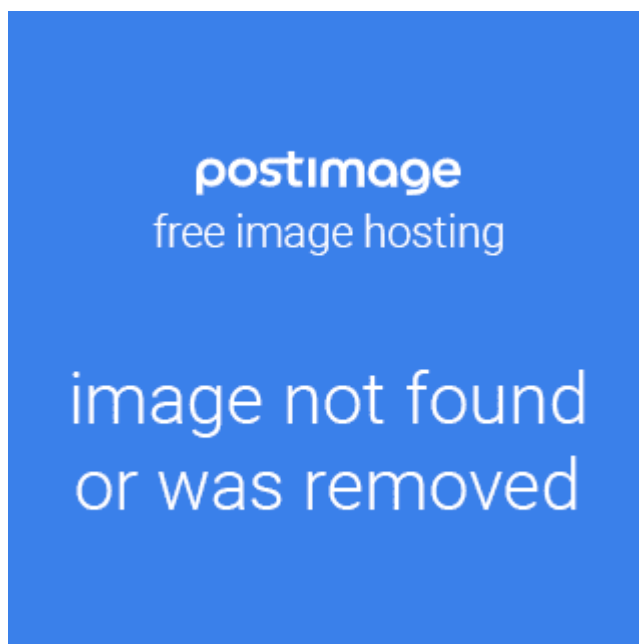
And the bit that makes all the difference, the cylinderhead. Salvatore took a leaf from the top engine builders of the 1970's, and decided to raise the inlet port. A cross sectional drawing showing his plans.



and a cutaway of a cylinder head showing the machining involved.



The process involved machining a new port, and then welding in alloy tubes to define the new inlet tract. Included at the manifold end of the port was the mounting plate for the custom injection manifold. After welding the head / port were hydraulic tested to make sure there are no leaks.



The custom injection manifolding.

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### Engine assembly tips.

Definitely give the block to your machinist as clean as you possibly can, he will appreciate it. Make especially sure that the water jacket galleries are cleaned out well, as the last thing you want is a chunk of rust getting under the boring bar or the machining table and the bore going off crooked, believe me it does happen. You should remove the water jacket plates and the block core plugs then get in there with an old screwdriver and scrape away, you will be amazed at the amount of scale and rust that comes off. A bonus is that it now it can't dislodge and find its way forward into your radiator, so get the water jackets as clean as you can.

You should also invest in some good quality thread chasers and clean every threaded hole in the block. Cheap taps will do more harm than good and remove metal from the threads. Use plenty of kerosene as a lubricant too as this will also help lift any crud out of the threaded holes. Head bolt and main cap threads being the most important. Once you have the block cleaned then take it to your machinist along with the pistons.

The block should be bored and then the bores honed to suit the individual pistons. The pistons can be numbered with a felt marker on top, and that's the bore they should end up in. The 'old school' way starts with cylinder 3, then 1,

then 4 and then finally number 2. The thought behind this is that no two adjacent cylinders are bored or honed straight after the other, so any thermal transfer and expansion is evened out and it leads to a more round bore. The machinist should try to find the true center of the bore and set up on this, as not all bores are correctly centered and perpendicular to the crank.

Ideally you should then bring the block home, clean it thoroughly and install at least pistons 1 and 4 into their bores. After determining true TDC you can make an assessment on where the piston sits in the bore. Use a straight edge and a feeler gauge to measure the clearance of the piston over each end of the gudgeon pin, this tells us if the piston is square in its bore. Deck height should be the same on both ends when measured from the main bearing saddles. If it's not then pistons 1 and 4 don't reach the same height in the bores. If you want to change the blocks deck height, then take it back to the machinist to remove that amount. When resurfacing the block it should be set up on the surface grinder with these measurements as reference. The original surface may or may not be accurate and most shops will resurface using the original surface to set up the grinder, the deck should also be perpendicular to the bores.

For the head use a straight edge and a depth gauge to measure the depth of the combustion chambers. This will tell you if one end of the head is cut deeper than the other. From the factory the level is usually very good, but if the head has been resurfaced in the past you can't assume that it was skimmed square. After measuring all of the depths, you can cut the head to give as uniform depths as possible

Block and head skim are standard procedure for a performance engine build, the stock finish on the block deck isn't what I would call a fine finish and the head should be skimmed to assure absolute flat. If both surfaces are true then the head gasket can seal and do it's job. Total material removal is minimal, approximately 0.1mm each (approx 4 thou - so under 10 thou in total)

Set the ring gap with a feeler gauge by fitting each individual ring to its bore. It doesn't matter if the piston came with it's rings fitted, take them off carefully and do this step. They would be fine for a production engine as they sit on the pistons from the manufacturer, but we are going to a bit more effort than that and correct ring end gap is important so we leave nothing to chance.

When you have the pistons installed you need to determine true TDC, take a few measurements and then you can calculate what the static CR will actually be. True TDC is simplest to determine by the 'positive stop' method. I have a metal strap which can be bolted down to the block face, and roughly centered in the bore is a nut welded to the strap. I simply wind a bolt in/out of the threaded hole so it protrudes a small distance in to the bore. Spin the crank

over until the piston contacts the stop and mark this point off on the flywheel or the front crank pulley. Wind the crank backwards until the piston once again contacts the stop on the other side of TDC and mark again. Precisely half way between the marks is true TDC, this is a very important reference point and it needs to be determined accurately.

Once the pistons are in you should do a plasticine test for valve / piston and piston/head clearances. Pretty simple really, assemble the head to the block, only use 15lb/ft torque for the head bolts, before fitting head put small squares of plasticine about 6mm / 1/4 inch thick in a several spots around the piston crown and a larger square into each of the valve flycuts. Fit a cambelt and time the engine, rotate several times then remove the head again. The plasticine will be squashed so carefully remove it with a craft knife and cut thru the sections at what looks to be the thinnest part, measure with calipers. Valve to piston should be a minimum of 1.50mm, piston to head and SQ clearances should be 1.0mm minimum. Head gasket crush will be approx 0.4mm for a retorquer type gasket and approx 0.2mm for a non-retorquer gasket like Astadur and Fel-pro and this crush allowance should be subtracted from the plasticine measurements.

If your going to be Tuning this engine and using a vernier cam gear to set cam advance / retard then you should do this step again with the cam set at 4 degrees each way. This is one of those 'peace of mind' steps that will inspire confidence for when the time comes to turn the key and vital to know if your tuning for performance. While your at it, when you take the head off each time measure the valve lift directly at each advance /retard point and at TDC. Write all measurements down so they can be recalled with confidence.

There is a lot of time and care that must be taken to ensure that everything fits as it should. The payoff is an engine which is more than just the sum of its components. What you want is to ensure that each cylinder is an exact copy of the others, so that they all make equal and optimum power. The old analogy of a 'chain being as strong as it's weakest link' holds true and an engine will only produce as much power as it's weakest cylinder.

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**fiatfactory**

Steve Cecchele

Location:

Western Australia

## 1500 EFI test case

A forum member (Byron) who lives in Queensland has asked me for some guidance and to build a head for his 1988 Bertone. His brief is quite simple, he wants more power while retaining factory EFI manifolding and ECU, the car has to remain emissions compliant (has to keep it's cat conv.) and not loose it's 'manners' around town.

He would also like to do a complete head swap and retain the original head, wrap it in plastic and tuck it away in a corner of the garage. If he ever wants to sell the car, or wishes to return it to absolutely stock he can. It's a 14 bolt engine. He read what Dom Ciccorelli had achieved with his Bertone, and wants basically the same thing, but with some extra minor improvements along the way. The car has approx 100.000km, has had a series of quite careful owners, and at the moment is a daily driver, another reason why a complete head swap is how this will be done.

He doesn't really want to go with a punto / tipo style head, partly for the thermostat mounting and heater hose routing differences, but mostly so he can retain a completely original look.... so it's a 'sleeper' upgrade.

Fortunately I have a 14 bolt euro Carbed X19 head on the shelf, it actually came to me via Dom Ciccorelli in the first place. Dom wanted me to build this head for his Bertone originally, but my wife took very ill and I wasn't able to do the job for him, so now Byron gets it. Dom is also selling Byron a twin out exhaust manifold and euro 1500 camshaft that will also be used in this build.

I stripped the head this afternoon, nice clean piece of aluminium and a really good core! The intake valve guides are a bit worn (about 0.15/0.2mm of radial play) which is right on top limit for wear, so this head will get new guides. It's also going to be upgraded to 37.5mm intake valves and get a port and polish. I expect to be able to get very similar (if not exactly the same) sort of flow results as I did with Brian McKillop's cylinder head, so about 125cfm of inlet flow and approx 300fps of inlet air speed. The exhaust valves look like new and they are original Fiat items (I can see the Fiat logo etched at the top of the stem) so unless Byron really wants to spend the extra cash on new exhaust valves, I'll get these refaced and if they clean up nice (I think they will, but I've only quickly looked at them) will get re used. TRW 37.5 inlets, new inlet valve seats to suit with 34.0mm seat throats, the guides pushed out (to make the porting easier for me) and a glass bead blast are on the agenda for the head when I drop it at my machinists tomorrow. I'll pick it up when I'm next on R&R from work and commence the P&P work.

Other planned improvements are some Mondial 8551 pistons. These are 35.3CH with a 1.6mm dome. No need to have them re flycut as the valves will clear the stock flycuts. I've bought in some 86.4's for Byron as he's hoping to do a light hone and replace the pistons without the need to rebore... we won't know if this will work until the engine is opened up... but if he needs oversized pistons I can supply some, and then he can use the 86.4's in a 1300 rebuild he has planned for another of his X1/9's (the 1300 is 86.0 standard bore so that should clean up at .4 over)

He's looking for a suitable performance catalytic convertor and is planning on having a twin pipe fabricated to go from the OE twin out manifold, via the cat convertor, and use the original muffler, again so it looks and sounds stock (to the untrained eye)

So the final spec will be something like this... and **everything** will be from the Fiat parts bin - except for the front exhaust twin pipework which will be custom fit.

37.5/33.4 valve combination, Euro 14 bolt carb head (modified for EFI and ported to 125CFM/300fps) approx 10.25:1 static compression. 35.3CH 1.6mm dome pistons, OE euro 1500 carb cam (26/66 9.9 inlet lift) OE twin out exhaust

manifold, performance catalytic convertor. OE inlet manifolding, ECU, injectors AFM and throttle valve.

Estimated output... well 90 at the wheels would be nice (approx 105 at the crank) and we will see how close we can get to this with some good tuning. A vernier cam gear may be needed to get everything running smoothly ( to get a good manifold vacuum for a smooth idle)

Pictures of the stock head soon, modified head as I go along, pistons have arrived, cam etc etc as it all arrives. I'll be supplying the head assembled and ready to fit, Byron will be doing the engine assembly, honing, piston install, exhaust fitout, electrical changes to EFI (with Dom's help)

### **pictures of parts**

I stripped the 14 bolt carb euro head that is going into Byron's Bertone build, and had it glass beadblasted, larger inlet seats to suit a 37.5mm intake valve (33.5mm inlet seat throat) and had the valve guides removed (for ease of porting)

The head stripped.



Glass bead blasted, seats installed and guides removed.



It's now sitting on my porting bench, with about 4 hours into it so all the intake bowls are roughed out ... and I have a set of lower EFI manifolds that I'm having some welding done on the lower side close to the head so I can enlarge the runners in this area (otherwise it gets real thin really quick)



I also have a set of 86.4 8551 Mondial pistons in stock for this build, 35.3CH with

a 1.6mm dome, they won't require flycut enlargement as the stock flycut works just fine with the 37.5 intake valves. The original exhaust valves cleaned up well, so will be re used.



Byron has sourced a euro twin out exhaust manifold, and he's still looking for a euro 24/68 camshaft.

SteveC

Last edited: Nov 28, 2016

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**fiatfactory**  
Steve Cecchele

Location:  
Western Australia

## 1500 twin carb test case

1500 NOS short block being built by Nick (duderini) in Victoria

Here are some pictures of the port moulds taken from the Tipo head I'm prepping for him. Port moulds of the standard (RH curl) tipo port, and also a modified (LH curl) port that is from a head I'm building so that a clear comparison can be seen.

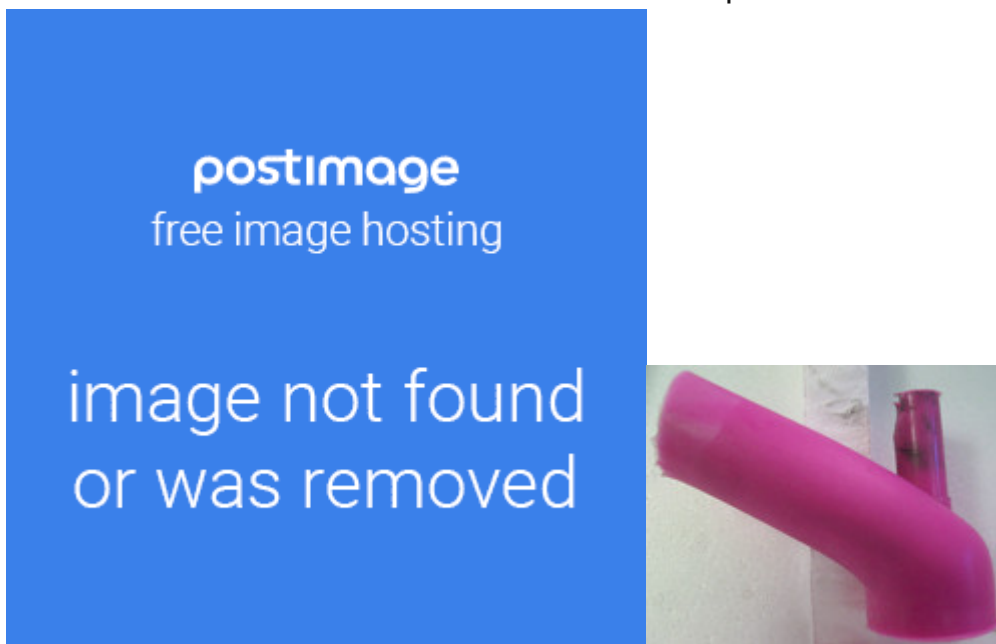
Standard port has been flowed at 123 CFM (+ - 1%) and the port for Nick's head I expect to be 140-145 CFM, based on previous experience.

Stock port is 35.5 seat throat, 28.5 port with a port choke at approx 27mm where the port necks down. Modified port is 36.5 seat throat, 29mm port and a port choke of 28.5mm.

Stock first / left, modified second / right. Clearly visible is the port bias to angle to flow away from the chamber wall side of the port and towards the centre of the cylinder in both cases.



Chamber wall side of both standard and modified ports.



Exhaust / centre of cylinder side of standard and modified ports.



Top view comparison



underside port comparison



SteveC

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**fiatfactory**  
Steve Cecchele

Location:

### 1600 EFI test case

Another forum member (Bob) has approached me to prepare a cylinder head for his planned 1600 sohc build. Bob's brief is simple... maximum power and torque from 1600cc (using a PBS 68mm stroke crank in a1500 block) BUT it must retain the stock intake manifolding. He's prepared to change the EFI control system to megasquirt or similar, but it MUST retain the OE look.



This is harder than it sounds as the standard EFI manifolding isn't what you would call 'performance oriented', but it does have some potential. I also have never played with an EFI head so modifying the EFI manifolding is all relatively new to me. With this in mind I purchased a pair of lower inlet runners from Matt at Midwest and began the development using an old 1300 euro head as a baseline.

It didn't take too long to realise the port dimensions and orientation were going to be TOTALLY different to any of the carburetted heads I had done in the past. This is because the EFI manifolding is very thinly cast and simply does not have the material to remove that would allow the port to be raised like I normally would. It also became evident that the runners would need some material added to allow any worthwhile modifications.

Here are some pictures of the EFI development head... if you look closely at the underside of the manifolding you can see the pinhole where I've broken thru to air...so this is out to the maximum possible size.



All material removal comes from the chamber wall side of the intake port, very little can be taken from the port roof. The offset bias is increased with this modification, and although I was only able to flow this head bare (guides are out so no valves can be fitted) it did show a considerable improvement in total flow.

So I sent the manifold off to be welded on the underside. It came back and I began on the Tipo head that Bob wants.

This is the modified port sitting against a stock head... yep that whole crescent of metal is going!



gone, like this!



stock manifold runner to the left, modified runner to the right.



It doesn't look like it in the pic, but the port is very OVAL shaped, rather than gaining additional CSA at the TOP of the port (roof) with the EFI manifold the only place to grab additional CSA is to the side.





Additional material added to the underside of the manifold runner to allow porting without breaking thru to air.



a port mould of a standard runner and modified runner will show this even better... and that's coming soon. At the manifold face the port dimension is roughly 33 x 29mm.

SteveC

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