Update

Rita D'Aquino

The Incredible Shrinking Sampling System

Sophisticated and reliable, today's process analyzers can do everything from measuring moisture in a single hydrocarbon gas stream, to monitoring fluid composition at a number of points in the process. But even the most advanced analytical device is only as good as the mechanical system that conveys the sample to it. In fact, sampling systems, which are responsible for extracting, collecting and preconditioning a sample; transporting it to the analyzer; and then disposing of the it (or returning it to the process line), are the cause of 70–85% of analyzer downtime, according to industry specialists. For the many who have tried to improve the design, the challenge has always been developing a sampling system that is easy to assemble and maintain, robust and precise in its delivery of the fluid.

Enter modular or surface-mounted sampling systems (SMSS), the applications for which originated in the semiconductor industry, and were adapted to the chemical, petrochemical and petroleum industry through the so-called Generation I (Gen. I) design modifications proposed by the Center for Process Analytical Chemistry's (Univ. of Washington, Seattle; www.cpac.washington.edu) New Sampling/Sensor Initiative (NeSSI), a neutral forum where users and vendors discuss ways to modularize, miniaturize and introduce "smarts" to process analyzer system components.

Comprised of close-coupled modular substrates, low-flow components and flow paths that minimize internal volume, thereby improving response time to the analyzer, SMSS won the hearts of vendors and users alike in 2002, when the ISA (Research Triangle Park; NC; www.isa.org) and ANSI (Washington, DC; www.ansi.og) passed ANSI/ISA-76.00.02, a standard that defines the dimensions of the interface between a sampling-system component and the flow substrate. "We wouldn't be as interested in this technology if it weren't for ANSI/ISA-76.00.02," admits Steve Doe, analytical market manager of Parker Hannifin Corp.'s Instrumentation Div. (Jacksonville, AL; www.parker.com). Parker officially entered the SMSS supplier's circle with the launch of its IntraFlow product line (Figures 1 and 2) at the ISA Expo 2003 (Houston, TX) in October.

Figure 1. (left) Parker Hannifin's IntraFlow system comprises modular components that maintain all flow paths on a single plane within the system.

Figure 2. (above) Contiguous internal fittings are intra-connected with slip-fit connectors, which permit 3-way functionality (*i.e.*, a three-way ball valve).

The fact that there are only two other manufacturers of SMSS in the analytical systems market — Swagelok Co. (Solon, OH; www.swagelok.com) and Circor Instrumentation Technologies' Hoke Div. (Spartanburg, SC; www.circortech.com; www.hoke. com) — suggests that suppliers have not fully appreciated the benefit of having a standard to follow that meets the common interests of end users in this marketplace.

Design and build for less

Each manufacturer approaches the concept of modularity differently, but their common goal is to improve the performance of process-analyzer sampling systems, while reducing the costs to design, build and maintain them. For example, the design-and-build costs of a traditional 20-position system can account for more than 50% of the total first-year costs. With the modular substrate system, those design-and-build costs can be reduced to less than 10%.

Moreover, software, such as Parker's IntraFlow DesignPro (IDP), which will roll out next March, and Swagelok's configurator software, which is available now, can cut the time to develop a process schematic from one week to about 1–2 h. The software enables the user to place, define and connect top-mounted components on a computerized layout grid via a drag-and-drop functionality. All of the additional flow connectors that are necessary to build the fluid system are identified, and a bill of materials and final diagram are generated. IDP will be provided as a web-based service run directly off of Parker's server, with access to topworks, such as mass flow controllers, that are not supplied in-house, and, as emerging technologies become available, parts for communications and control.

Not only can the modular platform reduce design costs of a sampling system, but their sheer smallness can reduce the costs of preparing for today's increasingly tighter regulatory environment, which is driving the need for more analyses, and thus, more equip-

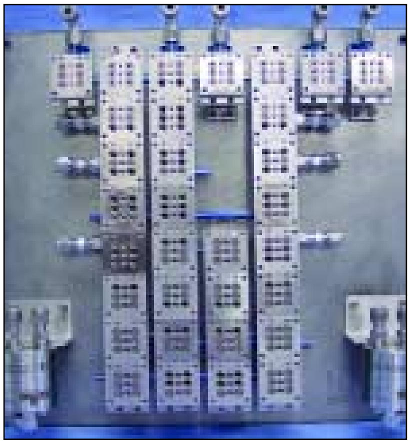


Figure 3. Hoke, Inc.'s µMS³ modular sampling system. Unique to Hoke's components are silicon dioxide coatings, Silcosteel (300-µm thick) and Sulfinert (1,300-µm thick), that make the parts highly inert to moisture and sulfur, respectively.

ment and instrumentation.When traditional analyzer shelters are filled to capacity, miniaturized, modular systems can be used to free up space more cost-effectively than building a new shelter — a job estimated to cost \$30,000 – \$40,000 for legacy analyzer sampling systems.

Added to that is the cost of the process analyzer system itself. A conventional system for NO_x analysis requiring eight calibration gases and featuring 30–40 topworks would cost around \$15,000, while modular system would cost \$16,500. "However, since it consumes 60–70% less space, and can reduce the cost of ownership by about 50%, you could wind up paying less, once the costs of enclosures and heaters (for sampling lines) are considered," Doe points out.

Ramping up reliability

"The greatest impact that we will see from the new modular sampling and analytical technology is a reduction in system downtime and an increase in reliability," says Bac Vu, analytic specialist for Dow Chemical Co. (Midland, MI; www.dow.com). Dow is currently evaluating the modular sampling and analytical products of four suppliers for a number of internal applications, both new and existing. "We are in the process of determining what substrate (flow channel) designs and component offerings (*e.g.*, valves, filters, flowmeters, sensors) will meet our needs," he says.

One possibility is the micro Modular Substrate Sampling System (µMS³; Figure 3), unveiled by Hoke in April 2003 at the ISA Analytical Div. Symposium in Calgary, Alberta, Canada. It has smaller flow paths, providing up to 50% less internal volume than the industry standard. This reduces sample volume, accelerates fluid transfer, and decreases the surface area exposed to a potentially reactive medium, says Robert Sherman, ISA Fellow and Circor process industry specialist.

Incorporating a building block and pre-welded flow tubesets, marketed under the tradename NuBlu, the µMS³ has unlimited multi-stream and block configurations, so it easily adapts to any process schematic. In addition, the flow path of µMS³ is completely external to the substrate, which allows for visual flow validation. An elastomeric seal on the external flow path provides for extremely simple field repairs, adds Sherman.

A significant challenge in the development of a SMSS concerns fluid flow and accuracy. The substrate tightly juxtaposes components, such as valves and filters, which are mounted vertically and arranged horizontally, with one right next to the other (Figure 4). Generally, fluid must flow downward out of one component, into the substrate, and up into the next component (Figure 5)," says Swagelok's manager of marketing resources David Simko. Swagelok addresses this challenge by directing fluid through flow components in the substrate. These components consist of a piece of tubing with stainless steel blocks that are precision-welded on each end. "Precision welding is very important because the sealing surfaces must align on the same plane and the overall dimensions of the component must be exactly accurate," Simko explains.

To the contrary, in the Parker IntraFlow substrate, all flow paths, regardless of direction, are maintained on a single plane within the system, requiring no lower level manifolds. Contiguous internal-fitting flow paths are intraconnected with slip-fit pressure connectors, allowing the 3-way functionality required by sampling systems. A threaded pegboard provides extra support and rigidity when fittings are mounted with cap screws.

Another advantage of modular sampling systems is the ability to obtain more-representative samples. Today, many analyses are achieved by extracting samples from all over the process and performing multiple analytical

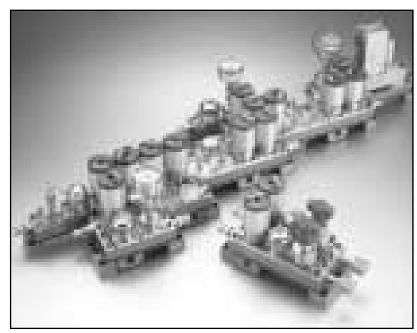


Figure 4. Swagelok's modular platform components (MPC) technology consists of components mounted on top of a substrate layer containing specialized flow channels.

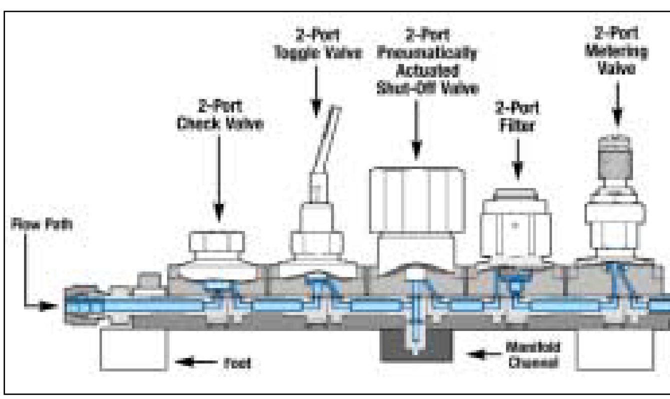


Figure 5. Components (and topworks) are tightly juxtaposed. Fluid is directed from one component to the next through flow components in the substrate. Sensors are manifolded into the substrate where needed.

Small, but mighty *smart*

Modular, substrate-mounted systems (SMS), which embody the Generation I (Gen. I) NeSSI design, afforded the chemical industry the freedom to design, install and build sampling systems using passive components, as needed for a process analytical application. However, in order to take full advantage of the functional capabilities offered by Gen. I designs, these sampling systems must be made "smart," as well as afforded a way to transfer signals and power onto and off of the sample system and sensor substrate. "Low-cost sensors and actuators (collectively referred to as transducers) must be built onto the substrate in a manner suitable for use in electrically hazardous areas (*i.e.*, must be intrinsically safe (IS)). Further, some degree of decentralized intelligence, including control, must be incorporated into the overall design," says Mel Koch, director of the Center for Process Analytical Chemistry (Univ. of Washington, Seattle; www.cpac.washington.edu), which oversees the New Sampling/Sensor Initiative (NeSSI).

The specification for making the sampling systems "smart," self-contained and "electrified" to meet the hazardous-area requirement is designated as Gen. II NeSSI, and is a platform for developing the emerging class of miniature sensors and microanalyzers — the Gen. III NeSSI products — that can be mounted on the substrate. System integrators, analytical device manufacturers and vendors, and sensor producers and developers are invited to build products for these "next generation" assemblages, with the goal of testing and ultimately commercializing them.

For instance, Honeywell Sensing and Control (Freeport, IL; www.honeywell.com) is actively working to provide a new generation of microanalytical sensors and analyzers, in addition to basic transducers, for NeSSI users. A major boost to this effort recently came when the company was chosen by the Dept. of Energy (DOE; Washington, DC; www.doe.gov) to lead a collaborative R&D project involving partners from industry and academia to create and field test an affordable, easy-to-use wireless network technology for industrial environments, along with sensor technologies for sampling and analyzing gas- and liquid-phase process streams. One focus of this effort will be on PHASED, a microscale gas chromatograph being developed at Honeywell Laboratories (Plymouth, MN) using micro electro-mechanical systems (MEMS) technology. A consortium of seven leading process industry companies will collaborate with Honeywell to field test NeSSI-based micro-analyzers as part of this project.

Bus protocol

Rob DuBois, senior analytical specialist at Dow Chemical (Fort Saskatchewan, Alberta, Canada; www.dow.com), is spearheading Dow's efforts in evaluating NeSSI Gen II and III technology and hopes to have "smart" analytical systems, as well as microanalytical systems, in place by 2006. "For monitoring and control at the sensor/actuator level, we are seeking intrinsically safe plug-and-play communications solutions (*e.g.*, for electrical devices within enclosures handling hazardous fluids, such as ethylene, ethylene oxide, etc.) that are priced competitively with 4–20-mA systems," he says. "We are in the process of selecting a communication standard that can do the job." At the high end (*e.g.*, from the sensor actuator manager (SAM) to distributed control system (DCS), the job may be accomplished using an Ethernet communications mechanism.

At meetings held recently at the Open DeviceNet Vendors Assn. (ODVA; Boca Raton, FL; www.odva.org) and CPAC to discuss the Gen. II specification, the proposed CANBus-DeviceNet protocol, which was thought to be the obvious choice, was found otherwise because it is currently neither IS nor cost-effective. An investment of about $750,000 would be needed to make the modular system smart using CANBus-DeviceNet, according to Koch. Also, it is limited in the things it can do for user (*e.g.*, amount and mode of data transfer, extracting most important data, trending, etc.).

The "plug-and-play" capability demonstrated by IS-enabled devices is a major driver in the design and standardization of Gen. II systems. IS-enabled devices may be wired without any special tools — just a simple connector, giving users the same Lego-like assembly freedom that they now enjoy on the mechanical side of things, courtesy of ANSI/ISA-76.00.02. The icing on the cake is that IS is acceptable to all global hazardous certification agencies.

Because some devices (*e.g.*, heaters and certain microanalyzers, due to high power consumption, cannot, by design, be intrinsically safe, alternative buses (including other CANbus variants, such as CANopen) are being considered, as well as the possibility of specifying different buses for different applications, based upon their need for IS, process control, bandwidth, etc. "Ideally, we would have a single multi-drop communication protocol and physical network for the sensor/actuator bus that is capable of handling both IS devices (with either an optical or a galvanic isolator), as well as non-IS devices," says DuBois. Development of Gen. II systems is underway. Alpha testing will begin when basic connectivity and communication solutions and certain smart devices become available.

tests in a centralized house where the sample is conditioned and the analyzers are contained and maintained. "By moving analytical systems closer to the point of extraction, we make it possible to get sample data more quickly, reliably and cost-effectively," notes Rob DuBois, senior analytical specialist at Dow Chemical (Fort Saskatchewan, Alberta, Canada; www.dow.com). "A small microclimate enclosure can be installed right at the pipe, stack or vessel, reducing infrastructure costs. Most importantly, an instrument that is closer to the pipe should be self-diagnostic so that you don't have to send somebody into the field to check it," he continues.

The key to reducing infrastructure costs associated with process analysis is to add intelligence to the sample-handling system, adds Robert Nickels, business development and technology leader for Honeywell Sensing and Control (Freeport, IL; www.honeywell.com), which has led the effort to define communications infrastructure for NeSSI Gen. II and Gen. III systems (sidebar). "For the past 50 years and more, sampling systems have been custom designed and built around an operations and maintenance model that is increasingly difficult for companies to afford," he says. The NeSSI Gen. II specification sets a high standard for sample-handling system components, which include, for instance, the physical property transducers that Honeywell is developing for measuring pressure, temperature and flowrate.

Delivering the goods

"Some companies spend a lot of time testing what would work in the plant and help customers design field-applicable systems, while others don't," says Dan Podkulski, senior staff engineer at ExxonMobil Chemical Corp. (Houston, TX; www.exxonmobil.com), who pioneered the ISA effort to write SP76 and is now buying and installing the modular systems at Exxon's Baytown chemical plant. "We're still trying to get our new modular systems up and running in the field," Podkulski continues. "It's not exactly like working with Legos."

Interconnectivity is a big issue. "Just because a component complies with the standard doesn't mean it will work on a SMSS," says Podkulski. This problem increases in complexity when trying to design a modular system for complex analytical applications in the field. Some components have large internal surface areas, which afford places for ppm concentrations of components to attach themselves, or are physically large with respect to the 1.50-in. × 1.53-in. substrate, which limits the NeSSI system layout and defeats the purpose of the small-base manifold format. Sometimes,vendors have even neglected to specify the clear space needed around a topwork in order or it to be mounted on the substrate.

Meanwhile, interest is growing in ANSI/ISA-76.00.02-compliant flowmeters that utilize newer technologies, such as Coriolis, vortex shedding, thermal and ultrasonics, and that target specific flow ranges of gases and liquids. Chemical companies are also eyeballing some of the best components available, wondering when they will comply with the ANSI/ISA-76.00.02 standard.

In that vein, Circor is working with third-party vendors to develop new ANSI/ISA-76.00.02-compliant instruments, such as oxygen analyzers and spectrophotometers, that would be useful to the chemical industry. Panametrics (Waltham, MA; www.panametrics.com) and Teledyne Analytical Instruments (Los Angeles, CA; www.teledyne.com) manufacture SP76-compliant oxygen analyzers, while Bühler (Winnipeg, Manitoba, Canada; www.buhler.com) is developing a NeSSI-based oxygen analyzer. Circor and KNF Neuberger (Trenton, NJ; www.knf.com) are also cooperating to commercialize a NeSSI-based diaphragm pump in the near future.

Suppliers who want a piece of this market might consider certain coalescing filters and dual-stage pressure regulators, notes Podkulski; or products that satisfy the NeSSI Gen. I specification for larger-diameter analytical sampling systems, which no vendor manufactures at this time. The latter would enable other industries, such as food, pharmaceuticals and heavier product refining, to benefit from standardization.

Lifecycle costs decreasing

NeSSI Gen. I designs strive to miniaturize and modularize the sampling system to reduce its lifecycle cost (LCC). The LCC of an analyzer alone is estimated to be five times its initial capital cost, according to PAI Partners' (Leonia, NJ) latest process analyzer industry report, *PAI 2004*. A modular process-analyzer system, which costs 15–30% more than a system using compression fittings and hand-bent tubing, could save 50%/yr for the next 10 yr on analyzer maintenance. Beta tests conducted at one California-based refinery have shown that the LCC of a NeSSI sample-conditioning system is about 80% less than that of a threaded-pipe sampling system and 40–60% less than that of a tubing system; and on-site construction cost savings for a modular vs. tubed system would be 40–60% of the labor savings.

One reason is simplified maintenance. "The entire toolkit for a NeSSI system comprises an Allen key wrench and a pocket full of industry-standard o-rings," says Sherman. If a sample-conditioning component in a tubing or piping system needs maintenance, the line has to be broken, and the new tubing or piping made to align with the old ones. This is very labor- and skill-intensive work, Sherman adds.

Further, in a NeSSI system, all of the functional components are accessible from the top of the assembly, enabling them to be serviced quickly and easily without disturbing any other components (Figure 6). "This design feature is important, since many SMSS are mounted against a vertical backplate (*e.g.*, in an enclosure)," says Simco.

Even better news for the user is that the cost of the SMSS is decreasing. In February 2003, the initial equipment cost for a Gen. I NeSSI sample-conditioning system was approximately three times that of a classic/legacy system. This factor has been reduced to 1.3 and could be 0.9 within the next year, and 0.7 within three years, given sales volume increases and advanced manufacturing techniques, predict process analyzer professionals.

Total system solutions may be the determining factor for vendor selection in this very narrow playing field. "Building an entire system that suits the customer's needs, taking responsibility for the performance of any third-party components and providing one-on-one assistance during commissioning is what many customers want," one vendor observes, adding the caveat: "If you won't warranty the components that are used on your system, or if the use of third-party components voids out the modular system's warranty, customers might think twice about giving you their business."

Figure 6. Hoke's µMS³ provides easy access to top-mounted components.

New Fullerene Production Process Makes Pilot Plant Debut

A scalable combustion technology that produces fullerenes at yields of 95% or greater without the use of solvents has been demonstrated at the several-hundred-kg/yr scale by Nano-C, Inc. (Westwood, MA; www.nano-c.com). Fullerenes are ball-shaped molecules of carbon comprising a cage of interlocking pentagons and hexagons of 60 or 70 carbon atoms. Conventionally, they are produced via the carbon-arc process, but with much lower yields. Even Nano-C's first-generation process, which burns a low-flow, low-pressure stream of hydrocarbons using a surface-stabilized flat flame fueled by benzene, produces roughly 10% fullerenes and 90% soot.

Nano-C's "second generation" combustion synthesis, based on years of work at the Massachusetts Institute of Technology (MIT; Cambridge; www.mit.edu), starts with a high flowrate of variable-molecular-weight hydrocarbon feedstock, including feedstocks common to the carbon-black industry. The feed is burned continuously in a 3-dimensional jet-stirred chamber, akin to the combustion chamber of a jet engine, at pressures from 20 to 100 torr and temperatures from 1,200°C to 1,700°C. Conversion to fullerenes takes place in the vapor phase in less than a second, with virtually no soot byproducts. The fullerenes precipitate as the combustion gases cool, and are recovered via filtration.

With the established carbon-arc method, production costs for pure C60 are $16,000/kg, mainly due to solvent usage during high-pressure liquid chromatography, which is used for fullerene recovery. Nano-C's sans-solvent approach costs $200/kg C60, which is a factor of ten less than the firm's first-generation combustion technology.

Nano-C has begun commercial tests with a variety of companies, including C Sixty, Inc. (Houston, TX; www.csixty.com), a biotechnology firm that is exploring the use of Nano-C's fullerenes to produce antioxidants for pharmaceutical applications. C-Sixty has recently formed an exclusive R&D, supply and commercial-license-option agreement with Merck & Co. (Whitehouse Station, NJ; www.merck.com), which is planning to use the antioxidants in two therapeutic drugs. Other markets for Nano-C's fullerenes include polymer electronics and specialty polymers.

A 12-h/d pilot reactor in Westwood, MA, produces fullerenes using Nano-C's solvent-free combustion technology.

EXXONMOBIL CHEMICAL UPGRADES XYLENE ISOMERIZATION PROCESS

ExxonMobil Chemical Co. (Houston, TX; www.exxonmobil. com) is now licensing a "new-and-improved" version of its xylene isomerization technology, called XyMax-2, that provides high yields over a wider range of temperatures and pressures. The key to XyMax-2 is a highly shape-selective, proprietary zeolite catalyst that can be used in a wider range of isomerization units, including those that could not previously utilize the original XyMax technology, due to temperature and pressure constraints. "It is now possible to convert many of these additional isomerization units to the XyMax-2 technology, while affording them high ethylbenzene (EB) conversion and exceptionally low xylene losses," says Doug Selman, vice president of R&D.

Like the original XyMax process, which was introduced in 2000 and is currently operating successfully at four sites, XyMax-2 uses a unique dual-bed catalyst system, with each bed tailored to perform specific functions that optimize EB conversion, non-aromatics cracking, and the isomerization of metaxylene and orthoxylene to paraxylene. The feed is a mixture of fresh and recycled C_8 aromatics in which the paraxylene concentrations are less than equilibrium. The mixed xylene feed, combined with hydrogen-rich recycle gas, is preheated and passed through the reactor, where EB is dealkylated to produce benzene and ethane, and xylene isomerization occurs to produce a paraxylene concentration in excess of 100% of equilibrium. Reactor effluent is cooled by heat exchange and the liquid products are separated from the recycle gas, stripped to remove light ends, and fractionated to remove benzene and toluene. Bottoms from the fractionation section are then recycled to the paraxylene recovery section.

"When installed in existing conventional xylene isomerization units, XyMax-2 can increase paraxylene capacity up to 40% with minimal hardware modifications," says Selman. The first two licensed applications of XyMax-2 are expected to begin operating in the second quarter of 2004.

Air Motors Reduce Power Consumption

An alternative to electric variable-speed and air-vane-powered motors for use in harsh, hazardous or ultraclean environments has been co-developed by Dynatork (Nottingham, U.K.; www.dynatork. co.uk) and Quadrant Engineering Plastic Products (QEPP; Reading, PA; www.qepp.com). Designated the Dynatork 3 non-lubricated air motors, they feature components made of QEPP's high-performance polymers and tout a simple, yet unique, design and operating principal, says Ian Thompson, Dyntork's managing director.

For the piston, Quadrant uses a polyethylene terephthalate (PET) called Ertalyte, which provides stability in wet-air operating conditions and eliminates the need for lubrication (silicone lubricants cannot be used in spray-paint shops). Further, the use of

Dynatork 3 air motors' components are made of high-performance polymers that eliminate the need for lubrication.

Ertalyte TX in place of brass in the cylinder liner results in closer dimensional control, which improves piston-sealing efficiency.

The motor has only four moving parts: the central drive shaft and three radial pistons set at 120 deg with respect to each other. It is commissioned with an air pressure below 10 psig that is increased by 10–15 psi (up to 120 psig) until the motor overcomes the load. At this point, it is in overdrive and must be throttled the back to the required speed. Such a feature, coupled with flowrates from 0 to10 ft^3/min at 700 rev/min makes the Dynatork 3 motors suitable for difficult applications, where they can be fine-tuned to suit the process.

An integral rotary valve controls the air supply and directs it to the three pistons. When the first piston applies pressure to an eccentric cam, the shaft rotates through 120 deg, and the second piston takes over and transmits the force to the third piston, which has been pushed into position for the next forcing stroke. These pistons drive a crank that imparts a turning motion to the motor's outlet shaft. Dynatork's high torque, variable low speed, and instant start/stop output, make it suitable for a wide variety of industrial uses, particularly paint-stirring and other liquid-blending applications.

Like all pneumatic equipment, the Dynatork requires a clean compressed air supply. One Japanese automotive manufacturer's plant in the U.K. that replaced 60 agitator vane air motors and their gearboxes with Dynatork 3 air motors reduced air consumption by 80%. "This saved 1,280 ft^3/min, enabling two compressors to be taken offline, thereby enhancing their operating life. The power savings amounted to $144,000/yr," says Thompson.

Dynatork has already converted four major automotive manufacturing paint plants in the U.K. with its motors — the cost of which varies from $689 to $3,054 depending on the model, gearbox size and operating conditions — and three other automotive plants are now testing Dynatork 3 motors, as well. While standard Dynatork air motors use high-quality cast aluminum for the body housing, an alternative design uses porosity-free Acetron acetal copolymer, which enables the air motors to meet FDA and EU regulations for applications in the food-and-beverage and pharmaceutical industries.

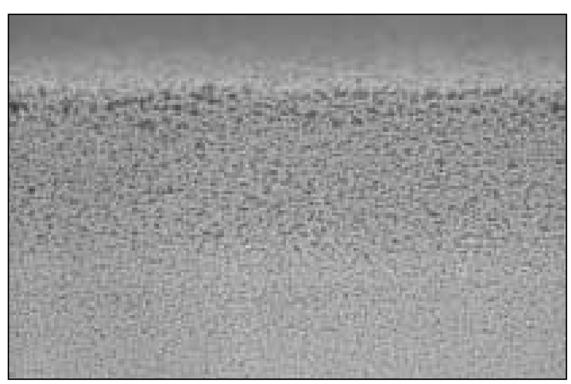
Membrane Gets High Marks for Speed and Throughput

Pall Corp. (East Hills, NY; www.pall.com) has developed a way to double the throughput of sterilizing membrane filters without compromising separation efficiency or increasing the membrane size. Designated as machV technology, it enables asymmetrical, or funnel-shaped pores to be mechanically formed in a membrane during its manufacture. Pall has demonstrated machV technology on its polyethersulfone (PES) membrane, Supor machV, which made its commercial debut in Nalge Nunc International's (Rochester, NY; www.nalgenunc.com) MF75 Series filter units and bottle-top filters in September. Nalge Nunc has also signed a multi-year, multi-million-dollar supply and co-branding agreement with Pall to exclusively use Supor machV membranes for the bottle-top-filter market.

Most sterilizing filters are designed with the same inlet and outlet pore sizes; optimal sterilization for biological applications requires 0.1- and 0.2-µm pores. On the contrary, machV membranes' inlet pore sizes are tailored for the application; outlet pores sizes range from 0.1–2 µm.

"The Supor machV membrane is approximately twice as fast as the existing Supor line for filtering buffers, biological solutions, protein additives and serum, and is an improvement over any other membrane filter on the market," says Ken Harris, president of Pall's Biosciences Group. For instance, Nalgene's machV bottle top filters provide flowrates of over 1,000 mL/min with cell growth media in a 10% serum. A typical water flowrate for Supor machV membranes is 40 mL/min/cm^2 at 10 psig.

Harris attributes Supor machV's performance to the low nonspecific binding characteristics of the membrane, which prevents the loss of critical protein components when filtering dilute solutions. "In a standard application, the user can increase throughput by 33% and save about 50% in disposal costs," Harris adds. Due to these cost savings, Pall says that Supor machV could warrant a higher price than conventional membrane materials. Pall will introduce machV in its own membrane-based products in January 2004.



The scanning electron microscope (SEM) image of the Supor machV membrane, shown at 350X.

SOFTWARE & INSTRUMENTATION

CFD Software Makes a Model a Minute

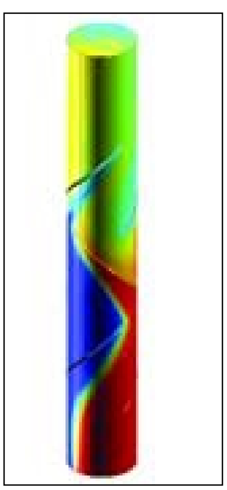
This month, COMSOL, Inc. (Burlington, MA; www.comsol.com) will begin shipping FEMLAB 3.0, the standalone version of this firm's equation-based, streamlined modeling package, which, until now, could only be used from within MATLAB software, a product of The MathWorks, Inc. (Natick, MA; www.mathworks.com). "It generally solves problems in half the time and with half the memory of the previous FEMLAB product. In some cases, it improves both speed and memory efficiency by a factor of 20–25," says COMSOL's president, Svante Littmarck. "On a standard desktop PC (a Mac-based version is not available yet), it handles problems in fluid flow, chemical reactions and heat transfer with as many as a million degrees of freedom, in 15 min to a couple of hours, depending on the solver technique and the speed of the computer," he adds.

The software has access to a library of more than 200 completely solved and fully documented models of systems, such as reactors, heat exchangers, fuel cells, mixers and microelectromechanical systems (MEMS). Once the model is selected, FEMLAB automatically sets up the corresponding equations; alternatively, users can also enter their own equations (*e.g.*, for arbitrary reaction kinetics or state equations) directly by typing them into a dialog box that serves as a free-form equation editor. Littmarck points out that other packages make it difficult to modify model equations, if they provide any access to them at all.

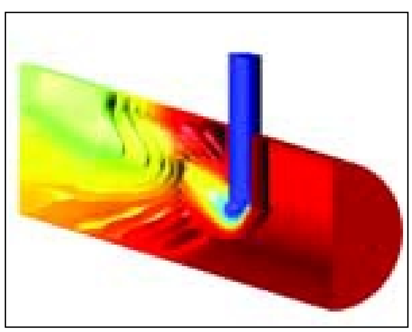
The proven finite-element analysis method is used to model virtually any physical phenomena that can be described with partial differential equations, including heat transfer, fluid flow, electromagnetics and structural mechanics.

After the software has computed the solution, numerical solvers implemented in C++ together with a sophisticated Java interface enables FEMLAB 3.0 to create complex 2D and 3D models in minutes (photos, below) — a task that was formerly performed by MATLAB. "No additional coding is necessary on the user's end," says Littmarck. The interface also allows realtime rotation of a 3D image in any direction. Furthermore, a researcher can investigate the interactions of different transport phenomena within one graphical interface, producing a solution within a few hours, vs. months as required with competing software.

A single-user license for FEMLAB 3.0 lists for $6,995, including support and automatic upgrades for 12 mo, but universities can buy it at a discounted price. The software may also be run from within the MATLAB environment, for those who wish to do so.



This example studies the flow field and species transport in a twisted-blade static mixer. Mixing performance is evaluated by calculating the standard deviation of the concentration of the dissolved species contained in one of the mixing streams.
Courtesy of COMSOl, Inc.



This model treats the flow field and species distribution in a fixed-bed reactor. It exemplifies the coupling of free and porous media flow and the simultaneous treatment of the chemical reactions that take place in the porous structure. Courtesy of: Univ. of Washington in Seattle and COMSOl, Inc.

Self-Healing Network Prevents Process Control Failure

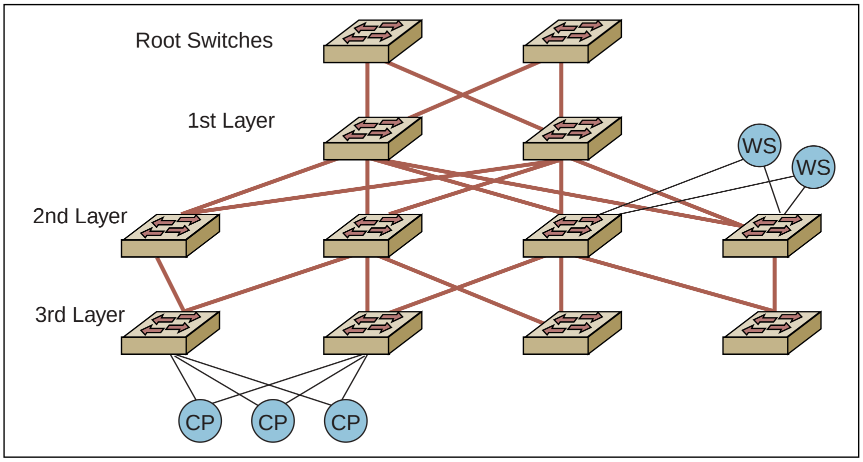
Foxboro Automation Systems (FAS; Foxboro, Mass; www.foxboro.com), a business unit of Invensys, has introduced a networking, or "mesh," technology for Invensys' I/A Series control system software that maintains communications between workstations (WS), control processors (CP), device integrators and fieldbus modules, even when faced with multiple points of failure, such as the simultaneous loss of a communications port and a wire break. "To the best of our knowledge, this capability is unprecedented in the process control industry," says FAS director of channels, David Shepard.

Within I/A Series systems, the Nodebus (a redundant communications network based on Ethernet technology operating at 10 Mb/s) has been replaced with a control network using industrial Ethernet switches based on IEEE 802.3u, the Fast Ethernet standard, and IEEE 802.3z, the Gigabit Ethernet standard.

Each network station device within the mesh system connects directly with fiber ports built into the controllers, the I/O subsystem communication modules, and the network adapter cards within the workstations. Although competing systems can deploy mesh networks directly at the workstation level, they typically rely on proprietary schemes for connecting controllers and I/O, notes Shepard.

The network's integrity is maintained through a hierarchy of four layers of switches in an inverted tree topology (figure, p. 16), which provides for expansion of up to 2,000 stations within a mesh. All stations interface to two switches so that a redundant path is always available. In the event of a failure of one or more network faults, the processors in the switches, configured with patented Rapid Spanning Tree (RST) software, reroute the communication paths in 0.5 s or less.

Standard IP addresses are used to route the messages, thereby preventing multiple messages from trying to get through one switch and preventing sta-



Foxboro's mesh network technology uses a hierarchy of Ethernet switches to manage alternate communication paths between control processors (CP), workstations (WS) and other devices running Invensys' I/A control system software.

tions from seeing traffic not specifically addressed to them.

The degree of fault tolerance is better than 99.99%, which is typical of most redundant systems, notes Shepard. But because of the mesh network, Foxboro's system can tolerate multiple faults, vs. one or two faults at most, for traditional redundant systems, before the control system's performance is degraded.

Mesh network technology can be used to configure: a high-performance (100 Mb or 1-GB) link between I/A Series control processors and their associated Fieldbus (I/O) modules; field networks for new I/A Series systems; and networks to extend existing I/A Series Nodebus-based systems. "The cost of implementing a mesh network depends on the application and on how extensively the accompanying control technology is equipped for Ethernet networking," says Shepard, adding that many new workstations come already equipped for Ethernet networking.

A managed Ethernet switch, which typically costs about $3,000, would connect to a controller with a built-in fiber optic Ethernet interface, such as any new Foxboro I/A Series controller. Each workstation on the network would require a commercial off the shelf network interface card, which costs about $500."The return on investment depends on the installed base of the system," notes Shepard. "You're not going to make money just by having information flow better, but you will get better productivity (*e.g.*, reduction in maintenance and higher availability of the system) from advanced control it enables," he concludes.

Analytical Balance Boasts Better Speed and Accuracy

Mettler-Toledo, Inc. (Columbus, OH; www.mt.com) has rolled out an analytical balance designated the XS Series that reaches a final weight 20% faster than competing devices and speeds up the overall weighing process by a factor of 5 to 6, without any loss in measurement accuracy. At the heart of the instrument is SmartGrid technology — a revolutionary slotted weighing pan that removes buoyancy effects of air currents generated by temperature differences in the immediate surroundings of the pan. "One contract R&D lab reduced the time required to weigh 2,000 samples from 133 h to 106 h when it switched to the XS — realizing a payback period of three weeks based on a salary of $25/h," explains Mettler-Toledo marketing manager Ian Ciesniewski.

Mettler-Toledo's XS analytical balance has a grid weigh pan that eliminates the effects of air buoyancy.

XS overcomes the tradeoff between speed and accuracy typical of most analytical balances with a novel weighing system that uses a weigh cell that is linked directly to the grid weigh pan, in conjunction with ProFACT automatic calibration, which utilizes two weights. Initially, both weights are loaded to measure the sample weight at "zero" and "full capacity"; then, one weight is removed to check the weighing system's linearity. "This allows for a span adjustment, which ensures the measurement is on spec every time," notes Ciesniewski. The balance is 1.5–2 times more accurate than average balances when measuring weights below 200 mg. For instance, at five decimal places, a 50-mg sample can be weighed with a repeatability in excess of 0.015 mg.

The XS costs $3,300–$5,300, which is in the ballpark of the nearest competitor's prices for a 4–5-place analytical balance, says Ciesniewski. Moreover, XS offers: built-in features to aid compliance with good laboratory and manufacturing practices; new ancillary software called LabXPro, which aids 21 CFR Part 11 compliance; and the unique capability (for analytical balances) to link up two devices simultaneously, such a printer and a computer, without additional software.

REGULATORY & GOVERNMENT

European Proposal Poses Major Challenges to Chemical Industry

The final draft of the European Union's (EU; www.europa.eu.int) proposal to develop a new system for registration, evaluation and authorization of chemicals (REACH) was issued at the end of October, requiring manufac-

turers and importers of more than one metric ton of an unregistered chemical to register that chemical by providing hazard data and information on its intended uses. The proposed system of disclosure would affect not only chemical manufacturers but also downstream users, who will need to participate in the preparation of both the new chemical safety reports and chemical safety assessments that are required under the EU's legislation.

More specifically, registration will be necessary for all substances currently listed on the European Inventory of Existing Chemical Substances (EINECS), which were grandfathered onto the inventory in 1981, in much the same way that the original Toxic Substances Control Act (TCSA) inventory was established in the U.S. in Dec.1977, points out Patrick Nolan, senior research analyst for Ariel Research Corp. (McLean, VA;www.arielresearch. com). The new European Chemicals Agency (ECA) will further evaluate the data submitted for registration of chemicals of concern, such as persistent, bioaccumulative and toxic substances (PBTs) and carcinogenic, mutagenic and reproductive toxins (CMRs). Substances suspected to pose danger might be banned or restricted to certain applications.

"The prospect of registering thousands of chemicals that have been marketed and used in Europe for two decades has created a wide range of concern throughout the global chemical industry, particularly regarding the actual costs of bringing the plan to fruition — a projected \$3 billion to \$35 billion — and the plan's impact on access to EU markets," says Nolan. To offset concerns about cost, proponents of the proposal point to potential health and environmental gains, the benefits of which are estimated by the EU Commission to range from \$20 billion to \$60 billion.

The American Chemistry Council (ACC; Arlington, VA; www.americanchemistry.com), while fully supporting the health and safety goals of the REACH proposal, has expressed concern regarding the plan's disruption of global trade as per World Trade Organization (WTO; Geneva, Switzerland; www.wto.org) rules because it relies on volume-based thresholds for applying the regulatory requirements. Moreover, the specific information required of chemical manufacturers and importers under REACH's registration process may result in the disclosure of proprietary information.

The proposal has been presented to the European Parliament and the Council of Ministers and must be approved by both before becoming law, which is expected in 2005. Legislation can be tracked at http://europa.eu.int/eur-lex/en/com/pdf/2003/com2003_0644en.html.

The EPA Will Move Forward Under Leavitt's Leadership

Last month, the U.S. Senate confirmed Utah Gov. Michael Leavitt (R) as head of the Environmental Protection Agency (EPA; Washington, DC www.epa.gov). Backed by 88 votes to eight, Leavitt, a nominee of President George W. Bush, will replace Christine Whitman, the former governor of New Jersey, who resigned from the post in June 2003 after finding herself at odds with the Bush Administration on issues such as global warming. Leavitt has not disclosed how he would run the EPA, stating only that his goal is to improve the environment and to leave the air cleaner by the time he is finished.

3-A Sanitary Standards Set a Pharmaceuticals Milestone

The first major initiative to expand 3-A standards outside the area of dairy and food processing is underway. 3-A Sanitary Standards, Inc. (3-A SSI; McLean VA; www.3-a.org) is planning to develop new equipment standards for the pharmaceutical industry. The P3-A Standards, expected to roll out in late 2004, will ensure that equipment used in domestic and international pharmaceutical applications meets specific criteria for hygienic design and cleanability.

"Common equipment standards that can be applied across site locations will enhance the inspection authorities' equipment-cleaning validation process," states 3-A SSI executive director Timothy Rugh.

The P3-A steering committee, which includes senior engineering representatives of major pharmaceutical manufacturing companies and equip-

FDA ISSUES PROGRESS REPORT ON PHARMACEUTICAL MANUFACTURING

This fall marked the first anniversary of the Food and Drug Administration (FDA; Rockville, MD; www.fda.gov) 21st strategic initiative to modernize the regulation of pharmaceutical manufacturing and product quality (*CEP*, May 2003, p. 12). "This '21st Century' initiative is aimed at ensuring that regulatory review, compliance and inspection policies are based on state-of-the-art pharmaceutical science, and do not impede the rapid adoption of new technological advances by the pharmaceutical industry," explains FDA Commissioner Mark McClellan.

One of the key steps the FDA is taking to enhance the consistency and coordination of its drug-quality regulatory programs is the release of five new guidance reports. At the top of that list is the final draft guidance for 21 CFR Part 11, FDA's regulations for the use of electronic records and signatures. "The guidance puts pharmaceutical companies in a better position to apply risk-based approaches and to determine critical control points in applying Part 11 controls," says Joseph Famulare, director of FDA's Div. of Manufacturing and Product Quality, Office of Compliance. Plans for rulemaking to revise Part 11 will begin immediately, addressing concerns expressed by the public and providing further clarifications and adjustments that are consistent with the principles and enforcement policies described in the guidance document.

ment-design specialists, will follow the requirements of the American National Standards Institute (ANSI) in developing the new standards. 3-A SSI recently launched a new Third Party Verification (TPV) program to verify conformance to 3-A standards; a similar program will be designed for the new P3-A Standards.

Brominated Flame Retardants to Be Voluntarily Phased Out

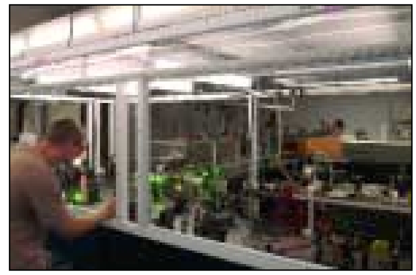
By the end of this year, Great Lakes Chemical Corp. (GLCC; West Lafayette, IN; www.greatlakes.com) will voluntarily cease production of two widely used flame retardant chemicals for foam and plastics — penta-PBDE (penta) and octa-PDBE (octa) — which the U.S. Environmental Protection Agency (Washington, DC; www.epa. gov) has found to be bioaccumulating in the environment. These additives are members of a group of chemicals called polybrominated diphenylethers (PBDEs), which belong to a broader class called brominated flame retardants (BFRs).

GLCC, the only U.S. manufacturer of penta and one of a small number of octa manufacturers, will replace penta and octa with Firemaster 550, the first in a new family of environmentally sound flame retardants that meets the fire-safety performance standards (*e.g.*, Underwriters Laboratory Flammability Standard and the California Technical Bulletin 117) that are necessary for use in consumer products."

EPA will transition GLCC's customers away from penta and work with formulators on the development of PBDE substitutes and alternatives. Plans are also underway for the EPA to conduct health-and-exposure testing on the substitutes. Mark Bulriss, CEO of GLCC attributes Firemaster 550's success to the fact that it is safe and has commercial applications beyond those of the products it will replace, including use as a flame retardant in foams found in sneakers, padding commonly used on beds, packaging foams and insulation and acoustic foams.

NSF Invests $68 Million in the Future of Engineering

The National Science Foundation (NSF; Arlington, VA; www.nsf.gov) has awarded four new Engineering Research Centers (ERCs) an estimated $68 million over the next five years to conduct pioneering research in emerging technologies (table) and train the next generation of engineers. Each center, while based at a university, is a collaborative partnership that will draw together individuals and resources from other universities, industry and state governments to tackle everything from clean chemical manufacturing to implantable electronics for treating incurable diseases, says John Brighton, assistant director for engineering at NSF. NSF will provide approximately $17 million to each center for 10 yr, after which the ERCs are expected to become self-sufficient.



Researchers explore new sources of light generation in the extreme ultraviolet light spectral region. Courtesy of Colorado State Univ. and the National Science Foundation.

Each center focuses on a specific area of research. For instance, the Engineering Research Center for Environmentally Beneficial Catalysis (CEBC), with potential partnerships with DuPont, Praxair, Rohm and Haas and Procter & Gamble, intends to transform chemical manufacturing by developing processes that minimize environmental pollution and energy use. Meanwhile, the Center for the Development of Extreme Ultraviolet (EUV) Lasers (photo) will provide a foundation for routine microscopic observations and manipulations at the nanoscale in times measured in femtoseconds (10^{-15} s). Researchers will explore new sources for coherent light generation in the EUV spectral region, as well as sophisticated optical components and detection systems.

Table. National Science Foundation Research Centers.

Centers	Headquarters	Research Activities
Engineering Research Center for Extreme Ultraviolet Science and Technology	Colorado State Univ. Fort Collins	Develop short wavelength, optical measurement instrumentation to foster nanoscience and and nanotechnology research.
Engineering Research Center for Environmentally Beneficial Catalysis	Univ. of Kansas Lawrence	Develop environmentally benign catalytic processes to reduce pollution from the manufacture of chemicals.
Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere	Univ. of Massachusetts Amherst	Develop sensing networks and information systems to improve detection and prediction of environmental hazards.
Engineering Research Center for Biomimetic Microelectronic Systems	Univ. of Southern California Los Angeles	Develop enhanced microelectronic systems that enable implantable devices to treat blindness, paralysis and loss of cognitive function.