CHEMICAL PROCESSING
LEADERSHIP | EXPERTISE | INNOVATION

Ponder These **Pressure Measurement Best Practices**

PutmanMedia®

TABLE OF CONTENTS

AD INDEX

Take the Pressure Off Troubleshooting

Understand the factors that affect getting correct local measurements

By Andrew Sloley, Contributing Editor

Process engineers always want more instruments. However, project managers invariably balk at the cost, especially for devices not needed when an operation is running right. The usual compromise leads to a mix of instruments (some tied into the control system and others purely for local indication) as well as connection points for future instruments.

When a process has problems, the local instruments and connection points may play a critical role in finding the culprit. Local pressure readings often are essential.

These pressure readings usually rely on either a mechanical or electronic gauge. The most common conventional gauges use a Bourdon tube to measure the pressure. This coiled tube uncoils when the pressure differential between the inside and the outside of the tube increases. A mechanical linkage converts the Bourdon tube movement into a dial reading.

ASME Standard B40.100, "Pressure Gauges and Gauge Attachments," covers mechanical, analog, dial-type gauges that use elastic elements (including Bourdon tubes). The standard specifies several accuracy grades. Grades 1A (±1% of scale) and 2A (±0.5% of scale) suit many uses. Grades 3A (±0.25% of scale) and 4A (±0.1% of scale) are expensive enough that plants rarely have them, and usually require special effort to get. Other, less-accurate grades are available. Whenever you use a pressure gauge, check its grade and look up the accuracy rating.

A liquid-filled gauge or a pulsation dampener tend to reduce accuracy.

The accuracy ratings assume good mechanical handling, specific operating conditions, and no vibration or other mechanical damage. I've found that even gauges in "good" nominal condition in the field frequently have two-to-three times the error of the manufacturer's stated values. This reflects age, handling practices (dropping, etc.) and how the plant's instrument shop reconditions the device. Gauges in semi-permanent installations for long periods of time often have larger errors.

When using a pressure gauge attached to a rarely turned valve, the key question is what happens if you can't shut the isolation valve again? Recommended practice is to put a new valve and bleeder between the pressure gauge and the process. This way, if the current valve doesn't seal completely, you can resort to the new valve. Then, you can remove the old gauge and install a plug if needed.

Other key questions in valve selection include materials compatibility, process pressure and temperature, ambient conditions, service specific requirements, size, mechanical conditions of the service, and mounting.

To check materials compatibility, review the gauge materials, the piping materials and the process fluid involved. Materials must be safe to use and not contaminate the process. Additionally, if the gauge is to remain in place for an extended period, the materials shouldn't create a corrosion weak point or promote corrosion elsewhere.

You must select a gauge with the right pressure range for useful readings. It also must offer safe mechanical characteristics and adequately tolerate the maximum possible pressure and expected temperature ranges for the process. In addition, it must suit ambient conditions, including the possibility of dust and harsh weather as well as locally corrosive atmospheres.

Specific services may impose special requirements. These may stem from industry standards, regulatory requirements, corporate guidelines or prudent judgment. Common services requiring specific gauge choices include acetylene, ammonia, oxygen, severe chemical applications and lethal services.

Larger gauges are easier to read but usually are more expensive and harder to find a location for mounting. At a minimum, opting for a gauge with a nominal 4-in. (100-m) face is good practice for taking accurate readings.

Vibration poses the most significant mechanical issue for a gauge. It can make the gauge difficult to use and also lead to mechanical fatigue. When the needle is oscillating, how do you take a pressure reading? Mechanical vibration of the pipe and equipment or pressure fluctuations in the process can cause such shuddering. The most common tactic to dampen vibration is to use either a liquid-filled gauge or a pulsation dampener; however, both tend to reduce gauge accuracy.

Liquid-filled gauges have larger possible errors due to temperature effects but improve gauge life, dampen needle vibration and decrease corrosion problems inside the gauge. Pulsation dampeners tend to reduce gauge sensitivity and plug more easily than conventional gauges.

Consider these factors when selecting a pressure gauge. However, often a troubleshooter must use whatever instrument the plant has available. In that case, understand the gauge, safety requirements and the likely accuracy or error in a reading. ●

ANDREW SLOLEY contributes monthly to the Plant InSites column. Email him at ASloley@putman.net.

Deflate Random Errors

Take steps to minimize their impact on the accuracy of pressure readings

By Andrew Sloley, Contributing Editor

In "Do Simple Things Right!" (see page 9 of this eHandbook) I looked at overcoming bias in pressure gauges. The gauges also may have random errors in readings. When purchased, pressure gauges should come with paperwork showing the expected error of the gauge. It should include both the bias and the random error.

What's a typical error? A good gauge well suited for most troubleshooting work has an expected error of 1 or 2%. This percentage may relate either to the entire range of the gauge or the particular reading. If given as a percent of reading, the error may apply only to a restricted range on the gauge.

To see what this means for us, let's go back to last column's example of using a 0–100-psig gauge to take readings from 81 to 49 psig. Table 1 lists some readings and the expected error for percent-of-range versus percent-of-reading. It shows that percent-of-range gauges really give a fixed error amount and that percent-of-reading gauges tend to be more accurate. However, the latter are more expensive. Unless you're careful, your purchasing department will get the lower accuracy gauges.

Reading, psig	Possible error, percent-of-range	Possible error, percent-of-reading
81	± 1	±0.81
74	± 1	±0.74
71	± 1	±0.71
64	± 1	±0.64
61	± 1	±0.61
49	± 1	±0.49

GAUGE WITH 1% ERROR

Table 1. Error as percent of range is fixed but varies as percent of reading.

Some larger plants have internal instrument shops that repair out-of-specification or damaged gauges. If that's the case at your site, do you know the accuracy of the gauge you're getting back from the shop? Often, the answer is no. Lack of knowledge adds uncertainty. Unless the gauge is tested, assume it has an error of 2% of range or more.

At the start of any pressure survey, put all the gauges on a common point with steady pressure and take readings. Then, don't use any gauge that is more than the error range away from the average.

Reducing the effect of random errors requires different techniques than those for addressing bias. Using multiple gauges at the same location and at the same time can cut the consequences of random errors. Whether or not you must resort to this depends upon the accuracy and precision necessary to justify a conclusion.

Consider a situation I faced a while ago. It required measuring four points to create a pressure profile. The pressure ranges were from 5 psig to 22 psig. The most important range was 12 psig to 22 psig; that range demanded an accuracy of ±0.25 psi to enable a valid decision.

Set	Reading	Range for values, high minus low, psi
1	A	0.3
1	B	0.6
1	C	0.5
1	D	0.2
2	E	0.5
2	F	0.6

TWO SETS OF GAUGES
Table 2. Using two sets of four gauges provided accuracy close to ±1%.

We had 0–30-psig and 0–60-psig gauges available. At the start, we assumed all gauges had an accuracy of ±2%. This created a problem. Relying on single gauges would cast real doubts on the certainty of our conclusions.

So, we used eight gauges split into two sets. One set contained two 0–30-psig and two 0–60-psig gauges. The second set consisted of four 0–30-psig gauges. During use, we identified one gauge as being damaged and removed it from service. Table 2 shows the variation found among the gauges at common points. Assuming random errors, the accuracy was closer to ±1%.

The eight gauges allowed us to deploy four gauges at each location to average out random errors. Taking two pressure surveys with the sets switched enabled us to remove biases from the readings. Both techniques together generated a usable pressure profile and helped identify the process problem.

Even simple jobs such as taking pressure readings have a right way. Performed correctly, pressure profiles can be an invaluable troubleshooting tool. ●

ANDREW SLOLEY writes the Plant InSites column for *Chemical Processing.* Email him at ASloley@putman.net.

Do Simple Things Right!

Getting accurate pressure measurements is harder than it might seem

By Andrew Sloley, Contributing Editor

Occasionally I teach a seminar on troubleshooting. Attendees may include plant engineers or operators. At one such recent event, a participant commented the discussion was too simple and the points made were "just common sense." I didn't argue. However, a modified version of the well-known statement of Carl von Clausewitz in "On War" certainly applies: Everything is very simple in troubleshooting, but the simplest thing is difficult.

So let's look at a simple thing — taking pressure measurements — to see how to do it right.

Let's say we're looking for possible fouling or plugging problems in a heat exchanger train. Troubleshooting here involves using gauges to take pressures at various points in the preheat train. Subtracting one reading from another gives the pressure drop between the two points on the train. Three technical constraints limit useful data from pressure gauges in determining accurate pressure drops.

1. *Pressure changes caused by factors other than fouling or plugging during the measurement*. Examples of such factors include modifications to pump operation, static head or flow rate.

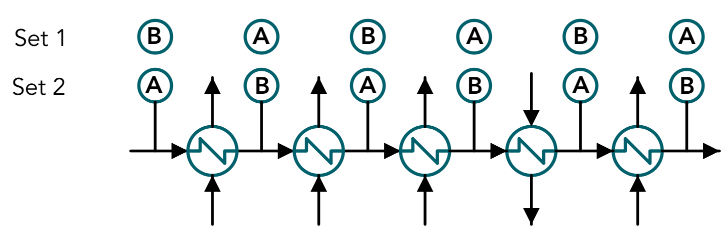
2. *Accuracy in measurements*. Both bias (offset in readings) and random error will influence the usefulness of the results.

3. *Accuracy required to get a useful value where a small number is generated by subtracting two large numbers.* This makes accuracy errors much more difficult to handle.

We could use a single gauge and move it to take all the readings. Relying on the same gauge helps reduce or eliminate the effect of bias on the readings. However, moving the gauge takes time. Moreover, it's difficult to determine outside factors that might affect the next reading.

Instead, we could use two gauges — installing them at adjacent measurement points and then taking readings at the same time. The difference between the readings indicates the differential pressure between the two points.

Gauge Locations for Pressure Readings



Pressure Readings and Pressure Drops

Readings 1	81		74		71		64		61		49
Drops 1		7		3		7		3		12	
Readings 2	79		76		69		66		59		51
Drops 2		3		7		3		7		8	
Average Drop		**5**		**5**		**5**		**5**		**10**	

BEATING BIAS

Figure 1. Using two pressure gauges and taking two sets of data can provide results that minimize the effect of each gauge's bias.

However, this measurement suffers from bias. The pressures labeled Set 1 in Figure 1 show the result of bias. Gauge A always reads too high and Gauge B always too low. So, the differential pressures calculated show a seesaw deviation. The first calculation is too high — this is the result of a too-high reading minus a too-low reading. The second is too low — the result of a too-low reading minus a too-high one.

How can we make our pressure readings better?

One way is to take a second set of readings. Switch the gauges and start over. Set 2 in Figure 1 shows these readings. This time we end up with the same seesaw of inaccuracy but in the opposite directions from the first set. Averaging the pressure drops from both sets of data (the lower line in Figure 1) eliminates the bias of both gauges. In this case, the last heat exchanger on the right has twice the average pressure drop of the other exchangers!

Of course, this approach has its own assumptions. The biggest one is that the bias on each gauge remains constant. So, I highly recommend adding a step to the

For every reading, record the gauge used as well as the pressure.

procedure: Put both gauges on the same point and compare them. At a minimum, do this at the start of the first survey, when you begin the second survey with switched gauges, and when the survey is finished. For every reading, record the gauge used as well as the pressure. Clearly label the gauges!

This technique helps decrease the effect of bias when gathering plant data. It doesn't address random errors in readings — future columns will look at techniques to reduce the consequences of random errors on pressure readings to calculate differential pressures across equipment.

Yes, taking pressure readings is simple, but the simplest thing can be difficult!

ANDREW SLOLEY is a contributing editor for *Chemical Processing.* Email him at ASloley@putman.net.

ADDITIONAL RESOURCES

EHANDBOOKS

Check out our vast library of past eHandbooks that offer a wealth of information on a single topic, aimed at providing best practices, key trends, developments and successful applications to help make your facilities as efficient, safe, environmentally friendly and economically competitive as possible.

UPCOMING AND ON DEMAND WEBINARS

Tap into expert knowledge. *Chemical Processing* editors and industry experts delve into hot topics challenging the chemical processing industry today while providing insights and practical guidance. Each of these free webinars feature a live Q&A session and lasts 60 minutes.

WHITE PAPERS

Check out our library of white papers covering myriad topics and offering valuable insight into products and solutions important to chemical processing professionals. From automation to fluid handling, separations technologies and utilities, this white paper library has it all.

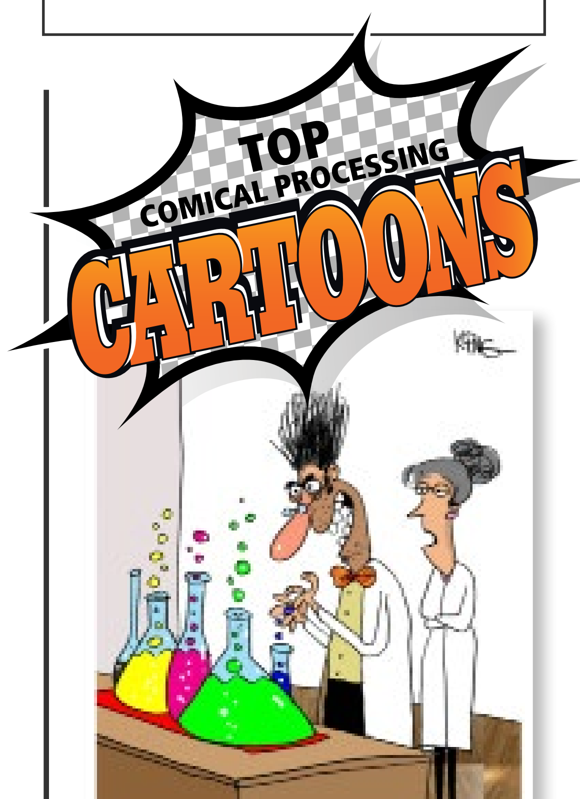
PROCESS SAFETY WITH TRISH & TRACI

Trish Kerin, director of IChemE Safety Centre, and *Chemical Processing*'s Traci Purdum discuss current process safety issues offering insight into mitigation options and next steps.

ASK THE EXPERTS

Have a question on a technical issue that needs to be addressed? Visit our Ask the Experts forum. Covering topics from combustion to steam systems, our roster of leading subject matter experts, as well as other forum members, can help you tackle plant issues.

JOIN US ON SOCIAL MEDIA!



Visit the lighter side, featuring drawings by award-winning cartoonist Jerry King. Click on an image and you will arrive at a page with the winning caption and all submissions for that particular cartoon.