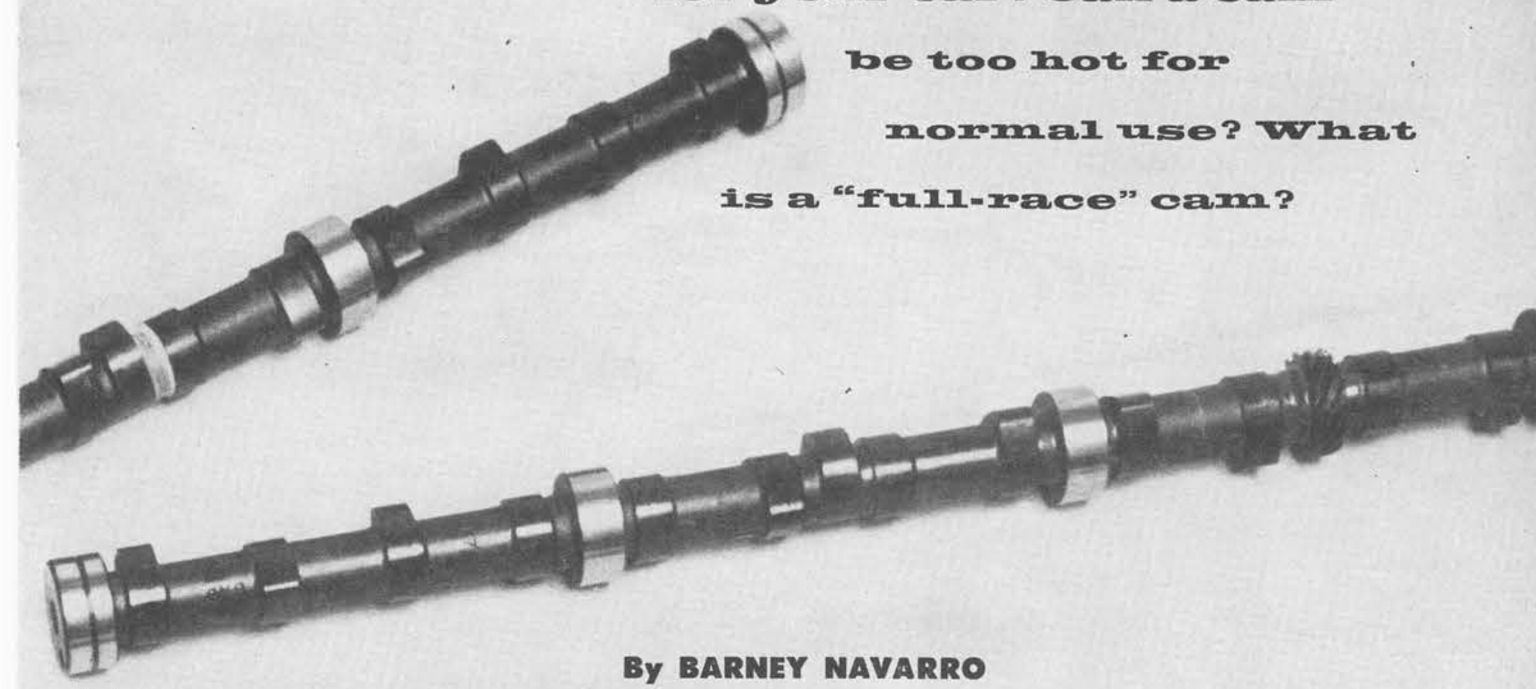
ANSWERING QUESTIONS ABOUT CAMS

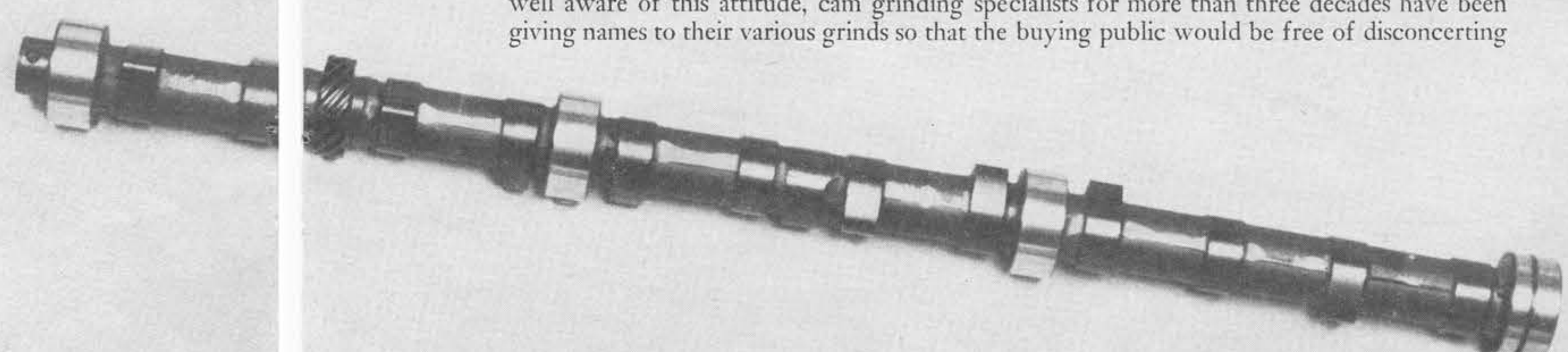


What is the proper cam timing for your car? Can a cam be too hot for normal use? What is a "full-race" cam?

By BARNEY NAVARRO

THE KNOBBY shaft that opens and closes valves is by far the most misunderstood part of an engine. Many enthusiasts view its function more as a form of witchcraft than physics and mechanics. Such faith and the absence of logical analysis cause many needless disappointments. This can be rectified easily by studying the basic problems that pertain to camshaft modification and selection before taking any course of action.

Perhaps the greatest obstacle to intelligent cam selection is the natural aversion that most people have for mathematics. This distaste fosters a complete disregard for numerical relationships and the total rejection of any description that requires the use of numbers. Being well aware of this attitude, cam grinding specialists for more than three decades have been giving names to their various grinds so that the buying public would be free of disconcerting



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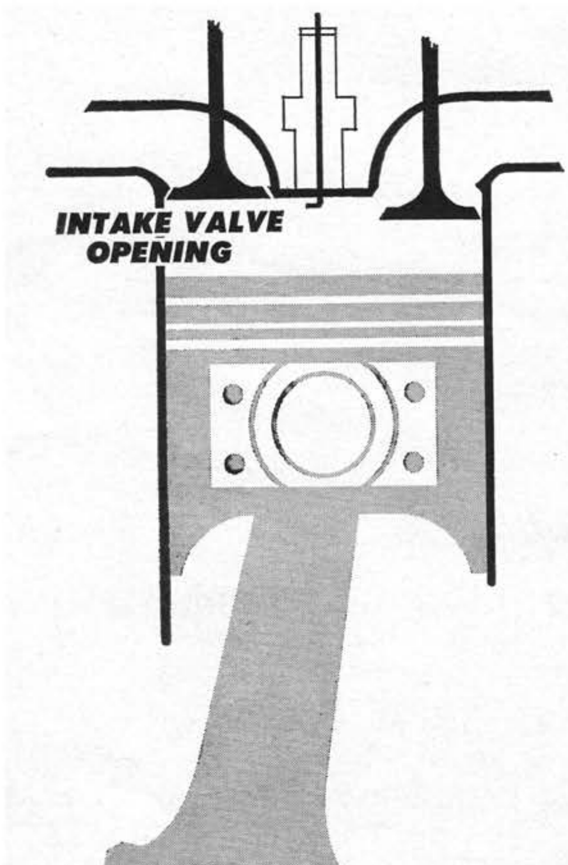
numbers. Names that simplify a description have a great value if the meanings are universal among all cam grinders and identify an exact set of specifications. Since no standard specifications have been adopted by the various cam grinders, personal concepts determined the timing covered by each name. Mild cams were called "semi-race" and all-out grinds received the "full-race" label until there developed a demand for greater diversification. At this time there appeared "three-quarter" and "super-race" timings to choose from—the "supers" being more radical than the "full-race."



INTAKE VALVE starts to open before the piston finishes its upward travel on the exhaust stroke. This illustration demonstrates the crankshaft, connecting rod and piston relationship at the 40 degree early opening used in some racing engines. Modern economy engines, however, may not open the intake valve until the crank rotation is some 15 degrees before top dead center.

Much to the detriment of complete understanding, cam grinders quite often fudged a little on specifications so that their product might make a better showing. One grinder might provide a set of timing figures in his "three-quarter" grind that were equivalent to the specs of the competition's "full-race" offering.

Contrary to popular belief, the fellow who buys a cam under the assumption that he **is** getting a "three-quarter race" cam and receives one with far more radical timing than he expected, is not getting more for his money. The difference in machining time is so small that the labor cost to produce either cam can be considered equal for all practical purposes—hence, they are even priced the same.

What is more important than getting a little extra valve opening duration for the money, is the contribution to the engine's performance provided by the cam. Specifically, did the cam do what its owner expected? The hotter cam may make it possible to obtain more horsepower at high rpm, but if it does this at the cost of ruined low rpm performance, the enthusiast doesn't receive a bargain if he still wanted to retain a smooth idle.

When selecting a camshaft it is foolish to judge value in terms of quantity. Just because a certain grind keeps the valves open longer doesn't automatically make it better for every application. The duration of valve opening influences more characteristics of an engine than its ability to produce high horsepower figures. Some of its effects can actually create a number of undesirable traits; for this reason, the fellow who appeared to get a better cam than was bargained for really may have been cheated since he may have preferred the milder cam to avoid the disadvantages of the so-called "full-race" grind.

Because buying by classification is impractical, successful selection of the proper valve timing for an engine requires more than a minimum of information on the subject. These pages cannot present a single simple solution to the problem of making a correct choice, but a large portion of the factors involved can be examined so that relationships will become apparent. In short, the enthusiast cannot avoid the necessity to do some thinking after acquiring some knowledge of the subject. He cannot avoid mental effort by patterning his choice from some champion drag racer's performance. The worst possible way to choose a cam is to use some quarter-mile record as proof of superiority.

If selection by name or label isn't practical, then there has to be another means of determining the proper grind. Obviously, there is a way and it is dependent upon the valve timing specifications of the cam. These timing specs naturally eliminate the difficulty experienced with the variations in grinders' opinions of what should constitute a "three-quarter" or "full-race" grind. The cam for an engine is then chosen for its specific numerical designation instead of an uncertain name.

Knowing the timing figures of a camshaft will do no good unless the significance of those figures is understood. Both the good and bad contributions of each set of numbers must be recognized if a wise choice is to be made. In simple terms, the reasons for a specific choice must be logically established instead of using the "copy-cat" procedure.

We all know that the basic purpose of a camshaft is to open and close valves at the proper intervals. So determining what is proper is the problem faced by anyone interested in modifications. Though the four-stroke cycle of an engine is always described as four well-defined strokes, all bearing the names of their specific actions, there is considerable overlapping of functions and actions because of valve timing characteristics. Valves don't open and close at the beginning and end of strokes but before, after and during.

Since we must have a starting point in tracing the valve-to-piston-motion relationship, the opening of the intake valve can be the beginning. A number of years ago this valve didn't start to open until the piston started down on the intake stroke. It is for this reason that engines in the "twenties" would idle as

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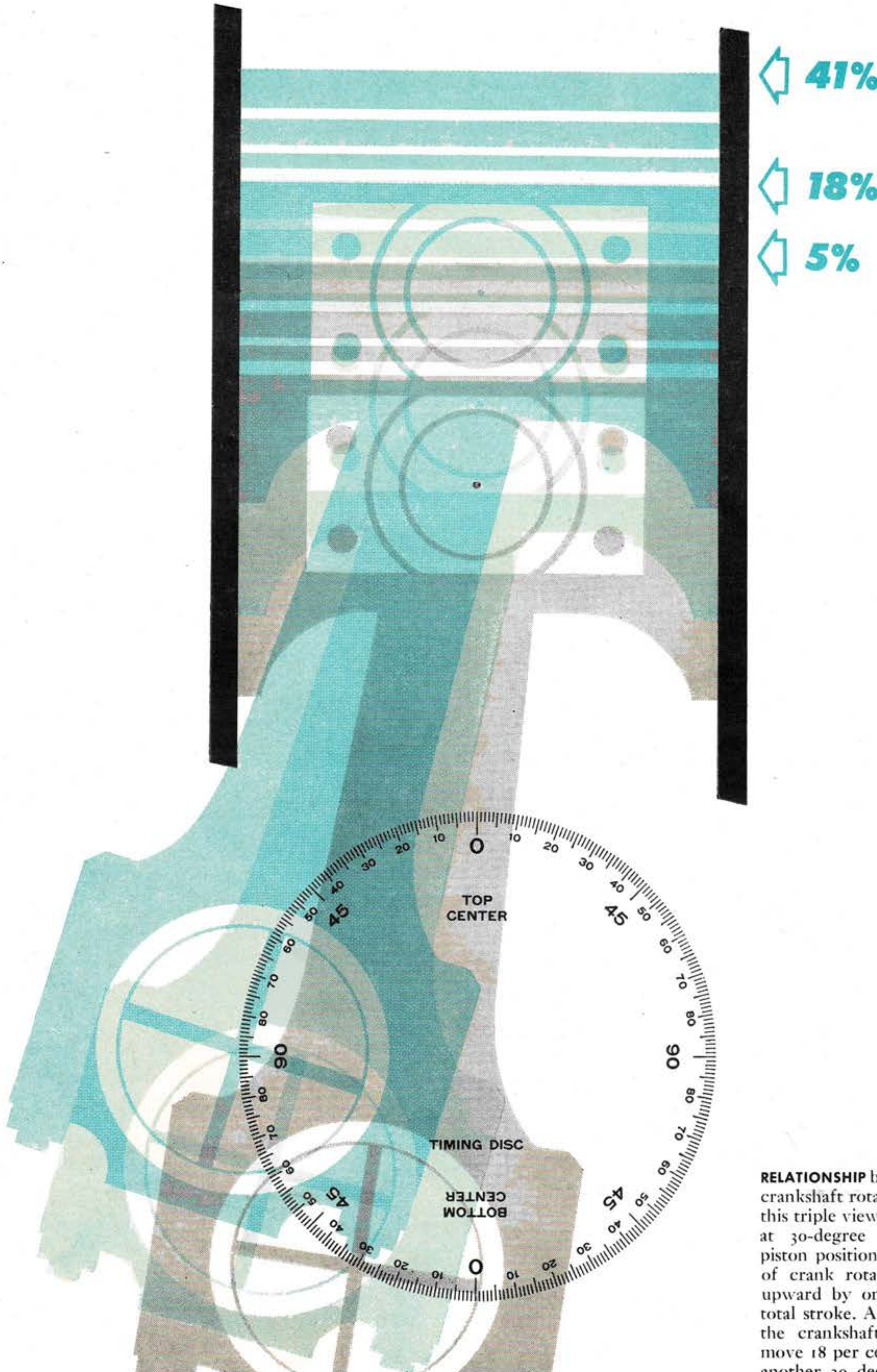

RELATIONSHIP between piston travel and crankshaft rotation is demonstrated by this triple view of one assembly shown at 30-degree intervals. The lowest piston position reveals that 30 degrees of crank rotation moved the piston upward by only five per cent of its total stroke. At 60 degrees of rotation the crankshaft causes the piston to move 18 per cent of its travel. Adding another 30 degrees of crank rotation contributes more to piston movement than the first 60 degrees. The increasing effectiveness of later intake closing is well shown by the distance the piston travels with 90 degrees rotation.

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slowly as a watch ticks. Today's engines open this valve while the piston is still travelling upward on the exhaust stroke and while the exhaust valve is still open. This early opening ranges from a very few degrees in economy engines to as much as 40 dgrees in all-out racing machines.

At the other end of the intake stroke it follows that the intake valve should be closing. Again we find that the valve action doesn't coincide exactly with piston movement. Intake closing always takes place after the piston has reached bottom dead center and has started up on the compression stroke. Economy engines close the valve 30 degrees after the compression stroke has started; a few all-out racing engines, 80 degrees after.

The total open time is referred to as duration of opening, or more concisely, just duration. It is easy to see that the extreme racing timing illustrated in the foregoing would keep the intake valve open for a total of 300 degrees of crankshaft rotation, 60 degrees short of one complete crank rotation or two strokes of the piston. Obviously, such valve duration presents a number of disadvantages.

Despite the low-speed disadvantages of early open and late closing of intake valves, certain benefits are derived at high engine rpms. Keeping the valves open for such long intervals helps make up for the engine's decreased breathing ability resulting from increased air flow resistance and inertia problems inherent in starting and stopping the columns of fuel mixture.

Late intake closing actually turns the inertia problem into something beneficial, inasmuch as the momentum of the inrushing column of fuel mixture is used to help ram more charge into the cylinder. Chrysler ram induction is an applied example of this principle. At high rpm this ram effect does not cause the cylinder to take on a charge of greater volume than the cylinder's capacity. This ram super-charging merely helps counteract a deficiency and makes it possible to operate an engine at higher rpm without the cylinders becoming so starved as to make it unprofitable.

Although late intake closing can be used to advantage, it has shortcomings that must be recognized. Consideration must be given to these shortcomings when cam modifications or the purchase of a hot factory option is anticipated. An engine that employs 80-degree late intake closing cannot be as economical to operate as one that closes the intakes 30 degrees after bottom dead center. Eighty degrees late closing allows the piston to travel one-third of the way up the compression stroke with the valve still open. Obviously, at low rpm, when ram charging is at a minimum, the piston will push almost one-third of the charge back into the induction system. An engine of this type with a 12-to-1 compression ratio operating at low rpm will have an effective compression pressure almost comparable to an engine using a 9-to-1 ratio but with early closing. The loss in the volume of the charge and the low compression pressure both result in a loss of low rpm torque when such valve timing is attempted without the accompanying high compression used in the illustration. Using a high compression ratio helps reduce the loss in torque but it is far from being a substitute for more fuel mixture charge.

When judging the detrimental effects of late closing, the comparison in degrees cannot be viewed as if the piston moves the same amount for each degree of crankshaft rotation. When the piston is at the bottom of the stroke, the first 30 degrees of crank rotation impart very little movement to the piston. In fact, the piston will only travel roughly five per cent of its stroke in the average engine. If the number of degrees of crank rotation is doubled to 60 degrees, it will be found that the piston moves upward for 18 per cent of the compression stroke before the intake valve closes. An extreme case of 90-degree late closing, would result in 41 per cent of the compression stroke being traversed by the piston. These comparisons graphically illustrate the importance of apparently small increases in duration of opening and why the extra 10 degrees, added to a 60-degree late closing, do so much for high rpm performance and so much to reduce low rpm torque.

Whenever a cam appears as a factory option with a later intake closing than standard, a higher compression ratio is usually provided because it can be used safely and is very necessary. When contemplating the installation of a special cam in the family transportation model, you won't go wrong by patterning the compression ratio rise after factory practice.

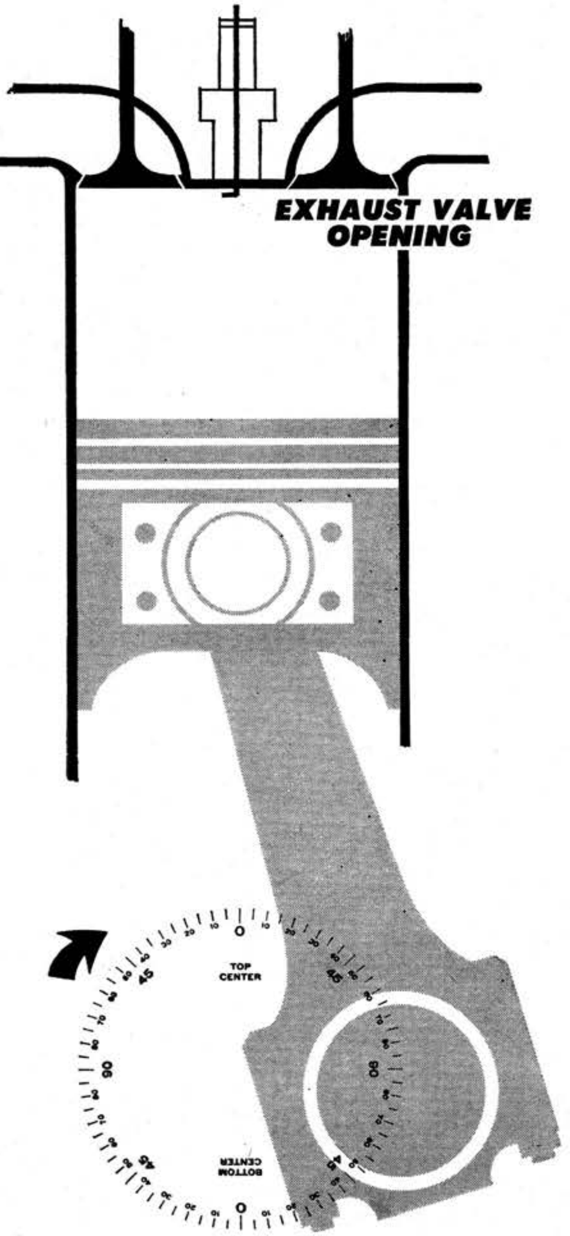
Just as inertia and friction play a part in the timing of intake valves, so do they determine exhaust opening and closing. Again it will be observed that valve opening and closing doesn't occur at the ends of the stroke. The exhaust valve is always opened a considerable distance before the end of the power stroke. This early opening has a twofold purpose: since the burned gases in the cylinder have expanded so much after 120 degrees of crankshaft rotation that they exert comparatively little pressure on the piston, there is no point in leaving them there any longer. Coincidental with this condition is the necessity to start the exit of waste material early enough so that a minimum pressure will exist when the piston starts upward on the exhaust stroke.

When the exhaust valve opens it has an effect on both economy and power. Starting the escape of the burnt gases 50 degrees before the piston reaches the bottom of the power stroke makes it possible to extract more useful energy from the fuel of a low rpm economy engine. However, a high-speed engine would lose power at its peak because too much waste material would still be present when the piston started upward. Radical cams for high rpm operation open the exhaust valve 70 to 80 degrees before bottom dead center.

Disadvantages evolving from the various possible points of exhaust opening are minor inasmuch as they only deal with power and economy, but near the top of the exhaust stroke an action takes place that causes the most obnoxious behavior in engines with radical cams. It is the overlapping of exhaust and intake timing. As much as 40 degrees before the piston arrives at the top of the exhaust stroke, the intake valve starts to open, as pointed out earlier. Forty degrees after the piston passes top dead center the exhaust valve closes. The 80 degrees of valve opening overlap, that result from this extremely radical example of a racing cam, perform a useful function at high rpm, but it creates a horrible set of conditions in a family car—the greatest market for hot cams.

Early opening of the intake valve makes it possible to get the valve open wider by the time the piston starts down on the intake stroke. Instantaneous opening is a mechanical impossibility so early opening is the compromise imposed by the laws of nature. Coincident with the aforementioned, is the draft effect produced by high velocity exiting exhaust gases. This draft effect actually helps draw fuel mixture into the combustion chamber before the piston has moved far enough to induce a flow. In some engines a certain amount of the fuel mixture passes the exhaust valve and goes out the tailpipe (contributing to smog). Fuel mixture that passes the exhaust valve helps to cool it.

Long overlap is the only portion of a long duration cam that causes an engine's idle to be rough. Fuel mixture dilution by exhaust gases and uneven charges to the various cylinders causes

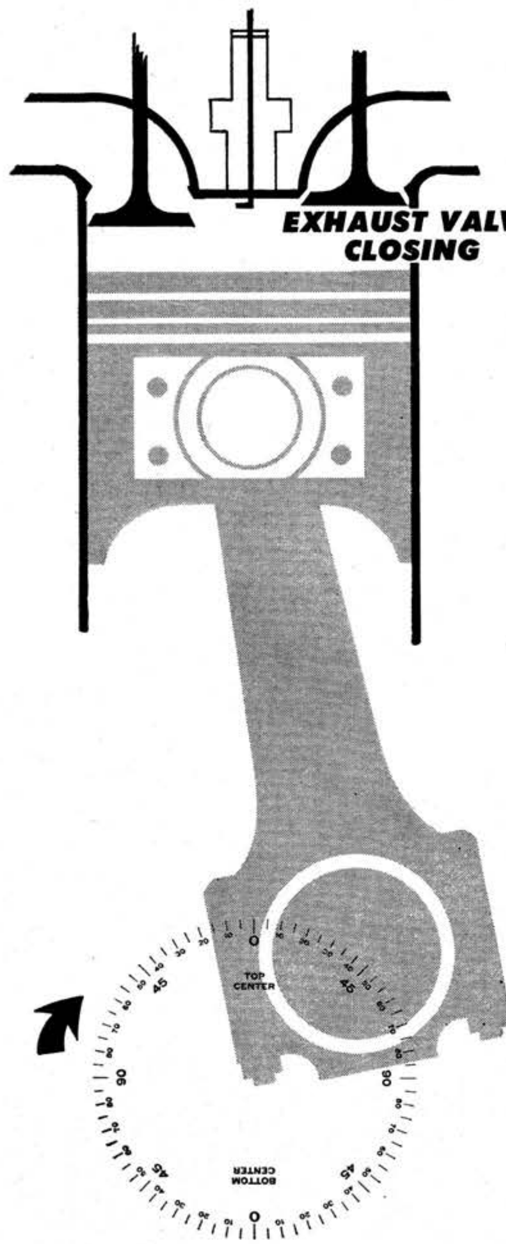


MANY RACING engines start opening the exhaust valve at 80 degrees before the end of the power stroke. The expanding gases have done most of their useful work at this point so they must escape to prevent inhibiting the pistons' upward travel on the exhaust stroke. Economy engines, designed for low rpm efficiency, don't open valve until 45 degrees before end of stroke.

the engine to gallop as if two or three spark plug wires are removed. These undesirable conditions actually cause spark plug fouling at low rpm. The more degrees of overlap, the faster the engine must be idled to keep it from dying completely.

Analyzing the combustion chamber activity during overlap makes it very apparent that big numbers describing this period also indicate high fuel consumption. It will be observed that economy engines always keep the overlap spread to a minimum. Chevrolet Sixes during the early 1930's employed no overlap whatsoever; in fact, they had a period in their intake stroke where both the intake and exhaust were closed for five to seven degrees.

Now that the problems surrounding the selection of proper valve timing have been touched upon, it becomes obvious that specific advice cannot be given. The offering of specific advice can be compared to limiting the number of musical compositions possible with 88 notes to a mere three dozen. Your final selection of cam timing will be best accomplished by your becoming thoroughly familiar with the foregoing and then deciding what sacrifices you can tolerate. •



MODERN ENGINES close the exhaust valve after the piston has started down on intake stroke. This late closing can range between seven and 40 degrees depending on whether racing or economy timing is employed. The 40-degree late closing of the illustration coupled with a 40-degree early opening of an intake valve produce 80 degrees of overlap, poor idling characteristics.