

Development Of Precision Flow And Leak Test Benches

By Jim Bailey

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Vernay Laboratories, Inc. is in the business of making precision molded rubber components the majority of which are used in fluid flow applications. To assist us in better understanding our own products and providing detailed and accurate data to our customers, we undertook the task of building two new automated flow test benches.

Design Objectives

Our objectives were speed, accuracy, repeatability, compatibility with office tools and data systems, traceability, and search-ability of the test results. We felt that we should be able to fully characterize a single check valve in ten to twenty minutes. We expected this characterization to have one hundred or more data points covering both the positive and negative pressure ranges with the pressures and flows accurate and repeatable to +/-2% of the reading. We also wanted to be able to place this data into spreadsheets and a database which statistically characterizes a set of twenty or more parts. We expected to be able to search over all of our historical testing to find parts which meet specific functional criteria.

All of these objectives could best be addressed in the context of a highly standardized system with as much commonality of components as is practical and with computer automation. It was our experience that a major problem with test work time was that the test fixture had to be plumbed to the appropriate instruments each time. This was also a source of errors.

Major concerns were inconsistent system losses resulting from variations in the plumbing and fixture designs, variation in the precise timing of the data collection - because rubber parts have some degree of drift - and errors in recording the data. So, we borrowed from the SMED (single minute exchange of dies) manufacturing concepts and devised ways to minimize the time required and the changes to the flow geometry. We also surveyed available pressure regulators, flow and pressure sensors, and fittings and did considerable experimentation with these before settling on a system design.

We test in both water and air. For water we wanted clean, temperature controlled water. Our biggest concern with air was to make sure our data was properly adjusted to standard conditions. We surveyed our parts and established the ranges of pressure and flow. We needed a wide range because our parts vary considerably in size and we wanted to be able to measure the smallest reverse leakage in the same test system with the largest forward flow. This was important for us because we did not want to re-fixture the part between the forward and reverse tests as the behavior when transitioning through the origin is a great interest to us and to our customers.

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We selected sensors so as to measure to +/-2% of the reading over the following ranges:

	<u>Air</u>	<u>Water</u>
Pressure drop:	1 mbar - 7 bar	1 mbar - 10 bar
Flow rate: L/min	0.1 cc/min - 250 L/min	1 cc/min - 75

Note that for some situations we are interested in the onset of flow which means we need only to detect and not accurately measure flow. For those situations we can detect flow rates well below those listed above.

Our Design

Air flow rates are measured with a combination of six laminar flow elements (LFE). These devices report a pressure drop between two taps from which can be calculated the flow in standard conditions. These sensors come with NIST trace-able certificates. Water flow rates are measured with a combination of two magnetic flow meters and a single LFE. Magnetic flow meters use Hall effect and insert no obstruction into the flow path. They have high turn-down ratios so that two flow meters were enough to cover all but the lowest flows. For those we switch in the small LFE. Water flow rates are easily validated by doing timed fill experiments with an accurate scale.

Our fixturing applies the SMED principles in two ways. First we use interchangeable seats which install into interchangeable housings. The only geometry which changes with a new part is the seat. The housings are all made to fit interchangeably into the test systems, either air or water. Second, we measure the system loss of the entire system and by having all this interchangeability, we only have to characterize the system once. The custom plumbing is gone so we always know what the test system is contributing to the readings. All the fixtures and housings are made of clear plastic so we can see that the parts are correctly installed and can see details of their operation. The holder for the water housings is made to be turned ninety degrees so the technician can purge any air bubbles before turning it level again for the test. The housings use the same pressure taps located in the same relationship to the seats for every test. These are plumbed with the same small diameter lines to the same transducers.

In designing these test systems, it was necessary to pay a lot of attention to the construction details. Special care was taken in sizing the tubing and valves and in keeping the geometry as ideal as possible with runs as short as possible.

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Water is less of a problem because the flow will be everywhere the same. But with air, because gas is compressible, there is a trade-off between pressure losses due to the restriction of smaller diameters and measurement sensitivity. The solution is to hold the pressure steady and wait long enough for steady-state conditions. This is in fact what we do, through automation described below, but in the design phase we wanted to find the best balance between these two factors, restriction and excess volume. (See the photo of the air test system.) Real world valves and fittings make this a bigger challenge. Valves must be large enough so as not to restrict flow too much, have a minimum of wasted volume, and be leak free. We settled on the clean, pack-less valves used in the semi-conductor industry. Because we measure low levels of leakage, special care was also taken to evaluate fittings, especially those which have to be accessed frequently. Electrical layout is also important. We divided our controls cabinet into two halves, one for signals and one for power. Care was taken with grounding and shielding to minimize cross-talk and noise pickup.

To quickly and automatically control pressure we evaluated and chose electronic PID pressure controllers. These use air pressure to pilot- regulate larger air and water regulators. There are two feedback loops for smooth control. By programmatically switching the feedback transducers, we can obtain a very wide range of pressure control. Note that although the computer commands various pressures with a nominal degree of accuracy, we don't rely on this but rather measure the delta pressure directly across the part. To measure pressure over so wide a range, we found it best to use multiple pressure transducers permanently plumbed in parallel. These are chosen with high proof pressure (maximum pressure without damage) but with full-scale ranges in decades. This way the computer can automatically choose the best gauge for accuracy at any given time. The pressure gauges read both positive and negative pressure. When we want to sweep water pressure through the origin, we counter-balance a standing column of water on one side of the part with the regulated pressure on the other. This gives a pressure offset so we can smoothly sweep the pressure through zero pressure across the part. If a higher offset is needed we have valves to put air pressure over the standing column of water to further increase its counter-pressure.

We chose LabView™ for our automation. This provides a very flexible and relatively easy to program control system. We built manual control panels in software to run and verify all the measuring and control aspects of the test systems. These remain available for troubleshooting or special tests. Once the function of all the individual sub-systems was known and proven, we then built the automation around those sub-systems. LabView™ makes this relatively easy because the software tools are based on building modules and

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incorporating them into larger systems. The final control systems are user-friendly control-panel-like displays which allow the technician manual or automatic control with lots of visual and auditory queues as to what is happening. With this level of automation, the technician is freed to work on reports and other duties while testing is underway.

The automation has functionality to make the best trade-off between speed and accuracy. As testing progresses, the computer simultaneously reads delta pressure/flow pairs and stores them in memory. Pressure is swept across the entire selected range of interest in small steps. At each step the pressure/flow pairs are tested statistically for stability. Factors which contribute to instability are the response times of the regulators and flow meters, the delay due to flow downstream of the media, and the viscous response of the part itself. When stability is determined to be within a tolerance, then data is stored and the next increment of pressure is taken. The operator is provided with a real-time graphical display of this stability check to facilitate troubleshooting. The result is a series of pairs which are stable and which have been collected in the minimum time.

The typical end product of our testing is a flow curve with three-sigma limits established based on a sampling of multiple parts. Therefore, it is necessary to establish the flow for each of the sample parts at a specific schedule of pressures. Because a large data set is collected for each sample part, it is easy and reliable to interpolate the flow rates from this data to the specific schedule pressures. When this is done, the mean and sigma for all the sample parts at each scheduled pressure is computed and graphed. To facilitate this process, the LabView control system does the interpolations and exports the flows as a function of the pressure schedule for further processing in Excel. After review by the test engineer, the mean and sigma values are computed and loaded into a proprietary data base on our network. With this data base we can search for parts tested which meet specific criteria of flow and/or leakage. This facilitates our sales effort and research into product design.

Challenge testing is an import activity in any lab. We routinely measure system pressure losses and run specific rigid orifices in our system before and after each test series. These results are plotted on control charts to check for out-of-control conditions. The automation makes this a simple and routine matter. We also have a regular schedule of calibrations with all gauges traceable to NIST standards, either by having certificates for specific gauges or by performing calibrations with traceable test standards. Our most valuable test instrument is a Druck pressure tester. This is a very versatile and highly accurate pressure and temperature standard.

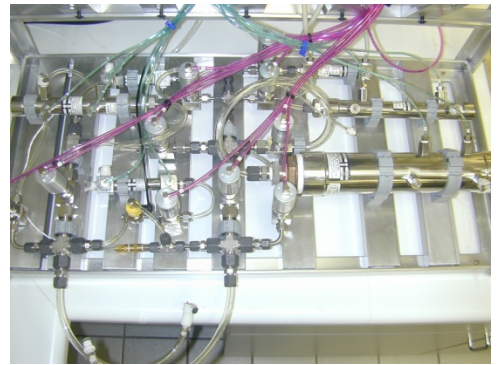
TECHNICAL WHITE PAPER

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It has taken about five years altogether to learn enough, experiment enough, and then build and validate these test systems. The benefits are that we have a high degree of confidence in our data, that the data is well organized and easily accessed on our network. As a result we have a continuously growing knowledge of our products and how they work.

Jim Bailey, Vernay Laboratories Inc.



Air Test Bench with Plumbing View

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Water Test Bench with Fixture View

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