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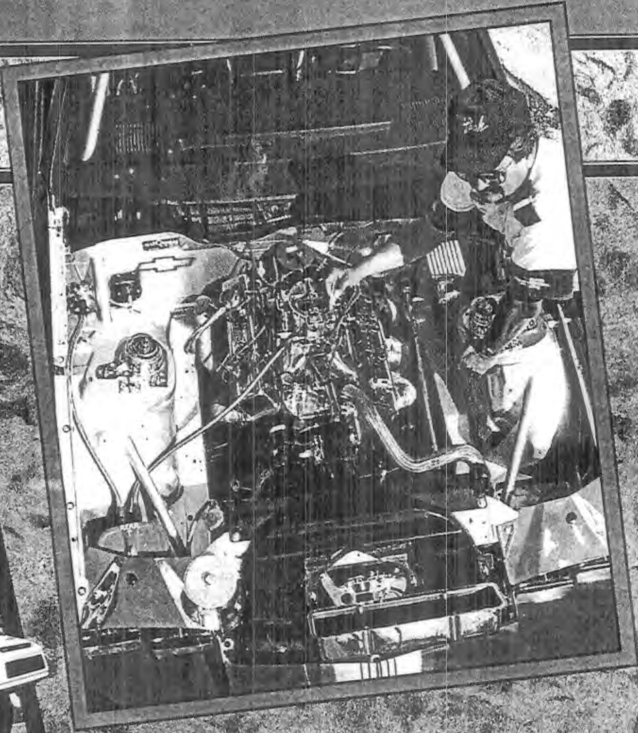
Racer profiles, Sportsman basics, features, how-to and tech stories, and more, all geared toward NHRA Sportsman racers and race cars



Sportsman SPECIAL

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Sportsman SPECIAL

THE PAPER DYNO

How to determine your engine's horsepower output and its relationship to torque, force, and acceleration

by Frank Leany

You used to hear a lot of talk about power: horsepower, and plenty of it. These days, if you ask somebody how much power their car has, you're likely to get an answer like, "150 watts per channel." A lot of racers could have the motor from their mom's vacuum cleaner under the hood for all they care, but they have a stereo amp that could weld deck plates on a battleship. But because you're reading this article, you're probably interested in power, namely horsepower, just like those you're racing against. You know that power's good and more power's better, but sometimes it seems like there's a lot of confusion about exactly what it is.

Take for example that time you and your buddies were changing the fuel pump in Randy's Camaro. As usually happens when friends get together, the discussion turns to horsepower. Everyone's talking about the astronomical amounts of power the engines had back in the 1960s, and someone mentions how engines now are rated in net horsepower. Randy's about to get in a fight with Scott about whether a 350 Chevy puts out more horsepower than a 351 Cleveland. Then Dave, who's been talking about his classes at the community college instead of getting his hands dirty, chimes in with, "Of course. Everybody knows that torque accelerates, not horsepower."

"Oh, yeah, yeah, sure, everybody knows that," the collective assembly mutters. And you're all thinking, "Wow. That sounds really technical. All this time, we've been talking about horsepower, and now the in thing is torque."

So is power not important, or what? Saying that horsepower isn't what accelerates a car is true but misleading because it implies that torque and horsepower are independent, which certainly is not true. The intent of this article is to provide a tool by which you can plot a curve of the torque and power your car is putting out, but first the mystical relationship between torque, horsepower, and acceleration must be sorted out.

Conceptual definitions

The most basic definition of horsepower is that it is the rate that torque is being output. Let's begin with an example to calibrate our thinking. Think back to the fuel pump we changed in Randy's Camaro. If we put a pressure gauge in the fuel line, we see an interesting phenomenon. When the needle valve on Randy's double pumper is closed, the pump is developing high pressure in the lines. Then, at higher flows, the pressure begins to go down. As the flow increases, it eventually will outrun the capabilities of the pump. A more powerful pump will be able to maintain a higher pressure at a high flow. Hold that thought while we apply that same principle to a moving car.

When you had to push Randy's car home with a bad fuel pump, you applied a force to the car. When the car was completely stopped with the brakes applied, you could exert a certain force on his car that you could have measured with a bathroom scale against the bumper. As the car begins to move, you'll be able to exert a good amount of thrust for a while, but as the car moves faster, the force will become less. Think about that a minute. Torque is a particular kind of force. Is it beginning to make sense? A more powerful person (or engine) will be able to keep the numbers on the bathroom scale high at a faster speed. That's what power is: a measure of the rate that force is applied.

Here's one more quick example to help us visualize this. You've probably seen wheelstanders like Ed Jones' Jolly Rancher fire engine that pull the front wheels and keep them up all the way down the track. What raises them into a wheelie is the physical quantity torque; the continued application of that torque that keeps the wheels up while they accelerate down the track is a measurement we call horsepower.

Mathematical definitions of power

The technical definition of power is rate of work, or work divided by time (W/t). Because we know that work is Force times distance (Fd), we can write the power equation as follows:

$$P = \frac{Fd}{t}$$

Notice that the less time it takes to do the same work, the more power you're talking about. Now, because we know that distance divided by time is velocity, let's change the equation slightly to make it more useful to us.

$$P = F\frac{d}{t} = Fv$$

Interesting. Power is equal to force times velocity. That goes along with our definition of power as the rate that force (torque) is applied. Though it's technically correct to say that torque accelerates, we can see from the P=Fv equation that horsepower does have a torque component (F). What we're really pursuing, after all, is acceleration, which occurs as a result of force acting against a mass and is defined as follows:

$$a = \frac{F}{m}$$

What we've done here is sort out the relationship of power to force (torque), which is the physical quantity that accelerates. If we know the force (or torque) involved and the rate it's applied, we know the power.

The rate that work is done is only one definition of power. A physicist would say that power is the time rate of change of energy. Just for the fun of it, let's multiply power by time. That gives us energy. If you have an appliance that draws 100 kilowatts (power) and you run it for one hour, you have 100 kilowatt hours of energy. Wait a minute. If you divide work by time to get power, then multiply by time to get energy, you're back where you began. Are work and energy the same thing? Exactly. That's called the work-energy theorem, which is just a highbrow handle for a handy principle that allows us to find power directly if we know an initial and final energy state and the time it took to get from one to the other (at an assumed constant rate).

A vehicle's energy is a function of two things: its mass and the square of its velocity.

$$E = \frac{1}{2}mv^2$$

Your Aunt Hilda gets on the freeway and three exits later has her Yugo XL going 60 mph. Your race car weighs the same as your auntie's Yugo, but it's doing 60 by the time it goes 120 feet down the track. At that point, the cars have the same energy. Now take that energy and divide it by how long it took each one to get there, and you have power.

$$P = \frac{E}{t}$$

Notice the denominator "t." That's all important. The smaller that is, the more power you have for the same energy. Now look at the equation for energy again. At one point you have a certain energy, at some point later you have a different energy. The mass is still the same (unless you're in a rocket or accelerating close to the speed of light), so all we have to measure is the change in velocity and the time it took to occur. You'll recall that we call that acceleration. The only way to accelerate a mass is with a force, which brings us full circle in our definitions.

Horsepower versus torque

Now that we have a feel for power the physical quantity, let's examine horsepower in particular. When I was a kid, I had a job driving a tractor. One day, it came up in conversation with my boss that the John Deere I was driving had a 90-horsepower engine. That seemed really low to me; cars at that time were coming from the factory with 350-horsepower engines. Then I realized what the deal was. "But the gearbox multiplies that horsepower, right?" "Wrong," my boss said, and I went away thinking my boss didn't know anything about horsepower. The flaw in my thinking is obvious. The gearbox multiplies torque but divides speed, so higher torque is put out at a lower rate, resulting in the same power (disregarding friction). Remember the relationship of torque to power: Power is the rate that torque is output. The equation looks like this:

$$hp = \frac{tq \times RPM}{5{,}252}$$

The derivation of how we got from P=Fv to this monster is described in the sidebar on page 72. The equation illustrates that how much power is being output depends on where on the rpm range how much torque is being developed. Look closely at this equation. At 5,252 rpm, horsepower and torque are equal. Always. Below that rpm, you're going to have more torque than horsepower, and above it you'll have more horsepower than torque. That's where I always was confused. All this talk about torque and horsepower had me thinking that you could build either torque or horsepower at a certain point on the rpm band, which is not true, of course.

For any torque amount at a certain rpm, there is only one horsepower value. When you increase the torque anywhere, you increase the horsepower according to that rela-

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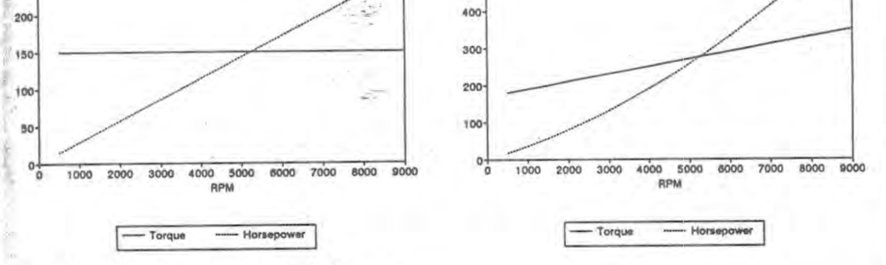

Figure 1: Relationship of horsepower to torque

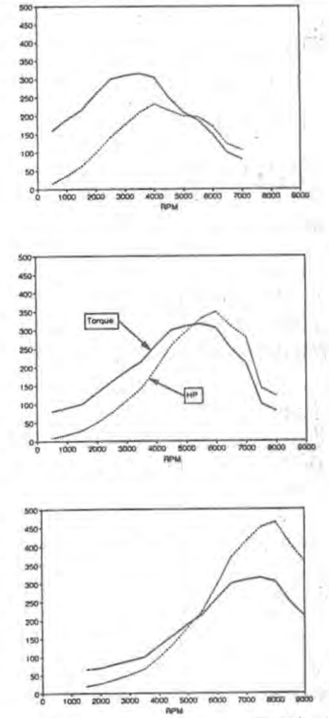

Figure 1: Effect of shifting torque curve

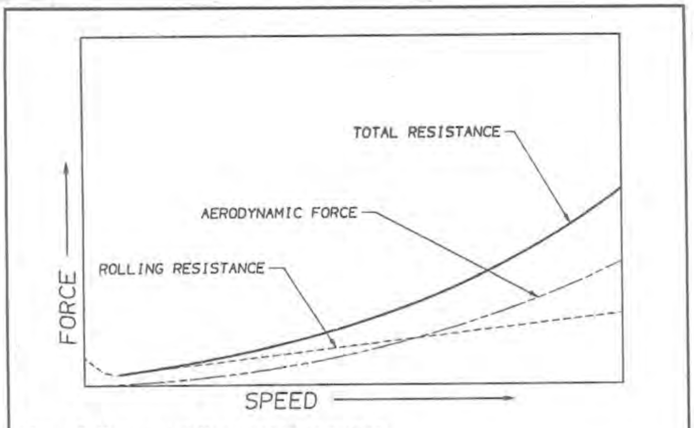

Figure 3: Forces resisting a vehicle's motion

DYNO

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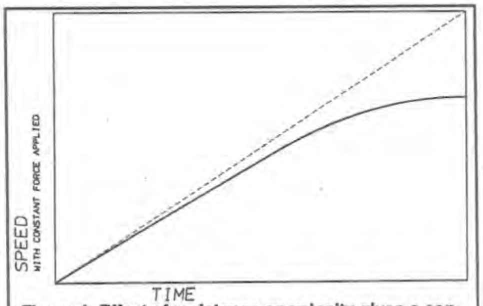

Figure 4: Effect of resistance on velocity given a constant applied force

tionship, which you can't change. Figure 1 shows a flat torque curve and one where the torque is a straight line with a positive slope. Here's a clue to the nature of the relationship between horsepower and torque. Notice that as the torque is constant the horsepower increases in a straight line, and as the torque increases in a straight line, the horsepower curve curves upward. That means that an increase of 10 foot-pounds in torque on the upper end of the curve yields a larger horsepower gain than the same increase on the low end. That's borne out in the next set of graphs. The three torque curves in Figure 2 are identical except for being shifted. The difference in the horsepower curves emphasizes the aspect of power as a measurement of rate. Not only do the shifted torque curves show higher horsepower figures for the same amount of torque, but the rate the horsepower increases for a given torque increase is higher, just as we would expect.

Net force and acceleration

So, what's the role of power? It's useful to think of power as a measurement — a number or an indication. The statement that torque, not power, accelerates is 100-percent true in physics books, but what accelerates a race car in the real world is net force. That is the sum of the forces making the vehicle accelerate minus the forces resisting that acceleration. At higher speeds, the forces resisting the car's motion are higher (Figure 3), so higher horsepower figures (shifting the torque curve up on the rpm range) indicate that the vehicle will be capable of pushing air at faster speeds. Figure 4 illustrates how these forces have the effect of bending the velocity curve downward by reducing the net effect of a constant force as speed increases.

The Paper Dyno

Now that we've figured out what power is, let's move on to determining how much we're getting out of our vehicle. If you have access to a chassis dyno, put this article away; you're done. Some garages advertise that they have a dyno, but, as it turns out, the dynamometer at your local tune-up shop usually is nothing more than a roller that simulates the road resistance of a vehicle on the highway. I'm going to show you a way to make use of the handy relationship between work and energy to draw a torque curve for your engine. To do that, we're going to make some timed acceleration runs and record the results.

I've provided a work sheet called The Paper Dyno to plan, record, and calculate your data. You'll want to make photocopies of the original so you can scrawl freely. Remember that this document wasn't found under a burning bush — modify it any way you want to make it more useful to you. Follow along on the chart while you read through the explanation of how to do this. It's really easier done than said.

The first thing we need to know is how much mass we're accelerating. Most truck stops or metal-salvage yards will let you use their scales for a small fee. Or, go sell that scrap engine block that's been kicking around your shop for so long. The scrap yard has to weigh your car before and after you unload it, so ask to keep the weigh slip when you're done. If you haven't made a lot of modifications that would affect your car's weight, you can use its original ballpark weight from the blue book as a last resort. Write the weight you come up with in the appropriate box in the upper right-hand corner.

At this point, we need to introduce a concept called the thrust index because thrust is what actually accelerates a vehicle. The physical quantity is called force, and you already know how it's related to torque. A force applied to the end of a wrench times the length of the wrench is the torque output to the bolt (Figure 5).

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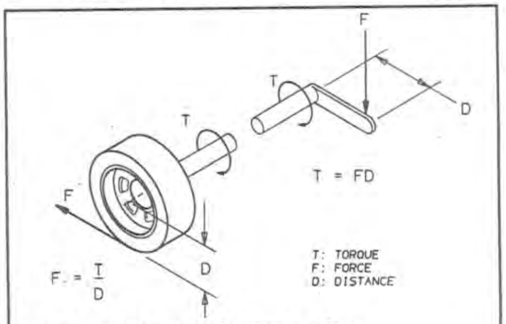

Figure 5: Relationship of torque and force

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WEIGHT W= [LBS]

THRUST INDEX "I"

TIRE DIA D= [IN.]

REAR END R_R= [:1]

GEAR	RATIO	I=24R/D
1		
2		
3		
4		

EFPA
k
$= \frac{400 F_d}{v^2}$

GEAR	SPEED 1	SPEED 2	ΔV	V_{avg}		ACCELERATION Δt	THRUST $\frac{W \Delta V}{21.95 \Delta t}$	COAST DOWN Δt	DRAG $\frac{W \Delta V}{21.95 \Delta t}$	CORR. THRUST $F = F_a + F_d$	TORQUE $T = F/I$ $= 5250P/N$	HP $P = TN/5250$ $= FV/375$
1	RPM	RPM			1.	SEC	LBS	SEC	LBS	LBS	FT-LBS	HP
	MPH	MPH	MPH	MPH	2.							
NOTES:					3.							
2					1.							
					2.							
					3.							
3					1.							
					2.							
4												
					2.							

RPM $N = 14Iv$

SPEED $V = N/14I$

$a = \frac{\Delta V}{21.95 \Delta t}$

$F_d = \frac{kv^2}{400}$

$k = \frac{18.22 W \Delta v}{v^2 \Delta t}$

$P = \frac{W(V_2^2 - V_1^2)}{18466 \Delta t}$

DYNO

from page 59

To find the force from a torque, divide the torque by the length of the moment arm it acts on, in this case, the radius of the tire. What the thrust index ("I") represents is the effective final drive ratio of your car. It's equal to the final drive ratio times 24 divided by your tire diameter.

$$I = 24 \frac{R}{D}$$

That's the same thing as your rear-end gears divided corrected by the ratio of your tire's diameter to a "standard" diameter of two feet. That allows you to find the thrust of your car by multiplying the torque by the index or the torque by dividing the thrust by the index. For example, a car with 3.73 gears and a 26-inch rear tire would have a thrust index of 3.44. In a gear other than high (1:1), multiply the rear-end ratio by the gear ratio to get the specific thrust index.

Using the thrust index easily yields speed by dividing the engine speed in rpm by the thrust index divided by 14.

$$\text{Speed} = \frac{\text{RPM}}{14xI}$$

Calculate your thrust index and specific indexes for the gears you will be using in the test and enter them in the boxes provided.

You need to calibrate your speedometer by timing it between mile markers or some other suitable way that would give you confidence in its accuracy. Alternatively, you may decide to use your tach and translate its readings into speed using I as indicated in the formulas on the work sheet. Whichever way you choose, record the values you plan to use. What you want to do is cover enough of the rpm band that you can draw a complete curve from our data. You probably will have to run in a lower gear to get values for the higher rpm ranges. Running the tests at lower speeds has the added benefit of reducing the effect of aerodynamic and rolling resistance.

The spaces for speed and rpm are pretty self-explanatory. If you're using a speedometer, the rpm space is for information only. The space for delta Δv (delta v — delta being the highbrow word for difference) is just the speed range you'll be timing acceleration over, and the v-average is right smack in the middle of the high and low. Whenever a formula calls out v (as opposed to Δv), it's this average of the span that's required. When planning your ranges, remember that a larger span reduces the effect of timing imprecisions (clicking the stopwatch and deciding exactly when the needle is crossing the speed) and flattens the real curve by averaging the acceleration over that range. A range of about 10 mph might be a good starting place, but if your car's a real screamer, that might be too fast to click a stopwatch.

With the form filled in to this point, let's go for a ride. You'll probably want a friend along to run the stopwatch. Just remember to include his or her weight in the calculations. You'll be doing multiple runs at each speed range and averaging the results to smooth out the variance. The column has space for three trials, but you can run as many as you like. It's best to run trials for each condition in both directions to cancel effects of wind and road slope. Start accelerating at full throttle a few mph below the low end of the speed range where the stopwatch is started and keep in the throttle for a few mph after you stop the timer at the high end of the speed range.

After doing the acceleration runs, you'll do some coastdowns over three or four speed ranges to determine the resistance forces acting on your vehicle at speed. Kick the car into neutral a few mph above the target range and time the deceleration over the range. It's important that these be run in both directions and averaged because the forces are lower and deviations have a greater effect.

After you record the results of your runs, it's time to do the calculations. Dividing

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26X8.5-14		$130.00	31X13-15		$161.00
26X10-14		$141.00	31X14.5-15		$175.00
28X9-14		$139.00	32X14-15		$178.00
28X10.5-14		$136.00	32X14.5-15		$190.00
26X8.5-15		$135.00	33X14-15		$189.00
26X10-15		$141.00	33X15-15		$194.00
28X9-15		$138.00	33X16-15		$200.00
28X10.5-15		$142.00	33X17-15		$210.00

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26x4.5-15 $120.00
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28x7.50-15 — $95.00
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26x4.5-15 — $95.00

M&H
3.5x22-15 — $100.00
3.6x24-15 — $103.00

MOROSO
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710 x 15 — $89.00
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SIZE	SPORTSMAN PRO	SPORTSMAN
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26X10.50-15	$118.00	———
26X12.50-15	$129.00	———
28X12.50-15	$130.00	———
29X12.50-15	$138.00	$128.00
29X15.50-15	$155.00	$151.00
29X18.50-15	$195.00	$189.00
31X16.50-15	$198.00	$190.00
31X18.50-15	$209.00	$198.00
33X19.50-15	$216.00	$209.00
33X21.50-15	$268.00	$257.00

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.	13X13X8	$89.00
.	17X17X8	$89.00
L.	17X17X11	$95.00
16 GAL.	23X17X11	$99.00
16 GAL.	W/SENDER	$160.00

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DRAG RACING SEATS FROM RCI ARE TIG WELDED 5052 GRADE ALUMINUM WITH EXTRA THICK PADDING THAT COMES IN FOUR COLORS. RED,BLUE,BLACK,AND YELLOW. $125.00

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$65.00

DRIVER'S SUIT 1 PIECE
COLORS AVAILABLE
SFI APPROVED
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G60X15	DIRT BOZZ	$102.00	19X8-10	JR DRAG	$99.00
245/60-15	QUICK TIME	$127.00	26X8-15	DRAG SLICK	$139.00
275/60-15	Q.T.	$127.00	26X9-15	"	$144.00
275/50-15	Q.T.	$131.00	28X9-15	"	$155.00
295/60-15	Q.T.	$135.00	28X10-15	"	$160.00
295/50-15	Q.T.	$136.00	29X9-15	"	$155.00
325/50-15	Q.T.	$141.00	29X10-15	"	$165.00
31X16.50-15	"	$180.00	29X11-15	"	$173.00
31X18.50-15	"	$190.00	29X12-15	"	$186.00
33X22.50-15	O.E.T.	$256.00	30X9-15	"	$161.00
			30X9(R)-15	RADIAL	$178.00
			31X14-15	DRAG SLICK	$200.00
			32X12-15	"	$199.00
			32X13-15	"	$205.00
			32X13.5-15W	"	$214.00
			32X14-15	"	$216.00
			32X14.5-15W	"	$222.00
			32.5X16.5-15	"	$232.00
			32.5X17-15	"	$236.00
			33X16-15	"	$241.00
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			33.5X16-15	"	$252.00
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ALL QUICK TIMES,DIRT BOZZ AND OUTLAW E.T. ARE D.O.T. APPROVED

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PERFORMANCE WHEELS

SIZE	AUTO/DRAG	PRO/STOCK	CONVO/PRO
15X3.5	$89.00*	$113.00**	$125.00**
15X7	$124.00*	$135.00	$150.00
15X8.5	$128.00*	$139.00	$155.00
15X10	$137.00*	$158.00	$176.00
15X12	$152.00*	$170.00	$189.00
15X14	$166.00*	$183.00	$200.00
15X15	$169.00*	$193.00	$217.00
17X2.5	$215.00		$235.00

** ON THE PRO/STOCKS AND CONVO/PRO THE SIZE IS 15X4
* ADD $10.00ea FOR POLISHING ON AUTO/DRAG ONLY

GOODYEAR

26X8-15---$154.00	30X9-15------$173.00	32X14.5-15---$230.00
28X9-15---$166.00	30X10.5-15--$190.00	32X16-15------$231.00
28X10-15--$171.00	30X11.5-15--$192.00	33X12-15-------$219.00
28X11-15--$178.00	30X12.5-15--$199.00	33X13-15-------$220.00
29X9-15---$169.00	31X13-15----$218.00	33X15-15-------$234.00
29X10-15--$181.00	31X14-15-----$219.00	33X16-15-------$230.00
29X11-15--$190.00	31.5X14-15--$223.00	33X17-15-------$241.00
29X12-15--$192.00	32X14-15-----$227.00	33.5X15-15-----$230.00
30X9-15R-$195.00 (RADIAL)	33X14.5-15--$231.00	36X17-16-------$285.00

FREE UPS GROUND ON (2) REAR DRAG*

WELD RACING

SIZE	DRAGLITE	PRO/STAR	ALUMA/STAR
15X3.5(STD)	$86.00	$92.00	$131.00
15X3.5(SPEC)	$102.00	$109.00	$150.00
15X5	$108.00	$120.00	-----
15X7	$114.00	$120.00	-----
15X8	$118.00	$125.00	$246.00
15X10	$139.00	$149.00	$249.00
15X12	$151.00	$161.00	$252.00
15X14	$165.00	$179.00	$252.00
15X15	$169.00	$182.00	$261.00
17X2.2	$185.00	$195.00	$230.00

TRUCK DUALS
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$175.00 (PER SET OF FOUR)

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DRAG RACE OR CAGE MT. SWITCH PANEL	$90.00
SUPER COOL CAN	$60.00
3" WHEEL STUDS PK OF (5)	$12.00
ELEC. WATER PUMP KIT	$65.00
RACING OIL FILTER	$13.00
CAR TIE DOWNS	$27.00
CHROME WHEEL BUTTONS PK OF (20)	$15.00
OPEN END RACING LUGS PK OF (10)	$15.00

M&H RACEMASTER

235/60-14	RACEMASTER	$132.00
G60 X 15	"	$134.00
J60 X 15	"	$138.00
275/50-15	"	$149.00
275/60-15	"	$148.00
255/55-15	"	$146.00
265/55-15	"	$153.00
305/50-15	"	$155.00
N50 X 15	"	$165.00
29X12-15LT	"	$164.00
305/40-16	"	$155.00
29X17-15	"	$208.00
29.5X17.5-15	"	$216.00
30X17.5-15	"	$225.00
30X18-15	"	$234.00
33X18-15	"	$235.00
33X18-16	"	$238.00
12.00X16	NOSTALGIA SLICKS	$235.00

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VIDEO review

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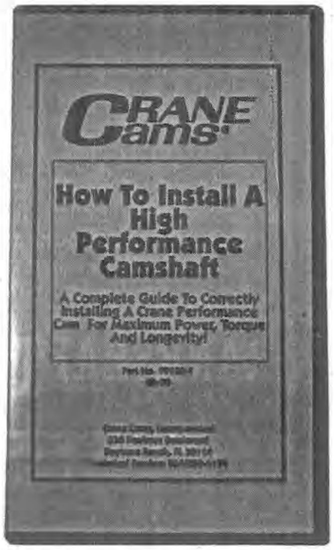
HOW TO INSTALL A HIGH-PERFORMANCE CAMSHAFT, ***Crane Cams (26 minutes)*** — One of the easiest ways to improve the horsepower of an engine is to upgrade the camshaft. It's not a difficult job, but it can be intimidating to first-timers.

Camshaft installation is one project easily presented by video, and Crane Cams has produced one that features noted tech writer Dave Emanuel.



The two-part video first offers practical tips, like having access to a friend with a second car who will play taxi driver to the parts store. It opens with a series of shots from a dyno session that gives the viewer a sense of the power that's created by a high-performance engine. Is this subliminal testimony to the power of a new Crane cam? Sure it is; that's how professional video companies like Video Tech,, which produced this video, earn their money. This video production is above average for our industry. The lighting is generally good to excellent, even when shooting at the black-painted surface of the lifter valley.

The technical content of the tape is simple yet thorough. Part one presents a basic and specialized tool list and shows the disassembly of vacuum lines, throttle linkage, electrical wires, power steering, alternator, radiator, carburetor and manifold, and distributor. After a brief commercial message, part two covers pre-lubing and installing the cam, checking the timing with the crank, and ir[illegible]ng the distributor.

[illegible]nuel offers many practical tips, like m[illegible]ng electrical wires and vacuum lines with like-numbered pieces of masking tape before disconnecting them. He also gives tips during the disassembly phase that help eliminate distributor problems during reassembly.

The video gives a step-by-step look at installing the cam and includes different applications when it comes to cam sprocket designs and how different versions fit. Every nut and bolt is considered as Emanuel explains the process. If a young gearhead is looking for some visual assurance that he or she can install a camshaft correctly, this tape provides that.

The video is flawed slightly in its presentation, the result of good post-shoot editing that sometimes requires that audio levels from the original tape be matched to levels taken later. In the confines of an insulated studio, not a metal-walled shop, voice levels rise and fall, depending on the audio quality at the time of the original taping. It is obvious that some of the audio was recorded in a studio while some was read on the original set. The overall effect is one that sounds like a patchwork of photo captions, not a flowing script with transitions from scene to scene.

This shouldn't deter viewers from appreciating the most impressive aspect of the video: its thoroughness and attention to detail. Young or old, if you haven't swapped cams but are thinking about it, this is a good place to begin your education.

The most impressive aspect of this video is its thoroughness and attention to detail. It sells for $15.96 plus shipping and handling (Florida residents add state sales tax). To order a copy of Crane Cams' *How To Install A High-Performance Camshaft* (part number 99180-1), call (904) 252-1151, or write to Crane Cams, 530 Fentress Blvd., Daytona Beach, FL 32114.

DYNO

from page 62

the speed range by 21.95 and the time elapsed over that range yields acceleration (in Gs). Multiplying that acceleration by the weight gives thrust.

What you have at this point are uncorrected values for the force your engine is applying to the road. This is where the data from the coastdown runs will be used. The force the engine is transmitting to the road is reduced by the forces acting against the car. Because force accelerates (deceleration is acceleration with a negative magnitude), we can determine the forces resisting the car's motion by measuring the deceleration. The trick is that the force in this case varies with the square of the velocity. That means that we have to find the force at that particular speed (v average on the chart). Finding that force is pretty simple once we know the drag constant, "k."

What we're going to call the drag constant is actually the product of the drag coefficient and the frontal area of your vehicle. An engineer would call that the effective flat plate area (EFPA), which is the size of a flat plate that would offer the same resistance as your car if pushed through the air. Because the components that make up the EFPA occur together, we're going to take a shortcut and just call them k. To find this magical constant, apply the following formula:

$$K = \frac{400F_d}{v^2}$$

The Fd (drag force) is determined the same way the acceleration force was, by multiplying the acceleration in Gs by the vehicle weight. There is space on the work sheet for four coastdowns over four different speed ranges. Theoretically, the k value you get should be the same for each of those ranges. That's probably not going to happen, but we hope it's close. If the numbers always worked out exactly right, what would the challenge be? Racers just would get together with their calculators, and in the end whoever had the tallest stack of money would take home the trophy.

Now apply the k value to the average speed for each of the runs according to the formula for aerodynamic force:

$$F_d = \frac{kv^2}{400}$$

That gives you the force that was resisting the acceleration, which you will then add to the net thrust to find out the corrected thrust yield of your car. Now you can find the engine torque by simply dividing the thrust by the thrust index, I. Then horsepower is just the torque times the rpm divided by 5,252.

It's safe to say you're going to be disappointed with the numbers you'll get from this method, but remember that these are "where the rubber meets the road" numbers, not laboratory values. Quoting large horsepower numbers means nothing when you're looking at taillights. The value of this exercise is plotting the shape of the net torque curve. That will go a long way toward understanding what your engine is doing and taking advantage of its strengths. This isn't going to be 100-percent accurate, but it's a lot cheaper than buying a dynamometer.

Let's get technical

We know that horsepower is the rate that torque is developed, but where does the equation

$$hp = (tq)\ \frac{RPM}{5252}$$

come from? There's no voodoo involved here. All we're doing is changing the units we have into units we can use. This is done by multiplying by conversion factors and canceling units until we get the ones we want.

You're familiar with the general idea of converting units. For example, speed is distance divided by time, but speed in feet per seconds doesn't mean a lot to us. So we divide the number of feet per second by 5,280 feet per mile and multiply by 60 seconds per minute, then multiply again by 60 seconds per hour. The seconds cancel each other, as do the feet and the minutes, leaving us with miles divided by hour: miles per hour. We do the same sort of thing to derive the torque to horsepower equation. We just begin with the definition of horsepower as the relationship of force and velocity and convert it into units we can use.

1. $P = Fv$

2. $F = \underline{T\,\cancel{\text{ft}}\,\text{lb}\;R}\;\frac{2}{D\,\cancel{\text{in.}}}\;\frac{12\,\cancel{\text{in.}}}{\cancel{\text{ft.}}} = \frac{24\,TR}{D}\,\text{lbs}$

3. $v = \frac{V\,\cancel{\text{rev}}}{\text{min}}\;\frac{\cancel{\text{rev}}}{R\,\cancel{\text{rev}}}\;\frac{\pi D\,\text{in.}}{\cancel{\text{rev}}} = \frac{\pi DV}{R}\,\frac{\text{in}}{\text{min}}$

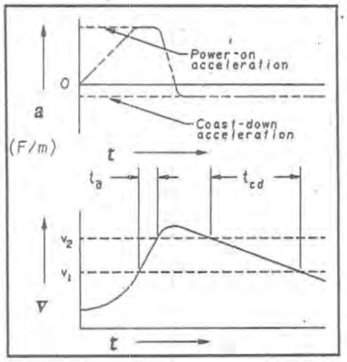
4. $P = \frac{24\,T\cancel{R}}{\cancel{D}}\,\cancel{\text{lbs}}\;\frac{\pi \cancel{D}V}{\cancel{R}}\;\frac{\cancel{\text{in}}}{\cancel{\text{min}}}\;\frac{\cancel{\text{ft}}}{12\,\cancel{\text{in}}}\;\frac{\cancel{\text{sec}}\ \text{hp}}{550\,\cancel{\text{ft}}\,\cancel{\text{lb}}}\;\frac{\cancel{\text{min}}}{60\,\cancel{\text{sec}}}$
$= \frac{TV}{5252}\,\text{hp}$

We begin with the definition of power as force times velocity (Step 1). In the next two steps, we calculate each of those terms (force and velocity) separately.

In Step 2, we determine the force (thrust) on the rear tires by beginning with the torque (T), multiplying it by the total gear ratio (R, which we'll later see drops out) to give us the torque to the rear wheel. Then we change that torque to force on the perimeter of the tire by dividing by the tire radius (D/2), then multiplying by 12 (inches per foot) so that we can cancel the foot units with those in pounds-feet of torque. The D term drops out later, but we need it now to straighten the units out. Cancel all the similar units in the numerator and denominator. The units we end up with are pounds, which are the units of force we were looking for.

We tackle velocity in Step 3. Beginning with engine rpm (V), we divide by the gear ratio (engine revolutions per wheel revolution), then multiply by pi and the tire diameter to get inches per revolution. That leaves us with inches per minute. We usually think of speed in terms of miles per hour, but we'll see in the next step that these units cancel more neatly.

Step 4 is pretty straightforward. We just multiply the terms we developed for force and velocity. That leaves us with units of inch-pounds per minute, which aren't too useful. So we divide by 12 inches per foot (cancel inches), then divide by 60 seconds per minute (minutes cancel), which would leave us with foot-pounds per second. Now we're getting closer. We know that there are 550 foot-pounds per second in a horsepower, so we divide by that to cancel everything else, multiply the numbers and, voilá! We have horsepower.



Here's what's happening on the acceleration runs. The top curve represents your speed from v_1 to v_2 (dashed horizontal lines), then coasting down again. The time t_a is the timed acceleration run, and t_{cd} is the time to coast down over the same range. The instantaneous slope of the curve at any point is the acceleration and is graphed in the lower curve. Because acceleration is force divided by mass, multiplying acceleration (in Gs) by the weight (in pounds) yields the force.

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