# Vacuum Systems Laboratory Development

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***Abstract.*** *The implementation of new associate degree programs in semiconductor manufacturing at community colleges across the country has created a critical need for vacuum technology courses and supporting laboratories. Unfortunately, few resources have been available to support technology-level courses in vacuum systems. This paper describes the results of a two-year project to develop a vacuum technology course, implement a vacuum systems laboratory, and provide faculty enhancement activities.*

## Introduction

Vacuum systems are used in virtually every functional area of a wafer fabrication factory (referred to as a wafer fab) to create the proper processing environments for manufacture of integrated circuits. Because of the pervasiveness of vacuum technology in the wafer fab, most two-year, associate degree curricula now require at least one course in vacuum technology. Unfortunately, support for technology level courses in vacuum technology have been lacking in terms of textbooks, vacuum training systems, and laboratory manuals.

In 1995, Portland Community College, with funding from the National Science Foundation, began development of a generic vacuum technology course and supporting laboratory. [1] A team of community college faculty and industry experts was formed, and the team was charged with the task of developing a vacuum technology course, complete with supporting laboratory.

The course content was specified without much difficulty. Using available resource materials, [2,3] the development team recommended that the course begin with a review of gas laws from chemistry and then progress from rough vacuum to high and ultra-high vacuum regimes, examining the underlying gas dynamics, pumping methods, and pressure measurement techniques for each pressure regime. The team also recommended that advanced topics, such as leak detection and gas analysis using residual gas analyzers or RGA's, complete the course of study.

The more difficult issue was definition of the laboratory portion of the course. Research had shown that community colleges that had developed their own vacuum technology courses supported these courses with custom-built training systems, assembled out of donated and salvaged vacuum components. This development was usually the result of the work of one "expert" faculty member. The development team rejected this approach since most community colleges do not have an adequate level of expertise to build their own custom systems nor may they have a source for donated vacuum components. Rather, the team sought an off-the-shelf approach whereby community colleges could purchase a commercially-available vacuum trainer.

Beginning with Varian's mini-pumping station design, they added a baseplate/bell jar chamber, roughing line, and additional gauges. The resulting vacuum trainer is capable of reaching pressures in the high vacuum regime.

At this critical juncture in the development process, Varian Vacuum Products, at their expense, built a prototype of the vacuum training systems and made it available to the development team. Using the Varian training system, ten basic vacuum experiments were then written.

In 1996, Portland Community College received an Instrumentation and Laboratory Improvement (ILI) Grant to equip a five-station vacuum systems laboratory. [4] The five systems were installed during Spring Term 1997 and were used to teach vacuum technology courses during the Fall quarter of 1997.

In addition, Portland Community College and the Maricopa Advanced Technology Center (MATEC) are co-sponsoring three-day faculty enhancement workshops in vacuum technology. These workshops provide high school and community faculty not only with laboratory experience with the Varian vacuum trainer, but also with an excellent opportunity to collaborate with their fellow teachers on the design of new experiments and demonstrations in vacuum technology.

## Vacuum Training System

The Varian vacuum trainer, shown in Figure 1, is a high vacuum pumping system. The trainer has two pumps: a Turbo-V70LP turbomolecular pump backed by a MDP 30 mechanical diaphragm pump. A roughing line connects the MDP 30 to the baseplate/bell jar chamber and includes a hand-operated block valve (rough valve). A parallel path (foreline) to the bell jar includes a hand operated block valve that connects the mechanical pump to the Turbo-V70LP, a butterfly valve, and a linear gate valve located between the turbo pump and the bell jar.

Vacuum gauging on the trainer includes three thermocouple gauges--one in the roughing line, one in the foreline, and one attached to the chamber--and one Bayard-Alpert Ionization Gauge. The trainer uses a Multi-Gauge Instrument Controller to operate all four gauges and provides an RS-232 serial link to a PC.

The trainer also has two vent valves--a hand-operated vent valve for the chamber and an automatic vent valve for the turbo pump. The base plate has fittings for a gas feedthrough, rf feedthrough, and two additional ports.

The Varian vacuum trainer has an ultimate base pressure in the rough vacuum regime of approximately 0.5 torr, essentially the rating of the MDP 30 mechanical pump. Ultimate pressure in the high vacuum regime varies from system to system and ranges from 1 x $10^{-5}$ torr to 5 x $10^{-6}$ torr. The ultimate pressure in the high vacuum regime is limited by the outgassing of the glass bell jar and the stainless steel components in the high vacuum portion of the trainer.

Several problems with the initial design were addressed. These problems resulted from incompatibility of the Multi-Gauge firmware and having both thermocouple and Convectorr control boards in the system. This resulted in problems reading gauge pressures on the Multigauge Controller and in communicating via the RS-232 link to the PC. These problems were resolved by updating the Multi-Gauge firmware and removing the redundant Convectorr gauging from the system.

Use over two academic quarters has shown the systems to be relatively reliable. Maintenance has been minimal.

## Vacuum Experiments

The development team authored nine experiments that could be performed using the basic Varian vacuum trainer.[5] The experiments ranged from simple pumpdowns to surface area outgassing and leak detection experiments. The nine experiments include:

Experiment 1: Rough Pumpdown from Atmospheric Pressure: Air Environment

Experiment 2: Rough Pumpdown from Atmospheric Pressure: Nitrogen Environment

Experiment 3: High Vacuum Pumpdown from Atmospheric Pressure: Air Environment

Experiment 4: High Vacuum Pumpdown from Atmospheric Pressure: Nitrogen Environment

Experiment 5: Heated Chamber Pumpdown

Experiment 6: Liquid Nitrogen-Assist, High Vacuum Pumpdown

Experiment 7: Rate-of-Rise Experiment Following High Vacuum Pumpdown

Experiment 8: Surface Area Experiment: Outgassing

Experiment 9: Conductance and It's Effect on Pumpdowns

## Residual Gas Analyzer

To enhance the capability of the Varian vacuum trainer, a Stanford Research Systems residual gas analyzer was added to the trainer. The RGA-100 is a 100 atomic mass unit residual gas analyzer. In the analog mode, the RGA produces a graph of partial pressure versus amu.

From an instructional point-of-view, it is a significant advantage to be able to analyze the gas being evacuated from the chamber. For example, with an RGA, students can measure the amount of water being outgassed during the initial stages of pumpdown as opposed to the later stages of pumpdown. Students can also view the relative partial pressures of other gases such as nitrogen, oxygen, and carbon dioxide.

Another use of the RGA is for leak detection. The RGA can be configured to monitor the partial pressure of helium and a helium gas bottle can be used as a source for leak checking the vacuum system.

The two additional experiments were added to the list of experiments performed on the Varian trainer:

Experiment 10: Residual Gas Analyzer: Air Pumpdown

Experiment 11: Residual Gas Analyzer: Unknown Gas Mixture

## Faculty Enhancement

Four faculty enhancement, vacuum technology workshops were held during the 1997-98 academic year: September, 1997; December, 1997; March, 1998; and June, 1998. The workshops were sponsored by the Maricopa Advanced Technology Education Center (MATEC). MATEC provided lodging and meals and paid for the cost of the workshop. Participants paid for their travel to Portland, Oregon, and paid a $125 workshop registration fee. Portland Community College hosted the three-day workshops at the CAPITAL Center.

The three-day format provided participants with ample opportunity to answer the questions "What do I teach in a vacuum technology course?" and "How do I teach the material?" The workshops are envisioned as dialogues between teachers who teach vacuum technology courses at the high school and community college levels.

Thirty-one teachers have participated in the MATEC sponsored vacuum technology workshops during the 1997-98 academic year. Three were high school teachers and the remainder community college teachers from nine different states.

Two community college teacher had just received their Varian vacuum trainer just before coming to the vacuum technology workshop. For them, the workshop provided an excellent opportunity to work with the Varian trainer before returning to his home institution to unpack and install their own trainer.

For other participants, the workshop provided not only a review of vacuum principles but also an opportunity to compare training practices with their colleagues. Many wanted more laboratory time to use the trainers, to build

systems from scratch, and to have problems to be solved (system troubleshooting).

The workshop also gave participants experience in searching for sources for information. For example, part of the first lab session was spent on the Internet looking for sources for instructional materials, demonstrations of vacuum principles, and products.

## Future Enhancements

Future enhancements to the Varian Vacuum Trainer include the addition of rf generation, mass flow control, and a redesigned chamber to add rf plasma generation capability. By so doing, the basic vacuum trainer can also be used to support a rf plasma systems course in a two-year semiconductor manufacturing technology curriculum.

## Conclusion

The development of a vacuum technology course and laboratory taught us more than just what equipment to purchase. The close collaboration between Intel Corporation, one of our premier semiconductor companies, Varian Vacuum Products, a major supplier to the semiconductor industry, and community colleges set an important precedent for future projects. The collaboration between community colleges, in itself, was a direct result of a National Science Foundation Advanced Technological Education grant that has supported activities to encourage partnerships and networking between community colleges across the country.

The five student station laboratory has not only served students in the Microelectronics Technology Program at Portland Community College, but has also supported faculty enhancement workshops sponsored by the Maricopa Advanced Technology Education Center, helping high school and community college faculty update their understanding of vacuum technology. Over thirty faculty will attend MATEC-sponsored vacuum technology workshops at Portland Community College during the 1997-98 academic year.

## References


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5. "Vacuum Technology for Semiconductor Manufacturing," Committee Report, February, 1997.


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Funding for this project and the equipment for PCC's Vacuum Technology Laboratory was provided through grants from the National Science Foundation, Division of Undergraduate Education: Advanced Technological Education Program, Grant Number DUE-9454589 and Instructional and Laboratory Improvement Program, Grant Number DUE-9650916. (Matching funds provided through a grant from Intel Corporation. Technical support provided by Varian.)



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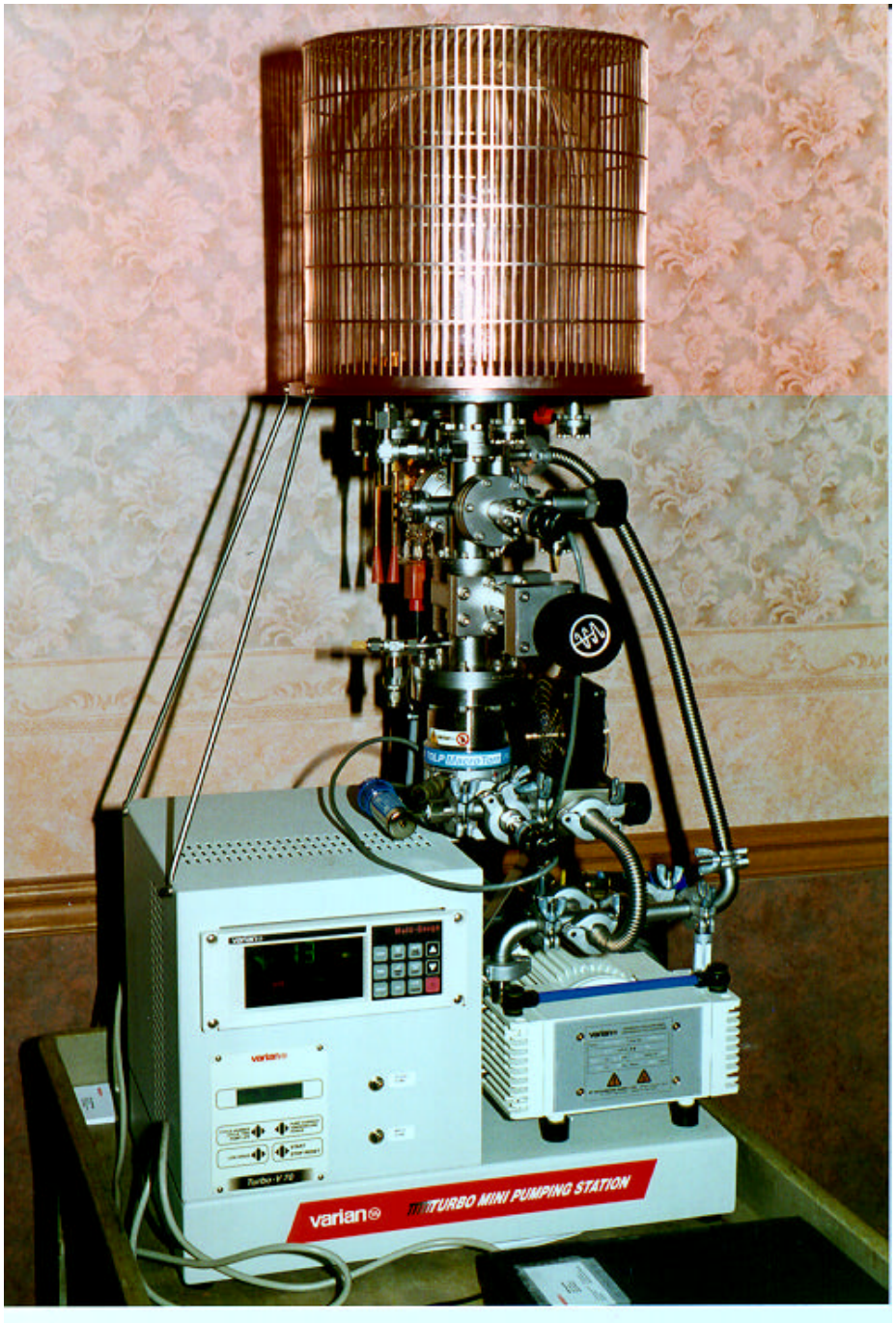


Figure 1. Varian Vacuum Training System.