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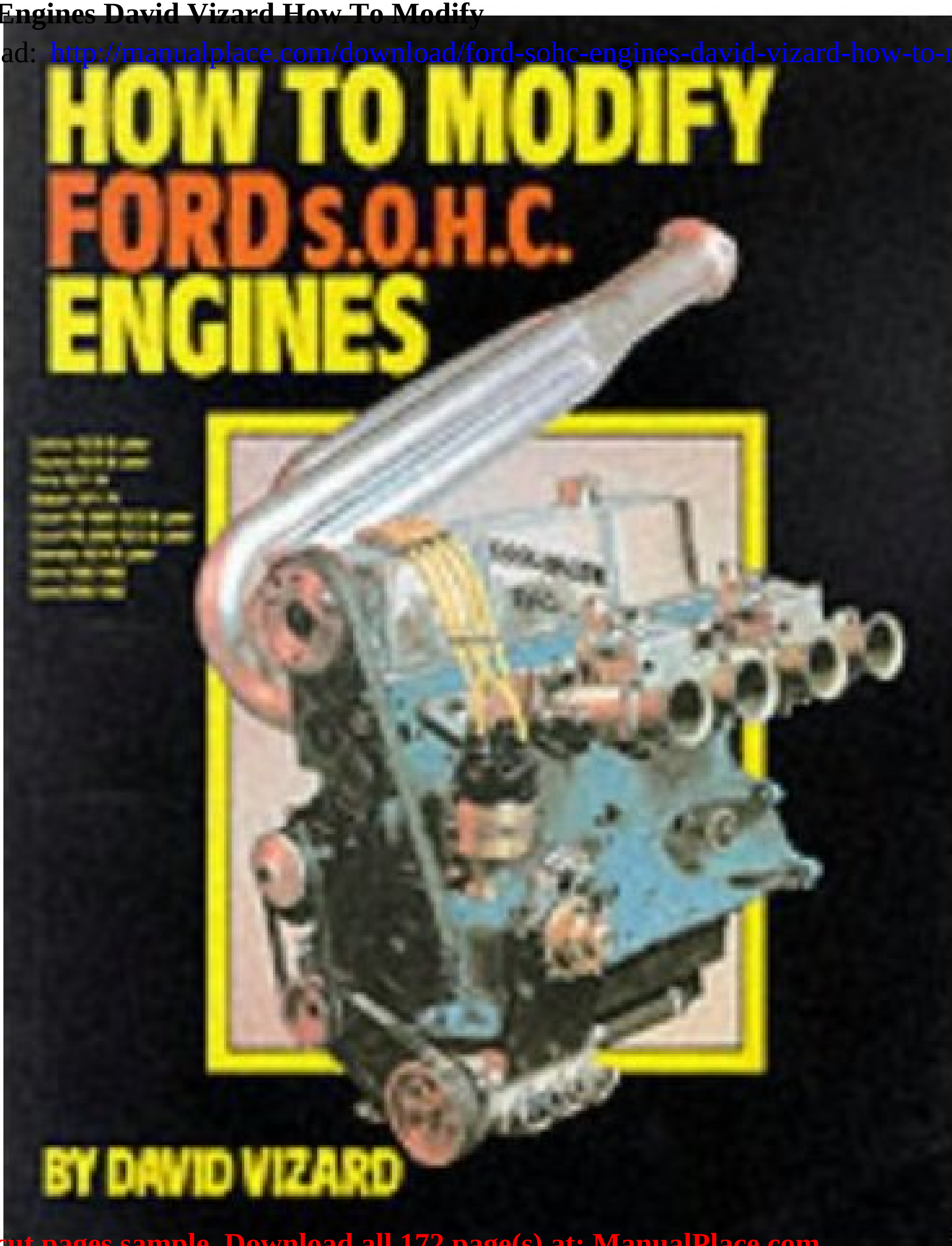

HOW TO MODIFY FORD S.O.H.C. ENGINES

BY DAVID VIZARD

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Contents

CREDITS

Writing a book like this is never a five minute wonder. A lot of time, effort and hard thinking went into it, but it would all have been for nothing if it had not been for the generous assistance of many people. Some people were able to help more than others, and almost all helped as much as they could.

My special thanks must go to Duane Esslinger, Jim Flynn, Carl Schattilly, Denny Wyckoff, Dave Egglestone, Keith Roof, Doug Somerville for many, many hours of assistance. To these I must add the names of my able Australian contacts, John Bruderlin and Doug Huntley. From here, the names belong to people all over the English-speaking world, so here are sincere thanks to all the following: Racer Walsh, Steve Burton, David Ray, Bill Quinne, Sig Erson, Harvey Crane, John Reid, Barry Reynolds, Ron Capron, Ak Miller, Jerry Branch, Darryl Koppel, Dan Swain, Ken Johnson, Mike Urich, Derek Sansom, Geoff Howard, Bill Nelson, Kevin Rottie, Joe Antonelli, John Campanelli, Terry Davis, Frank Casey, Harold Bettes II, Gary Polled, Mike Anson, John Shankle and John Lievesly.

To this I must add a special thankyou to Daphne for one year's hard typing.

Introduction

The Ford Motor Company introduced their single overhead cam (SOHC) engine in 1970, and since then they have been installing it in close on a million vehicles a year. This means that by now there are a lot of these engines around.

In Europe, this engine fulfils a number of duties ranging from everyday workhorse requirements to the higher performance needs of Ford's more sporting vehicles like the RS Escort. The same basic engine can displace 1300, 1600 or 2000cc. In some countries such as the USA, only the 2000cc engine was used, this being installed in Capris, Pintos and Bobcats. This is Ford's universal engine, a power unit designed to be put to as many uses as possible.

I had the opportunity to pull one of these engines apart not long after their introduction and from the racer's point of view, I liked what I saw. At the time I was writing a technical chat page for *Cars & Car Conversions* magazine in England and I did not hesitate to extol the virtues of this engine, as well as criticising some of the possible drawbacks as I saw them. I pointed out that this engine had all the ingredients for high horsepower outputs at modest cost. Its overhead cam, eight port. crossflow head should, I said, be capable of allowing this unit to produce in excess of 100 bhp per litre in normally aspirated form, and twice that amount per litre in supercharged form. With all it had going for it I expected this engine to be an instant, overnight hit with the speed equipment companies and the general public alike, just as the British Leyland Minis had been eleven years previously.

You don't have to be a student of automotive history to know that my enthusiasm was not shared by all and sundry. After my initial acquaintance with this engine, many years were to pass before one came into my hands again. During those intervening years, one of the great unsolved mysteries of life for me was – why hadn't performance-minded people "discovered" this gem of an engine? True, a few enterprising folk did spend some time making them produce more power but few, very few, remotely approached anything like the true potential of an engine of this configuration. Those clever souls who did manage to produce reasonable horsepower from Ford's single overhead cam (SOHC) engine usually found a very limited response to their efforts by the public.

About 1976 I became re-acquainted with Ford's SOHC engine. I became the proud owner of a MK III 1600 Cortina GT. Although it was not quite the car I expected, I grew very attached to the machine, and as a result I slowly became more involved with the performance aspect of its engine.

As time passed, I began to formulate a theory as to why this engine had not achieved wholesale acceptance by motoring enthusiasts. Ford's European competition involvement is probably well known throughout the free world. Their principal competition engine is the Cosworth/Ford BDA four-valve-per-cylinder engine. This unit is available from Ford at displacements from 1100- 2000.cc. Power output in excess of 280 horsepower normally aspirated can be achieved with this engine, though for long distance events such as rallies, 220 bhp is considered the norm. Since Ford already possessed a highly successful engine, it seemed to them to be pointless to develop its poorer, less-endowed cousin the SOHC engine. Having acquired the easy-to-come-by horsepower from the SOHC engine, they appeared, at least to outsiders, to have drawn the departmental line. At time of writing (1983), if you built an engine using Ford parts, about 155bhp would be the limit you could reasonably expect. I am sure you will agree this is not a lot for an almost bullet-proof SOHC engine. The argument that since Ford has the Cosworth in its stable, why should it spend time and money on an alternative unit holds water except for one point: not everyone can afford the price of a four-value-per cylinder engine. On the other side of the coin, a lot of vehicles are already equipped with the SOHC engine.

If Ford has to date, declined to explore the true potential of the engine, what have the privateers done? Many people tried their hand at making the engine go but precious few, it seems, have actually found the key to unlock the true horsepower potential from this unit. You would think that the efforts of those who did make horsepower would be readily received, like exhaust into a vacuum. Unfortunately, it appears that the reverse applies. The situation seems more akin to a castaway on a Pacific island, reading the national news. Was this apathy on somebody's part? I think not. Ineffective lines of communication would describe it better.

My low acceptance theory is based on what I have already said. It hinges on the fact that for an engine to be an instant performance hit, we must see leadership from the factory to constantly keep the unit in the public eye. Morever, it must be responsive to even the simplest modifications. The factory leadership we don't have, but this situation is changing with the increasing popularity of Group I now group A competition (the use of mass-produced vehicles with factory speed equipment). The engine itself is only semi-reponsive to simple modifications but highly responsive to the *right modifications.* Making horsepower is only a question of finding the weak link in the chain of power production events. Those few who did find the way to high horsepower outputs were not in a position to publicize their findings in a wholesale manner. Instead, the information filtered down through the ranks so that now, a decade or so after it introduction, the engine is only now beginning to achieve the status it deserves. The validity of this theory will be difficult to prove one way or the other but to my mind it contains enough seeds of truth to cause me to restructure the concept of this book. Normally I would start with simple, bolt-on modifications and from there, each subsequent chapter would delve deeper into the engine in the search for more and more horsepower and, of course, reliability.

Not so with this engine.

As I have already said, it is only semi-responsive to relatively simple, conventional modifications. This is part of the reason for its slow acceptance, and I do not intend to be found guilty of further retarding matters. Indeed, my intention is the reverse.

Whether you are looking for a big horsepower increase or a small one, you need to have a reasonable understanding of the device you are dealing with. Hopefully, this book will give you a good insight as to what you can expect the results of any modification to be. It should also allow you to get the best increase in performance for the money you intend to spend. If you are anything like me, economics play a vital role as to what you can do to your vehicle.

Bearing these factors in mind, I intend to go straight into the engine and deal with its idiosyncrasies first. When you have a greater understanding of the engine, we will then deal with the speed equipment, which falls into the more accepted bolt-on category. This and the more complex task of building a competition engine will be dealt with last. In other words I will deal with the sum total when I have dealt with the comprising parts.

CHAPTER ONE

How Do We Make Horsepower

I am going to stick my neck out and tell you that really there are no such things as speed secrets. If more power is required from an engine, then improvements must be made in one or more of the following areas: 1. Increased volumetric efficiency; 2. Increased thermal efficiency; 3. Increased mechanical efficiency.

Let's look at each of these three factors in turn and analyse them in a little more detail. First of all, increasing volumetric efficiency. In simple terms, this means improving the breathing efficiency of the induction and exhaust system. When you realize that at 7,500 RPM a typical engine has only six thousandths of a second to fill or expel the gases in the cylinder, you will realize the ease of doing so becomes important. To improve volumetric efficiency, we make changes to air filtration, carburation, manifolds, intake ports, valves, combustion chambers, exhaust ports, exhaust manifolds and silencers (mufflers). Into this cauldron of parts, throw the effect of the camshaft profile on engine performance, and you will begin to appreciate there are a lot parameters affecting the end product. While on the subject of cams, I should point out that high performance cams very often (but not always) increase high RPM breathing at the sacrifice of low RPM breathing. In other words, they trade low end performance for top end. Improving the breathing ability of the engine is the most important single factor affecting power output. Because of this, it's hardly surprising this book deals with various aspects of improving the volumetric efficiency in detail. Pay attention to that detail and you will find the extra power you are looking for.

The concept of volumetric efficiency is relatively easy to understand, but the term thermal efficiency, for many, is not. Let me explain: when a certain quantity of fuel is burnt, it releases a certain known quantity of heat. All forms of energy are interchangeable. If our engine converted all the heat energy to mechanical energy, it would have a thermal efficiency of 100% Remember, the fuel is burnt to heat the air in the cylinder so that it expands and pushes the piston down the bore. The more heat the air contains, the higher the pressure it reaches and the harder it pushes down on the piston. If, after burning the fuel, the heat is taken away from the air, it will not want to expand as much, so cylinder pressures will be lower and the power will be down. Typically 80% of the fuel we burn in our engine is wasted heating up the rest of the world. The remaining 20% is all that is converted to mechanical energy to propel the vehicle. Heat that is dissipated in the cooling system or goes out as hot exhaust is heat that the engine burned fuel to produce and did not convert to mechanical energy. The factors which affect thermal efficiency are important to those of you requiring fuel economy as well as horsepower. The principal factors affecting thermal efficiency are the quality and correct timing of the ignition spark, proper atomization or vaporization of the fuel in the airstream, correct cylinder to cylinder distribution, and correct calibration of the carburettor to deliver the optimum air/fuel ratio. The compression ratio is also a factor. The higher this goes, the better the thermal efficiency gets. Reducing heat losses to the cooling and lubrication system increases the thermal efficiency. Lastly, reduced frictional losses help thermal efficiency, but this really comes under the heading of mechanical efficiency.

As far as mechanical efficiency is concerned, the biggest step you can take to improve it is to build the engine to the finest tolerances possible. Things like con rod accuracy, crankshaft straightness, piston to bore clearances all affect the final frictional losses the engine will have. Care in selecting and establishing the right clearances when building the engine will produce higher mechanical efficiencies.

The overall concept of building a high performance engine is attention to every detail, big or small. In the following pages I will elaborate on the points that were touched upon here. I will give you the necessary details or acceptable ground rules so you can successfully build or modify an engine to your particular needs.

Heads for Power and Economy

Today, the challenge of coaxing extra horsepower from a modern cylinder head produces interesting (!) problems. Gone are the days when a little thoughtful use of the grinder, plus a set of larger valves, were all one needed to get one step ahead of the competition.

No Sir.

These days sophisticated equipment is required to produce cylinder heads of advanced performance. Foremost among this hardware are the flow bench and dynamometer. But, unfortunately, such equipment is outside the financial means of most enthusiasts.

Fortunately, though, I have over the years acquired such equipment. Thus, in the following pages I will detail certain easier modifications, as well as many more exotic modifications; all have been developed on the flow bench and thoroughly dynamometer-tested. As a result, the changes will help the engine develop the amount of power one would expect from a SOHC, canted-valve engine.

ELEMENTARY PRINCIPLES

The production of horsepower depends to a large extent on air flow. If a head has insufficient air flow, it will *never* produce good horsepower but good air flow or an air flow increase does not guarantee a horsepower increase. Sometimes achieving extra air flow into the engine may upset some other aspect of the engine's functioning, leading to a situation where little or no gains are made. A rule which works almost 100 percent of the time is *if air flow increases and nothing else changes, horsepower will increase.*

Other factors affect horsepower apart from air flow, these being principally fuel atomization, combustion efficiency and heat losses. To optimize the cylinder head, attempts must be made to impove all these areas.

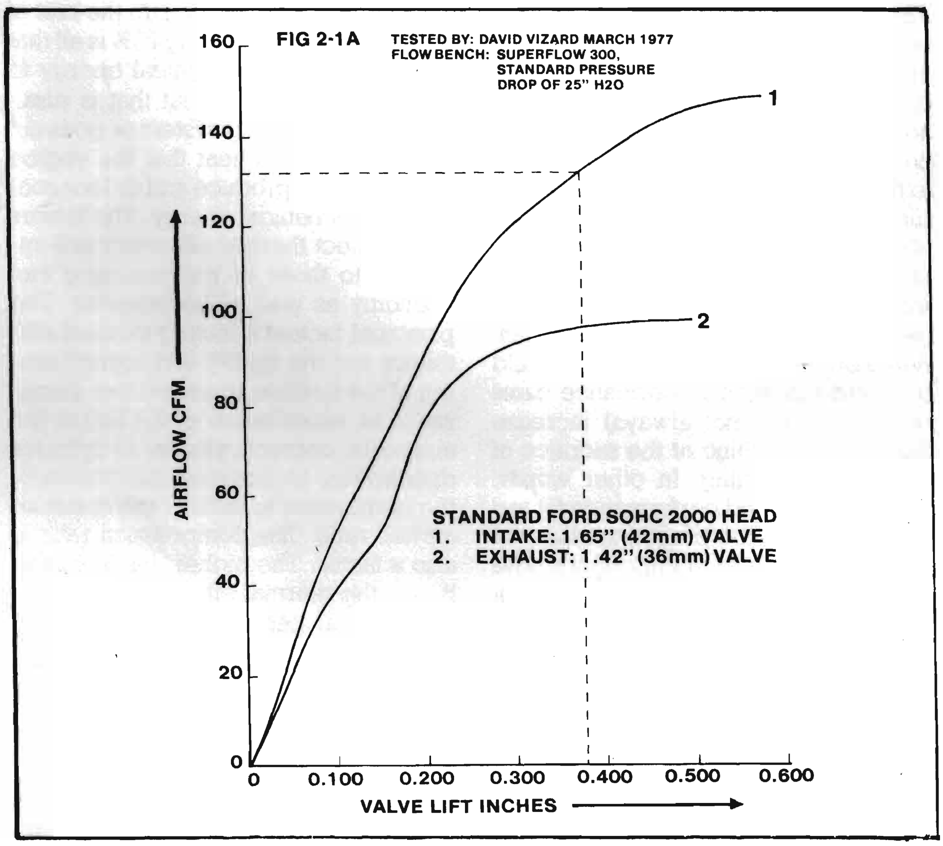
There is no doubt that cylinder head design is a very complex subject. It is often regarded by laymen as being a black art. As a result, many myths exist, and one of these is that polishing the ports is the trick to make a head work. Nothing could be further from the truth. *A polish does nothing to increase the power of an engine.* In fact on occasions it can reduce horse-power.

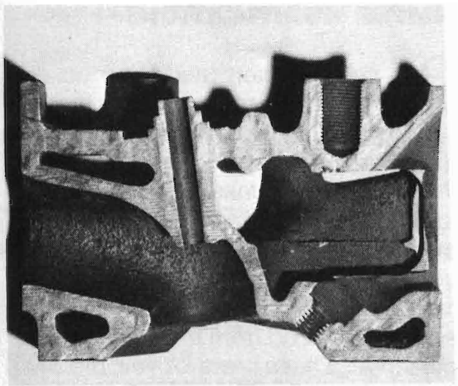
Another myth you should dispel, especially with the Pinto, is that big ports produce flow. They do not; an excessively large port will sometimes flow less air than a smaller one.

The most important factor in cylinder head development is shape. This is the most important consideration with any cylinder head modifications. The shapes of the ports, combustion chambers and valves dictate just how effective that cylinder head will be. If you intend to grind your own cylinder heads, don't worry about a polished finish. A rough-ground finish is usually entirely adequate.

THE STANDARD HEAD

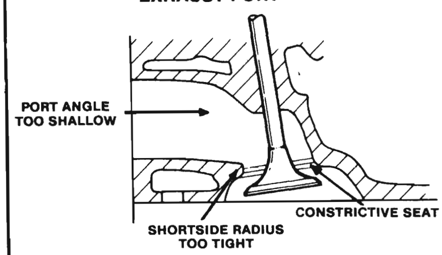
The first step toward improving a

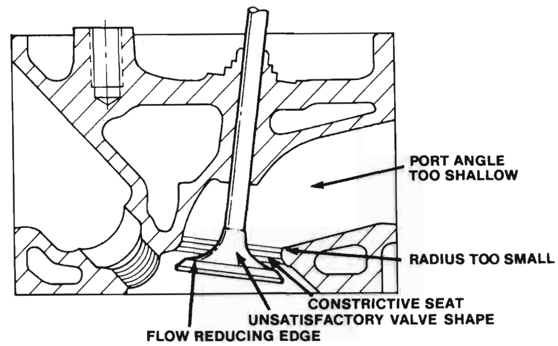




2-1. A section through an unmodified 2000 head reveals that if nothing else, the intake port has plenty of area.

FIG 2-1B





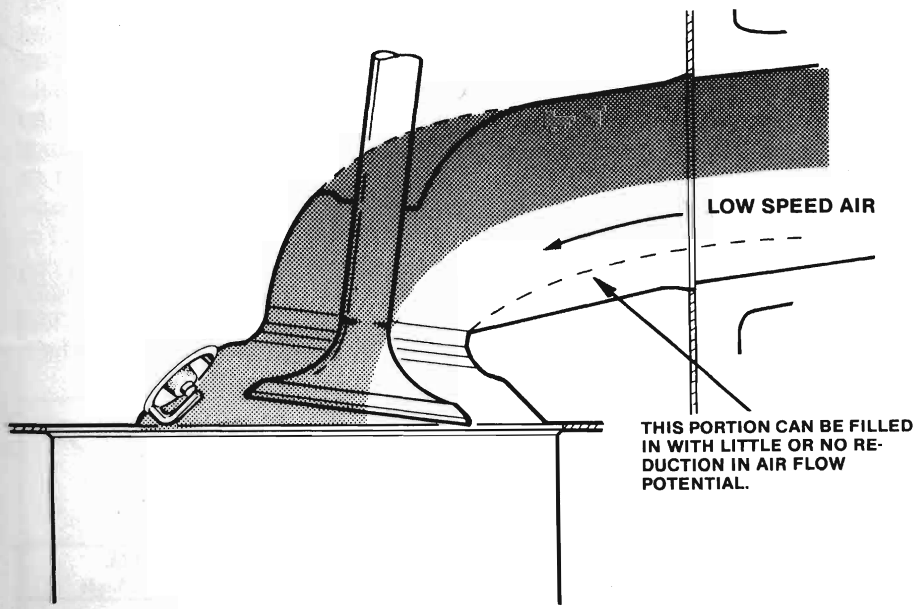


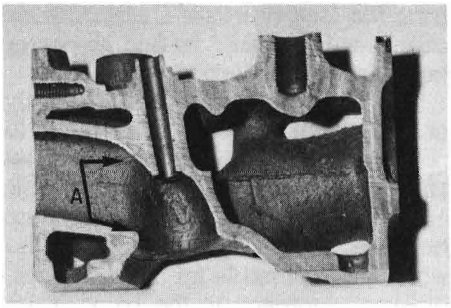
FIG 2-1C AIR FLOW PATTERN IN STANDARD INTAKE PORT

mechanical contrivance is to understand the nature of the device. To do this let us analyse the standard head in a little detail. Take a look at the graph Fig. 2-1A. This shows the amount of air that can be passed through the standard ports on a 2000 head. The dotted line starting on the horizontal axis of the graph is a typical maxium lift achieved with a standard camshaft. Follow it up until it meets the inlet flow curve. Then turn 90 degrees and follow it to the vertical axis. This indicates that the head flows 131.5 CFM at 375 thousandths lift. For a 1.65 inch diameter valve at this lift, this is not a very good showing. In fact the head, for all its promising looks, does not deliver the goods. As it comes from the factory it falls short on many counts as far as air flow and its power potential are concerned.

First of all, the valve seats, especially on the intake are very constrictive to flow. Secondly, the shape of the inlet valve is far from optimum. The port angle in the head is also disappointing, because it closely approaches the worst angle possible for flow. And last, the final approach to the back of the value is too short. In other words there isn't enough length of straight port behind the valve head to allow the air a more direct shot to the back of the valve. Interestingly, 1600 and 1300 heads don't suffer in this respect quite as badly as the 2000 head. Both 1600 and 1300 heads have shallower chambers and longer valves. This means the air can make a more favourable approach to the back of the valve, especially on the floor of the port around the tight turn just upstream of the valve seat. Fig. 2-1B shows the main restriction points. Apart from its breathing ability, the inlet port does suffer one other ailment: the port itself appears to be too large for the engine. The resultant slow gas speeds allow fuel to drop out of suspension easier than if the port were smaller. A study of the air flow pattern in the port reveals that most of the air flows at the top of the port, and the bottom of the port is almost redundant. Fig. 2-1C shows what I mean. Flow bench tests show that if the bottom of the port is filled in as much as ¼ inch, *almost no drop in air flow results.* Any modifications to this engine must be done bearing in mind that *fuel dropout* can occur. When fuel dropout takes place the engine will lose horsepower, economy and throttle response. Any changes which help produce a more homogenous mixture entering the cylinders will usually improve the engine's performance in these areas. Straight away this should tell us two things about these heads: enlarging the ports is definitely out, and polishing them is not a good idea because a coarse finish is more likely to reintroduce puddled fuel back into the airstream. A shiny finish will allow fuel to stay on the surface as a liquid or drops which will run into the cylinder and subsequently pass through the engine unburnt.

EXHAUST PORT

The exhaust port suffers many of the

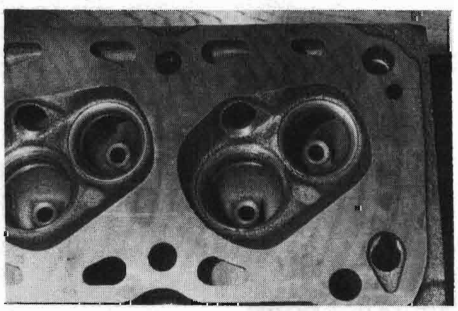


2-2. Too many abrupt changes in direction mean bad flow through the standard exhaust port. Arrows indicate the prime sources of inefficiency.

same ailments that the inlet port has. The valve seat geometry needs improvement. On the other hand, though, the exhaust valve shape, unlike the intake, is reasonably satisfactory. The exhaust port shape, however, is even worse than the intake port; its flow figures are way below those attainable by a highly developed port.

COMBUSTION CHAMBER

I am not suggesting this head is junk. Far from it. The factory designed the head to do a particular job, and this it does in a satisfactory manner. They did not design it for racers and for high performance it will need some redesigning. You may well ask if there is *anything* that doesn't need modifying? Certainly. The combustion chamber is a very good design and has many factors in its favour. Many production cylinder heads suffer from what is known as valve shrouding. This is the situation where, as the valve opens, the gap between the edge of the valve and the combustion chamber wall is insufficient to allow air out. On vertical valve engines, the cylinder bore will almost always cause shrouding. Although the Pinto engine has inclined valves, the inclination is not sufficient, nor is it in the right direction to obviate shrouding.



2-3. Valve shrouding caused by the unnecessarily close proximity of chamber walls to valve heads is all but non-existent on the standard cylinder head.

Unnecessary shrouding by the chamber though, is virtually non-existent. The only shrouding suffered is caused by the proximity of the cylinder walls and there is little we can do about that.

IMPROVING THE HEAD

The prime factor of an engine's power characteristics, be it a well developed unit or not, is the cylinder head. Because of this, I will deal in depth with head modifications and how they affect airflow. I will show precisely what modifications are needed to produce the required results.

Improving airflow is finding the right combination of shapes. Two head modifiers starting off with the same basic head casting may arrive at two different combinations of parts and shapes to produce compatible airflow figures. And importantly, trying to combine the specifications of one with the other may well produce worse airflow figures than you started off with. A more precise example: let's say that somebody develops a trick valve shape which really turns the flow on with a standard port. There is no guarantee such a valve is going to work in the same manner if the port is steeply downdrafted. It all comes back to *combinations* of shapes. In other words, don't reckon on producing a super trick head by using what may appear to be the best points of several different heads. More than likely, whatever you do will be worse, as this is not an easy head to improve upon. The only way to find out what will work for sure is by testing on the flow bench and dynamometer.

SIMPLE MODIFICATIONS

My policy, when modifying an engine, is always to try the simple modifications first in an attempt to extract the most for the least. In the category of simple modifications, we have such things as multi-angle valve seat jobs, removing sharp edges from valves, plus going into the port with a grinder and just taking off any flash marks or sharp edges produced from machining in the port. Well, I have news for you; the 2000 head does *not* often respond positively to such moves. In fact, the first week I spent on the flow bench with one of these heads produced a large number of negative results. Whoever designed this head, made it so you have to fight all the way to get any flow increase.

Let's consider those multi-angle valve seats that are often touted as the trick thing for a few extra horsepower for next to nothing. I tried such valve seats on brand new heads, and believe me, the usual result is reduced airflow compared with the standard 30, 45, 60° seat that Mr. Ford puts on the head. This doesn't mean we can't improve the head; it just means that an elaborate 75, 60, 45, 30, 15 seat is not what's needed. Take a look at the chart (Fig. 2-2) and you will see the typical difference between a standard valve seat and a multi-angle one. To be truthful, taking the sharp edges off the valve makes things even worse. If you do any grinding on the back of the valve, it must be a substantial 30° cut as shown in Fig. 2-3. For such a simple modification, as you can see from the graph, the flow was substantially increased. This led me to test many valve shapes to determine which

FIG 2-2

Comparison between standard valve seat and multi/angle seat.

Valve Lift In Inches	C.F.M. Standard	C.F.M. Multi/Angle
0.025	12.0	11.4
0.050	26.6	25.9
0.082	44.8	41.6
0.165	76.1	72.9
0.247	108.3	110.8
0.330	125.7	128.7
0.412	137.6	134.6
0.495	143.4	140.6
0.577	147.3	144.5

NOTE: **Standard width valve seat used in all tests. Test pressure drop 25" H_2O.**