HIGH-PERFORMANCE BRAKE SYSTEMS

DESIGN, SELECTION AND INSTALLATION

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Front Cover:
There is more to upgrading your brake system than just shopping for the best looking parts. While aesthetics certainly are important, consideration must also be given to system-level performance. Picking the right parts is usually more complicated than physically bolting them on–they have to work together. (Randall Shafer)

Title Page:
During track use, rotors are squeezed with thousands of pounds of clamp force, twisted by thousands of foot-pounds of torque, and heated to over 1,200 degrees F. Heavy cars with large engines such as these only make the demands that much more intense. (Wayne Flynn/pdxsports.com)

Back Cover, Top:
Designing a hot rod brake system from scratch may seem intimidating at first, but the fundamental concepts of gain and balance still apply. What really differentiates these brake systems are unique design and operating requirements that may require different compromises than would be appropriate for an all-out racecar. (Randall Shafer)

Middle:
Because experience is the best teacher, the final four chapters of this book are dedicated to sharing our years of upgrade know-how with you. Whether you are upsizing your front rotors for track use or converting your muscle car from rear drum brakes to rear disc brakes, grab your wrenches and head out to the garage with us. Just be sure to wear your safety glasses! (Randall Shafer)

Bottom:
Motorsports can place extreme demands on your brake system, and if your hardware is not up to the task, performance can suffer dramatically. A solid understanding of brake system fundamentals greatly increases your likelihood of ending up in the winner's circle on race day. (Wayne Flynn/pdxsports.com)

CHAPTER 8

Brake Calipers

While calipers need to convert hydraulic fluid pressure into clamp force, they also must look good doing it. A little advertising never hurts either. Can you guess the manufacturer of this caliper? (Randall Shafer/Baer)

In recent years, brake calipers have transformed into a prominent automotive accessory for the image-conscious consumer. Yellow, red, silver, black, and even bright gold examples can be found on the front and/or rear axles of many performance vehicles. Caliper bodies have even been converted into miniature billboards for the caliper manufacturers themselves.

While these new caliper trends are pleasing to the eye, the basic role of the caliper has remained unchanged since its inception. The caliper must simply convert the hydraulic fluid pressure generated in the master cylinder into a linear mechanical clamping force against the brake pads. At the same time, the caliper will usually locate the brake pads and supports the torque generated by the brake rotor, but these are secondary functions.

Caliper sizing and selection is generally a function of the required hydraulic gain, with larger calipers providing more output than smaller calipers. For this reason, calipers like this eight-piston monster designed for the Hummer H2 would be complete overkill on a smaller, lighter vehicle. (Randall Shafer/StopTech)

Hydraulic Gain

As you have already learned, the caliper clamp force can be calculated based upon the brake fluid pressure generated by the master cylinder and the inboard caliper piston area as follows:

Caliper clamp force (lb) =
master cylinder pressure (psi) x
effective caliper piston area (in^2)

Note that although it wasn't mentioned explicitly back in Chapter 3, the *effective caliper piston area* is equal to the inboard caliper piston area multiplied by two.

Based on this relationship, it's common to select calipers and master cylinders in such a way as to amplify the force being applied to the master cylinder piston. Calculated much like the brake pedal ratio, the hydraulic gain of the system is equal to the effective caliper piston area divided by the master cylinder piston area. A more detailed description of hydraulic gain can be found in the sidebar, but in summary, the hydraulic gain can be increased by reducing the master cylinder area or by increasing the effective caliper piston area.

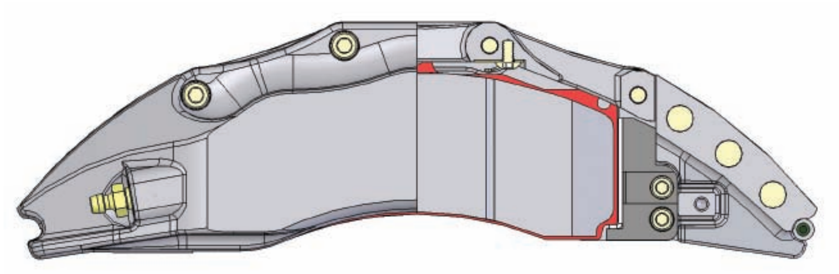
Caliper Components

It has already been stated that the caliper functionally resembles a common master cylinder, but in order to fit around the spinning rotor it must be shaped like a C-clamp. This isn't necessarily a good thing, as the clamping force generated at the open end of the caliper will always attempt to spread the caliper body apart. This distorts the caliper body, which exaggerates the P-V relationship. In short, more caliper deflection results in more brake pedal travel.

Two significant mechanical attributes of a caliper are its *stiffness* and its *strength*. Not to be used interchangeably, stiffness indicates how much deflection a caliper exhibits for a given amount of clamp force, while strength is a measure of the absolute force that can be sustained before failure of the caliper. Consequently, high stiffness is desired for good pedal feel while high strength is required for mechanical integrity.

Body

The *caliper body* is typically made of cast iron in production vehicles. It locates the piston and supports the clamp force exerted on the brake pads. While cast iron is acceptable from stiffness and strength perspectives (especially at elevated temperatures), its weight makes it undesirable



Caliper strength and stiffness are two key characteristics for optimum performance. Recent advances in computer modeling and simulation have allowed for significant improvements in both of these areas without the penalty of increased weight. (StopTech)

Hydraulic Gain Example

If a vehicle was designed with a 0.75-inch-diameter master cylinder piston and a 2.00-inch-diameter caliper piston, one could calculate their effective areas as follows:

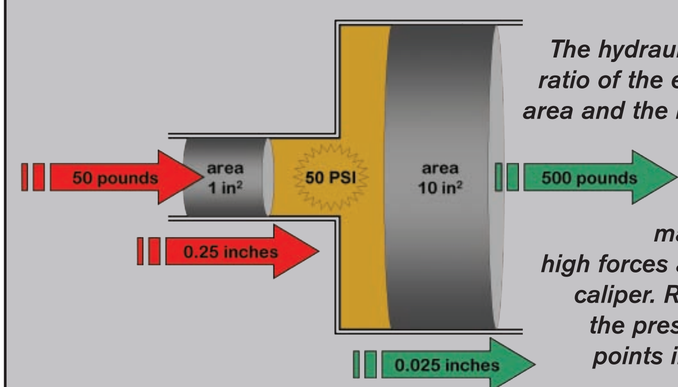
	Diameter (in)	Inboard Area (in^2)	Effective Area (in^2)
Master cylinder	0.75	n/a	0.44
Caliper	2.00	3.14	6.28

Recalling from the body text, the hydraulic gain of the brake system is simply the effective area of the caliper divided by the effective area of the master cylinder, or in equation form:

Hydraulic gain (unitless) =
effective caliper piston area (in^2)
÷ master cylinder piston area (in^2)

Consequently, the hydraulic gain of this system would be 14.2:1 (6.28 square inches divided by 0.44 square inches). In other words, for every pound of force applied to the master cylinder piston, 14.2 pounds of clamp force is generated by the caliper.

The hydraulic relationship also dictates that the linear travel experienced by the master cylinder piston will be 14.2 times greater than the linear travel experienced by the caliper piston relative to the caliper body. For example, if the caliper piston required 0.010 inches of travel to overcome compliance, the master cylinder piston would need to travel approximately 0.142 inches (14.2 times as far) to accommodate the P-V need.



The hydraulic gain is equal to the ratio of the effective caliper piston area and the master cylinder piston area. As illustrated here, low forces and long travel at the master cylinder result in high forces and short travel at the caliper. Regardless of the gain, the pressure is constant at all points in the hydraulic circuit.

The basic caliper structure consists of body sections and bridge sections. In some applications, these may be discrete components assembled together. In the case of this early Porsche 911 Turbo caliper, two piston housings are bolted to two bridge sections to finalize the caliper assembly. (Randall Shafer)

in performance applications. Consequently, aluminum alloys are employed when circumstances dictate the lowest weight possible (in fact, aluminum caliper bodies are nearly universal on modern high-performance vehicles), but their reduced stiffness can lead to excessive caliper deflection without appropriate design countermeasures.

The body consists of three main parts: an inboard body section (which almost always contains at least one piston bore), an outboard body section (which may or may not contain additional piston bores), and a bridge, which connects the two. In some applications, calipers can be fabricated from three separate components, but most often times are combined in a number of creative ways.

Bridge Reinforcement

In order to facilitate caliper inspection and brake pad replacement without caliper removal, it's common to have large openings in the caliper bridge. Unfortunately, these openings can greatly reduce the stiffness of the caliper, resulting in poor brake pedal feel. The term *open caliper* is often used to describe this type of arrangement.

Consequently, select manufacturers implement an auxiliary *bridge reinforcement* to regain the stiffness lost by open caliper design. This component is not required with *closed calipers* where pad