DIAL VERSUS DIGITAL INDICATORS

When digital electronic indicators were introduced in the early 1980's, some observers expected them to blow mechanical dial indicators out of the water. But in spite of electronic indicator's clear superiority for use in statistical process control and data collection systems, mechanical indicators retain other advantages and they are still frequently specified by many sophisticated users. Neither type is "better" than the other: the choice depends upon the application and the user's personal preference.

The clearest advantage of electronic indicators is in their use for data collection in process control. Electronic indicators can output measurements directly to printers or SPC programs with no operator errors in reading or recording. The operator only has to position the workpiece and press a button: he needn't even read the measurement. With dial indicators, the operator must interpret the pointer's position to read the measurement, then he must record it--generally by hand--and finally the data must be keyed into a computer. That makes three steps during which errors can and frequently do occur. In any situation, where data must be entered into a computer system, digital indicators are the only way to go. Of course, the user pays for this convenience: digital indicators usually cost significantly more than their mechanical counterparts.

Aside from the cost benefit, there is a great deal to be said for mechanical dial indicators. In many ways, the human brain is like an analog device, and it can often gather more information, more quickly, from an analog readout.

Remember how soundly the marketplace rejected digital speedometers in cars? When a measurement need only fall within a certain tolerance range, analog dials are often quicker and easier to read. An experienced gage operator can simply see whether the pointer is within tolerances without taking the time to actually read and interpret the numbers on the dial.

I have seen QC inspectors make consistently accurate go/no-go readings with dial indicators even before the pointer has stopped moving! They can tell at a glance approximately where the pointer will stop, and in many applications, that is close enough. Electronic indicators don't give you the option of approximating. When a digital device is flickering between six and seven, all of the elements in an LCD display may be lit, appearing as an eight. See accompanying illustration.

Skilled operators can "split grads" with dial indicators, i.e., resolve the pointer's position to an accuracy of about one-fifth of the gage's stated minimum graduation value. And analog dials enable the machinist to observe the direction his process is headed. If reading #1 measures 1/5 of a grad over zero, reading #2 is precisely zero, and reading #3 is 1/5 of a grad below zero, the user may be able to draw valuable conclusions about the condition of his tool. In other words, dials can provide more information than simply the dimensional measurement. a digital readout would read zero in all three cases, depriving the user of this additional information. On the other hand, for statistical process control purposes, it is necessary to eliminate all such interpretive data, which again recommends the digital solution.

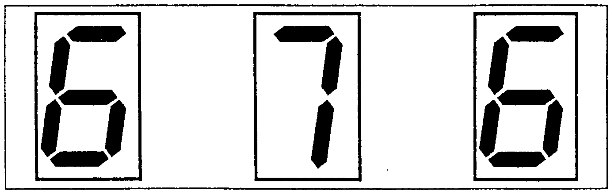
A common, serious problem among users of dial indicators is the failure to notice when the pointer makes a full revolution or two. Parts that are grossly out of tolerance may appear to be within tolerances to an inattentive operator. In contrast, digital indicators never come "back to zero," eliminating this problem entirely. Furthermore, all digital indicators can be made to signal out-of-tolerance dimensions.

Many electronic indicators have some form of supplemental analog display. These electronic emulation's of analog performance serve to eliminate some of the cognitive disadvantages of digital displays and make electronic indicators "user-friendly."

In spite of initial doubts, electronic indicators have proven to be highly reliable in the shop floor environment. Most have only a single moving part, so they may require less frequent cleaning than their mechanical cousins. With proper care, however, dial indicators last forever, and they never need batteries.

Finally, there are somewhat broader ranges of accessories for mechanical indicators, and they are more readily customized for special applications--the subject of next month’s column.

While electronic indicators are superior for use in data collection and SPC applications, “threshold” readings can sometimes cause problems. When a digital indicator flickers between six and seven, for example, it is very easy to misread the digit as an eight.



TEST INDICATORS VS. DIAL INDICATORS

Test indicators are pretty distinct from dial indicators. The immediately obvious difference is that test indicators have lever-type contacts, while dial indicators have plunger-type contacts. Test indicators are also smaller and lighter than dial indicators. In general, the two tools are used in different applications, although there are areas of overlap, where either tool can do the job.

Dial indicators excel at repetitive, comparative measurements: when mounted in a fixture gage, the dial indicator's straight, vertical motion ensures that the contact always lands in the same place, relative to the fixture. This means that the indicator must be oriented vertically to the feature being measured, but for rapid quality inspection of part dimensions, a fixture gage equipped with a dial indicator is unbeatable in most circumstances.

Test indicators excel at consistency measurements, as opposed to comparative ones. They are used most often to explore relatively broad part surfaces in either one or two dimensions -- for example, measuring variations in height, flatness, or roundness. Test indicators are often used in combination with a height stand and a surface plate, and either the workpiece or the stand can be moved around freely on the plate. When combined with a V-block or a pair of centers, test indicators can be used to test for roundness or runout on cylindrical parts. The angular motion of the test indicator's lever allows the contact to ride easily over irregularities on part surfaces. This capability is lacking in dial indicators, because the vertical-action plunger may resist responding to surface irregularities pushing "sideways" against the contact.

This ability to ride over irregular surfaces also makes test indicators well suited for use in machine setups, particularly on lathes. The indicator is held by an articulated test stand, usually mounted right on the machine. The operator brings the indicator into rough contact with the chucked blank, then turns the spindle to obtain a very quick reading on runout. No mastering is required when checking roundness, runout, or flatness. You simply bring the indicator close to the part surface, push down on the lever to make contact with the part, and rotate the indicator's bezel to zero. It's far quicker than the typical setup for a dial indicator.

Test indicators can be oriented more flexibly relative to the workpiece than dial indicators, at a wide range of approach angles. The narrow lever and very small contact ball also fit readily into many places that dial indicators cannot reach, except with special attachments. On the other hand, test indicators cannot measure the depth of holes as dial indicators can. Neither are they well suited for use in most fixture gaging applications, nor in ID and OD gages, bore gages, thickness and height gages. These are all standard, no-questions-asked applications for dial indicators.

Spring force is much lower on test indicators, which may be desirable when measuring deformable materials. Test indicators are smaller and lighter than dial indicators, and these factors may be an issue in some fixtures. The dial itself on a test indicator is small, compared to those on dial indicators, so visibility is not as good. As with dial indicators, however, custom dial faces are available for test indicators for special applications.

Test indicators have generally higher resolution, but a shorter range of measurement, than dial indicators, although both factors overlap at the ends of the scales. Typical resolution (least grad) for test indicators is .0001" to .00005"; for dial indicators, it is .001" to .0001". Dial indicators usually have a total measurement range of at least .025", and .250" is also considered a standard figure, while long-travel units allow measurements out to several inches. The measurement range of test indicators is considerably shorter—usually between .008" and .030".

A few more differences to note: test indicators allow just a single revolution of the pointer around the dial (which is part of the reason for their relatively limited range of measurement), while most dial indicators allow 2.5 revolutions (or more, with revolution counters). Test indicator pointers always travel clockwise, and the dials are continuous reading—i.e., the numbers keep ascending until the dial comes back to zero. In contrast, most dial indicators are available with either clockwise or counterclockwise motion, and offer a choice of continuous reading dials or "balanced" ones, with negative values on one side of zero, and positive values on the other.

Test indicators are extremely useful little items that are sometimes overlooked in favor of the more familiar dial indicators. When choosing between the two, it's a matter of comparing their relative strengths and weaknesses in light of the requirements of the application.

DIGITAL INDICATORS REVISITED

Since this column last discussed digital indicators and how they compare in use with mechanical dial indicators (MMS, January, 1992), the technology has advanced. The major gage manufacturers have either recently introduced second-generation digital indicators, or are about to do so. Some of the former advantages of mechanical indicators no longer apply.

The new digital indicators can take and hold certain types of readings even while the workpiece is being manipulated. These "dynamic measurement capabilities" include "Min," "Max," and "TIR."

The Min (Minimum) and Max (Maximum) features enable the operator to capture the gage's smallest or largest measurement of a dimension without having to carefully watch the readout as the digits flicker up or down. This eliminates one of the liabilities of earlier digital indicators: the impossibility of taking a reading -- even an approximate one -- until both workpiece and gage were absolutely stationary.

Rocking-type bore gages will be a popular application for the Min feature. The operator inserts the gage in the bore, pushes a button to select the Min function, and rocks the gage. The indicator remembers and displays only the smallest dimension detected -- i.e., the true diameter. It ignores any larger dimensions, as when the gage is not perpendicular to the bore.

The Max feature can be equally useful. For example, when measuring outside diameters on a bench comparator, the operator rolls a part under the contact, and the indicator reads the largest dimension detected. The operator need not even look at the readout while handling the workpiece, because the reading remains on the display until the indicator is reset.

Min and Max features make the new digital indicators much more effective when used in conjunction with data collection systems. If a tolerance is unilateral -- i.e., only the Maximum or the Minimum reading is critical -- then the operator can transfer the reading even under dynamic conditions. It is no longer necessary to hold the gage steady while simultaneously attempting to press the "send output" button.

The Total Indicated Reading (TIR) feature is used most often in measuring the runout of shafts, so it is sometimes called Total Indicated Runout. But TIR can also be used to check thickness variation in flat parts, and in other differential applications.

In use, a shaft is put on a gage and rotated through 360 degrees or more. The indicator notes both the Min and the Max readings, but displays neither one. Rather, it remembers both readings, then calculates and displays the spread between them. (For example, if the Min is -.001" and the Max is +.003", then the TIR is .004".) The reading doesn't change even if the operator continues to rotate the shaft, for Min and Max remain the same.

Digital indicators were previously impractical for this application because of digital "float." TIR was therefore performed with dial indicators, but it was a time-consuming process with a large potential for error. The operator would first rotate the part to find the Min, then interpret the dial and record the reading. He would then do the same for the Max, then subtract the Min from the Max. New digital indicators with a TIR function thus eliminate several steps and several opportunities for error.

One more related feature is "hold/reset." This is used primarily where the readout is difficult to observe: for example, where the entire gage is inserted into a part to measure an awkwardly placed internal dimension. The hold feature allows the indicator to retain the reading so that the operator can extract the gage and view the readout, then clear it with the reset button.

Other important improvements in the new indicators are outside the realm of microchips and programming. The measuring range of the older digitals was usually 1/2"; most of the new ones offer a full inch. Accuracy has also been enhanced. First-generation digital indicators typically displayed resolution of .0005" and demonstrated repeatability of .001". Most newer indicators have resolution of .000050" and repeatability of .0001". The newest ones offer resolution of .000020" and repeatability of .000020". These refinements will be especially helpful in getting digital gages to pass GR&R studies.

But perhaps the best news is in pricing: for all their enhanced capabilities, the new digitals cost about the same as the "old" ones. At about $300, digital indicators can now perform almost all the functions of a $1,300 electronic amplifier coupled to a $500 electronic gage head.

LESS IS MORE WITH ONE-REV INDICATORS

Most dial indicators have a total measurement range of 2.5 revolutions of the needle, as per AGD (American Gage Design) specifications. Indicators that allow the needle to go around only once are comparatively rare, but because of some distinct advantages for shop-floor inspection applications, I expect their increased acceptance in the near future. They may even displace AGD indicators as the most popular type.

This added range in the traditional indicator was useful many years ago when machine tool accuracy demanded a broad measurement range to help machinists "creep up" on a specification. Nowadays, though, gaging suppliers recommend that an indicator be chosen so that the tolerance range for the parts being measured should cover between one-tenth and one-quarter of a single needle revolution. This provides a large enough tolerance zone to read easily, and leaves more than enough area on the dial to see what's out-of-tolerance. It's a rare occurrence when anyone actually bothers to read a gage if a part is more than a half-revolution out of tolerance.

Two and a half revolutions are simply unnecessary for most comparative gaging applications, and sometimes they're a real liability. Considering how quickly the needle swings on an indicator, it's not surprising that machinists occasionally miss a revolution. As shown in Figure 1, a measurement that is a full revolution out of tolerance can appear to be exactly on spec to an operator who is distracted -- or poorly trained, poorly supervised, or hurried. Errors may occur through simple inattentiveness, or through an absolute misunderstanding of how to set up and master the gage.

There is at least one documented instance in the aircraft industry where an entire run of oversize parts passed through inspection, and was assembled into components, which were subsequently installed in subassemblies. It is not documented what happened to the machinist/operator or his supervisor when this costly error was discovered. But the situation has surely been repeated in other companies and other industries.

Aside from better operator training, there are a couple of ways to minimize this problem. One solution is to use indicators with revolution counters -- little accessory dials that show the operator how many times the main needle has swung around. The problem here is that an operator can still ignore or misinterpret the tiny rev counter. Indicators with rev counters are actually better suited to long-travel applications, such as where the spindle must clear an obstruction on the part, or where measurements are absolute, as opposed to comparative.

A better solution is the one-revolution indicator, as shown in Figure 2. These have the same range per revolution as comparable AGD-spec indicators. (In other words, the needle moves the same distance for a given amount of spindle travel.) They also have the same amount of spindle travel, so they can be used on parts that are just as far out-of-spec. But in a one-rev indicator, the needle stops moving after one complete revolution (actually, a bit less: usually 340° to 350°), coming to rest in a "dead zone," even if the spindle keeps traveling.

One-rev indicators always have balanced dials, with zero falling between an "over" side and an "under" side: they don't allow continuous clockwise or counterclockwise readings. The needle of a one-rev indicator cannot come back to zero. It can't even travel a full 180_ from zero, so there is virtually no way that "over" can be confused with "under," or that out-of-tolerance can be construed as in-tolerance. For less sophisticated operators, or anyone who performs quick, repetitive part inspections in a production environment, one-rev indicators can eliminate a major cause of misreadings. Applications include snap gages, bore gages, and many other comparative–type inspection gages.

The only liability of one-rev indicators, relative to AGD-spec indicators, is that more sophisticated users will give up the capability to measure broader ranges of part variation -- for example, when an operator needs to know just how far out of tolerance a part is. Conventional multi-rev indicators still have an important role to play where greater measuring flexibility is required.

ONE “SPECIAL” -- TO GO

Gage users frequently ask about custom-engineered dial indicators. They are often pleased to discover that some manufacturers specialize in “specials” and make them an important part of their business. Better yet, re-engineering is rarely necessary. Minor changes suffice to make stock indicators appropriate for most unconventional uses. “Specials” can make indicator gaging easier, quicker or more accurate for many applications.

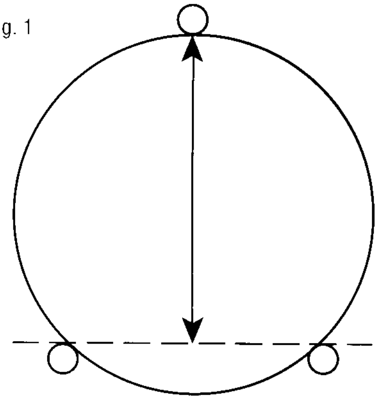
In many gage setups, the indicator’s sensitive contact moves in some proportion to a change in workpiece dimension. In the diameter gage shown, two reference contacts provide the benefit of self-centering positioning, but this means that the indicator's sensitive contact is measuring a perpendicular to a chord, not the diameter itself. There is a fixed ratio of 5:4 between the workpiece diameter and this perpendicular. The indicator has a special-ratio face that reads five units for every four units of movement at the sensitive contact, allowing for easy, "direct" readings. If the indicator has a stock face, the user would have to multiply all of his readings by 1.25 to find the diameter. The special-ratio dial saves time for the user, eliminates a source of potential error, and it requires no re-engineering--just a custom-printed face.

Stock indicators can be used to check gross dimensions--as in rough metal castings. An indicator whose total range is 0.100 inch can measure dimensions up to 1 inch by using a 10:1 lever at the sensitive contact. A special face converts 0.001 inch of movement at the indicator's sensitive contact into a reading of 0.01 inch.

If your shop works to both metric and inch specs, a combination dial, showing both types of units, may simplify setup and reduce purchasing requirements.

Fig. 1—Gages that automatically center the workpiece can greatly speed up the operation. The paired reference contacts quickly locate the part relative to the sensitive contact. However, as the arrows indicate, a chord is measured rather than a diameter. So, the dial indicator used has a special ratio and dial that shows the true diameter.

Fig. 1



Faces can be shaded for different purposes. In "spotlight gaging," the green-shaded area of the dial indicates that the workpiece is within tolerance, the yellow areas warn the user that he is approaching tolerance limits, and the red area means he is out of tolerance. Shaded dials can also be used to quickly sort parts by size, using color-coded bins to coordinate with zones on the dial. For go/no-go gaging, areas of the dial can be masked so that the pointer cannot be seen at all. If the pointer is not visible, the part is no good.

Dial indicators can be used to measure non-dimensional units. For example, where a relationship exists between temperature and the deflection of a material, a special dial may be used to measure in degrees of temperature. The penetration of a probe into a metal sample can be converted on the dial to read in units of hardness (e.g. Rockwell scale). Special dials can be designed to read in whatever units the industry or application requires. Other examples include: foot-pounds of torque, degrees of angle, pounds of impact force, spring force or cable tension, compressibility, and even diopters.

Beyond special dials, indicators can be modified for extreme environments. "Wet-proof" indicators incorporate rubber O-rings and boots, heavy-duty caps and double bezels for use in dirty or wet environments. Indicators engineered from carefully selected materials can be used at high temperatures-- up to about 600F.

In most indicators, the pointer moves clockwise as the plunger is depressed, and most dial faces have a plus sign (+) to the right of zero and a minus sign (-) to the left. Many depth gages and bore gages, however, put the plus sign (+) on the left, so that deeper holes or larger Ids read as "bigger" as the spindle moves farther out of the case. Some users, however, like to see the plus sign (+) to the right of O, even when they are measuring holes or bores. To accommodate this preference, indicators are available with reverse movements, in which the pointer moves counter-clockwise as the sensitive contact is depressed. In other words a "bigger" hole makes the pointer move into the plus (+) range, to the right of the zero.

In “push-down” movements, the spindle is at rest in the up, or retracted, position. To operate, the user presses the spindle down against the workpiece. This is useful to ensure proper location of the contact on parts with difficult contours, or to avoid interference with the indicator spindle when placing the workpiece in a fixture.

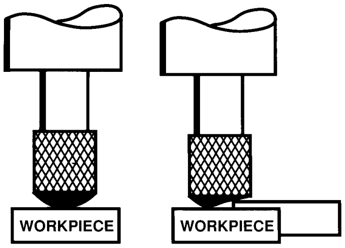
Long-range indicators have long spindle movement and supplementary dials to count pointer revolutions. These can be useful to provide clearance over obstructions, or to make absolute--as opposed to comparative--measurements of as much as six inches.

So when dial indicator gaging is difficult, time consuming of confusing, look beyond the manufacturer’s catalog and give him a call. Chances are, there is a “Special” to make the job easier.

TIGHT, CLEAN AND DRY: KEEPING YOUR DIAL INDICATOR RUNNING RIGHT

How to select a dial indicator was discussed in last month’s column. Now that you own it, here are a number of tips to keep it working smoothly and accurately.

First, mount your dial indicator correctly. The ideal method is to mount it from the back, using one of the optionally available lug or rack-type backs available from most suppliers. Mounting by the case or the stem is less desirable, because these components are part of the mechanism. Do not allow a setscrew to bear directly on the stem--the stem will deform, interfering with the movement of the spindle in its bearings. If the indicator must be mounted by the stem, it is essential to use a split bushing or a collet to distribute the clamping force evenly. It should go without saying that the indicator must be mounted securely to the fixture, with no wobble or play.

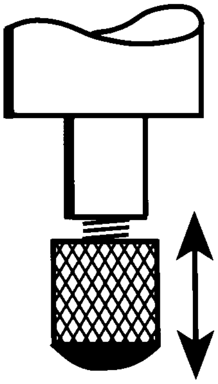


Workpieces should always be fully positioned under the measuring contact. When contact point is worn, an improperly positioned workpiece can cause significant error.

Worn or loose contacts can also cause false readings, so it is essential to inspect them frequently for wear and tightness. The contact should be screwed onto the spindle “fingertip tight”--just tight enough so it does not loosen up during use. Do not use pliers or a wrench--too much torque will distort the spindle, causing the mechanism to bind.

Replace contacts as soon as wear is detectable. If wear is rapid, consider changing to a harder material.

Hardened steel contacts wear quickly when used against rough or abrasive surfaces and may also be affected by corrosive agents in the work environment. Chromium steel contacts offer better corrosion resistance, but are only marginally tougher than hardened steel. Tungsten carbide or diamond contacts are often the most cost-effective, even though they are the most expensive. They resist wear much longer, thus reducing the need for replacement parts and labor. More importantly, less wear means the indicator will produce fewer false readings.



Loose contact points are one of the most frequent causes of measurement error.

If the indicator has been sitting idle for a while, the spindle may stick. Do not oil it. Work it in and out a few times by hand: chances are it will free up. Oil acts like a magnet for dust. Every time the spindle retracts into the case, it will pull contaminants into the indicator's precision movement. The oil, itself, will also harden with time, causing even more sticking. Too often, the problem of sticky oil is improperly treated by adding more oil, until the movement gets loaded with a gummy mess.

The only part of an indicator that should ever be lubricated is the jeweled movement. Manufacturers typically use the point of a pin to apply a minuscule amount of watch-grade oil at this location (a drop of oil from a can would be about 20 times too much). Only individuals trained in the proper methods should open up the case to oil the jeweled movement. Dial indicators that have been cared for properly will rarely require this.

Use a soft, lint-free cloth to remove dirt and oil from the spindle. Clean the crystal with soapy water, benzene, or a soft eraser. Replace scratched crystals and illegible faces. If the indicator looks like it is in poor shape, chances are it will be abused even more. If you keep it clean, it will be treated like the precision instrument it is. And that will mean years--perhaps decades--of accurate measurements and trouble-free use.

WHEN INDICATORS GO BOTH WAYS

Measuring and gaging are two fairly distinct forms of dimensional inspection. Measuring is a direct-reading process, in which the instrument incorporates a continuous scale of units, against which the part is compared directly. Examples of measuring instruments include steel rules, Vernier calipers, and micrometers.

Gaging is an indirect-reading process, in which the instrument is first set to a standard or master, then the part is compared to that setting (usually defined as zero). This is usually done because the measuring capacity of the gage (i.e., the size of the workpiece it can accommodate) is greater than the measuring capacity of the indicating device (i.e., its range). Gaging instruments include snap gages, bore gages, height and ID/OD comparators, and many others.

There is also a class of instruments that go both ways, blurring the distinction between gaging and measuring. (Hey Gage, take a walk on the wild side...) These are instruments with indicating devices whose range is equal to or greater than the capacity of the gage. Instruments with long-range indicators can perform both direct and indirect measurements.

If zero is set at the reference surface on which the workpiece rests, the indicating unit will *measure* the part directly and display its actual dimension on its scale. Alternately, zero may be set against a master, in which case the instrument becomes an indirect-reading or comparative gage, and displays part size as deviation (plus or minus) from a pre-set value.

Long-range dial indicators that can be used in these "either-or" applications have existed for decades. Although they are familiar and reliable, long-range dial indicators are not easy to read. Workers often make errors when trying to interpret the rather complicated display, which, in addition to the main dial, includes one or two revolution counters rotating in opposite directions.

A recent development is the long-range electronic indicator, with a digital display that eliminates the readability problem of dial indicators. Long-range digital indicators typically have measurement ranges of 1/2"/12mm or 1"/25mm, and resolution of 50 microinches/0.001mm. They are invariably equipped with lifting levers so that the contact point may be easily raised and lowered. In comparison, long-range dial indicators have ranges from 1/2"/12mm to 3"/75mm or more, but resolution is rarely better than 0.0001"/0.0025mm, and sometimes as coarse as 0.010"/0.25mm.

Long-range indicators are typically used on portable thickness gages or bench height/thickness stands. The portable gage provides flexibility for measuring a variety of parts anywhere in the shop, including parts on machines before, in the midst of, and after major stock removal, and multiple dimensions on the same part. Likewise, a bench gage like that shown in the photo can measure whole families of parts or multiple dimensions on the same part, including thickness, shoulder heights, depths, and outside diameters. Both types of gages offer potential time savings (from the elimination of mastering and setup changes) and cost savings (because one gage does the work of many).

Rules for the use of portable, long-range thickness gages mirror those for snap gages. Make sure the lower or fixed reference anvil is held firmly and squarely against the work, and do not allow the weight of the gage to bear on the sensitive contact. Aside from that, most gages equipped with long-range digital indicators are easy to work with, and highly adaptable.

ELECTRICAL LIMIT SWITCHES: NOT NEW, BUT TRIED AND TRUE

There is a category of gages that have been around for fifty years, are very inexpensive compared to alternate measuring methods, are fast, reliable, easy to set up, and can work for manual or automatic operations. I'm referring to mechanical gages that incorporate electrical limit switches. These include a number of different instruments that operate essentially as mechanical displacement gages. While they look and act like mechanical dial indicators or comparators, they include electrical contact points that can be adjusted to represent set points within the range of the indicator. Despite their age, these electric gages still provide the most economical means for classifying or controlling part size in many applications.

In a manual mode, when the switching indicator is combined with a light box, they provide a fast and sure way for operators to classify parts and reduce the possibility of misclassification. The other advantage of this type of gaging is in automatic or semi-automatic gaging operations. If the setup is fairly simple, with one or two gaging stations, there is probably no more cost-effective way to classify parts. Such a classifying indicator would be much less expensive than some of the alternatives, such as classifying amplifiers and related electronics.

There are basically three different types of switching gages.

The most basic type does not even include a dial indicator readout. It provides very repeatable switching within the range of the mechanical sensing head. The switching head typically has a high and low limit switch. These can be electrically combined to give the operator or machine a high, low, or good condition signal. The switching contacts on this type of device can be very accurate. In fact, one of the most impressive features of these gages is the discrimination sensitivity of the switching, which is typically 40 micro-inches, but some can be good to 10 micro-inches. This performance approaches that of some much more expensive types of classifying gages. The only drawback is that when using sensing heads without an indicator scale, the two limit positions of the gage must be set with the aid of two masters or gage block stacks representing the limit sizes.

The next style of gage electronic comparator, or electric dial indicator, has a complementary set of electrical contacts, and only requires a zero master for positioning and setting the limit switches. In use, the gage is set so that it is in the center of its mechanical range with the zero master. Then, using adjustment screws, the limits can be set for high and low limit switches. This makes the setup on the gage very fast and simple. It's also simple to adjust for changes in tolerance and adjustment of the part process when required, because it is easy to see the part being measured as the dial hand goes to the limit positions.

The key to any dial indicator with limit switching contacts is the way the contacts are used.

It's very important to put as little electrical stress on the contacts as possible. This means that the current going through the contacts should be minimal. Typically, the voltage level for switching is around 24 volts, but the maximum current should not exceed 100 ma. The purpose of this is to reduce pitting of the switching contacts. When pitting occurs, repeatability errors will increase.

Today, there is a new generation of "on the spot" classifiers. Instead of using the mechanism of a dial indicator and switches, the electronics of a digital dial indicator are given the ability to "look at" the reading, compare it to a set of preset tolerances, and provide an electronic signal representing the out-of-tolerance condition. The advantages of this type of electronic classification include:

- The ability to set the tolerances to the least significant digit of the readout.
- Repeatability of the switching to the least significant digit of the display.
- Operation features found in a digital indicator, such as presets, data output and dynamic measurements.

Sometimes it's easy to put together some of the latest technology to solve your measurement and classification requirements. However, there are some tried and true methods still available that will do an outstanding job and might cost only a fraction of the price you'd otherwise have to pay.

GOING TO EXTREMES
When You Can't Always Measure In Your Thermal Comfort Zone

When most of us think about measurement environments, what generally comes to mind are pleasant laboratories with temperatures controlled to 68°F/20°C -- plus or minus a degree or two. Or in the worst case, we picture a gaging shop with swings of temperature between 65° and 90° F.

Unfortunately, there are also gaging situations where measurements must be made in temperature environments well outside of the inspector's comfort zone. But it does not have to be outside the gage's.

1. Oh baby, it's hot in here.

Sometimes a request like this will come across my desk: Our research division is in need of dial indicators that will withstand working conditions of room temperature to 250°F. They will be used in 10,000 hour tests and must remain in the oven for the duration.

The customer was using an oven capable of cycling through a wide range of temperatures to test part performance. A customized indicator with a glass dial and chrome body was supplied to meet the sustained accuracy requirements in the face of frequent thermal cycling.

Here are some of the considerations that go into making a dial indicator worthy of high temperature applications:

Crystal. One of the most obvious considerations is the crystal. Most crystals today are made from plastic blends or alloys that can withstand temperatures up to 170°. To meet the 250°F temperature requirement, a glass crystal may be substituted.

Bezel. Bezels are typically made of plastic or zinc. For extreme high-temperature gaging, a steel bezel is the most likely choice.

Paints and Coatings. Another consideration is the paint on the indicator and dial. Most paints won't handle this type of temperature. We might consider a special temperature-resistant coating or, for the most extreme applications, none at all.

Lubricant. Technically speaking, indicators are not lubricated. However, a small amount of watch oil is applied to the jewel bearings. At high temperatures, a special Molycote can maintain lubricity when other coatings would break down.

Thermal Expansion Differentials. In dial indicators, there are some very tight clearances. Various materials used in making the indicator will expand and contract at different rates. So it's important for the manufacturer to use materials and clearances that will insure performance of the gage over the entire operating temperature range of the test.

Clearances between brass bushings and the steel rack, and between the brass gears and the top and bottom steel plates that hold them in place, must all be sized to eliminate the potential binding or slop due to differential expansion or contraction.

The expansion characteristics of the high temperature dial indicator should be provided to the user, making it possible to mathematically adjust measurements to compensate for different rates of expansion in the gage and the part.

Spring Performance. High temperatures may also diminish the force generated by take up and pull back springs within the dial indicators. As a result, better grades of steel and larger diameter wire may be needed to insure sustained performance of the gage. These types of customizations can accommodate for measuring applications in high temperature environments up to 600°F.

2. Whoa! I'm turning blue.

Sometimes measurements must be taken in environments that are mercilessly cold. The same thought processes are used to determine modifications that will keep the gage, but not the user, from numbing out. But usually lower temperatures are not the biggest problem.

Whichever direction the thermometer is moving in, mechanical indicators still can provide an economical solution to some of the most difficult measurement problems.

DIAL COMPARATORS BRIDGE THE RESOLUTION GAP

Sometimes it's necessary to measure with very high resolutions approaching 20µ"/0.5µm. Measurements at this end of the spectrum would normally be reserved for an electronic amplifier with high performance electronics. However, there may still be reasons to prefer a mechanical measurement tool for a given job. Primary among them are likely to be budgetary restrictions, or a requirement for portability that would make cabling a hand gage to a transducer less than desirable.

The lowest priced measurement tool is, of course, the dial indicator. But dial indicators are not normally thought of as providing a high resolution readout. Their high confidence zone is typically up to .0001"/2µm. Manufacturing dial indicators to the highest possible standards will result in only modest improvement of resolution. This is because the substantial number of parts in a dial indicator generate a build-up of tolerances. The high amplification required for ultra-precision measurements tends to magnify these errors which can show up as degraded accuracy, hysteresis and/or repeatability.

This is why electronic amplifiers have become so important. With only one moving part and the stability of solid state electronics, the errors are extremely small. Even though an amplifier may have very high magnification, the total error occupies a very small fragment of the instrument's resolution. But again, because of price and portability issues, this may not be the answer you want to hear.

There is another form of mechanical gage that bridges the gap between dial indicator and the electronic amplifier. Known as the dial comparator, it solves the inherent mechanical problems of its close cousin, the geared dial indicator. Here's how.

- Travel of the spindle in a dial comparator is guided by a precision ball guide. This not only eliminates friction, but also provides strong axial stiffness. This assures results in a near one-to-one translation of the motion to indicator movement.

- The ball guide also reduces the long-term damage to the spindle which can result from side play created when parts are forced from underneath the contact.

- A shock proofing system isolates the spindle from shock created by banging of the gears during rapid movement.

- Many of the gear assemblies used in mechanical amplification have been replaced by simple levers. Fewer components result in a reduced opportunity to magnify errors.

- Jeweled components provide maximum sensitivity and accuracy in the movement of gears and levers.

- A built-in compression spring provides a constant measuring force over the entire range of the indicator.

- Built-in calibration adjustment allows for fine tuning out of even the most minute errors.

While all of these features assure the highest accuracy, the dial comparator still retains all those features which make dial indicators extremely practical and easy to use. These include:

- A built-in, lockable, fine adjustment control.

- Adjustable tolerance markers.

- Very fast response indicator hand.

- Remote cable retraction of the spindle.

Any analog device has range versus resolution constraints -- the dial comparator is no exception. Since it has much higher resolution, the dial comparator also has much less range than the dial indicator. However, this might even be an advantage in some measuring processes. Since these comparators are used in very high tolerance work, limited range is probably not a major factor and might even prevent some measurement errors. Some dial indicators employ a revolution counter. In instances where the operator fails to pay attention to the counter, recorded measurements may be off by a full revolution. A dial comparator is very much like a one rev indicator. The part has to fall within the measuring range of the indicator or else it shows up as being off scale. There is no chance of being read incorrectly.

So what's the bottom line here? A dial comparator has five to ten times better resolution and accuracy than a dial indicator. The electronic amplifier has about 10 times better resolution and accuracy than the dial comparator. A good dial indicator can cost about $150. A dial comparator runs anywhere from 30% to 100% more. The cost of an electronic amplifier and probe is almost seven times the price of a good dial indicator. So where range is not a concern, the comparator is your best resolution and accuracy value. If you need high performance on a budget that's a little tight, the dial comparator could be your solution.

DIAL INDICATORS ARE ON EVERY GOOD TEAM'S BENCH

Do's and Don't's for Keeping Them in the Game

Just because dial indicators have been around since the early 1900s, don't expect them to fade away with the last century. This tool's long-term popularity is well earned. Dial indicators offer good resolution at low cost, but that is not the main reason people still use them.

Beyond providing easy-to-read quantitative measurement, dial indicators give users a comparative sense that their parts are in the ballpark. You simply see if the indicator's needle is within tolerance bands or, simpler still, lies within red sections highlighted on the dial. No interpreting is necessary. Every result may not read like a home run, but as long as it's not in the outfield, it scores as a good part.

Dial indicators vary widely in type, size and range. All translate variations (through internal movement of a plunger) into dial readings. Some will indicate dimensional variations as small as 0.00005". So you must handle these sensitive mechanisms with the same devoted care you give to other precision equipment.

To maintain high levels of quality and precision, take heed of the following tips.

By All Means Do:

- Mount dial indicators close to short support columns on test sets or comparators to avoid holding rod deflection.
- Keep the reference surface clean and level, with the test set base clean and seated positively.
- Mount your indicator securely to the fixture or holding device.
- Keep the indicator spindle and point clean, using a soft, lint-free cloth.
- Make sure the indicator hand moves toward the minus side of the dial as workpiece dimension decreases.
- Handle the gage lightly, so it can seat itself on the workpiece.
- Use diamond, tungsten carbide or hard chromium-tipped indicator points whenever it's likely that the contacts will be subject to heavy wear.
- Store your dial indicators in a safe, dry place and cover them to keep the dust and moisture out.
- Test your indicators under gaging conditions at intervals during the operating day. You can do this by gaging a part twice, then comparing its readings to a master part.
- Clean dials with soap and water, benzene or soft eraser. Frequency of cleaning depends on the type of gaging and the contaminants.

For Heaven's Sake Don't:

- Don't subject indicators to harsh, sudden blows. If blows are unavoidable, use a cushioned movement indicator.
- Don't overlook accessories that will make your indicator more efficient, more adaptable and more versatile, e.g., lifting levers, right angle attachments, maximum point hands and weights for measuring compressible materials.
- Don't oil spindle bearings except under special conditions. Then do it sparingly and never use grease.
- Don't tighten contact points or adapters too far against rack spindle, as the strain will cause distortion, make the spindle bind, the mechanism stick or the guidepin loosen or shear off.
- Don't clamp indicator against the stem with a set screw. Too much pressure will make the rack spindle bind, causing the indicator to become sluggish and sticky.
- Don't lock the indicator in position until you've set it carefully under proper gaging tension, that is, at least a quarter turn from its "at rest" position.
- Don't oil an indicator that has been idle for some time. If the spindle sticks, work it in and out by hand until it slides freely on its own bearings.
- Don't drill holes in the back of the case. Chips will get inside and ruin the movement.
- Don't use an indicator that has been dropped or struck until you have it tested thoroughly. Test it on a

comparator set or some other supporting device to make sure it's precisely calibrated. Then re-set the indicator in position as precisely as you set it the first time.

- Don't use your dial indicator for anything but what it is intended for – accurate gaging. It's not a jackhammer or paperweight. It won't give good service unless you treat it the same as your other precision instruments.

By following these tips – what to do as well as what not to do – with your dial indicator gages, you can keep them accurate and in the game for a long time (maybe even long enough to see the Red Sox win the World Series).

THE DIAL TELLS IT ALL

You've seen one, you've seen them all—a dial indicator. They are all over the shop, and as you walk around they all look the same to you. But step closer and take a long look, because here we are going to examine the indicator dial in detail. No, we are not going to go inside. We are going to look at the way the indicator presents information to the user—on the dial. There are different styles of dials, and the type is determined by how the indicator is used.

Indicator dials come in two basic formats: balanced and continuous. The reason for using one or the other is very often determined by the gage and the range of the indicator. However, in general, if the tolerances are bilateral, such as +/-0.001", the balanced dial is preferred. If the tolerance is unilateral such as -.000 to +.002", a continuous dial would be the preference.

Some dial indicators are sold with a very limited range, so limited that the dial only displays one revolution of measuring range. These one-rev indicators, with balance dials, are designed for high magnification, and to eliminate miscounting the number of revolutions the hand of the indicator travels.

Since the dial indicator is often used on a handheld gage, such as a bore gage or snap gage, the mechanical travel of the gage is really the limiting factor in the measuring range. Therefore, there is no need for the dial indicator to have long range. And, since most tolerances are bilateral, the most common dial is the balance type.

Revolution counters are used on balanced dial indicators, even though they might have only two revolutions of total travel. This is because the hand may move so fast that the eye can't keep up. A balanced dial might indicate +0.010", when in reality the hand has made an additional revolution and the actual measurement is +0.110". In this case the rev-counter is a safeguard for assuring the correct reading.

But what if that dial indicator in now mounted to a test stand or a hand gage such as a portable thickness gage? The dial indicator is now in a gage that can measure by comparison, or if the range is long enough, it could even be used as a direct measuring gage.

In the comparison mode, the dial would be of the balance type, but we have to start watching out for how many times the hand revolves, and keep track of this. Otherwise, we could make significant measurement errors and be off by a complete revolution of the dial. This is where the rev-counter adds a degree of safety to the result. By reading a combination of the rev-counter and the dial, a proper result can be obtained.

When the indicator is used to make a direct measurement from the reference surface, the rev-counter in conjunction with a continuous dial is an absolute necessity. Some long-range indicators can have 10 or more revolutions, which would be too hard to try to count and remember as the hand went around. The result of the measurement is the number of revolutions plus the amount read on the continuous dial. But of course, you have to know how much one revolution is worth.

For example, the figure below, the revolution counter shows two revolutions of the hand, or .200", and the big hand has come to rest at the 15 main dial division, or 0.015". The sum of the two readings is 0.215". Some dial indicators have more then one rev-counter since they may travel more then ten revolutions of the dial. In these cases, each rev-counter is marked with its range, and the measurement is simply the sum of the three dial readings. Here it's pretty simple to take the sum of each indictor for your total reading.

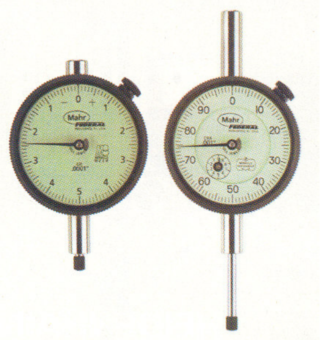
Very often we take the indicator we use for granted—but take a moment and examine the indicator dial. You'll see there's a reason it looks the way it does.

ALL OVER THE DIAL

There are endless variations in the dials used on mechanical dial indicators. In most cases though, they can be broken down into two distinct styles: Balanced and Continuous. Let's take a look at both.

With a balanced dial, the graduations around the dial represent the smallest value, or resolution, as marked on the dial face. The numbers on the indicator face are an aid in counting the value of the divisions, usually grouped by 10, but also representing 2, 5 or 20 steps around the dial.

In reading a balanced dial indicator, keep in mind that you are using a comparative indicating device, and the indicator reading usually means nothing by itself. The indicator reading must be added to, or subtracted from the value of the reference or master to which the gage was set.



Revolution counters are those extra little hands on indicators that keep track of the number of times the big hand completes a revolution. These may seem a little strange, as the typical ANSI balanced dial indicator has less then three revolutions available, but it is much easier than it might seem to miss a revolution. A warning that the indicator has gone through, or not reached its "zero" point, is very helpful in preventing bad parts from being accepted.

But the warning can also tell you more than that. The revolution counter can tell you whether the indicator is within its measuring range, or in the pre-travel or over-travel area. It can warn you that the indicator may be too high in amplification for the application, and that perhaps a slightly longer range, lower resolution indicator would be better. Or it can provide an indication that something has shifted in the gage setup, or even that the part being measured is out of control, indicating that something in the process has shifted.

On the cautionary side, the revolution counter should not be relied on too heavily as a measurement device. The counter is pretty small, so to use it as part of the measurement is not always reliable. And, as with all mechanical indicator specifications, the longer the range, the more open the performance tolerances become. On balanced dials, use revolution counters for their intended purpose: a warning indicator. They can be a sure sign that something is wrong.

Continuous dials are usually found on long rang indicators that typically have more than the standard 2-1/2 dial revolutions. Some may even have extremely long measuring ranges. The dial is read much like a balanced dial, but there are no minus readings and generally larger numbers. And long range dial indicators will almost always have a revolution counter. Here the revolution counter is invaluable. It is used to keep track of the number of times the indicator hand has moved past zero, much better than your eye could. With a combination of the revolution count and the graduation count, a measurement can be determined.

The great range of these indicators is a valuable characteristic in many applications. Typically, long range indicators will be used on a bench stand, allowing the user to measure a wide range of parts using the base as the reference point. The long range indicator can also be used on a machine to monitor the position of a slide to aid in manufacturing a part. Both are acceptable applications.

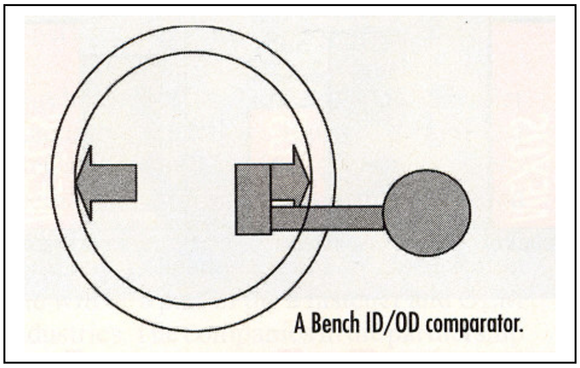
It's important to keep in mind that long range dial indicators are also comparative instruments, even though they may have measurement characteristics. Used improperly, they can cause potentially serious errors. As we noted, the longer the range with these indicators, the larger the acceptable error. In some cases, a 2% error is typical. Since 2% of 4" is 0.080", this level of inaccuracy could constitute an error larger than the tolerance range on many parts. The proper method to use the indicator would be to set the gage with a master at 4". The rev counter and the hand might be set to "zero" as the 2 rev position for its starting position. Then the gage would act as it was intended—as a dial comparator.

REVERSE POLARITY: COUNTERING YOUR CLOCKWISE INDICATOR

Last issue we looked at the advantages of balanced and continuous dial indicators. There are also measurements that require dial indicators with a counterclockwise dial. The counterclockwise dial can have the same characteristics as the balanced or continuous dial—except that it is reversed. A balanced counterclockwise dial would be indicated by having a plus (+) sign on the left, while a continuous counter-clockwise dial would count from zero, counterclockwise around the dial face.

With a counterclockwise dial, the hand travels the same as it would normally, but the scale is reversed. In effect the dial indicator has had its polarity reversed.

The golden rule is that a clockwise dial indicator should be used when the indicator and/or the sensitive contact is on the opposite side of the part from the reference point, while the counterclockwise indicator is used when the indicator and the sensitive contact are on the same side as the reference point.



A Bench ID/OD comparator.

For example, when an indicator is used on a bench stand, the anvil is the reference point. The part rests on the anvil and the indicator and the sensitive contact touching the part are opposite the reference, as shown in Fig. 1. This application would call for a clockwise dial indicator.

On the other hand, when using a bench thickness gage, as seen in Fig. 2, the reference, the sensitive contact, and the dial indicator are all on the same side of the part—thus the need for a counterclockwise movement. In this bench type of application, when a groove depth gets shorter, it pushes in on the indicator. On a normal indicator this would generate a plus reading. But with a counterclockwise/reversed dial, the indicator reads the correct polarity: i.e., a smaller reading.

Let's look at some other examples to demonstrate our golden rule:

First, take a look at the Bench ID/OD comparator in Fig 3. When set up for an inside diameter measurement, we have a reference contact on one side of the part. On the opposite side of the ID is the sensitive contact with the dial indicator on the same side, but on the outside of the part. In this case, as part size increases, the sensitive contact moves away from the reference contact and towards the dial indicator. This requires a plus reading and thus, a clockwise dial.

Now lets imagine a horizontal bore gage (Fig 4) where the reference contact, the sensitive contact, and the dial indicator are all on the inside of the bore being measured. In this case, as the sensitive contact moves away from the reference contact, the hole is getting bigger, but the indicator would normally display a smaller reading. With a reversed dial this reading would be corrected.

Finally, one of the most common uses of the counterclockwise indicator is in a variable plug gage. At first glance this may appear to contradict our golden rule mentioned above. In this case, the body of the plug is the reference surface. The contacts are on the same side as the reference surface, and so is the dial indicator—but only through its transfer mechanism. Therefore, as the rule states: when all three are on the same side, a reversed indicator should be used.

With mechanical dial indicators, it is a bit difficult to change the dial to/from normal (clockwise) to reverse (counterclockwise) readings. However, with the digital indicators and electronic amplifiers available today—this switching is done with the push of a button.

THE PLUSES AND MINUSES OF INDICATOR DIALS

Despite their many "faces," dial indicators and test indicator dials tend to look pretty similar in that they all have graduations and numbers. This similarity is especially true of dial indicators that have balanced dials. Such a dial might have "0" at the top and a number on the bottom – maybe a "10". On both the right and left could be the number "5". These dial indicators are generally used for comparison measurements, and when the indicator hand moves clockwise or counterclockwise, it's counting 0-5-10. Both the test and dial indicators are virtually the same.

Most dial indicators are used in an upright position – usually in a height stand – and as the contact point is pushed in the part getting larger: therefore the dial indicator will have a plus sign (+) on the right, and a minus (-) sign on the left.

Dial indicators can also be used to measure long travel, such as on a machine table or mechanical slide. When these indicators are used for displaying a position on a machine table, they tend to be placed in front and on the right side of the table. This is because the indicator is being used to measure the X and Y coordinates of the table, and the indicators have to follow those coordinates. As such, when the table gets closer to the indicator, the clockwise movement caused by the inward movement of the indicator displays a plus value.

However, this is not to say that the movement of an indicator can't be changed to go in the opposite direction, or that the minus sign might be placed on the right. Exceptions like this are generally made for gages where an outward movement indicates a plus value, as in a mechanical fixed plug gage. In these indicators, as the spindle is pushed in, the part is actually getting smaller.

Test indicators are often without this important indication. This is because of the versatility they offer and the way they are used. Test indicators have long probes (contacts) that extend away from the indicator and allow it to get into grooves and measure on the tops and bottoms of lands. Because of this versatility, and depending on the way the test indicator is positioned, upward movement of the probe may sometimes mean plus, or it may mean minus. To reduce the potential for misreading these indicators, the “+” and “-“ signs are left off. However, this really puts the weight of dial interpretation on the user. Test indicators are not for the light of heart and are generally used by skilled technicians, capable of doing a variety of measurement tasks. They are trained to do these set-ups and inspections and to properly analyze and report the results.

Most older test indicators had a lever on the side to reverse the sensing direction when oriented for different applications. Today’s indicators have built-in direction sensing and can display a value when the contact probe is approached from either the top or the bottom.

To complicate matters even more, on some test indicators the dial is not lined up with the contact point movement at all, and the operator has to take care to properly interpret these values. These indicator dials may be mounted on the top, end or even the side. The type of measurement to be made and the ability to see the indicator face determine the choice of indicator style.

All of these test indicator choices share one common difference from a dial indicator face. While they all may have a balanced dial, they are missing the “+” and “-“ sign, and both direction and size interpretation must be determined by the user.

So, the next time you pick up a test indicator and notice that the dial looks different from a dial indicator, take it as a reminder that you need to understand the way the test indicator will be used and add the results up for yourself.