InterTech

Assembly & Test White Paper

Test-Centric Assembly

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What is “Test-Centric Assembly”

Test-Centric Assembly is best defined as the upfront consideration of real-world test requirements in test-intensive assembly operations that is proven to lower production line inefficiencies.

Test-Centric Assembly is a best-practice approach for any test-intensive assembly operation. A common, but far less satisfactory approach to machine building of test-intensive assemblies is to consider testing as an afterthought to overall machine design. This often means that the real testing requirements of an assembly and test application are misunderstood. This less than optimal approach typically compromises Gauge R&R. In many cases, defective part problems are predominant and there is an inability to diagnose whether testing processes are lacking and creating erroneous defect readings or if real defects in the parts are at issue.

Hallmarks of test-centric assemblies are expert fixture design and integration of both hardware and software at the system level. Test-centric assembly refers to the entirety of the applications engineering knowledgebase that enables testing experts with a singular focus on testing to improve production speed and yields in test-intensive operations.

This white paper reviews the general principles of test-centric assembly for manufacturers and machine builders more accustomed to streamlining assembly operations where testing is absent or plays a minimal part.

18-station assembly chassis optimized for test-centric assembly

End of Line vs. In-process Testing

In many manufacturing scenarios, there are considerable advantages to focusing on in-process testing as opposed to end-of-line testing. As a part or assembly is built, material and labor costs are added constantly. The total value of a production component is usually a function of its percentage completion and includes both labor and material costs built into the item. If one integrates testing throughout an assembly one can avoid the costs of adding material and labor to defective production components.

In-process testing minimizes rework and scrap costs

Some examples of how costs for rework and scrap can be avoided by in-process testing are as follows:

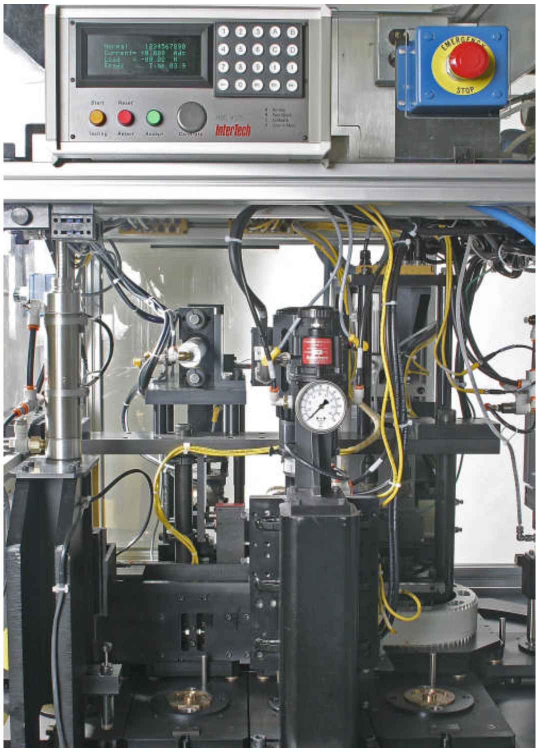
- Functional testing to verify electrical, pneumatic and mechanical part characteristics before further assembly steps.
- Automatic resistance measurements in stations that follow the addition of coils, heaters or resistors.
- Leak test following ultrasonic welding of two plastic housings.
- Leak testing following spin riveting of a cover to a pump housing.
- Leak testing after the insertion of an “O” ring or other seal.
- Machine vision systems or probes used to ensure that parts are positioned properly.
- Dimensional gauging stations, especially after a crimping or staking operation.
- Electrical testing of continuity, voltage, current and contact bounce.

When in-process testing becomes a centerpiece of an assembly and test operation, a re-design of the chassis used in the assembly is recommended. The ease with which one can relocate or remove work stations and accommodate test operations with different times in each test station is key. A power-and-free conveyor, while offering flexibility and asynchronous operation have inherent disadvantages of increased work in process and the need for fairly complex control systems that become especially burdensome in test-intensive operations.

For better efficiency in test-centric assembly, testing applications engineers designed a standardized heavy duty in-line chassis that provides for a flexible workstation setup and retooling, including double dwell time at selected stations without slowing cycle times throughout the machine. These are typically small footprint machines, e.g. 40 inches (1016 mm) x 90 inches (2286 mm) long for 18 stations or 61 inches (1549.4 mm) long for 10 stations. Assemblies can be made of multiple standard testing chassis, combining standard units end-to-end, side-by-side, or end-to side for assembly and test operations requiring additional stations. Servo drives allow one to optimize the transfer rate depending on part inertia (weight) without requiring any machine component replacements or mechanical adjustments. Individual station base-plates are used to simplify adding, removing or retooling any station without disturbing the others. These standardized chasses for test-intensive operations accept a wide range of standardized tooling and robotics or customized equipment needed for other parts of the assembly process. What differentiates these test-intensive assembly chasses from power and free systems is twofold—1) the use of quick change fixturing and 2) the ability to double up stations for greater flexibility and to reduce work in process (fewer pallets).

Test-centric assemblies also always have the ability to track the contents of each pallet and report to control systems on conditions of parts. In this way the control system can identify the presence or absence of parts on a pallet, whether or not the part has passed or failed a test, and in some applications, also will identify if the part was tested yet. Different signaling systems to gather this information, with the more sophisticated systems including a means of reading the pallet number so the system can track information on a particular pallet, in addition to identifying the aforementioned status of the pallet contents.

Test-centric assemblies not only have the means to test and track parts but to handle rejected pallets. One method for doing so is to have rejected pallets continue down the line but ignored by succeeding operations until unloaded at an intermediate reject position or immediately after testing. Rejects can then be sent to a parallel repair line. Whatever method is used, its objective is to avoid any further work on a rejected or defective part, which is the overriding advantage of in-process testing.



Fixture design is critical to test process integrity

Defective parts or defective tests?

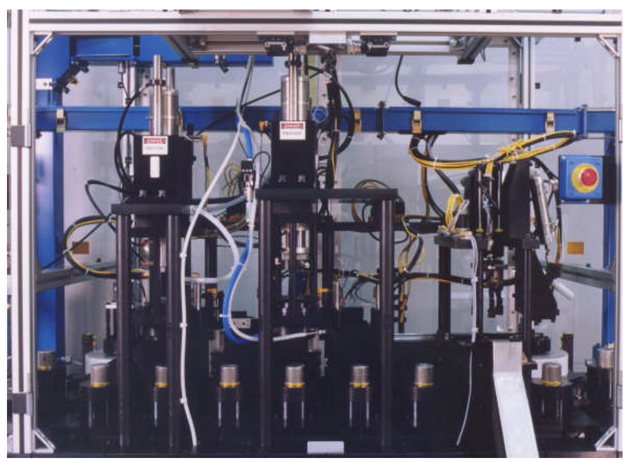
The inability to differentiate good parts from defective parts may be due to faulty testing methods, which in turn are usually the result of inadequate understanding of real testing requirements. An example is found in test results with insufficient signal to noise ratios. In leak testing there are often problems with seal creep. Another example is in-process gauging stations that are insufficiently rigid or do not have the correct reference.

Thus, the first considerations in test-centric assembly are developing a thorough and detailed understanding of required testing accuracies, the best methods to achieve the required results, and a detailed understanding of how the tests actually proceed such that one does not unwittingly undermine the test process.
In leak testing, for example, the choice between methods is driven by a compromise between a leak detector's performance and cost of purchasing a highly specified piece of equipment. There are various methods that one might choose from--- simple pressure decay testing, differential pressure decay testing; mass flow leak testing, and helium mass spectrometer testing. The lowest cost method, pressure decay testing, actually has lower *initial* costs for fixtures etc, but may in fact be more costly due to longer test cycle times and is wholly unsatisfactory for testing for small leaks under 5sccm. Differential pressure decay testing methods are superior to simple pressure decay testing for small leak testing or for testing at high pressures, but are similarly inadequate for testing parts where temperature compensation is an issue. Both pressure decay and differential pressure decay test methods involve increased cycle times compared to other dry air test methods.

(Note: The most common mistake made by those without testing expertise is to select the lowest cost instrument off the shelf . However, this does NOT imply that higher cost test methods are directly correlated to the best test technology choices. High cost helium testing, especially costly in the current context of rapidly rising helium prices worldwide, is RARELY justified except for aerospace and similar applications where potentially hazardous gas leaks less than 0.01 sccm need to be detected. In most applications requiring detection of low leak rates, the lower cost mass flow testing method using customized sensors is actually preferable, since it has the shortest possible testing times, can readily compensate for temperature, and overall delivers the best accuracy for applications where testing is required at 0.05 sccm or larger.)

The details of how a test is performed can be all important in determining if the testing process is adequate. Often this means having the ability to test the test process as testing proceeds. In downstream mass flow testing, for example, where there is zero pressure from atmosphere, it is not possible to know if a valve used in testing is working or not unless extra steps are taken. A zero leak measurement could otherwise be due to a dysfunctional valve or a line being plugged. For that reason, accurate downstream mass flow test methods will always employ a bias leak that verifies that the entire system is working and that the test circuit's integrity is not compromised. A bias leak is simply the introduction of a known leak as a self-check of the testing system. If valves are not operating properly and test seals are insufficient the bias leak will not measure as a leak, indicating that remedial actions on the test system need to be taken.

Similarly, test systems should be frequently AND ACCURATELY calibrated and validated. Mistakes are often made by relying on antiquated mechanical calibration methods that have inherent limitations such as pneumatic valves and other moving parts that can stick or wear, and/or small orifices that can clog. Today's test-centric assemblies rarely use human error prone mechanical calibration methods but rather rely on electronic technology for calibration and validation of testing. These electronic test methods are not only more reliable but are fast, which is one of the reasons why test-centric assemblies generally have significantly higher yields and shorter test times.



Test-centric assemblies automatic defective parts removal

Differences in fixtures for Assembly vs. Testing

It often comes as a surprise to those familiar with building standard assemblies that the fixtures they take pains to create for fastest assembly throughput often have quite the opposite characteristics of what one would want for failsafe testing in most assembly and test operations. This is why one is best-advised to consult with applications laboratories dedicated to developing best-match test processes to help with test fixture designs.

For example, if you have a part that is driving a screw you generally want a lot of float. However if you are leak testing that same part you would have to seal it on dead nuts so the sealing location would interfere with other steps of the assembly operation. This is why one generally does not use the same pallets during leak testing as in other phases of assembly and test

In dry air leak testing, another issue is part damage during sealing. A simple clamp and cylinder could eliminate deflection of a part during testing BUT it can also crush the part. Then there is also the problem of masking leaks. If you have a weld and the part is operated under pressure, you want to make sure that if the weld opens up you have a leak to atmosphere. If you are restraining the weld motion you are restraining the leak. As another example, if a fixture has threads and you are trying to pull down to a certain vacuum level, air will escape as you pull the vacuum down if the threads aren't slotted. This could appear as a gross leak or prevent the desired vacuum level from being achieved and make it impossible to do reliable testing with that fixture design. Thus, expert fixture designs for dry air leak testing have several factors that they are managing: the part cannot have any creep or motion, it must be stationery; the part cannot be crushed or damaged; and the fixture design cannot mask leaks.

From a fixturing perspective, helium leak testing has yet another set of challenges. In helium testing, you need to ensure that you do not trap or retain any helium in seals. In helium or any tracer gas application what happens to tracer gas at the end of the test is critical because if you have any trapped test gas staying around after the test sequence it contaminates the following test. This is not the case with dry air testing. On the other hand, deflection issues are less critical in helium leak testing than in dry air testing. One needs to understand the different requirements of each test method vis-à-vis fixture design and how improper designs will compromise that specific type of testing.

In many assembly and test applications there is also a need to orient the part being tested in the same orientation that it will have when in use in the field. The applications where this is an overriding feature of fixture design are quite diverse—from automotive valves that are referred to as 'true car position' when functionally tested to respirator components in the medical field.

In some instances assembly and test fixture designs must also take into account and simulate the parts to which parts are to be joined. This is very predominant in leak testing medical devices. For example, if the device has an O-ring you will generally want to mimic the mating surface. In the automotive industry while leak testing a transmission casting you would try to mimic the paper gaskets that will be in use in the field, as opposed to actually using paper gaskets since these wouldn't hold up during the testing process.

Fixture design is often mediated by how automated the overall assembly and test operation is and at the specific testing stations. In manual systems the sealing and fixturing may be more difficult because of ergonomic issues. Clearance for loading and unloading may be an issue. Poka-yoke considerations (a Japanese term meaning mistake-proofing) are such that often a fixture design will anticipate human errors of placing wrong parts in the testing stations. A poka-yoke informed fixture design will make sure that only parts with the correct dimensions will be tested.

The above is only a brief discussion of some of the factors that testing applications engineers take into account. Since fixture design can make or break your assembly and test solution it is generally advisable to enlist only testing engineers with experience in building many turnkey testing solutions. One needs a nuanced understanding of leak test and functional test requirements to bear on fixture designs that allow superior test instruments to deliver their promised performance. In fact, the growing use of off-the-shelf fixtures such as expandable seals is a reflection of how little the real requirements for fixture design during testing are understood. Reliable and reproduceable gauges almost always require custom fixture designs given the unlimited variety of geometries in parts that are tested.

<u>Generic vs. Customized Software/Instrumentation</u>

Testing experts know that there are no one-size-fits-all generic testing solutions
Taking short cuts by selecting the lowest cost instrument from the shelf and placing it into assemblies rarely achieves Gauge R&R in acceptable ranges because the test sensors and software programming are not well-matched to application requirements.

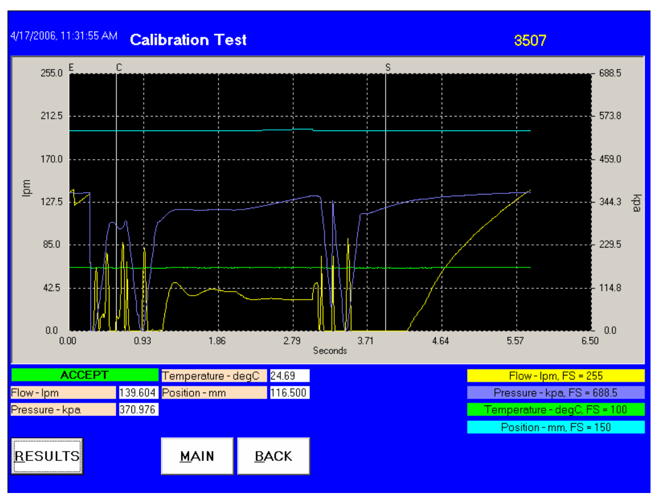
In fact, most of the assembly and test solutions that do not meet the test-centric assembly standard are easily identified by their use of one or another generic off-the-shelf software packages. This probably reflects the fact that the lion's share of assemblies has been configured by machine builders who have little training or inclination to master software engineering. In truth, test-centric assemblies require expertise in both mechanical engineering and software engineering.

In most cases custom software for test-intensive assemblies is actually less expensive than a generic off-the-shelf application because it is designed to meet real business needs and does not encumber users with the costs for program features and functionality that is not actually required. Moreover, many general applications are not especially easy to use, or do not reflect the real data handling requirements of the application.

Most test applications require software that works in real-time, for example, which is usually not the case with off-the-shelf packages. It is important to have the means to view real time traces of test instrumentation transducers' performance, as opposed to simple test cycle times. Slower and less detailed applications do not process data quickly enough to provide for meaningful test control and/or test method calibrations. If the required data analysis is more complicated than generating a simple line graph, the off-the-shelf software packages that are commonly used similarly fall short. The best-in-class custom software for test-centric assemblies will also automatically calculate R&R percentages based on the number of trials performed.

How networks are built is also important in fully integrating testing into assembly operations. When there are steep requirements for testing, there is inherently a lot of data that typically has to be processed and also sent to a plant-wide network. BUS compatibilities need to be considered.
State-of-art test-centric assemblies have Ethernet capabilities that allow the huge datasets from intensive testing to be distributed to plant-wide networks for analysis. Internet-based remote diagnostics are another feature of the best-in-class test-centric assemblies.

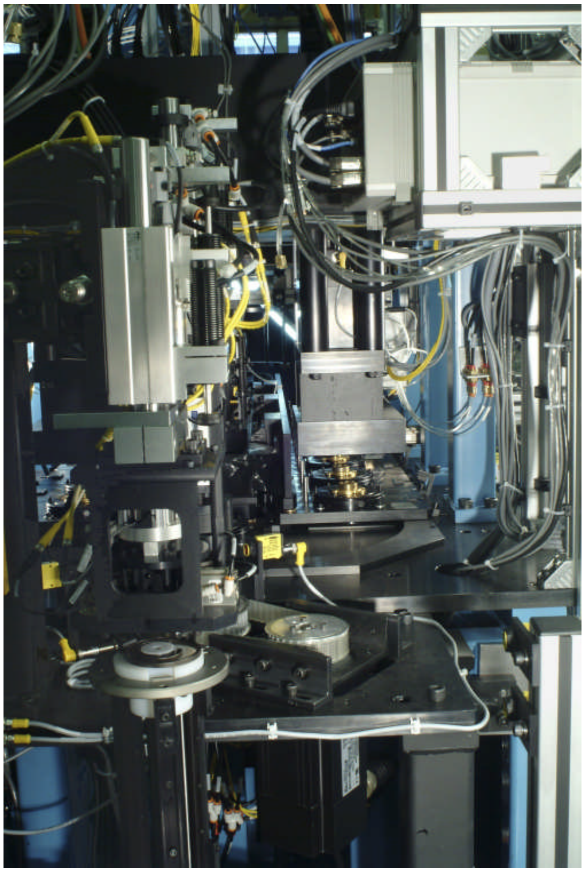
Custom software development for test-centric solutions starts with identifying business goals as to how the data and information garnered during testing will be used not just in initial production but also during the entire lifecycle of the product being produced in the assembly and test operation. This is of growing importance to the many industries that now want processes to attach data to products from cradle-to-grave to assist with recalls or reducing time-to-market in new product development cycles



Custom software for test-intensive assembly helps cut costs

Summary—Multiple Cost-Savings

A tell-tale sign of a less than optimal assembly and test operation is one where the machine builder defines testing gauge R&R in terms of those proffered by the manufacturers of the test instruments. Gauge R&R of the entirely assembly and test solution is what counts, and this is what must be guaranteed to users of the test-centric assembly and test solution. This explains why the most savvy machine builders around the world are now incorporating applications engineers with a sole focus on testing into their project development teams.



Up to 70% reduction in test cycle times is standard in test-centric assemblies

The improvements to be expected from a test-centric assembly approach are not trivial. Leak test and functional test cycle times can be decreased 25% - 70% in the best-in-class examples, and yields increased proportionally.

There are numerous cost-savings from implementing a test-centric assembly approach. First, is the greater return from higher yields in test-centric assemblies by using better fixture designs and customized test instruments and related software and high throughput chasses designed for test-intensive operations. Second, in-process testing cuts the added costs for finishing products that will ultimately be deemed defective. Third, defective parts are not misclassified as "good" parts and returns are minimized. Last, but not least, time-to-market for new product development can be decreased by as much as 10% by mining extensive test data from assembly and test operations

The author, Jacques Hoffmann, is President of InterTech Development Company InterTech Development Company (www.intertechdevelopment.com) is a world leader in test-centric assembly specializing in automated leak and functional testing with 7 patented mass flow and hydraulic technologies, as well as, helium mass spectrometry (ISO-9001-2000 International Standards for Quality Management). InterTech Development Company-engineered solutions are used by hundreds of manufacturers worldwide. InterTech Development Company's worldwide support organization maintains offices in North America, Asia, and Europe.

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