Cutaway shows ball bearing planetary drive. Torque is transmitted by the rolling friction of five steel balls pressed between inner and outer races. Note outer race is split and spring loaded for constant frictional pressure.

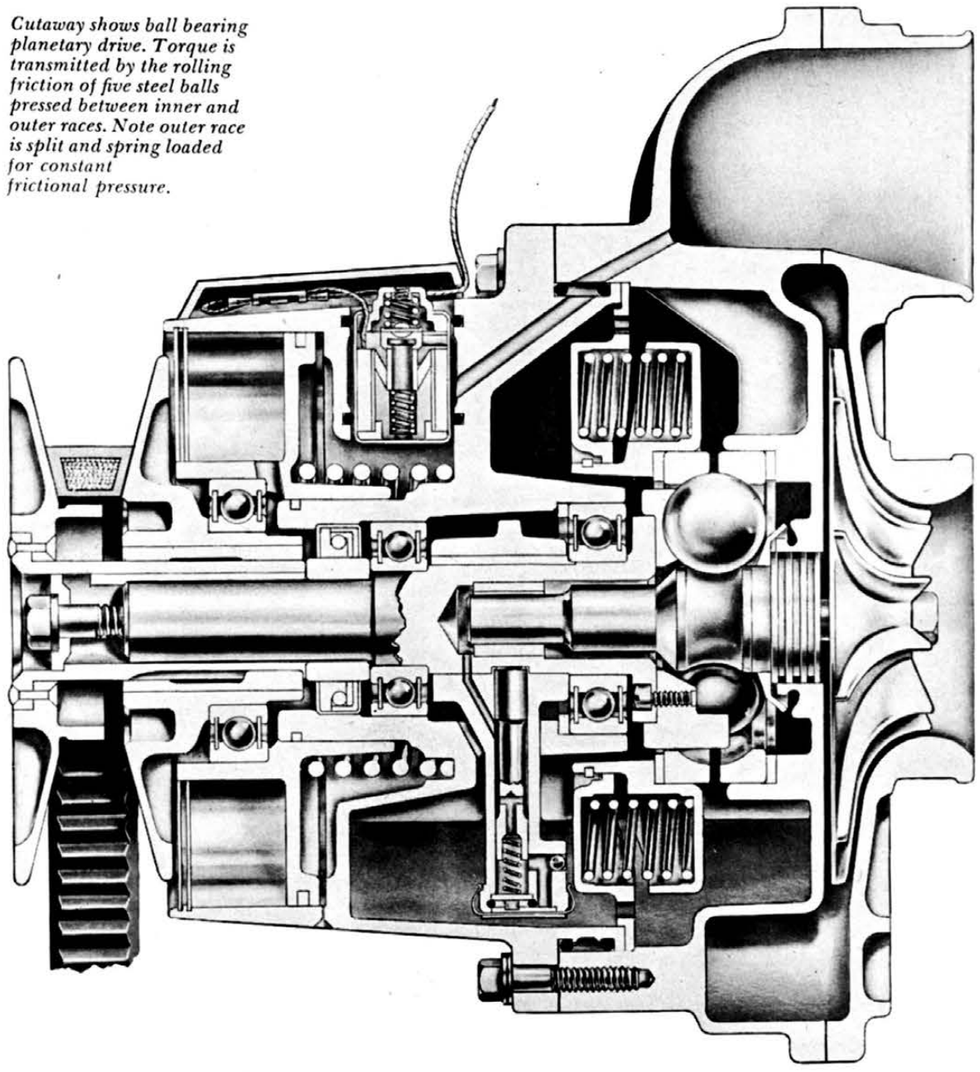
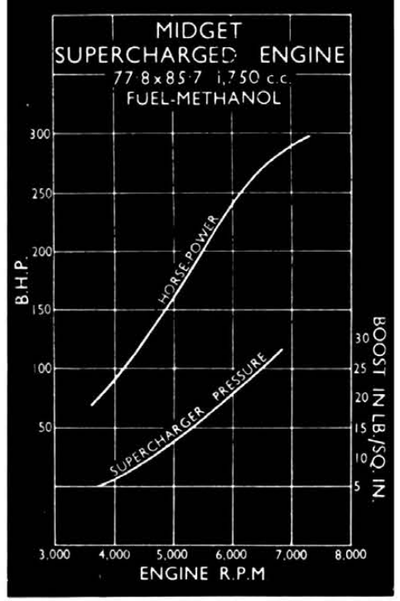
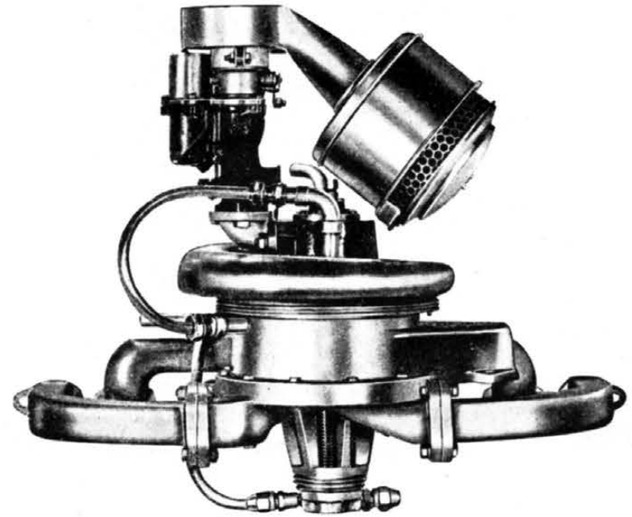


Photo courtesy of McCulloch Motors Corp.



Graph shows the boost pressure and corresponding power output of a supercharged Offenhauser midget engine — nearly 300 hp at 7000 rpm.



Early Besasie-Chevrolet exhaust-turbo supercharger designed by Besasie Engineering Co., utilized exhaust to turn impeller relatively faster than low engine rpm to make up pressure loss at slow speeds.

Supercharging the RIGHT Way

PART I

By ROGER HUNTINGTON, SAE

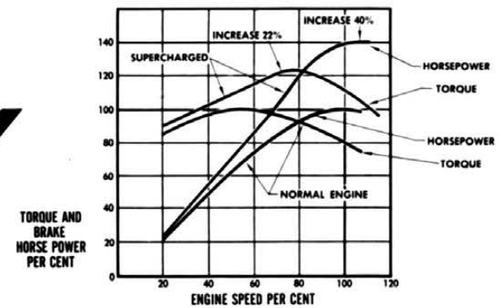
SUPERCHARGING is an *absolutely necessary evil* if you're after the ultimate performance with a piston-engine automobile. There are no two ways about it.

All the quickest cars in the world have for many years — and still do — feature pressure induction. The world-record 400-mph Railton used two blown aircraft engines. The Auto-Union's world acceleration records for the standing kilometer and mile are not apt to be broken by an unblown car. It took 15 lbs. per square inch boost pressure and 700 hp in an 1800-lb. car to set them. Goldie Gardner could never have pushed his 66-cu. in. MG Special over 200 mph without a supercharger. The latest scourge of the California drag strips — Ernie Hashim's "thingie" — is running a big Roots-blown, 600 hp Chrysler Firepower. As this is written he's turned an elapsed time of 9.1 seconds and top speed of 153 mph on the standing quarter!

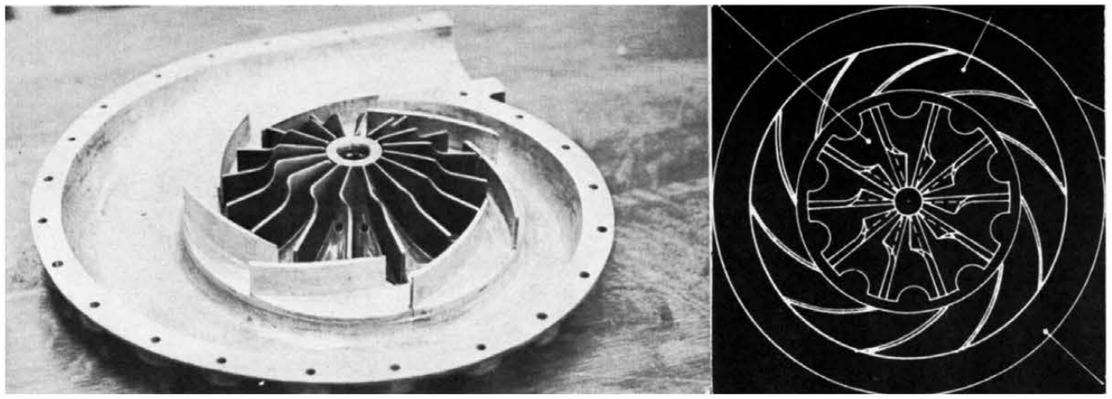
Let's state right off that there's no substitute for a good supercharging system. The theory is very simple: The power output of any internal-combustion engine is a function of the amount of heat that can be released from the fuel and converted into pressure on the piston heads per minute. It makes no difference whether you boost this heat release by packing fuel-air mixture into the intake manifold under pressure, or whether you "supercharge" the air supply by using an oxygen bearing fuel like nitro-methane . . . except that the ultimate horsepower potential is always much more with pressure induction because of the weight of the compressed charge. Supercharging is definitely the answer to super performance.

But now let's speak very frankly for a moment. It is well known that supercharging has never been a really popular hop-up trick among performance-minded American auto enthusiasts, either in the hot rod, sports car, or "Detroit" field. It has never been exploited by large car manufacturers who had the money and facilities to develop it. Anticipated wide use of the brilliant McCulloch design as optional equipment on some Detroit models has so far failed to materialize. And for that matter, we've done very little with supercharging on our American *competition* cars.

So how come? If supercharging is the answer to super performance, certainly performance is an important enough selling point these days to create a demand for it. The fact of the matter is that supercharging has been spending the last 25 years earning a *bad name* for itself on this side of

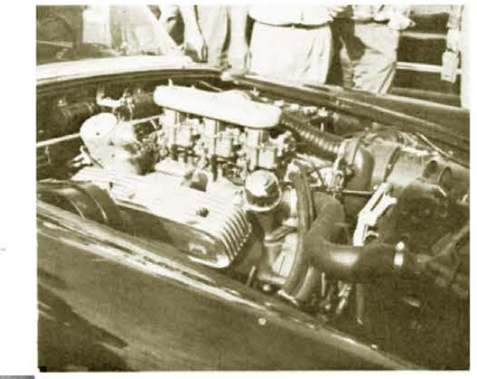


ENGINE PERFORMANCE COMPARISON



Impeller assembly of aircraft centrifugal supercharger converted for use with high-output automotive engine (400 hp.). Air enters above vanes and is centrifuged against diffuser blades and into spiraled outlet collector duct.

Several adaptors are now being produced by McCulloch for dual four-barrel carburetors. But engine size and horsepower are critical factors which determine the amount of boost that can safely be extracted from the blower.



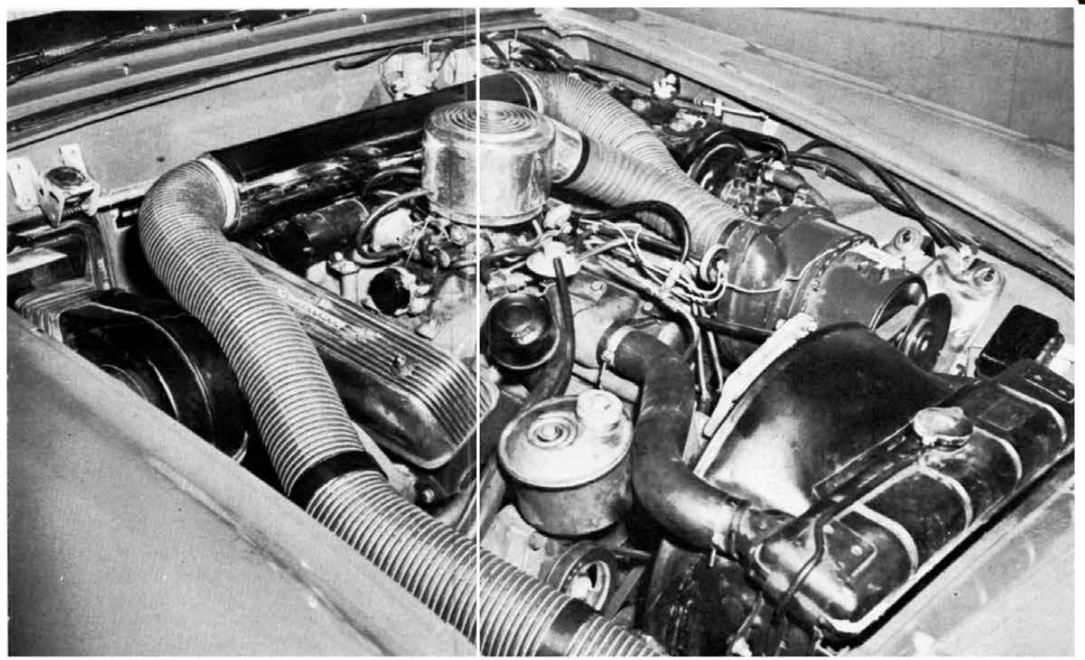
Here a McCulloch is hooked to a hand-made adaptor which links three Holley two-throat Carburetors in an Edelbrock triple manifold mounted on another Ford T-Bird. Obviously this setup needs heavy duty drive.

the Atlantic. A supercharger is a gimmick that requires a lot of babying and a lot of understanding to stay healthy. It's not something like a hot coil or a dual-carb manifold that you can bolt on and forget. A blower requires regular attention and some degree of driver care in its use. The European motorist is happy to accept plenty of compromises if he can get a 0-30 mph time of 5½ seconds out of his little 60-cu. in. crackerbox.

Not so over here. To 95 percent of the American motorists a car is no more a plaything than a refrigerator or lamp – and it's not expected to demand much more attention. If an accessory like a blower won't run, say, 30,000 miles without causing any trouble and practically without being looked at, and under all kinds of driver abuse, it just isn't considered "practical." Unfortunately, no supercharger yet built – not even the highly-developed McCulloch – is in this category. Goodness knows the old "Supercharger" cars – the Grahams and Auburns – weren't. Remember how the Graham blower would chew up shaft bushings and start sucking oil out of the crankcase by the quart? Remember the noisy roller drive on the Auburn blower? These rigs didn't help to earn a good name for supercharging in America.

Well, this is all a round-about way of saying this: if you're not ready and willing to *baby* your supercharger – put a little time and effort into regular maintenance (and never *neglect* that maintenance) – use a little discretion on the throttle and gear shift end of the deal – and accept a few compromises in general operation, like more noise, fuel and oil consumption, more frequent plug changes, etc. . . . then better forget the whole thing. Maybe some day we'll have a sealed blower unit that you can exchange every 50,000 miles or so, that won't make a whisper of sound, won't make any unreasonable plug demands, won't require belts. Until then . . . well, as I said; just get ready to learn the care and feeding of a new gimmick!

And there's another thing: A supercharger, even if properly nursed, is no performance cure-all. I've seen run-of-the-mill supercharged jobs blown off by well-tuned and driven standard versions of the identical model at more than one



McCulloch installation on Ford Thunderbird. Intake filtering is important to reduction of air whistle on blower inlet side.

drag strip or airport road course. And it doesn't take a "full house" of the more conventional hop-up tricks, like hot cams, dual carbs, overbores, milled heads, etc., to stay with a properly-set-up supercharger kitted car. A lot of fellows expect too much of their $250 blower kit. After all, a 5-lb. manifold boost pressure, after you deduct the power required to drive the blower, is about equivalent to a "full-race" road cam grind, a slight raise in compression ratio, and a doubling of carburetor capacity – at least at the peak horsepower point. Torque at low and medium rpm would probably be more with the blower, giving more snap on the highway and around the road courses; but in most forms of all-out auto *competition* high-speed power is usually the deciding factor.

Look at it this way: A supercharger is just another piece of hop-up equipment, to be used alone *or in combination* with other items of speed equipment. A blown engine isn't going to die – or come apart – if you give it a little help with a hot cam, stroker, or some extra carburetion. It'll go better. It's when you combine pressure induction with just the right amount of cam, carburetion, compression, spark advance, and a dozen other "criticals" that . . . well, you should've been in that blown T-bird I rode in the other day! Experiences like that make me quite confident that supercharging offers a lot more future than nitro.

Now that we've cleared up a few things, let's get down to cases and see what's available and what we can use in the three general types of supercharger – the centrifugal, the Roots type, and the rotary-vane blower:

CENTRIFUGAL SUPERCHARGERS

The only centrifugal-type supercharger being produced at present for passenger cars is the McCulloch. Complete "bolt-on" kits are available for practically all late U.S. cars, plus a few trucks and popular foreign cars (see tables). Junkyards and basements and garages of auto enthusiasts can still yield a number of defunct models. Graham had supercharged models in their catalog from 1934 through '41; Auburn offered blown models in '35 and '36, and Cord offered this same basic supercharger unit on their front-drive V-8 in 1937. Several accessory companies have produced centrifugal blowers in limited numbers as a bolt-on

(Continued on page 58)

Supercharging

(Continued from page 27)

accessory for certain popular car models in the last twenty years. McCulloch had one for pre-war Ford and Merc V-8's. The Besasie Engineering Co. of Milwaukee put out a very few exhaust-turbine-driven centrifugals for Ford, Chev, and Chrysler products about six years ago. And the Frenzel Engineering Co. of Denver produced a vertical, belt-driven centrifugal blower for the Ford-Merc V-8 around 1950.

Actually, you're not going to have a wide variety of equipment to choose from in the centrifugal field. The Detroit stuff has been out of production for many years, and units in decent shape are scarce. Besides, none of those blowers had either the capacity, efficiency, or durability to satisfy our requirements today. Both the Auburn-Cord roller drive and the Graham worm drive look doubtful, especially in view of modern accelerating loads.

Chances for using defunct specialty blowers look even worse. They're very scarce. I would be surprised if over 25 Besasies and over 300 Frenzels were ever produced. You still see a few old McCullochs knocking around . . . but from the efficiency and durability standpoints, these would be no more promising to invest time and effort in than, say, an old Graham unit. Frankly, about the only one of all the above-mentioned defunct centrifugal units that shows any promise is the Frenzel. It had a rugged gear drive and plenty of impeller blade tip width, and it seemed to be quite efficient from the air-flow standpoint. We'll confine our discussion below to this and the current McCulloch design.

HOW A CENTRIFUGAL WORKS

A centrifugal supercharger is nothing much more than a very efficient fan. You have a flat "impeller" disk with a number of radial blades on one side rotating in a casing. Air enters near the hub of the disk, is scooped up by the blades and whirled; centrifugal force pulls the air toward the outside edge – where it jets off into the outlet collector duct at very high velocity. It is this velocity that builds up pressure in a centrifugal supercharger. In the new McCulloch layout, for instance, an impeller tip speed (approximately equivalent to the air velocity leaving the wheel) of 720 ft. per second builds up about 5.2 lbs./sq. in. gauge pressure. (This pressure figure is influenced by the shape of impeller blades, width at the tip, size of blower inlet pipe, shape of outlet duct, etc., as well as the impeller tip speed – though the tip speed is by far the most important factor.) Obviously this high tip speed required is going to mean very high rotational speeds for the impeller. Automotive centrifugal superchargers generally turn between 20,000 and 35,000 rpm to develop their rated pressure!

Now, since pressure here is more or less a function of the impeller tip speed, basic physical law says it will *vary* as the *square* of that speed. (It's the same general principle that pours *four* times as much heat into your brakes when you stop from 100 mph as when you stop from 50.) Similarly, if we cut our impeller in half, we divide the pressure output by four. This points up the basic weakness of the centrifugal supercharger . . . its pressure output drops off rapidly as impeller speed is reduced. If you drive the impeller at a fixed speed ratio in relation to crankshaft speed, and select this ratio to keep from overboosting in the 4500 rpm range, then your blower is practically useless to you below 3000-3500 rpm. The blower will be just so much excess drag at low speed.

McCulloch is the first manufacturer who has successfully done something about this problem. (They don't have the "ideal" blower yet, but it comes a lot closer to the ideal pressure curve than anything else around.) They have rigged a clever *variable drive ratio* on their blower unit. The outer flange of the blower V pulley is moved in and out to change the effective diameter, and therefore change the impeller speed ratio. Blower pressure acting against a spring-loaded piston provides the force to move the pulley flange, and this pressure is cut on and off by a pressure-sensitive solenoid valve. (This valve only regulates at full throttle; at cruising load you have, in effect, a constant-ratio blower.) Overall result is that we get a constant pre-selected boost pressure over a speed ratio range of roughly 1.7:1. Most standard McCulloch kits have pulley sizes selected to give about five lbs. boost at full throttle from 3000 to 5000 rpm. Below 3000 the pressure falls off just like a fixed-ratio drive.

This high supercharge pressure over a wide rpm band gives the new McCulloch a tremendous margin in overall road performance over any other type of centrifugal supercharger. You can start to feel its effect as low as 1500-2000 rpm, and by 3000 you've got a whopping boost in torque. This is so far superior to any other centrifugal blower that's ever been on the market for road cars that there's no comparison. And for that matter, even other types of superchargers that feature high boost at low speed cannot match the *overall* performance of the McCulloch without going to a considerable higher peak boost pressure, with its attendant problems.

Now let's look at the Frenzel and McCulloch blowers more closely. . . .

THE FRENZEL SUPERCHARGER

If you can find one of these for a reasonable price, I think it might offer possibilities for some interesting experiments. The air volume and pressure output appear to be good. At the rated impeller speed of 24,000 rpm (790 ft. per second tip speed) and pumping approximately 20 lbs. of air per minute, it developed six lbs. pressure when drawing through two Ford-Stromberg 97 carbs. Early models used ¾-inch helical teeth (ratio 4.14:1) to reduce noise. Both setups were positively lubricated by engine oil pressure. It was a very rugged gear train, though noisy in both cases. A quick slide rule check of the gear train and impeller stresses suggests a maximum safe impeller of not over 30,000. (Even then, I wouldn't guarantee the life of the unit beyond four or five hours continuous running.) This speed should yield a boost of about nine lbs. with two 97 carbs . . . which is a "very useful boost," as the Britishers would say.

The standard Frenzel-Ford kit used a belt pulley ratio of 1.4:1, so you would hit 30,000 rpm of the impeller at about 5200 rpm of the engine crankshaft. This is above the maximum safe continuous speed of the engine, so there would be no danger of overspeeding the blower on the road. This 1.4:1 belt ratio is recommended for road installations. Only if you wanted to use the blower on a moderate-size competition engine designed for crank speeds of 6000-7000 rpm would it be imperative to lower the drive ratio. At, say, 6500 rpm crank speed it would require a belt pulley ratio (or gear or chain ratio) of about 1.15:1 to put the impeller at 30,000.

McCULLOCH

The current McCulloch centrifugal supercharger design is a beautifully engineered piece of equipment. It's relatively efficient from the air flow standpoint, quiet, extremely responsive to the throttle on the road due to the "stand-by" boost feature, and the whole unit appears to be quite durable in terms of thousands of miles of every-day driving.

Its "Achilles Heel," so to speak – or the point where you've got to baby it a little – is the unique ball-bearing

planetary drive. As you may know, the principle behind this speed ratio step-up device is the same as that of a planetary gearset, except that instead of transmitting the torque through gear teeth, it is transmitted by the rolling friction of five steel balls pressed between inner and outer "races." The input drive is through a cage that also locates the balls. Friction is produced by spring-loading the stationary split outer race.

Now there is always a certain amount of slip or *skid* between the balls and races, and this slip increases with the horsepower being transmitted. When the slip exceeds about two percent (when rubbing speed is two percent of rolling speed) temperatures shoot up, the oil film breaks down . . . and you've got a $150 repair bill on your hands. McCulloch now has two drive capacities for this ball drive, the difference being in the coil spring compression on the outer race. The standard drive is for engines consuming less than 1600 lbs. of air per hour (equivalent to about 210 hp), and will handle about 17 hp. For larger engines a Heavy-Duty drive will transmit 21 hp before slip becomes excessive.

This is a round-about way of saying that *it's all too easy to burn up this cute little ball drive on your McCulloch blower!* It's all a matter of the relationship between engine air consumption and blower air output. Look at it this way: At a given impeller speed the air flow through the supercharger is going to depend on how fast the engine is gulping down the air on the other side. At the same time, the impeller and air ducts can be designed to reach maximum efficiency at only one air flow point. The pressure output will be highest at that point, and will fall off somewhat with lower *and higher values* of air flow.

To illustrate: At the rated 29,000 rpm impeller speed the standard McCulloch will pump 23 lbs. of air per minute at a gauge pressure of 5.2 psi. This air consumption is equivalent to about 200 hp. At this point it requires 13 hp to drive the blower. Now if you turn the impeller at 29,000 rpm on a small engine that develops only, say, 100 hp, the air flow through it will be only 12 lbs./min.; then the boost is down to 4.9 lbs., and horsepower required is only eight. On the other hand, if you hook a big engine onto the McCulloch and turn the impeller 29,000 rpm the air flow and power consumption shoot up. At 35 lbs./min. air flow – equivalent to 280 hp – the boost is 4.4 lbs., and 17 hp is needed to turn the impeller. This is right on the ragged edge for the standard drive.

So it's obvious that engine size and

(Continued on page 60)

The Real Cost of a Sports Car

IT ISN'T the initial cost or even the upkeep that flattens the bank account of the sports car owner. Instead it's those hidden costs. We offer in evidence the poignant record of our office accountant, a systematic and orderly type.

The first entry was written in a firm, sure hand.

1956 . . .		
May 1 - 8	— Expenses for old auto while shopping the foreign-car lots	$ 2.91
May 8	— Flowers for wife to introduce subject of bargain TC just found	2.50
May 8	— Evening at O'Brien's bar after argument	4.75
May 9	— Dinner for wife to lure her by car lot to see TC	7.75
May 10	— New hairdo for wife after demonstration ride	4.00
May 10	— Bought TC	1,100.00
May 11	— Bought babushka for wife so hair wouldn't blow	.65
May 12	— After dramatic scene, traded babushka on special hardtop	75.00
May 13	— Friend who claimed to be expert demonstrated speed shifting. New third gear	43.65
May 14	— Wife bought sweater to match car	25.00
May 18	— Raced with TD on way to work. Speeding citation	25.00
May 19	— Wife bought slacks to go with sweater of May 14	19.95
May 20	— Had car modified to Mark II specs. Raced TD on way to work. Speeding citation and modifications	245.00
May 21	— Neighbor's five-year-old son drew crayon picture on upholstery. Leather cleaner	1.50
May 22	— Settled out of court for clobbering neighbor's son	50.00
May 23	— Wife bought shoes to go with slacks which went with sweater that matched car	16.95
May 24	— Expert friend showed me how to adjust carburetor. Replace four burned pistons	52.95
May 25	— Evening at O'Brien's after argument resulting from returning handbag wife had bought to go with shoes which went with slacks, etc.	4.75
May 26	— Raced with TF1500 on way to work. Speeding citation	25.00
May 27	— GB plates, Badge bar, badge starter set	11.75
May 30	— Had car modified to TF1500 specs.	175.00
June 10	— Added up all figures listed above. Told wife she'd have to economize. Evening at O'Brien's	4.75
June 15	— Expert friend demonstrated proper cornering technique. Repair right front fender	19.00
June 19	— Party to placate expert friend and wife after heated discussion. Gin, vermouth, canapes	9.10
July 1	— Taught wife to drive TC. New clutch	39.00
July 2	— Gave wife second lesson. Evening at O'Brien's	4.75
August 1	— Wife raced Porsche Super. Speeding citation	25.00
August 2	— TC expenses while shopping the foreign-car lots for Porsche Super	1.75
August 9	— Porsche Super, used, good condition	2,975.00

Simple addition proves that the price of a good TC, used, is somewhat more than the guidebooks tell you. Our accountant has added some gray hair, some lines to his forehead. The bonding company has sent us three warning notes about his credit standing. We sent the bonding company a short, curt reply in return. Their own accountant owns a Porsche Super and we've heard his wife tried to go against a Mercedes 300 SL.

Who bonds the bonders?

—george laws

(Continued from page 59)

horsepower are going to be the critical factors determining the amount of boost pressure we can safely pull out of the McCulloch. As mentioned earlier, the boost here is controlled by a solenoid regulator mechanism. The pressure at which this regulates is adjustable by a screw under the medallion plate on top of the blower. This little screw has been the downfall of more than one exuberant enthusiast! I've heard of people turning it down the limit and reading more than *seven lb. pressure* on good-sized engines. Many have burned up their drives pulling only 5½ lbs. on big OHV engines. After all, to pump enough air to produce 350 hp at five lbs. pressure would require 32,000 rpm impeller speed and over 27 hp on the McCulloch. It would burn it up in about one minute flat.

Units from the factory are pre-adjusted for 4½ to five lbs. pressure, depending on engine size. We can safely pull a bit more than this under certain conditions. Here are my recommendations: First, figure that your true horsepower as installed with the McCulloch blower is roughly 10 percent above the advertised rating of the engine in question. If this horsepower figure falls below 150 you can safely adjust the screw regulator to hold as high as 6½ lbs. boost. If the calculated power falls in the 150-210 hp range, I'm sure you could stretch a point and adjust for 5½-6 lbs. with a decent safety margin. Above the 210 hp point you should either regulate down to the 4-4½ lbs. range or use the Heavy-Duty drive. With the H-D drive you can safely pull five lbs. boost up to a calculated hp figure of at least 300, and 5½ lbs. up to maybe 275. In the higher air flow ranges the power requirement of the impeller rises at such a rapid rate that the McCulloch design is all but useless for anything over 350 hp.

And here's another little-understood point that has clobbered more than one McCulloch under a lead foot: Since the ratio spread on the variable pulley layout is limited to less than 1.7:1, the whole thing is going to be, in effect, a fixed-ratio drive above the "maximum rpm" point of around 5000 rpm. That is, the factory selects pulley sizes to give rated boost in the 3000-5000 rpm range; if the engine is wound above 5000 the impeller speed will increase in direct proportion . . . and the pressure output will shoot up as the square of rpm. This will kill your McCulloch as quick as anything. I'd be afraid of anything over maybe 5300 rpm crank speed with a standard McCulloch setup.

Next month we'll take up the Roots blowers. #