# Air gaging:

## An “Old Tool” is Ready for the 21st Century

### Simple in principle, air gaging excels at complex, high-accuracy measurements.

**By George Schuetz**

**Air gaging’s principles haven’t changed in more than 50 years of existence. But as new methods of gaging emerge, air gaging remains very capable of high accuracy, high throughput dimensional inspection in a production environment.**

**Tomorrow’s gaging challenges are predictable. Tolerances will continue to tighten, and ±10 or 20 microinches will be the norm in many industries. As that occurs, the effects of hitherto insignificant geometry or form errors may become significant. For example, out-of-roundness of approximately 10 microinches may throw a part out of tolerance. Production runs will shorten, placing more demands on gaging efficiency and versatility. And of course, customers will continue to demand higher levels of quality assurance, increasing the need for data collection.**

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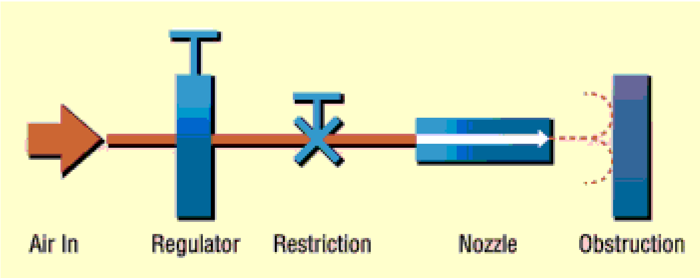
**Air gaging meets these challenges because of the following:**

- **It is capable of high resolution, 5 microinches, or a long range of up to 0.020 inches.**
- **A single indicating unit can be used on a variety of gaging tasks by changing the tooling. Some units also offer adjustable magnification, with discrimination ranging from 10 microinches to 0.0002 inches.**
- **Virtually any kind of machined feature can be measured for dimension, position, clearance and interference, and form errors.**
- **It is noncontact measurement that works well with compressible materials, and the gage won’t mar delicate surfaces.**
- **With no moving parts, maintenance requirements are minimal. The tooling is durable, and some types of air gages offer drift-free performance, so mastering is required only at startup.**
- **It involves minimal training.**
- **It is well suited for 100% inspection.**
- **It can be readily interfaced with electronics for data output and collection, incorporated into fully automated gaging systems, and used in automated manufacturing cells that rely on in-process gaging.**

**Despite these benefits, many professionals are unfamiliar with air gaging. Newer, flashier technologies, including optical systems, electronic gages, and coordinate measuring machines, receive the most attention. Also, lasers and digital electronics are seen as inherently precise, and air as unsuitable for high-accuracy work. However, air gaging is eminently capable of producing high-accuracy measurements for the most modern statistical process control (SPC) systems.**

**Principle of operation**

A basic air circuit consists of a regulated air supply, a shutoff restrictor, and a precision orifice, or "jet," at the end of the line. When the restrictor is open and the orifice is unobstructed, air flows freely through the line with minimal internal pressure.




The principle of operation for air gages is straightforward: the closer the orifice gets to the obstruction, the greater the internal air pressure, and the lower the velocity of flow.

Bringing a solid object near the orifice obstructs airflow. The closer the object comes, the more it slows flow rate and causes air pressure to rise within the system. Completely blocking the orifice triggers airflow to stop and pressure to build until reaching equilibrium throughout the system.

This is the basic principle behind air gaging. Jets are installed in the gage tooling that are positioned against a reference surface on the workpiece. The closer the jets are to the workpiece, the slower the airflow and the greater the pressure. Both the flow-vs.-distance and pressure-vs.-distance curves are linear within limits. It is possible to relate pressure or flow to a part's dimension, to the relative position of features, or to aspects of a part's geometry.

Three types of gages exist. "Simple" or single leg, back pressure systems have adjustable magnification so that a single gage can be used interchangeably for high resolution or long range measurements. This also enables the gage to accept tooling from various manufacturers for practical cost and logistical benefits.

Differential systems also operate on the back pressure principle, but have two legs with the pressure meter in between. The system has increased resolution, mastering using a single-setting master, and excellent stability. The twin-circuit design supports a variety of measurements such as relative position, clearance and interference, and complex geometry measurements.

A third type of gage uses a float in a vertical, calibrated glass tube to measure the velocity of airflow. The faster the flow, the higher the float rises. Flow type systems are relatively inexpensive, and the vertical configuration of the gage lends itself to side-by-side installations of multiple gages. But flow systems are uncommon because of their sensitivity to contamination.

**Air tooling flexibility**

Air gaging is usually applied to inside diameter (ID) inspection with air plug tooling, which can be handheld, mounted on the indicator unit, or built into a special fixture.

Because air plugs have large surface area compared to other gage contacts, wear is minimal and longevity is great. They also have few components and no moving parts. Each plug measures bores of a specific nominal size, so the tool is self-centralizing. It's virtually impossible to put it in the bore incorrectly, so measurements are quick and accurate with no special skill involved.

In the typical air plug, an air circuit feeds two diametrically opposed jets. Thus, the gage can self-correct for noncentralization. Even if a jet is slightly closer than the other to the part's ID, the total back pressure and system flow remain the same.

The plug can "explore" a bore for errors of geometry. Tapered conditions are detectable by sliding the plug slowly in or out of the bore while watching the indicator unit. Likewise, out-of-roundness can be checked by rotating the plug relative to the bore.

However, the manufacturing process can influence geometry errors. For example, centerless grinding usually produces out-of-roundness with an odd number of "lobes", usually three or five, while other manufacturing processes may produce even-lobed roundness errors. Three-point out-of-roundness is undetectable with a standard two-jet plug, because the part's high and low spots are diametrically opposed. So the part's diameter remains fairly accurate, while its geometry is poor. With an understanding of potential errors, it is usually possible to detect them by specifying an air tool configuration. In the case of a bore where errors of three-point out-of-roundness may occur, an air plug with three jets spaced equally around the diameter will detect the problem. After determining that the manufacturing process is subject to certain errors (by using a circular geometry gage) air gaging can regularly monitor those conditions.

Outside diameter (OD) parts are usually inspected with air rings. As with ID, OD parts can be explored for size, taper, and out-of-roundness conditions. The air fork, which is half of an air ring, permits access to OD features anywhere on a part. Air forks are also useful for measuring parts while they are between centers on machine tools.

Air jets can be arranged within tooling to measure special features or conditions. On plugs or rings, four jets in a single plane will measure a part's average diameter, even with two-point out-of-roundness. Six equally spaced jets will measure average diameter even when two- and three-point out-of-roundness exist simultaneously. Out-of-squareness and out-of-straightness are detectable by placing the jets in different planes.

With two air circuits, differential-style air gages provide flexibility to measure and compare two features or dimensions simultaneously. Parts that are intentionally tapered can be inspected for rate-of-taper or angular accuracy with inside or outside diameter taper tooling. Pairs of jets on separate air circuits are arranged on two planes. If the part's taper is accurate, the clearance between the part and jets will be the same at both locations, as well as the air pressure in both circuits. Deviation in the rate of taper will cause a relative change in pressure between the two circuits, which will be reflected on the gage's readout. Applications for taper gaging are as diverse as V-flange and HSK tool holders for machine tools, gas fittings, and medical prosthetic implants.

## Special air gages

In addition to measuring inside and outside diameters, air gaging has many other applications. Special fixtures can be readily configured to inspect parts or features. For example, a "flatness" gage may consist of a special air jet, called an air probe, installed flush in a surface plate or other reference plane. The user slides the workpiece across the surface, and the gage detects changes between the distance of the jet and the part. Gages that measure

**height, thickness, parallelism, and squareness are nearly as straightforward.**

**Air jets are one of the smallest gaging "contacts," and have no moving parts, so engineers can design air gaging fixtures that measure multiple features simultaneously, including features that are close to each other. With multiple display units, there are few limits to the number and type of measurements that can be performed on a part using a single fixture.**

**Air gaging measures dimensional relationships, such as distance between centers of ID or OD features; parallelism of bores, or parts' top and bottom surfaces; concentricity of ID and OD surfaces on a ring; coaxiality of two journals on a shaft; and runout.**

**"Match gaging" maintains tight clearance specifications between mating parts such as fuel injector plungers and bodies, and inner and outer races for high-precision bearings. One of the gage's two circuits has a plug for the ID parts, while the other has a ring for the OD parts. If two correctly sized mating parts are placed on the tooling, pressure in both circuits will be equal and the gage will read zero. This indicates the specified, nominal clearance. If both parts are equally over- or undersized, both circuits will register equal pressures, indicating that the clearance between the two parts—if mated—is correct.**

**If one part is over- or undersized, or both parts are off nominal in opposite directions, the circuits will register different pressures. Also, the gage will indicate a greater or lesser clearance dimension than the nominal specification. The user could then leave a part on the air tooling, and test a number of mating parts until finding a "match" with the correct clearance.**

**To maintain assembly clearance accuracy of ±10 microinches, the diameters of mating parts usually must be maintained ±5 microinches. Achieving this level of process control is difficult and expensive, but match gaging with air is an economical alternative. By allowing the diameter dimensions to drift slightly and matching the parts with air gaging, clearance specifications ±10 microinches can be economically maintained.**

**When companies become involved in advanced quality assurance regimes, they may concentrate on the statistical bases of quality. As long as the gages are generating output, data can be captured and massaged, accompanied by reams of documentation. However, that statistical analysis is only as precise as the data that flows into the system. Air gages are among the most accurate methods to produce high-resolution measurements, and are capable of meeting diverse, demanding gaging challenges for the 21st century.**

| Air Gage Comparison | | | |
|---|---|---|---|
| **Air Pressure** | **Back pressure**<br>High<br>(best self cleaning) | **Differential**<br>Medium<br>(good self cleaning) | **Flow**<br>Low<br>(poor self cleaning) |
| **Mastering** | Two required<br>(good traceabilty) | One required<br>(easy and quick) | Two required<br>(good traceability) |
| **Jet Size** | Small<br>(application flexibilty) | Small<br>(application flexibility) | Larger |
| **Magnification** | Adjustable<br>(easy tool sourcing) | Fixed<br>(good linearity) | Adjustable<br>(easy tool sourcing) |
| **Linearity** | Better | Best | Good |
| **Range** | Short to medium | Relatively long | Short to medium |
| **Stability** | Medium | High | Low |