Optimizing Leak Test Performance

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SUMMARY

Once a Sentinel I-21/B-21/C-20 instrument is installed and powered, the user usually attempts to calibrate the instrument and run several leak tests. In most cases, the test performance isn't as good as it could be. This document discusses test optimization in a step-by-step fashion. The last portion of the document reviews some common tooling mistakes that should be corrected prior to optimization. In most situations the user has a limited amount of time to conduct the leak test. For arguments sake, we have assumed that the total test time (Gross + Fill + Stab + Test) presently consumes the maximum time allowed for the application. Since longer test time almost always improves performance, you should extend the total test time to the maximum allowed before beginning the optimization process.

DISCUSSION

Calibration of the Sentinel I-21/B-21/C-20 instrument is defined as the establishment of No-Leak Loss and Reject (Hi Limit) Loss values for the part (look under the PRESS (MENU) key for these values). The No Leak Loss is the pressure drop associated with a leak free part (almost all leak free parts have a non-zero pressure drop). The Reject (Hi Limit) Loss is the pressure drop associated with a part that leaks at exactly the reject rate and is found by placing a known leak into the test circuit (e.g. the orifice). The Reject (Hi Limit) Loss is always a larger value than the No Leak Loss.

Preliminary Actions

Prior to beginning the actual optimization process, check the following items:

1. Establish a master, leak free part for calibration purposes. If possible, this part should be marked and used as a reference whenever a future calibration problem arises.
2. Verify that the test circuit and master part is leak free. To do this, place the master part in the tooling fixture and run a test. As soon as the instrument enters the "Test" portion of the leak cycle, push the HOLD button (the hold light should turn on). Now watch the displayed pressure loss value. If the part and tooling are indeed leak free, the reading will eventually stabilize around a fixed value. If this doesn't happen, use a water and soap solution to find the leak. As an interesting experiment,

Cincinnati Test Systems, Inc.
Member of *TASI* - A Total Automated Solutions Inc. Company
5555 Dry Fork Road, Village of Cleves, OH 45002 • Tel. 513-367-6699 • Fax 513-367-5426
Website: www.cincinnati-test.com • E-mail: sales@cincinnati-test.com

grasp the brass test port with your hand. As the heat of your hand warms the metal, the pressure in the test circuit increases (the pressure loss on the display decreases).

3. Make sure the relax timer is long enough to assure repeatable calibrations. The purpose of the relax timer is to allow a delay between subsequent tests (including the calibration tests) so that the part can return to a virgin state. The amount of time required depends on your part and the test pressure. If you are unsure, start at about one minute and perform successive calibrations. If the difference between Reject (Hi Limit) Loss and No Leak Loss increases with increasing relax time, then continue to increase the relax timer until this difference stays approximately constant. Some typical relax times are:

Fuel injector (60 psi test pressure, small steel part): 15 - 20 sec.
Power steering pumps (15 psi, steel or cast iron): 30 sec.
Power brake reservoir (5 psi, blow molded plastic): 2 min.
Exhaust manifold (120 psi, cast iron): 8 min.
Thin lexan cube (5 psi): 1 hour

Once the preliminary items are checked, we proceed with optimization by calculating the pressure loss associated with the specified reject rate. Since the difference between the Reject (Hi Limit) Loss and No Leak Loss is ideally due only to the orifice, the calculated pressure loss should approximately equal (within 15%) this difference.

$$\text{Pressure loss}_{\text{(calculated)}} = \frac{\text{(Leak Rate)(Test Time)(14.7)}}{\text{Volume} \times 60}$$

Where:

- Leak Rate is in cubic centimeters per minute
- Test Time is the "test" portion of the leak test in seconds
- Volume is the entire test volume (part + test line) in cubic centimeters
- Pressure Loss is in pounds per square inch
  Note: 16.39 cc/cu. in.

Pressure loss $_{\text{(actual)}}$ = Reject Loss - No Leak Loss

If Pressure loss $_{\text{(calculated)}}$ ~ Pressure loss $_{\text{(actual)}}$, then there are no unusual forces at work and we can skip to timer optimization section below. Otherwise, we have to investigate non-linear optimization.

<u>Non-linear Optimization</u>

In this segment of optimization, we will try to determine why the calculated and actual pressure losses don't agree. The ideas listed below must be tested individually. To test an idea, implement the recommendation and perform a calibration. Then calculate the new Pressure loss $_{\text{(actual)}}$. If it is within 15% of Pressure loss $_{\text{(calculated)}}$, you've solved the non-linear problem and can move on to the Timer Optimization section. Otherwise, remove any changes you made and proceed to the next idea. Combining ideas can be tried as soon as you've become comfortable with the optimization process.

1. Re-confirm that the calibration orifice is not plugged. Nine times out of ten, this is the root cause of calibration problems.
2. Use a second master part for calibration. Some parts (taillight assemblies comes to mind) require very long relax times to return to virgin condition (24 to 36 hours is not unusual). Since a 24 hour relax timer is not very realistic, these companies use two master parts; one for the No Leak Loss

test and another for the Reject Loss test. The tooling must release the part between the two calibration tests to permit the exchange. If you are using the Sentinel I-21/B-21/C-20 for tooling control, set the Auto Cal Method to Manual (Orifice in Panel).

3. Unclamp the part between auto cal tests. Similar to idea #1, some parts (or the tooling seals) are slowly deformed by the tooling forces that retain it. If this happens, the part volume changes differently between the two calibration tests. Again similar to #1 above, release the part during the relax time of auto cal. This time, however, use the same master part for both tests.
4. Increase the Test timer at the expense of the Fill or Stabilize timer.

<u>Timer Optimization</u>

Optimizing timers simply involves moving time from one of the three critical timers (Fill, Stab, or Test) to another and evaluating the resulting performance by running multiple tests. Values for the other timers (Gross, Exh) can be set per the rules below.

The Gross timer value is the <u>maximum</u> time allowed to reach the minimum test pressure (Min Test Press). The actual time used is almost always less than the timer value. Once the part reaches the Minimum Test Pressure, the instrument automatically moves on to the Fill timer. Therefore, the user will usually make this timer about twice as long as is normally required to fill the part.

The exhaust timer is used to vent air from the part upon completion of the test. Releasing the part before it is fully exhausted can cause the seals to blow out of the tooling and can also be unsafe. The actual value required depends on the test pressure and the part volume.

Since the part must exhaust through the Sentinel instrument’s valve manifold, it may take 2-3 seconds or more to exhaust large parts. One shortcut is to add a normally closed 120 vac valve (with a 0.25 inch or larger orifice) to the test line, wired to the EXHAUST output and common of the instrument. The part will now exhaust through both the manifold and the NC valve. Such a valve can significantly reduce the exhaust time. However, the valve is now a part of the test circuit. If it leaks, it will appear that the part leaks. A good quality, bubble tight valve must be used.

Once the Gross and Exhaust timers are selected, our focus turns to the Fill, Stab and Test timers. The Fill timer is the time during which the pressure regulator is filling your part. This time should be long enough to insure that the part is completely filled. The stabilize time is something of a delay for part expansion, air absorption, adiabatic heating, etc. that cause transient pressure loss to subside before the actual test begins. Since these transient pressure losses are also occurring during Fill time (Fill just has the regulator in the pneumatic circuit), the Fill and Stab timers are often lumped together as the Fill/Stab time. You can watch this transient pressure decay occurring during the Stabilize time on the display. In general, <u>we will want to select a Fill/Stab time such that most of this transient decay is finished before the test time begins.</u>

The Test time is the time during which we make high resolution pressure measurements to determine if the part is accepted or rejected. If the Fill/Stab time is too short, the value displayed on the screen during Test will increase very fast, even on known leak free parts (indicating a significant transient pressure loss). This is undesirable but unavoidable to a certain extent.

Optimizing test performance will boil down to deciding where to spend the available test time; in Fill/Stab or in Test. To help decide, we need to look at the calibration data. The No Leak Loss (NLL) value is the pressure drop for a good part (e.g. 0 sccm). The Reject (Hi Lim) Loss (RL) value is the pressure drop for a part that leaks at exactly the Reject Rate. Both of these values are found in the PRESS (or MENU) display and both are established during a calibration. (Note: if you run a successful calibration right now, these values will be updated). Calculate the calibration ratio (CR) for these calibration values:

CR = RL / NLL (> 2 is desirable)

Ideally, the NLL is very small (e.g. < .0010 psi). This will occur if all the transient pressure loss effects can decay to zero during the Fill/Stab time. Also, in our ideal world, the RL would be very large (e.g. > 25 times as large as the NLL). This will occur when the Test timer is very long, providing plenty of time for air to escape out of a leak in the part. Therefore, our ideal leak test has the following calibrations:

NLL:	< .0010
RL:	> .0250
CR:	> 25

Values this nice rarely occur. If they did occur, I would strongly consider reducing either the Fill/Stab or Test timers to improve production throughput.
A more realistic situation is as follows:

NLL:	.0221
RL:	.0241
CR:	1.09

This calibration will work, but hopefully can be better. The difference between NLL and RL is very small. We could take time out of the Fill/Stab timers and put it into the Test timer, but this will provide less time for transient effects to decay thereby increasing the NLL value. We could be worse off! The only way to tell is by trial and error. Move time from the Fill/Stab timer to the Test timer and re-calibrate the instrument. (For better accuracy, re-calibrate several times, recording the NLL and RL values each time. If they trend, increase the relax timer).

NLL:	.0289
RL:	.0340
CR:	1.18

In this case, the CR is larger so the calibration is more robust. You should continue to move time to the Test timer until CR is maximized (it will eventually start to decline). Had the CR gotten smaller, you would move time from Test to Fill/Stab until the CR is maximized. Optimization is an iterative process. If possible, try to use several different parts throughout the procedure. Many parts will “work harden” from excessive leak testing, making the calibration process inaccurate. If you suspect that this has happened, run a calibration using your first set of Fill/Stab and Test timers. If the new calibration values are significantly different than the originals, get a new part before proceeding with optimization.

TOOLING and PROCESSES

Unreliable fixturing and improper part sealing is by far the biggest cause of unconfirmed rejects. Seals should be made of cut resistant urethane and no harder than 70 durometer (A scale). The seal holder cannot allow the seal to creep during test. Tooling cannot be allowed to deform the part during test or artificially help seal the part.
The test line should be made of 2000 psi Parker tubing and should be no larger than is absolutely necessary in order to minimize test volume. The instrument should be located above the part to keep contamination away from the pressure transducer and orifice.
Warm or cold air sources (radiant heaters, air conditioning ducts, etc.) should be avoided. They change the temperature of the part, causing the test pressure to fluctuate. Test parts should soak at room temperature before testing to assure consistent test performance

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