The 1985 Pittsburgh Conference: A Special Instrumentation Report

For the first time in its 36 years of operation, the Pittsburgh Conference and Exposition on Analytical Chemistry and Applied Spectroscopy had a sharp drop in attendance—down 16 percent to 20,731. That loss was attributed to the fact that the meeting was held in New Orleans for the first time, and most of the lost attendees were students and young professionals who had previously come for only 1 day. The number of exhibitors and the number of booths, however, were both up about 15 percent, to 730 and 1856, respectively. A large proportion of that increase was contributed by foreign companies exhibiting for the first time, but there were also some well-known names, such as General Electric and Xerox, making first forays into analytical chemistry. There was also a sharp increase in the number and type of instruments displayed. "The key skill now in analytical chemistry," says Perkin-Elmer president Horace McDonell, Jr., "may be simply finding the right tool to obtain the answers you need." The predominant theme of the show, as it has been for the past few years, was automation of both laboratories and instruments. That trend is having major effects in chemical laboratories, but it is also affecting the instrument companies themselves. At large companies such as Varian, Beckman, and Perkin-Elmer, as much as 50 percent of the research and development budget is now going toward development of software—a much higher percentage than it was even 5 years ago. Another trend in automation also seemed clear at the show. As recently as 2 or 3 years ago, much of the available software for chemistry was designed for Apple and similar computers. Now, the laboratory standard is the IBM PC. As a representative of another company that manufactures computers noted with only slight exaggeration, "There's probably not a booth on the floor that doesn't have one."

Robots Automate Sample Preparation

The weak link in the automated analytical laboratory is sample preparation, which is largely done by human technicians. The solution is to bring robots into the laboratory. One company, the Zymark Corporation (Hopkinton, Massachusetts) started the ball rolling 3 years ago with the introduction of a laboratory robot at the 1982 Pittsburgh Conference (*Science*, 9 April 1982, p. 164). Partly owing to Zymark's evangelizing, it now seems the concept is about to take hold for good.

Robots are cute (one waved a miniature American flag before starting a demonstration and another shook each test tube to get the last drop out after pouring the contents into a beaker), so the crowds at the booths of exhibitors showing the machines may have been due as much to fascination as to solid interest. But there are more substantive indicators.

Although other robots have shown up at the Pittsburgh Conference since Zymark's appearance, this year several companies, including industry giants Perkin-Elmer and Hewlett-Packard, either showed their own robotics wares or incorporated someone else's into their equipment. One of these, the St. Charles Manufacturing Company (St. Charles, Illinois), a maker of laboratory furnishings, exhibited prototypes of circular fume hoods designed explicitly for robotized sample preparation. Perhaps most significant of all is the dramatic increase over last year's conference in the number of papers describing the use of laboratory robots.

Productivity is the key word that accounts for the growing interest in laboratory robots. Horace McDonnell, Jr., president of Perkin-Elmer makes the familiar argument that laboratory automation is required for increases in productivity, but he then adds that the lack of productivity aids at the front end of the analytical process (that is, automated sample preparation) is the main factor blocking the way to a higher throughput, lower cost operation.

Robots have the obvious catalog of advantages, including the ability to run 24 hours per day without operator intervention but with high accuracy and reliability. At the moment, robots are generally slower than humans. However, Francis Zenie, the founder of Zymark, has noted that there is a way to use robots that more than makes up for their lack of fleet-footedness.*

The normal procedure is for the analyst to prepare large numbers of samples at once (a batch process) and then to transport them to the analytical instrument, which may be equipped with an autosampler that feeds each sample into the instrument sequentially. Computers are capable of coordinating several activities simultaneously, such as instructing a robot how to prepare a sample and controlling the analytical instrument. It therefore becomes practical to shift to a serial mode of operation in which each sample is a batch of one.

Time savings depend on the particular analytical procedure. In one hypothetical example involving sample preparation, incubation, centrifuging, and finally analysis, the total elapsed time for a batch of 24 samples was reduced from 7 hours, 8 minutes to 5 hours, 24 minutes by switching from a batch to a serial mode. An additional advantage of the serial style is that all samples are equally fresh at the time of analysis, whereas in the traditional method the first and last samples in a batch have substantially different "ages," which can be a significant factor, for example, in specimens that degrade when kept at room temperature.

Laboratory robots bear no resemblance, of course, to any of the metal marvels that have graced movie or television screens over the years. In fact, what constitutes a robot is a somewhat slippery subject, although most involve a movable arm with a fixture for grasping

*F. H. Zenie, "Trends in laboratory automation—technology and economics," in *Advances in Laboratory Automation Robotics*, G. L. Hawk and J. Strimaitis, Eds. (Zymark Corporation, Hopkinton, Mass., 1984), pp. 1–16.

objects. Zenie's definition seems as good as any: "Robotics extends programmable computers to allow computers to do physical work as well as process data." Laboratory robots at the Pittsburgh Conference divided into those bearing some resemblance to the familiar industrial robot arms that have pivoting and rotating motions and those with a simple *x-y-z* motion and a more specialized function.

In the former category were Zymark, Perkin-Elmer (Norwalk, Connecticut), Johnson Scale Company (West Caldwell, New Jersey), and GCA/Instruments and Control Group (Chicago, Illinois), while Cavro Scientific Instruments, Inc. (Sunnyvale, California), Gilson Medical Electronics, Inc. (Middleton, Wisconsin), the Hamilton Company (Reno, Nevada), and Tecan U.S., Ltd. (Chapel Hill, North Carolina) showed instruments of the latter type. Finally, Perkin-Elmer and the Varian Associates Instrument Group (Sunnyvale, California) added robot arms to autosamplers.

In the former category, Zymark is the trailblazer with its Zymate system. The company designed a robot arm from scratch with characteristics appropriate for the rather lightweight physical tasks around the laboratory. The maximum weight that can be lifted is 3 pounds, for example, because company engineers reasoned that a liter of water is the heaviest item likely to be encountered. Similarly, the four basic motions (a rotation around a vertical axis through the base of the robot, a rotation around a horizontal axis along the robot arm, a vertical linear motion, and a horizontal linear motion) were chosen to accommodate common laboratory tasks such as picking up, transporting, and emptying test tubes.

The robot itself does none of the sample preparation steps. For each of these, such as dispensing liquid samples, mixing the samples, centrifuging them, capping sample vials, and so on, the company has devices or stations that carry out these functions. The robot transports samples between the stations and takes them to the analytical instrument. Because the robot is fixed at one spot on the laboratory bench, the arrangement of the stations and instruments is in a circle around the robot, thus accounting for the geometry of the St. Charles fume hoods. The Zymark robot and computer controller costs $19,000, while the various stations range from $500 for a mixer to $4000 for a centrifuge. A typical complete system might total $35,000.

From the prospective user's point of view, a stand-alone robot of whatever

^{252}Cf Plasma Desorption Mass Spectrometer

The first commercial time-of-flight mass spectrometer with a californium-252 plasma desorption source for ionizing large biomolecules was displayed at the 1985 Pittsburgh Conference by Kratos Analytical (Ramsey, New Jersey). The new BIN-10K was designed by investigators at Uppsala University in Sweden and is manufactured by Bio-Ion Nordic AB (Uppsala), a company formed specifically for that purpose. The technology was actually developed in 1974 by Ronald Macfarlane and David Torgerson of Texas A&M University. The delay in bringing it to the marketplace was apparently based on a perception by manufacturers that there was no demand for mass spectrometers that could handle such large molecules.

In the BIN-10K, the sample is deposited on a thin sheet of nickel foil that is then placed close to a small amount of ^{252}Cf. Fission fragments from the radionuclide pass through the nickel foil, creating localized temperatures of 20,000° to 30,000°C for about 10^{-11} second. The high temperatures vaporize ion impurities in both the sample and the nickel, principally hydrogen, sodium, and hydride ions. These secondary ions react with heated sample molecules to produce quasimolecular ions that are accelerated by an electric potential. At a constant potential, the time of flight to the detector is proportional to the mass of the ion. Each ^{252}Cf fission also produces a complementary fission fragment that is detected by a scintillation counter located on the opposite side of the source from the sample. Detection of the complementary particle establishes the starting time for the time-of-flight measurement.

The technique provides an effective way to ionize biological macromolecules with little sample degradation; it thus provides a much more intense peak for the quasimolecular ion than do other sources. The upper limit of the mass range is listed as 15,000 daltons for the BIN-10K, but prototype instruments have recorded masses as high as 23,463 daltons for porcine trypsin. At delivery, the spectrometer is equipped with a source containing 10 microcuries of ^{252}Cf, which should be useful for at least 2 years. The base system for a user who already has access to a large computer costs $120,000; that price includes an electrospray unit for preparing samples. With a complete data acquisition system, the price increases to about $180,000.—**T.H.M.**

New Spectrometer for Remote Sensing

Improvements during the last decade in the ability of optical fibers to carry light for long distances without substantial losses of intensity have provoked substantial interest in the use of such fibers to carry light from a remote sample cell to a central spectrophotometer (*Science*, 26 November 1982, p. 875). Such devices are particularly useful for performing analyses in hazardous environments or for remote monitoring of many sampling stations in a production process, but they are also becoming more useful in laboratory situations where the nature of a sample precludes easy use of conventional techniques.

At the 1983 Pittsburgh Conference, J & W Scientific, Inc. (Rancho Cordova, California), introduced the Focus 2000, the first commercial spectrophotometer for use with fiber optics. A month after the conference, however, the company dropped the instrument, apparently because of high development costs, and no units were ever shipped. Some of the engineers from J & W formed a new company, Guided Wave, Inc. (Rancho Cordova), and developed a completely new spectrophotometer.

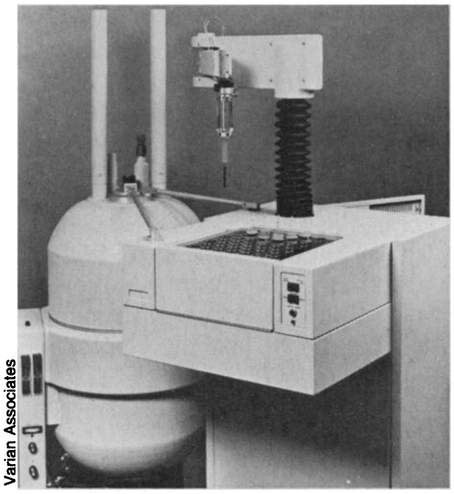
The Optical Waveguide Spectrum Analyzer displayed at this year's conference has been specifically engineered for use with fiber optics and can measure absorbance, reflectance, fluorescence, and turbidity at distances as great as 200 meters from the instrument. Wavelengths from 190 to 1800 nanometers can be scanned at rates of up to 9600 nanometers per minute with high accuracy and reproducibility. Optical waveguides transmit signals to and from up to six probes in sequence.

A variety of probes are also available, including a new probe with a type is of little help in boosting the productivity of an analytical chemistry laboratory. What the chemist wants, at least according to the manufacturers, is another one of this year's Pittsburgh Conference buzz words, an "integrated solution." Zymark does not make analytical instruments or computer systems, so the company is forming a series of more and less formal arrangements with other firms.

In the first category is an arrangement with the Mettler Instrument Corporation (Highstown, New Jersey), whereby Mettler's DL18 Karl Fischer titrator or DL40RC general purpose titrator and the Zymark robot system are mated by a jointly developed interface to create an automated titration system. Both companies sell the system. Somewhat different is the relationship with Hewlett-Packard (Palo Alto, California), which integrates the Zymark robot system into its own analytical instruments. For example, a new Hewlett-Packard automatic sample injector provides the interface between the Zymark system and a gas chromatograph.

On the less formal side, Digital Equipment Corporation (Maynard, Massachusetts) has an analog data module that permits Zymark robots to be integrated into a higher level computer system that could include a work station computer (Professional 380) for the work area and a powerful minicomputer (VAX series) that oversees operation of the entire laboratory, a so-called laboratory information management system (LIMS) (*Science*, 8 April 1983, p. 180).

In its first delve into laboratory robotics at the Pittsburgh Conference, with its Masterlab system, Perkin-Elmer took a hardware approach that differs from Zy-


Varian Associates

Robotic sample manager

The ASM 100 automatic sample manager for Varian's XL series of nuclear magnetic resonance spectrometers will be available this summer.

mark's in that the robot it uses is from Mitsubishi in Japan. The robot is a miniature version of the industrial-type robot and has five motions describable in analogy with the motions of a human arm. In addition to the rotation around a vertical axis through the base of the robot, there is a shoulder rotation around a horizontal axis, an elbow rotation around a horizontal axis, and two wrist rotations around two perpendicular axes. There is no strictly linear motion, as these are accomplished by way of the rotations.

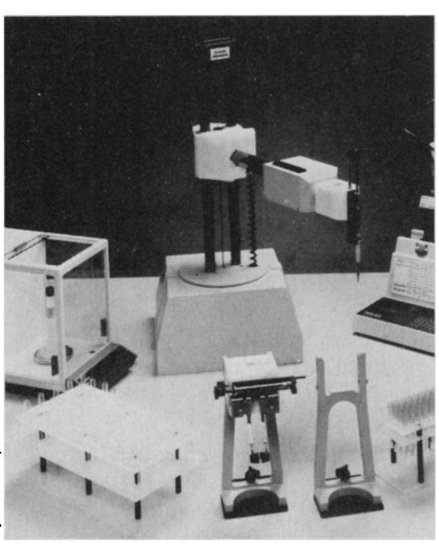
Perkin-Elmer's robot has a quite robust appearance. The robot lives up to its appearance, lifting heavier weights, moving faster, and positioning itself more accurately than the Zymark robot. Although some attendees wondered if the machine was not a bit of overkill for laboratory tasks, Perkin-Elmer did not want to reinvent an already well-developed technology.

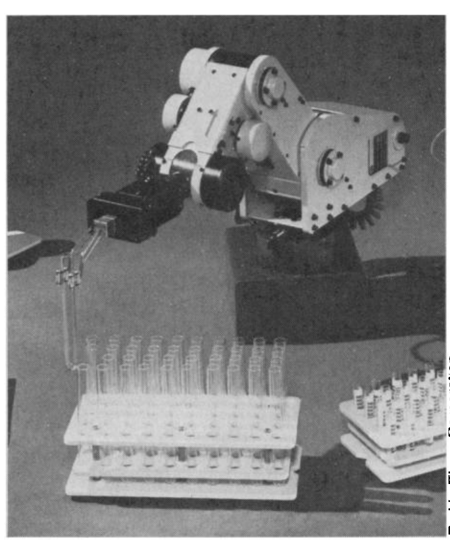
Another hardware difference is the computer that controls the robot system. Zymark built its own computer controller. Rather than using one of its own laboratory computers, the Perkin-Elmer chose an IBM PC, principally because of price. In other respects, however, the collection of sample-handling stations is similar to Zymark's, as is the circular arrangement of stations and instruments around the robot. The price of a minimum system (none have been delivered yet) is expected to be from $25,000 to $30,000.

When it comes to integrated solutions, however, Perkin-Elmer takes advantage of its prowess as an analytical instrument and computer manufacturer; that is, it does not have to go outside the company to assemble complete packages. At the Pittsburgh Conference, the company showed several integrated systems centered around its own instruments and computers, including an ultraviolet-visible spectrophotometer, a gas chromatograph, and an inductively coupled plasma emission spectrometer. Perkin-Elmer also offers powerful minicomputers with LIMS software, so one could purchase an almost paperless laboratory from one company.

The Johnson Scale Company and GCA/Instruments and Control Group were two other newcomers to Pittsburgh Conference laboratory robotics. Johnson used the same Mitsubishi robot model as Perkin-Elmer, whereas GCA showed the smallest model of its well-developed line of industrial robots. For combining brawn with speed and accuracy, the GCA robot was king of the show; however, the questions raised about the Mitsubishi robot would seem to apply in spades to this machine. Both companies claimed a willingness to integrate their robots into systems according to customer needs. Johnson's basic system comprising the robot and an Epson HX-44 control computer costs just under $15,000, while the price of GCA's robot with IBM PC controller exceeds $35,000.

How far can one stretch the term laboratory robot? The devices with the simple *x-y-z* linear motions certainly fit Zenie's definition of allowing computers to do physical work, but they do not have much of a robot flavor about them. They are designed primarily for liquid sample preparation and handling. A robot arm moves over a rack of test tubes or sample vials. Rather than a gripper, the arm holds a syringe that picks up liquids from one set of test tubes and transfers them to others in the course of


Zymark Corporation


Perkin-Elmer Corporation

Two robots

Robots sold by Zymark (left) and Perkin-Elmer (right) are designed to do pretty much the same jobs, but they look and operate differently.

distributing reagents, diluting samples, dispensing them, washing test tubes, and so on. Timing and sequence of events is completely user programmable. Hence it is possible to have automated preparation of various sample types at one sitting. Prices range from about $6600 for the Gilson 212B liquids handler with a built-in computer controller to just over $24,400 for the Hamilton Microlab 2000 with an IBM PC*jr*. computer.

Finally, Varian and Perkin-Elmer introduced autosamplers with robot arms. The arms allow user-programmable selection of samples in any order rather than in sequence from a rotating carousel. Varian's ASM (Automatic Sample Manager) 100, designed for the company's XL series of nuclear magnetic resonance spectrometers, has an internal microcomputer controller and can accommodate temperature-controllable trays of up to 100 samples. Among the interesting features is a test for the presence of a sample. If none is found in the designated location, an error message is sent to the computer overseeing spectrometer operation. Cost is $30,000. Perkin-Elmer's DSC-4 Robotic System allows unattended analysis of up to 48 samples in the company's TADS series of thermal analysis systems. Its cost is $14,500.—**Arthur L. Robinson**

A New Trend: Training on "the Tube"

A generation of young scientists who were raised on "Sesame Street" and "The Electric Company" and received at least part of their formal education through the use of instructional videocassettes may soon also be learning about instrument maintenance and usage through television. "There is a cadre of scientists out there who are all primed to use television to learn how to use and repair complicated instruments," says one media consultant. "The analytical instrument industry has been exceptionally lax in failing to provide for them. Videocassettes have so many advantages over a conventional instruction manual that it is virtually a crime for companies not to be using them."

That situation is changing, however. Three companies at the Pittsburgh Conference were actively promoting videocassettes and at least two more companies are using them in a more low-key manner. If these companies' efforts prove successful, says the consultant, "videocassettes may sweep through the industry."

One company in the forefront of the videocassette revolution is Finnigan MAT (San Jose, California), the largest manufacturer of mass spectrometers. The company has long played an active role in training MS users through its Finnigan MAT Institute in Cincinnati, which has trained more than 5000 individuals in 1-week courses since 1978. Finnigan's entry into videocassettes was catalyzed by the introduction 2 years ago (*Science*, 8 April 1983, p. 178) of its Ion Trap Detector, an inexpensive quadrupole MS designed as a detector for gas chromatography (GC).

"The people who buy one of our sophisticated mass spectrometers are eager to come to Cincinnati for a week to learn how to use it," says Don DeJongh of Finnigan, "but the ones who buy a $32,000 detector for a GC aren't willing to spend either the time or the money. We decided we had to find a better—and cheaper—way to reach them. The videocassette looked to us to be the ideal way to do it."

It is, perhaps, ironic then that Finnigan's first two videocassettes to reach the market are directed toward users of large instruments. Both describe preventive maintenance on Finnigan's 1020/OWA GC/MS/DS (GC/mass spectrometer/data system). One shows how to clean the ion source and related assemblies of the MS, and the second shows how to clean the quadrupole rods. The key word in both cases is "shows." "It's virtually impossible to learn these techniques from an instruction manual," says DeJongh, "but the cassettes lead you through them in step-by-step fashion so that it is easy to see exactly what is being done." One important advantage of the cassettes, he notes, is that all technicians who view it receive the same training; that is not necessarily the case when one individual in a laboratory trains another, who might then train a third.

The cassettes come with a manual containing the script for individuals who have difficulties with English. The packages will eventually also be available in other languages. Training cassettes for the Ion Trap Detector will be available later this year, and cassettes for other instruments are being planned.

EM Science (Cherry Hill, New Jersey) displayed a cassette designed for Hitachi HPLC's. The three-part cassette covers installation, operation, and troubleshooting for isocratic HPLC's, says Gene Desotelle of EM, and a companion cassette for gradient instruments is in preparation. The latter cassette is taking more time to prepare, he says, because the gradient systems are more complex and it is necessary to cover programming of the computers. EM has been using videocassettes for several years to train distributors and to demonstrate instrument capabilities for potential purchasers, he adds, and the extension to user training came naturally.

Varian Associates, Inc. (Palo Alto), did not display videocassettes at the conference, but the company has been using them for 2 years for analytical instruments and even longer for their other electronic products. The company now markets six tapes covering the operation of data systems, use and maintenance of GC's and LC's, and general principles of HPLC. Sales of the cassettes have gotten off to "a slow start," says Hal Hartman of Varian; "I thought it would go faster." He is optimistic about future sales, however, because of recent decreases in the price of videocassette recorders. "When VCR's dropped below $500," he says, "they became a petty-cash item, and I think more labs are now willing to purchase them."

A somewhat different approach to video is the production of cassettes that are oriented toward techniques rather than specific instruments. The American Chemical Society, for example, has been marketing such courses for 5 years. The courses, which include two to six cassettes apiece, cover such topics as gas chromatography, interpretation of infrared spectroscopy, toxicology, chemical engineering for chemistry, technical writing, and molecular reactivity (kinetics and thermodynamics). These courses can be rented for $200 to $400 per week or purchased for $720 to $1800. The society is not now preparing any new courses, says Harry Walsh, because sales have not been high enough to allow the program to be self-sustaining. Walsh is optimistic that sales will increase, however, and that new programs can be prepared in the future.

LC Resources Inc. (San Jose) introduced a new cassette series on principles