**Bore Gage Choices** April 1997

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Choose the Right Bore Gage for the Job
Bore-gage choices indicate there's more than one way to measure a round hole.GEORGE SCHUETZ

Round holes are probably the most common feature in machined workpieces--a fact that goes a long way toward explaining the variety of gaging equipment that is available to measure inside diameters. Bore gages are used to measure inside diameters (IDs) from about 0.060 in. to 24 in., at depths as shallow as 0.030 in. and as deep as 30 ft. Among the dozens of available variations, there are four basic types of bore gages: go/no-go plug gages, indicating plug gages, self-centralizing rocking gages, and non-self-centralizing rocking gages. Each gage type has benefits in certain measurement applications.

**Go/no-go plugs**
The go/no-go plug gage is a precision steel cylinder that has been machined to a particular nominal dimension. It is the simplest of the four gage types in terms of technical complexity and ease of use. If the plug fits into a bore of the same nominal dimension, the ID is big enough. If it doesn't, the ID is too small. Go/no-go gages may be double-ended, with one end sized to the lower tolerance limit for a particular bore, and the other end sized for the upper tolerance limit. If the upper-limit end fits into the bore, the ID is too large.

Go/no-go gages are so simple as to be virtually foolproof. Unless the user ignores the elementary rules of gage care (e.g., protect them from corrosion and rough handling and have them calibrated periodically), there's virtually nothing that can go wrong with them. Because of their inherent stability, go/no-go gages are commonly used as setting masters for outside-diameter (OD) gages. But they are not very useful in quality-control-inspection applications. Their inability to generate numerical results renders them virtually worthless from the standpoint of statistical process control (SPC) information.

**Indicating plug gages**
Like go/no-go gages, indicating plug gages are built to measure a particular nominal dimension. Unlike them, however, indicating plug gages generate numerical results. In fact, indicating plug gages are capable of high levels of accuracy, with readily achievable discrimination and repeatability of 0.00005 in., and very fast measurement results. The tradeoff for this performance, however, is a limited measurement range of 60.020 in., and non-adjustability. A different gage is required to measure each nominal ID.

The relatively long range of the rocking-style bore gage makes it more flexible than plug-type gages. The centralizer fixture is an aid to its use, but the gage still requires skill to obtain accurate results (top).

Plug-style gaging offers high resolution and repeatability. With an electronic indicator attached, the gage is will-suited to high-throughput inspection applications (bottom).

The modern version of the basic indicating plug gage is a mechanical plug with a digital, electronic indicator attached, although dial indicators can also be fitted. The indicator can be readily replaced with an electronic transducer, wired into a gaging amplifier. This is convenient for use in fixture gages and deep-hole applications, where the plug may be mounted on the end of a long extension rod.

Plugs are also available as tools for air gaging, with small orifices or jets replacing the mechanical contacts. Air gaging has certain advantages. The jet of air tends to clear away coolant and debris that would otherwise interfere with a measurement. The noncontact nature of air gaging is gentler than mechanical contacts on some delicate, highly polished surfaces. Also, the absence of moving parts makes air tooling more durable.

Liabilities, compared to mechanical systems, include the complexity and expense of providing clean, dry, compressed air, and the relative lack of mobility compared to a handheld mechanical gage. Both mechanical and air plugs are available in a standard through-hole configuration, with the contacts set back from the front face of the plug by 0.5 in. or more, and in blind-hole versions that can measure an OD as close as 0.030 in. above a counter bore or hole bottom.

The high accuracy and speed of use of the indicating plug gage is largely due to its self-centralizing nature. With designed clearances of only a few thousandths of an inch between the plug body and the sides of the bore, the contacts are always ideally oriented on the bore's true diameter.

Operation is a piece of cake. The user simply inserts the plug into the bore and reads the results on the display device. Because the gage remains centralized, bores can be explored axially to detect barrelshape, hourglass, or taper conditions, and radially to check for roundness. With an appropriate electronic indicator or amplifier, total indicator reading (TIR) can be calculated automatically.

**The best bore gage for the application**
The chart below provides a way to choose a bore gage for your application according to which performance criteria are most important to you, whether it be reliability, ease-of-use, etc. With 1 as the highest score per attribute and 4 as the lowest, you can quickly arrive at one or two choices.

| | Go/no-go plug gage | Indicating plug gage | Rocking gage w/centralizer | Rocking gage w/o centralizer |
|---|---|---|---|---|
| Reliability/durability | 1 | 2 | 3 | 4 |
| Ease & speed of use | 1 | 2 | 3 | 4 |
| Flexibility/adaptibility | 4 | 3 | 2 | 1 |
| Display results | go/no-go results | digital or analog | digital or analog | analog only |
| Range | n/a | 3 | 2 | 1 |
| Repeatability | n/a | 1 | 2 | 3 |
| Resolution | n/a | 1 | 2 | 3 |

Rocking or adjustable gages
Compared to fixed-size plug gages, adjustable, rocking-type gages provide superior flexibility, but at the expense of resolution, speed, and ease of use. Rocking-type gages can be readily adjusted to gage IDs across broad ranges of sizes. Only three such gages are required to measure any ID from 0.500 through 8.000 in.

Choosing between plug gages and rocking gages is generally a question of cost-effectiveness. Because they

are easy and quick to use, plug gages are appropriate for large production runs where inspection throughput is a priority and labor cost is an important consideration. Where throughput is not so important, and several diameters are to be measured, rocking-type gages may be more economical.

"Rocking" refers to the process of centralizing the gage in the bore to measure the true diameter. A bore gage can be incorrectly oriented in two directions: up and down, and side to side (see "Alignment is critical in bore-gage measurements," below). A certain amount of skill is required to position the gage properly. The user first moves the gage side to side until the indicator shows that the gage is on the centerline of the bore, and not measuring a chord of the circle. Then the gage is rocked up and down to set the contacts perpendicular to the bore axis. The minimum dimension shown on the indicator represents the bore's true diameter. Normally, the gage must be rocked back and forth several times, while the operator carefully watches the movement of the needle on the dial indicator.

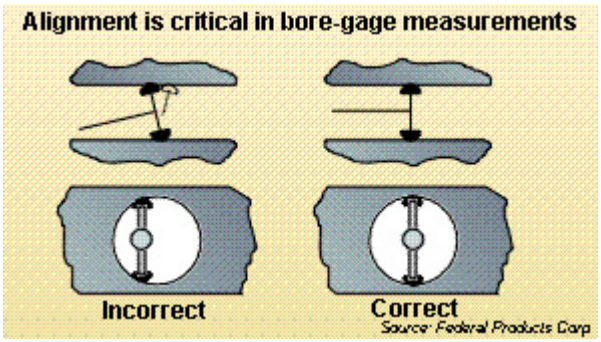


Illustration shows how practice is needed to align the tool properly. Left: Incorrect alignment of bore gage to bore. Right: Correct alignment.

Using a centralizer--two fixed contacts oriented perpendicular to the direction of sensitive contact motion--eliminates half the battle, ensuring that the gage is centered side to side in the bore. The gage must still be rocked up and down. Some advanced digital indicators have a dynamic function that automatically captures the minimum reading, further simplifying the process. The user simply rocks the gage once, then reads the results.

Provided they are manipulated carefully, rocking gages with centralizers are capable of high levels of accuracy. With a digital indicator installed, resolution and repeatability of 0.00005 in. may be attainable. Measurement range is short, however, typically limited to 0.020 in. Thus, performance specifications overlap those of plug gages, and the tradeoff is between adjustability on the one hand, and ease and speed of use on the other.

Rocking-type gages without centralizers offer much longer measurement ranges, anywhere from 0.125 in. to 1.0 in. As may be expected, the resolution of these long-range instruments is coarser, usually 0.005 in. or 0.01 in. Because they must be rocked in two directions, they require more skill to use and results take longer to obtain. They are, therefore, most appropriate for loose-tolerance, low-throughput applications. Dial indicators with revolution counters are the norm as indicating devices.

Non-self-centralizing, rocking bore gages are often equipped with a trigger to retract the contacts. This permits access to bores that are larger than the entry hole. With a wide selection of contact sizes and shapes available, these gages can also be used to measure special features, such as slots inside bores. They can even be used to measure non-bore features--for example, the distance between two parallel inside surfaces.

The choice between bore gages usually involves consideration of several performance factors. By choosing among them, the quality professional can select the right tool for the application.

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