amat manufacturing

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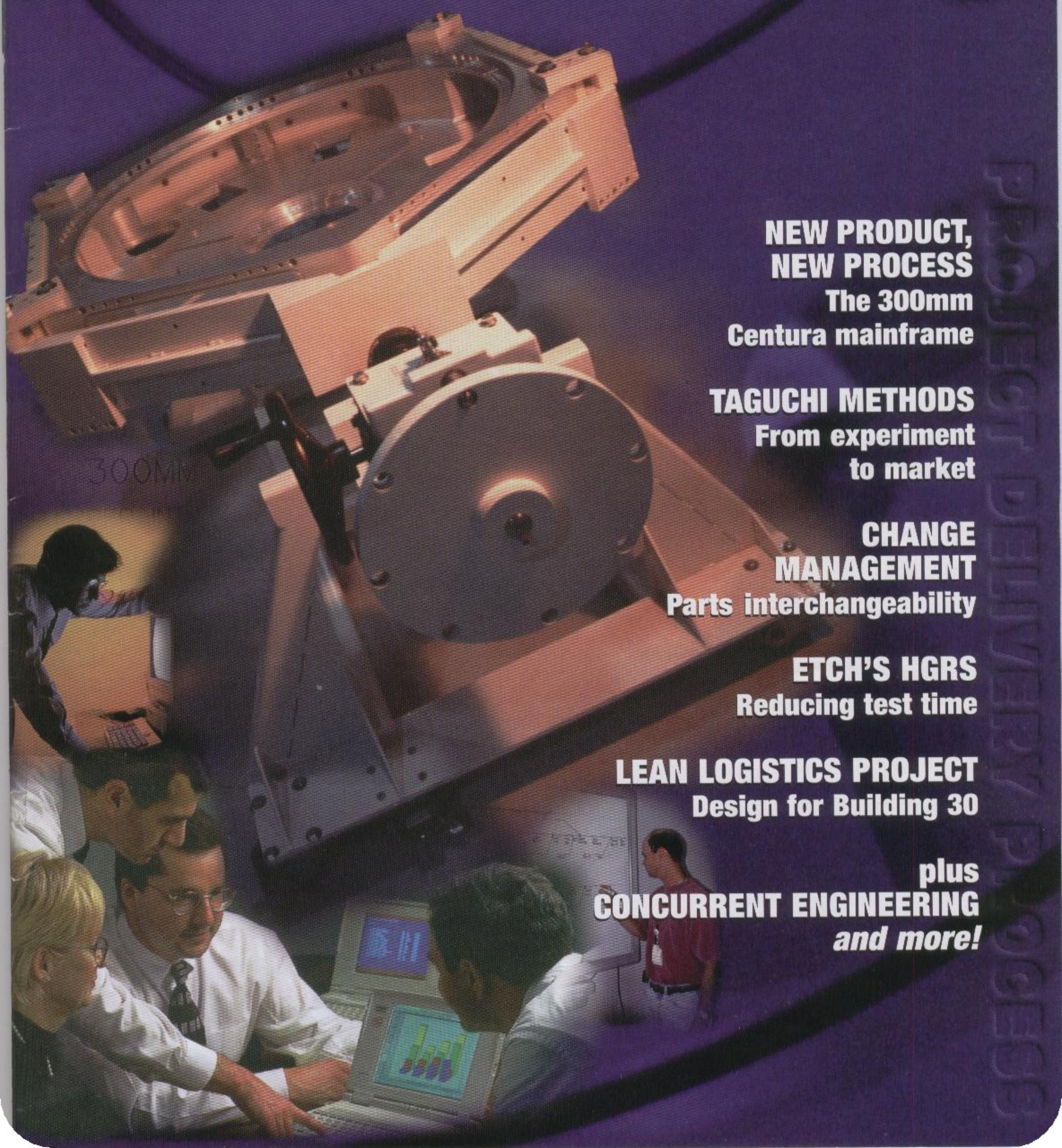


NEW PRODUCT, NEW PROCESS
The 300mm Centura mainframe

TAGUCHI METHODS
From experiment to market

CHANGE MANAGEMENT
Parts interchangeability

ETCH'S HGRS
Reducing test time

LEAN LOGISTICS PROJECT
Design for Building 30

plus
CONCURRENT ENGINEERING
and more!

Etch's HGRS...

Reducing cycle time without sacrificing ULMI's high standards for quality and customer satisfaction is a significant challenge for any segment of Applied's manufacturing and test operations.

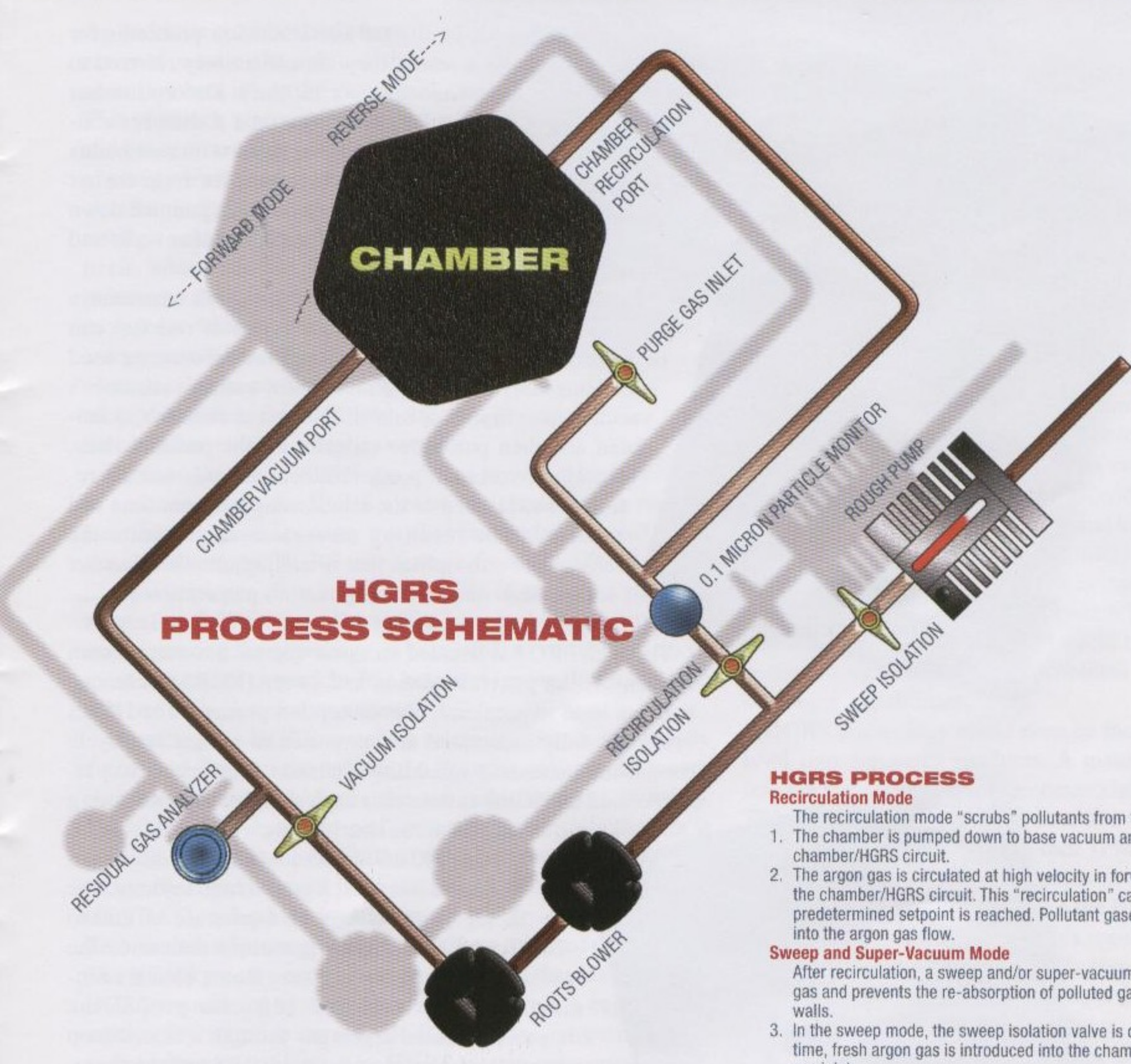
Applied Materials uses three major criteria to qualify a system for its customers—vacuum integrity, mechanical integrity, and electrical integrity. Reduction in production cycle time is essential to the success of Applied's Unified Lean Manufacturing Initiative. A substantial amount of cycle time resides in testing Applied's products. Reducing cycle time without sacrificing ULMI's high standards for quality and customer satisfaction is a significant challenge for any segment of Applied's manufacturing and test operations. Overarching programs, such as Zero Defect Control, have been implemented to assist in achieving these goals. These initiatives are important and provide focus and direction, but every opportunity on the manufacturing floor to reduce cycle time must also be optimized during production ramping.

Outgassing a chamber is one of the most time-consuming facets of system testing. There are two major components of outgassing—material outgassing and desorption. All material outgasses when put under vacuum. Loose molecules or atoms that are part of a container's material are "pulled" into the vacuum, contaminating the vacuum itself. This phenomenon is particularly evident in process chambers. Under vacuum, some of the gases and other particular matter that are part of the chamber body's material composition are drawn into the chamber. To test a chamber's vacuum integrity, it must be able to attain and maintain a base vacuum pressure. The outgassing of pollutant materials is one factor that inhibits a chamber from achieving this, consequently increasing test time. The ultimate base vacuum pressure is the lowest vacuum that a specific chamber model can achieve. This is determined by the chamber's material composition, design, and pumping arrangement. For example, a PVD chamber is made of stainless steel with copper seals and is capable of reaching a $9x10^{-9}$ Torr vacuum base pressure; whereas, an Etch chamber is constructed of anodized aluminum with O-ring seals and can only reach a lesser base pressure of $9x10^{-5}$ Torr.

BY VICTOR SAUERS AND BOB MARSELLA

Desorption, on the other hand, is the gas species—or unwanted pollutants—such as oxygen, nitrogen, and most notably water moisture, on the surface of the chamber body's internal walls. These molecules are also released into the chamber when it is put under vacuum. Both phenomena, material outgassing

Reducing Test Time



Chamber Type	Traditional Methods	HGRS
MxP+ Unibody Oxide P5000	162 minutes	85 minutes
Unibody Poly P5000	306 minutes	95 minutes
ASP 5200/P5000	180 minutes	70 minutes
Metal Etch DPS	90 minutes	39 minutes
Aluminum R2 Unibody 5200	240 minutes	74 minutes

The average outgassing cycle time for Etch chambers was 4 hours and 36 minutes. Since the use of HGRS, cycle time has dropped to an average of 1 hour and 19 minutes. Various chamber models have realized comparable results.

HGRS PROCESS

Recirculation Mode

The recirculation mode "scrubs" pollutants from the chamber walls.

1. The chamber is pumped down to base vacuum and argon gas is pumped into the chamber/HGRS circuit.
2. The argon gas is circulated at high velocity in forward and reverse directions through the chamber/HGRS circuit. This "recirculation" causes the gas to heat up until a predetermined setpoint is reached. Pollutant gases from the chamber's surface move into the argon gas flow.

Sweep and Super-Vacuum Mode

After recirculation, a sweep and/or super-vacuum mode removes the polluted argon gas and prevents the re-absorption of polluted gas species back onto the chamber walls.

3. In the sweep mode, the sweep isolation valve is open to a roughing pump. At the same time, fresh argon gas is introduced into the chamber/HGRS circuit through the purge gas inlet.
4. In the super-vacuum mode the recirculation isolation valve is closed and the whole charge of argon gas is evacuated from the system within 1 to 3 seconds.
5. The HGRS system repeats both modes until desorption reaches an acceptable level. Acceptable levels are determined by characterizing known leak-tight chambers for recipes based on chamber configuration, pumpdown times, conduction values, temperature ramp rate, and pressure values.

Cooldown

6. The HGRS system cools the chamber by slowly flowing argon gas at a low vacuum for repeated cooling cycles. This minimizes the effect that material outgassing will have on leak-up/rate-of-rise testing.

Rate-of-Rise

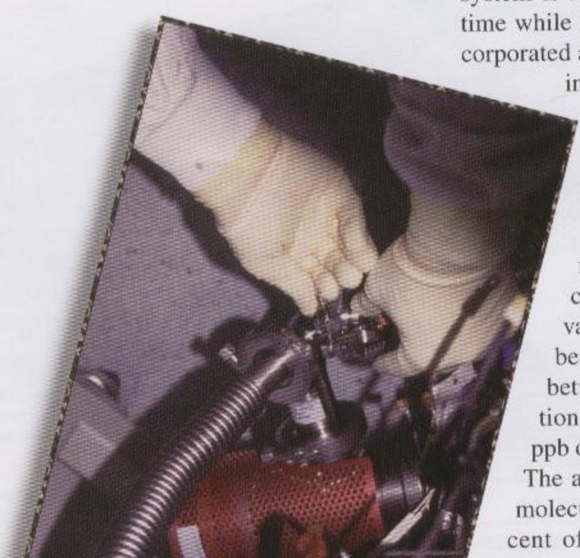
7. The chamber is pumped down to a base pressure where a vacuum gauge is known to be most sensitive to changes in chamber pressure. This practice is an improvement over the traditional practice of pumping down a vacuum gauge beyond its range of sensitivity and starting the rate-of-rise test at different base pressures for the same chamber types.
8. A rate-of-rise test and particle test is performed. The test results are electronically stored on the engineering server and printed out by the operator.
   After all testing is done, the HGRS fills the chamber with argon or nitrogen gas to protect it from recontamination in the event the chamber is exposed to atmosphere.

Etch's HGRS...

and desorption, result in similar contamination problems for wafer fabrication. As a result, they are collectively referred to as *outgassing* in the semiconductor industry. Desorption has the most bearing on manufacturing. Any time a chamber's internal surface is exposed to atmosphere, either with new builds or wet cleans, gas molecules and other particles from the air collect on the chamber walls. As the chamber is pumped down to vacuum, these particles migrate from the chamber walls and compromise the vacuum.

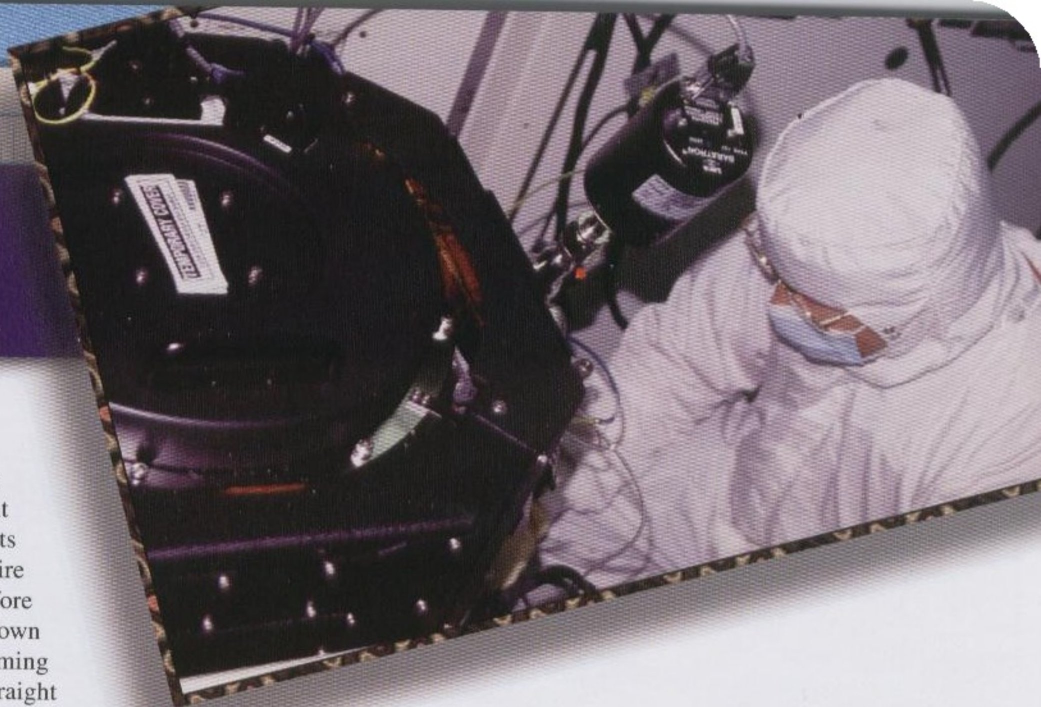
Manufacturing must contend with desorption whenever a chamber is outgassed before a leak-up/rate-of-rise test can be performed. The terms, *leak-up* and *rate-of-rise* are used interchangeably to refer to a method for testing a chamber's vacuum integrity. In a rate-of-rise test a chamber is isolated and then put under vacuum. As the pressure rises, readings are taken at predetermined intervals and the results are expressed as the relationship between time and pressure. The resulting measurements indicate the amount of atmosphere that is leaking into the chamber or the leak rate, assuming that no permeation or desorption is involved.

The Etch PBG has decided on a new approach to test vacuum integrity. A hot gas recirculation and sweep (HGRS) technique is being used to accelerate the desorption process. The HGRS system is fully automated and promises to reduce test cycle time while increasing reliability. Etch test engineering has incorporated an HGRS system into Etch chamber manufacturing in Building 33 at the Harris Branch facility in Austin.



The HGRS system works by moving a heated inert gas, argon, at high velocity. The argon gas is kept at a pressure of 200 to 700 Torr. Chamber configurations determine the exact pressure of the vacuum. Roots blowers running at a maximum of 150 cfm propel the compressed heated argon gas through a closed-loop vacuum circuit that includes the HGRS and the chamber under test. The gas temperature in the circuit is set between 70 and 120 degrees centigrade. The desorption rate is accelerated by using a very dry, less than 100 ppb of water, heated inert gas traveling at a high velocity. The argon acts as a scrubber and removes unwanted gas molecules, mostly H_2O which comprises more than 90 percent of the outgassed material, from the chamber wall surface. The HGRS system's high velocity flow allows the argon to also double as a carrier gas, vacating the gas species from the system.

Etch's previous efforts to accelerate the outgassing process utilized lamps, heat exchangers, turbo pumps, heater blankets, and process pumps. These complicated processes involved heat



ing the entire chamber body from external sources to achieve the necessary heat inside the chamber. This approach was very inefficient and time consuming. Large amounts of energy were needed and the entire chamber body had to cooldown before testing could continue. The cool-down itself, added another time consuming process to the procedure. Also, straight molecular vacuum pumping without a carrier gas relied on the random movement of molecules to remove the species. This method becomes less and less effective as the chamber reaches a higher vacuum.

Because the argon carrier gas moves at such a high velocity in a viscous state, the HGRS system has the ability to remove free-floating particles from the chamber body. Depending on the chamber type, HGRS can remove from 500,000 to 1 million particles per chamber. It is capable of removing particles as small as 0.17 micron. The HGRS's "scrubbing" ability gives manufacturing the advantage of being able to certify and document a chamber as particle-free before shipping the chamber to any customer, internal or external.

Operating the HGRS system is relatively simple and mostly automated. To start the system the operator only needs to connect the chamber, configure the test, and press the start key. This frees the operator to perform other tasks while the test is running, adding to the flexibility of the line. All test criteria and recipe files are retrieved from the HGRS data acquisition system (DAS), a database located on the Etch engineering server. Test results and process control recipes are archived on the DAS. The HGRS process control recipe editor, another feature of the HGRS monitoring system, allows manufacturing engineers to continually improve current HGRS recipes and easily create recipes for new products. The HGRS system can perform automated chamber cleaning, rate-of-rise test, particle count test, and can record and print the test results.

Before using a HGRS system, the average cycle time to outgas an Etch chamber was 4 hours and 36 minutes. With the HGRS system, outgassing cycle time has dropped to an average of 1 hour and 19 minutes, depending on the chamber type. The HGRS system is capable of reducing outgassing time by 50 to 70 percent, while maintaining a consistent test platform for leak-up and rate-of-rise tests.

Currently, Etch is using the HGRS system on their assembly line for the initial testing of chamber vacuum integrity. HGRS has proven particularly useful on new builds. Because the HGRS system removes a substantial amount of particles from the chamber vacuum, it increases the reliability of helium leak checks. Chamber leaks are detected more accurately and faster. This results in more vacuum leaks being found in the original workcenter before the problem can be passed down the line. Etch is also considering using HGRS technology to conduct full-blown system leak-ups after final integration in an effort to reduce final test cycle time. The traditional helium leak testing used in final integration has problems because of the larger volume in a complete system. Difficulties with purging helium from the system after testing can add 30 minutes to 2 hours to final test cycle time. HGRS has the potential to solve both these problems with its high velocity scrubbing capabilities.

HGRS technology could even be incorporated at the system level into Applied's products. A manifold could be designed into the system that would accommodate an HGRS roll-up unit. This would reduce the cycle time at a customer's site between regular preventative maintenance (PM) such as chamber wet cleans and requalifying the system to a customer's production specifications. In addition, using the HGRS system with cleaning recipes as part of the system's regular PM could extend the product life of the chamber and its components by dramatically reducing contaminants. A similar approach is already being used by one of Applied's major customers.

Solving a long-standing problem at the shop floor level in pursuit of ULMI goals can have far reaching results. A demand for HGRS technology has already been demonstrated and its efficiency in production has been proven. Using HGRS has shortened test times, contributing to a reduced product cycle-time; increased the accuracy of leak tests; removed duplicated vacuum testing from other work areas; and freed up manpower, increasing line flexibility. It follows that Applied can take the initiative to apply this technology across its product line and within its production facilities, establishing a competitive edge for vacuum integrity testing. The implementation of HGRS technology has the potential to make a significant contribution to ULMI goals and Applied's overall success. ■