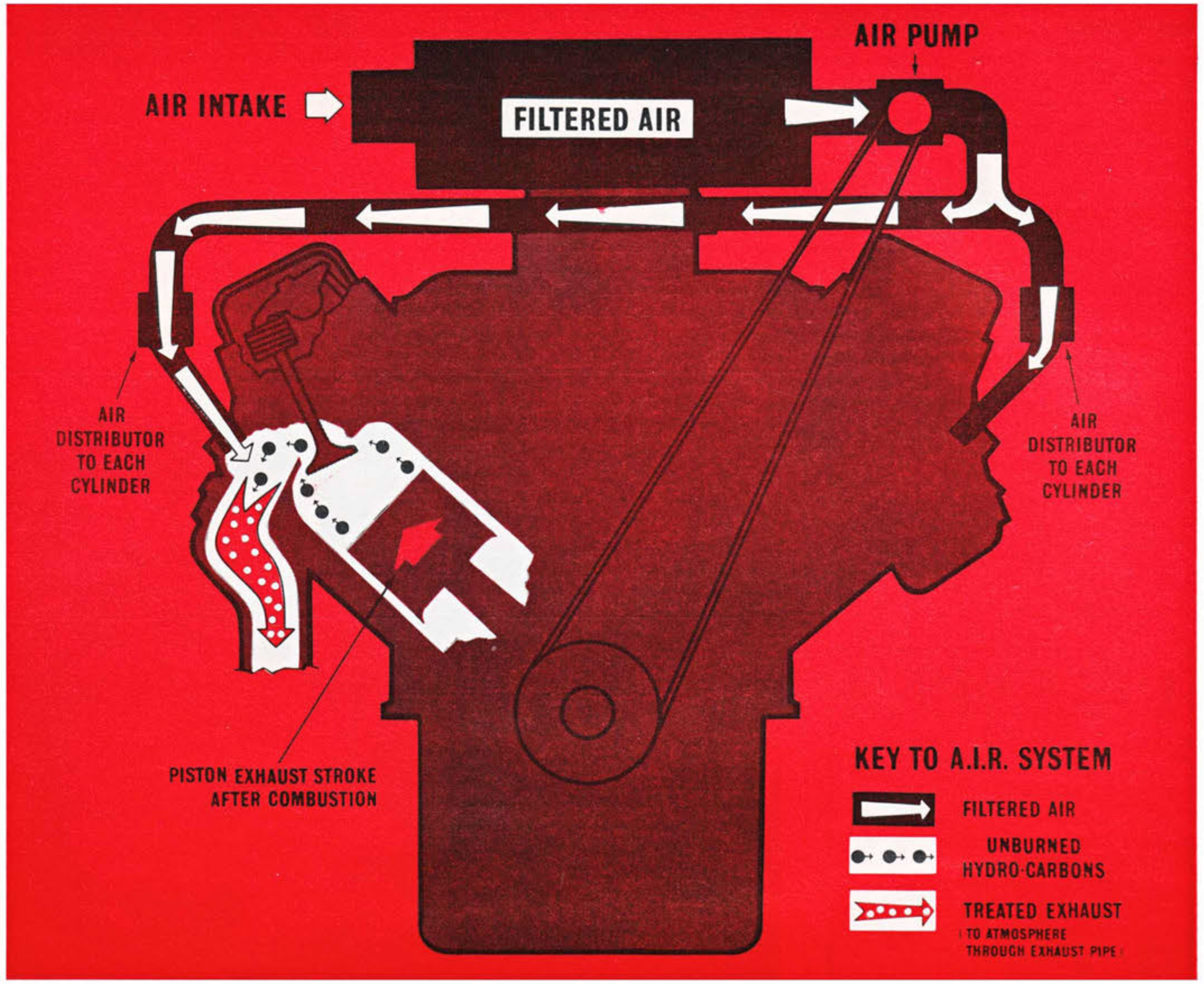


AFTERBURNER ACTION of GM air injection system is shown in this schematic diagram. Filtered air is pumped into exhaust ports to insure combustion in the exhaust manifold of hydrocarbons and carbon monoxide not burned within the cylinders.

SMOG vs. HORSEPOWER

Emission Controls May Reduce The Performance Potential

BY ALLEN HUNT

NEW FEDERAL laws to limit smog-producing automobile engine exhaust emissions could greatly affect performance of next year's cars.

Smog control has sneaked up on performance enthusiasts. The positive crankcase ventilation systems that came along in 1963 were a service nuisance but they didn't have any appreciable effect on brute performance. More sophisticated emission systems required on California cars since 1966 were of no concern to the majority of enthusiasts around the country.

Many still aren't aware that "California" systems will be required by federal law on practically all 1968 American passenger cars, in all states. The "problem" will become everyone's problem. The argument here is not whether these emission devices are necessary throughout the country, though this question has created a red hot controversy in several circles. Some Detroit observers say American car buyers are being taken to the cleaners by publicity-hungry lawmakers to the tune of $500 million a year, the approximate cost of the emission devices on full Detroit production. Smog people say it is necessary to reduce pollution for the sake of crops.

The important thing is that Washington says "go" on exhaust emission control. Detroit must comply. Carmakers know how to meet the new nationwide emission standards for '68, because they are identical to California standards which have been in force for the past two years. The problem is mainly one of refinement of the devices to make them just as simple, reliable and cheap as possible, then tooling up for mass production.

THE MAJOR concern, however, is the effect of emission control devices on road performance.

First the problem must be defined more closely. Right now the anti-air pollution people demand reduction in emission of unburned hydrocarbons, which are said to be a major factor in photochemical smog, and carbon monoxide, a lethal gas that results from incomplete combustion. A typical late passenger car, in normal city driving, emits 500-1100 parts per million (ppm) of unburned hydrocarbons in its engine exhaust, with usually 3-6% carbon monoxide (CO). The new federal law calls for reduction of emissions to 275 ppm of unburned hydrocarbons and 1.5% CO. Small foreign engines, under 140-cu. in. piston displacement will be permitted higher emission levels, as it's nearly impossible for these to meet standards that easily can be met by larger U.S. engines. It is apparent that Detroit must reduce exhaust emissions by 66%. Obviously more than a few minor modifications to the carburetor and spark advance will be required.

Essentially, the problem is one of incomplete combustion of the air/fuel mixture in the cylinders. Two general paths lead to solution of the problem. One is to design engines to produce more complete combustion inside cylinders. The other is to "afterburn" hydrocarbons and CO in the exhaust system after they have left the cylinder. Chrysler has followed the first path in meeting the 1966 California standards, with the Cleaner Air Package, mainly modifications to carburetor, choke and spark advance. GM, Ford and American Motors had no faith in this approach, hence they took the afterburner route, using belt-driven pumps on engines to inject pure air into exhaust ports, to provide extra oxygen to consume the hydrocarbons and CO in the exhaust pipe.

All manufacturers admit these current systems are only temporary solutions to the long-range emission problem. GM and Ford officials look down their noses at Chrysler's CAP, and state Chrysler was forced to lean down the carburetor to such an extent to meet the standards that many Chrysler Corp. cars don't have acceptable "drivability" characteristics. GM and Ford people say Chrysler products tend to surge and buck at low speeds, have poor warm-up characteristics and sluggish throttle response. On the other hand, GM's air injection system is much more complex and expensive than the CAP. List cost is about $45 vs. $25. There's more to go wrong with the belt-driven air pump.

Obviously, neither of the current emission systems will satisfy Detroit over the long haul, to put on 8 or 9 million cars a year for the foreseeable future. The current federal emission standards will be in effect at least through 1970 and from there on things may get even tighter. No haphazard solutions will do. Emission control already has become a major factor in Detroit engine design, along with the classic considerations of performance, fuel economy, smoothness, light weight, low cost and durability.

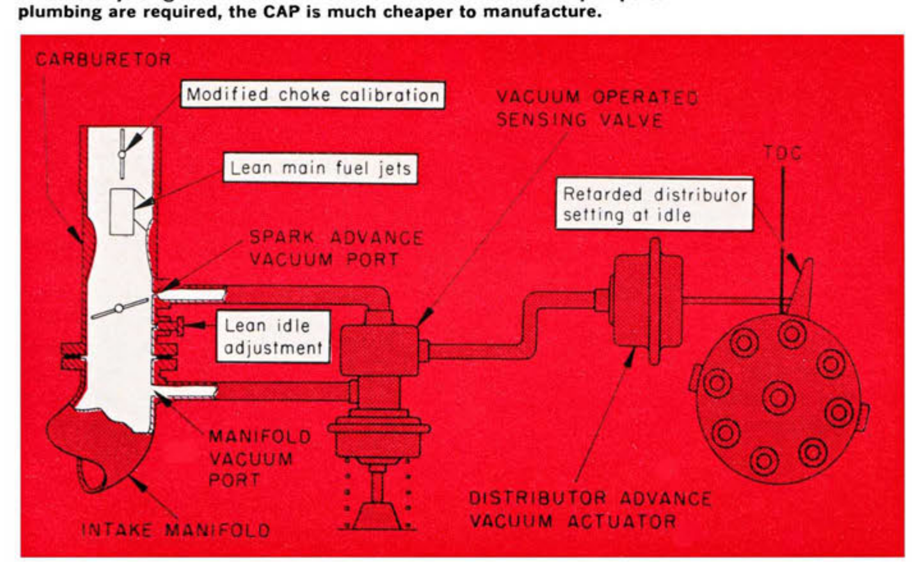
Detroit emission authorities agree the immediate answer, at least for the next three years, will be fairly simple modifications of existing basic engine designs, but not necessarily as simple as those in the current Chrysler CAP system, which is generally agreed to require too lean carburetion. Many 1968 models from GM Ford and AMC still will use the air injection system, but this approach will be used on fewer and fewer cars as time passes. By 1969 air injection probably will be confined to limited production models that have especially tough emission reduction problems. The mass produced models will solve their smog problems inside the engine.

Design modifications will involve coordinated adjustment of spark advance, carburetion and choke calibration, including inlet air temperature control, and a lower surface-to-volume ratio in the cylinder.

LATE MODEL American cars have their distributors arranged to produce full vacuum spark advance at idle. With the recommended initial spark lead on the distributor setting, this gives total spark advance at idle of 20-35° of crank travel before top center. This high idle advance delivers a somewhat rough idle and induces much more rapid combustion under exhaust gas dilution conditions. This greatly reduces the heat rejection to the coolant during idle and has made it possible to use smaller, lighter radiators on cars, and has improved performance from air conditioning systems. It was a clever breakthrough. The trouble is that high idle advance doesn't induce complete combustion. Emissions are high during idle and when the car is decelerating with closed throttle. Engineers have discovered that these emissions could be greatly reduced by retarding the idle advance to top center, or even 5-10° after TC. This produces a bit better combustion of the thin idle fuel mixture, but the throttle must be cracked open farther to maintain a given idle speed. This gives better mixture distribution and less exhaust dilution. Combustion is much more complete.

The 1968 models will have a special "ported" spark advance, with the vacuum take-off above the throttle plate so no vacuum advance occurs when the throttle is closed. In addition, the centrifugal advance system will be modified to allow a retard of 0-10° ATC at idle, and still provide full advance for maximum power at high speeds. Idle will be a bit smooth- ▶

CHRYSLER'S CLEANER Air Package uses retarded spark at idle, leaner carburetor jetting and modified choke calibration. Because no pumps or plumbing are required, the CAP is much cheaper to manufacture.



SMOG

er, but full-throttle power won't be sacrificed. Emission of unburned hydrocarbons and carbon monoxide will be reduced. The price will be a larger, heavier radiator that will cost more money, and possibly a stronger fan running at higher speed to move more air through the radiator at low speeds. This fan will absorb additional bhp at high speeds, but perhaps a special de-clutching fan will be used. The new emission systems probably will employ de-clutching fans as standard equipment on many cars. The "retarded" engine will burn more gasoline at idle and when coasting.

Carburetor calibration is mainly a matter of leaning the air/fuel mixture as much as possible without creating surging, bucking and poor response. Automatic chokes can be adjusted to open more quickly. Actually, little can be done by simple jetting changes. Carburetors already are nearly as lean as they can be and remain part of a drivable product. That Chrysler engineers accept drivability compromises not acceptable to GM and Ford engineers is the reason the CAP system meets current California standards. GM and Ford don't want to go this far, now or in the future. Chrysler carburetion may become richer in the future, too, if other simple engine modifications can be used to meet emission control standards.

GM HAS ANOTHER idea that may be an important factor here. This is Oldsmobile's new "Climate Combustion Control" system to feed warm air to the carburetor. This is an arrangement of vacuum-operated shutter valves in the air cleaner housing that automatically mixes hot air from a muff around the exhaust pipe with warm underhood air to maintain a constant 100-110° F temperature at the carburetor inlet. This permits the carburetor to be jetted strictly for the 100° air temperature—rather than the usual richer jetting necessary to allow for the 20-30° F underhood air temperatures in winter weather. Lean jetting delivers up to 1 mpg better fuel economy and, in normal operation, reduces exhaust emission by 50%.

Oldsmobile's hot air system, with the help of a ported distributor to reduce idle spark advance, recently passed California emission tests on the 1967 425-cu. in. Olds engine. At first glance this seems a fairly simple package to meet the 1968 federal standards without sacrifice in drivability. Indications are that other GM divisions, and possibly Ford, will develop similar systems for certain '68 models. The cost of the hot air system is less than the price of an air injection system.

Even this simple hang-on system is not attractive to economy-minded Detroit engineers, however. They desire to solve the problem inside the engine. Thus it becomes necessary to discuss the surface-to-volume ratio of the combustion chamber because the entire combustion process is completed when the piston is within a few degrees of top center. To put it simply, the minimum amount of surface area in the chamber, in relation to the volume is most desirable because the thin layer of fuel/air mixture next to the surface of the chamber simply does not burn. There is no way to make it burn. The mixture is chilled by the relatively cool chamber wall and the flame front is quenched when it reaches this mixture layer. The fire is extinguished. Even in air-cooled engines, in which chamber surfaces are nearly twice as hot as in liquid-cooled engines, a thin layer of mixture next to cylinder walls does not burn.

The obvious solution is to design combustion chambers for minimum surface-to-volume ratio. There are several ways this can be done. Surface area is proportional to the square of chamber dimensions, while volume increases as the cube of these dimensions. This immediately shows that large cylinders have a lower surface ratio than small cylinders because the area is increasing as the square, while volume goes up as the cube. The larger the engine the easier is emission control. Exhaust emission control efforts may bring 500-cu. in. engines to American cars more quickly than any other circumstance.

The stroke/bore ratio is a vital factor in surface-to-volume ratio. Combustion chamber surface area, like cylinder wall area, increases as the first power of stroke length, but as the square of the bore diameter. A longer stroke and a smaller bore produces less chamber surface. Thus, a strong trend to longer stroke engines throughout the industry in the next few years can be anticipated. Already Ford's new 410- and 428-cu. in. engines have unusually high stroke/bore ratios. Buick's new V-8 was designed with huge main bearings, so stroke length can be increased in the future without changing bearing sizes. Chevrolet will use the 327 crankshaft in the 283 block next year to produce an engine of 307 cu. in. The short-stroke 283 will be eliminated. The longer stroke will reduce exhaust emission and increase torque. Oldsmobile's 400-cu. in. 4-4-2 engine for 1968 will use the longer stroke crankshaft from the 425 engine, with the bore reduced to maintain 400-cu.in. The reduction in surface-to-volume ratio has an important effect on emissions.

A lower compression ratio aids the surface-to-volume ratio because it increases the volume of the chamber and volume increases at a faster rate, with increased dimensions, than does surface area. The shape of the chamber also has a significant effect. Hemispherical chambers with dished pistons offer the minimum surface-to-volume ratio. Conventional wedge-shaped chambers offer a greater ratio. Of course, a great deal of quench area over the piston is not desirable with the wedge chamber. The quench area is designed to intentionally chill the part of the fuel charge that is last to burn in order to control detonation at high compression ratios, but it is a headache because it leaves that much more unburned fuel in the exhaust.

THE OVERALL effect of increasing surface-to-volume ratios is very likely to be significant decreases in engine performance. A longer stroke increases engine friction and reduces rpm potential. Reducing the compression ratio harms performance. Carmakers have not yet reduced compression on specific engine models to meet California emission control standards, but they may be forced to do so with engines that tend to emit high levels of air pollutants. Compression ratio could be maintained with a reduction in quench area, but this might require higher octane fuel to prevent detonation and rumble. Many current engines are right on the edge of available octanes now. The petroleum industry may be forced to come to the rescue.

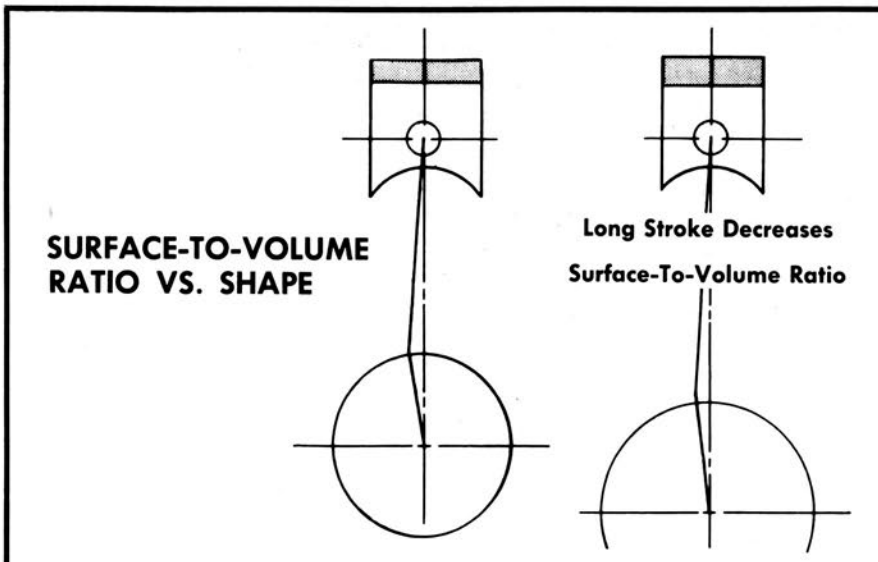
Detroit can improve performance in the face of these new emission laws, but can carmakers hold their own? There are some bright spots in the picture. For example, GM's little air pump for the air injection system, to be used on many 1968 models, absorbs only 2-3 bhp. This isn't a huge loss on a 300-bhp engine. Lean carburetion and modified spark advance systems apply only to part-throttle operation. Government emission tests for each engine model are run on chassis dynamometers with a cycle of operation that simulates normal city driving. There is no full-throttle operation. Thus full-throttle carburetion and ignition calibrations can remain as they are at present. Oldsmobile has seconded this motion by designing its hot air system so the hot intake air is automatically shut off when manifold vacuum drops below 6 in. Hg. Cool underhood air is drawn into the carburetor at wide-open throttle.

There is also some fine print in the federal emission control law that could be a loophole for special high-performance models. It says merely that specific engine models that represent less than 12.5% of the total production of that particular displacement size will not be required to undergo the emission tests. The purpose of this ruling is to reduce the number of specific engine models that must be tested each year, but it could allow some limited-production high-performance models to slip through. For example, the 325- and 350-bhp versions of Chevrolet's basic 327 engine would not represent 12.5% of the total production of 327 engines, so would not be required to meet emission control standards. Likewise Chrysler's 235-bhp version of the small 273 V-8 would escape testing, as could Pontiac's 360-bhp Ram Air version of the 400-cu. in. GTO engine. Ford's 335- and 360-bhp versions of the utility 390 block could go untested.

It is not to be said that these particular engines would not meet the emission control minimums as manufactured, but some federal tester won't be saying the company can't sell these engines because they do not meet standards. There will be no tests.

Detroit will just about hold its own on performance of 1968 models, with the new emission systems. There won't be significant gains or losses in the various classes of cars. Beyond 1968 it is unwise to speculate. A 1964 Cadillac was modified by GM to meet the new emission control standards. These modifications consisted of lengthening the stroke 0.25 in.; increasing piston displacement from 429 to 456 cu. in.; reducing compression ratio from 10.2 to 9.0, which had the combined effect of reducing surface-to-volume ratio from 6.4 to 5.7 sq. in./cu. in.; and installing special retarded spark advance and lean-limit carburetion. The extra displacement compensated for the reduced compression, so the 0-60 mph time remained constant at 10.2 sec. But, as might be guessed, fuel economy suffered. Simulated city mileage dropped from normal 12.5 mpg to 11.9 mpg with emission control equipment. Highway mileage dropped from 14.1 to 13.2.

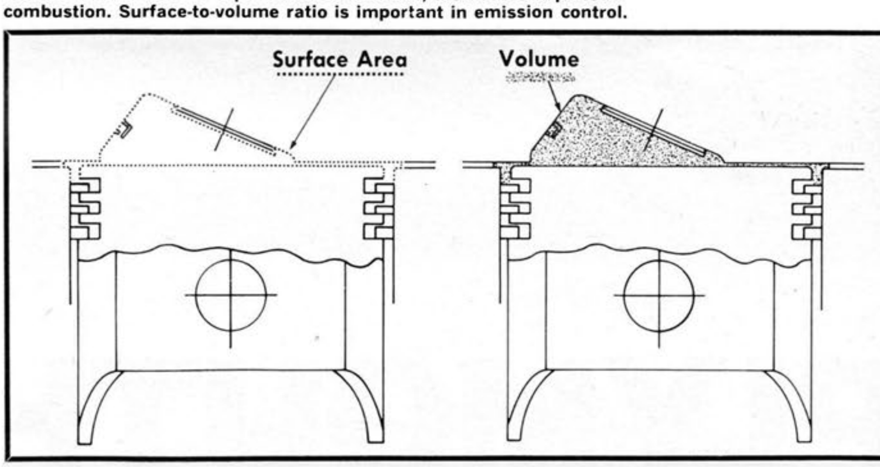
THERE'S THE bad news. Factory models with 0-60 times in the 5-6-sec. range will be available in 1968, as they are now. Whether Detroit can maintain past rates of performance improvement and development over the next few years absolutely cannot be predicted. ■



Displ. Per Cylinder	41	—=→	41
Bore	4		3.62
Stroke	3.25		4
Stroke/Bore	.813	—≠→	1.105
S/V	8.0		6.1

SMALL BORE, long stroke means lower surface-to-volume ratio. Shown are chambers with different bore/stroke ratios, but with like displacement.

THE LESS surface area exposed to fuel mixture, the more complete is combustion. Surface-to-volume ratio is important in emission control.



CHAMBER SHAPE influences surface-to-volume ratio. Drawings compare four shapes in terms of surface area in sq. in. per cu. in. of volume. The hemispherical chamber with the dished piston emits fewer air pollutants.