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AGRICULTURAL BIOTECHNOLOGY

At State's Universities, Not Even the Sky's the Limit

Editor's Note: This is the second part of a three-part series on agricultural biotechnology in Connecticut. The third article will describe ongoing research in industry.

Agricultural biotechnology is not just about farm produce anymore. True, it can dramatically improve field productivity. But, increasingly, the implications of manipulating plant and animal genes extend far beyond the dinner table. "You're making transgenic plants," explains Dr. Thomas Chen, director of the Biotechnology Center at the University of Connecticut (UConn), "not just to generate more corn, but for producing vaccines, or industrial enzymes." Or more. In fact, in the field of agricultural biotechnology, not even the sky is the limit.

Traditional goals, of course, remain. Horticulturists like UConn's Dr. Mark Bridgen, known for his work with the Chilean desert lily *Alstroemeria*, continue to provide nurseries with novel varieties of ornamental plants. But plant research provides other advances.

From the greenhouse…

UConn plant physiologist Dr. Mark Brand, for example, is developing a rhododendron that's resistant to the fun-

(See Ag Biotech, page 2)

FUELING THE FUTURE: This Arizona test facility, a joint project of Connecticut-based Proton Energy Systems, Inc. and Science Applications International Corp., demonstrates the concept underlying Proton Energy's UNIGEN™ system, in which a renewable energy source (wind, hydro, or in this case, solar) will be used in combination with advanced fuel cell technology to create clean, renewable, power that will be available on demand.

(Photo: Proton Energy Systems, Inc.)

FUEL CELLS: CLEAN, RELIABLE ENERGY FOR THE FUTURE FROM CT COMPANIES

There exists a means, right now, of producing an electricity supply which is ultra-reliable (computer-grade*), which can get twice the efficiency from hydrocarbon fuel as conventional combustion generators, which emits breathable air, potable water, steam, and heat as its exhaust products, and which is manufactured here in Connecticut.

This system is scientific fact, not fiction. Connecticut is home to some of the most advanced R&D, manufacturing, and maintenance of these amazing electrical power generators, popularly known as "fuel cells." They are found in submarines a mile and a half beneath the ocean's surface, and in all manned US spacecraft. They are beginning to make their presence known as ultra-reliable stationary power plants for hospitals, computer-based businesses, and in areas suffering from unreliable supplies of electricity from the existing power grid.

The Advantages and Disadvantages of Fuel Cells

Fuel cells alone can routinely attain 95% reliability, and can approach 80% fuel efficiency if heat is recycled. Conventional power is subject to fluctuations, spikes, down time, brownouts, and the like, and at best may attain 40% fuel efficiency. Also, because

(See Fuel Cells, page 9)

* "Computer-grade" power is electricity meeting the Institute of Electrical and Electronic Engineers (IEEE) Standard 446-1987, which sets time and voltage intervals which electronic equipment must tolerate without malfunction.

FROM THE ACADEMY

Automobile Emission Testing Revisited

This past year, the Program Review and Investigations Committee of the General Assembly asked CASE to revisit the issue of the efficacy of the Connecticut Motor Vehicle Emissions Testing Program in light of substantial improvements in the engineering characteristics of automobile engines in recent years. The Academy conducted a similar review in 1986 entitled *Automobile Emissions Testing*.

A study committee of the Academy, chaired by Norman Bowne, has completed its work, and the final report is under review by the CASE Council. However, the committee made a preliminary oral report to the General Assembly in December, 1999. What follows is a summary of those remarks.

Given the advance of technology in factory-installed automobile emission control systems, the study was asked to focus on the changing nature of the fleet of vehicles using Connecticut highways and the impact an emissions testing program can have on air quality within the state.

Annual trends show the peak concentrations of ozone decreasing regularly over the past twenty years. More than fifty days had ozone concentrations exceeding the standard in the 1980 to 1984 period. Less than twenty days had concentrations exceeding the standard in the mid 1990s. How much of that reduction can be attributed to the auto emissions inspection program could not be determined.

The reduction in peak ozone concentrations occurred over the same time period as significant changes in automobile emissions. Catalytic converters were introduced in the late 1970s. Changes followed through the next fifteen years as fuel injection replaced carburetors and engines became computer controlled. These changes were made to reduce the emissions to meet federal standards. For example, the oxides of nitrogen standard was 3.1 grams per mile (gpm) in 1977 and is 0.3 gpm today. It is proposed that it be further reduced to 0.07 gpm in 2004. The tenfold

(See From the Academy, see back page)

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Ag Biotech *(from page 1)*

gus phytophthora. "The fungus is everywhere that rhododendrons grow," he says. "It kills the root system, and the plant collapses."

With a gene gun that "shoots" DNA-coated gold dust into plant tissue, Brand has inserted a gene into rhododendrons that will, he believes, enable the plants to protect themselves. The gene, Brand explains, is based on one found in silkworms. "Its gene product is a small peptide that forms a hole, or a pore, in the fungal cell. That causes the cell contents to just leak out."

Already, Brand has achieved several separate transformation events, and he's been able to grow transformed cells into plants. "We've got those plants in the greenhouse, and when they're large enough, we're going to begin testing them by putting the pathogen on the plants, evaluating whether [the gene] is going to confer resistance or not."

But Brand's work goes beyond simply making one plant species resistant to one disease. "We're continually producing transformants," he says. Very little work has been done on altering woody plants like rhododendrons, and Brand is interested in developing procedures that can be used again and again, perhaps to modify flower color, or insert fragrance. "There's an increasing number of potentially useful genes out there," he says.

Like Brand, Dr. Yi Li, head of UConn's Transgenic Plant Facility, alters the DNA of plants. But while Brand is making plants more suitable to a nursery environment, Li produces plants that can thrive in far more exotic places. He works with a plant growth hormone known as auxin. Li induces plants to produce the molecule when and where he chooses. Commercially, auxin is used to encourage plant growth, root formation, and fruiting. Li uses the hormone for similarly varied tasks.

He relies on auxin, for example, in an improved method of growing seedless fruits and vegetables. The hormone, he explains, stimulates cell growth and expansion, which results in normal size

Left, two rhododendron shoots developed from tissue culture that have been stained for GUS, a common marker gene used in transformation experiments as a visual aid. The shoot on the far left is the normal, or non-transformed shoot. It is white because it doesn't contain the GUS gene and therefore cannot develop blue coloration. The darker shoot is a transgenic shoot that contains the GUS gene. It develops blue color (shown here as dark gray) when exposed to certain reagents because the GUS gene converts the reagents to blue indigo. (Photo: M. Brand)

fruits. But, the auxin is produced in seeds: without seeds, fruits are stunted, and unusable. Some seedless fruits, like the watermelons found in supermarkets, can be produced by other methods: traditionally, through a time-consuming series of crosses that alter the number of genes. (Tetraploid plants are crossed with diploid plants to produce triploid plants, which produce seedless fruit.) But Li's fruits require neither pollination nor special breeding.

"What we've done is, we've taken a gene promoter which is specifically expressed in developing fruits and flowers so that we could artificially increase auxin concentration at a very early stage of flower development. So you don't need to have seeds produce the hormone to have the fruits grow well."

A European company already uses Li's gene to produce seedless watermelon, and he is negotiating with companies here. He sees applications in other crops where seeds are undesirable, such as cucumbers, or where pollination is cumbersome, such as greenhouse tomatoes.

Li also works with NASA to develop plants that can grow in outer space, and here too, auxin plays a key role. The hormone performs tasks other than inducing growth: it also helps plants sense gravity. Plants need gravity, it turns out. Living under microgravity conditions puts them under stress.

Through a series of experiments conducted on the space shuttle, Li found that in plants grown in space, auxin is distributed abnormally. These unnatural concentrations of auxin, he says, increase the amount of ethylene, a stress hormone. One result is that the roots of unmodified (wild) plants do not grow properly on the space shuttle. But with molecular techniques, Li was able to bioengineer plants able to grow normal roots in space. In fact, he created plants impervious to stress hormones.

NASA funds this work because, says Li, on long-lasting space missions, space-adapted plants will be needed, both to supply fresh food, and to absorb pollutants. But wild plants grown under microgravity also have uses.

Certain scarce anti-cancer compounds, like taxol, which is harvested from trees, are produced most abundantly by plants under particular kinds of stresses, such as microgravity. By studying how these secondary metabolites are produced in space, where yield is high, it will, Li believes, be much easier to learn how these compounds are generated. And, he says, once you understand that, once you can clone the genes responsible for biosynthesizing that compound, it may be possible to improve the productivity of that pharmaceutical in plants on Earth.

Finding the "how" as well as the "how-to"

Many of the studies done in Connecticut have obvious practical application. But the state's agricultural biotech researchers also investigate more basic questions: the how as well as the how-to of plants and animals.

How, for example, do flowers develop? Dr. Vivian Irish, a plant developmental biologist at Yale University, hopes to help solve this problem. She studies *APETALA3 (AP3)*, one of the genes responsible for petal formation, and one of the questions she's asking is: how do cells in growing petals coordinate with each other? "If you think about developing a petal," she says, "remember that plant cells don't move relative to each other." To produce a petal, the organ's internal cells—the mesophyll—and its external cells—the epidermis—must divide in a certain rate and pattern. Something must coordinate these cells as they grow, and Irish believes that the proteins produced by *AP3* may be involved.

Irish's laboratory found that if the gene is expressed only in the epidermis, the organ is shaped like a sepal—the small pointed organs that cup the rest of the flower. However, if *AP3* is expressed only in the mesophyll, the entire organ, including the epidermis, takes on the spatulate form of a petal.

"This implies," she says, "that what's going on in the mesophyll is somehow telling the epidermal cells 'you're going to divide appropriately to cover this larger organ.'" It is the formal proof, she says, that the gene product of *AP3* "is involved in some kind of cell-cell communication event."

Exactly how this works, she doesn't yet know. But her laboratory is trying to find out. "This is a big effort that we're just beginning on," Irish says. "Not only do we want to find the genes involved in making petal epidermal cells look like petal epidermal cells, we also want to understand how this communication event actually occurs."

Dr. Stephen Dellaporta, a plant molecular biologist at Yale, also studies flower formation. He's investigating sex determination pathways in corn.

Usually, Dellaporta explains, a flower contains both male and female reproductive organs: the male stamen, which produces pollen, and the female pistil, which generates seeds and fruits. In about 10% of plant species, though, flowers are unisexual—either male or female, but not both. In corn, which belongs to that category, unisexuality has proven agronomically invaluable, fostering the cross-breeding, or hybridization, that has increased yields from about 25 to approximately 135 bushels per acre.

(see Ag Biotech, page 4)

Ag Biotech *(from page 3)*

Unisexual flowers begin as bisexual entities, explains Dellaporta, but during their maturation, either the male or female sexual organs fail to develop. This results, he says, from the complex interactions of three lines of genes: *tasselseed*, *silkless*, and *dwarf*.

"The biological process underlying the formation of unisexual flowers is a cell death process," explains Dellaporta. "It actually kills unwanted organs." Dellaporta's laboratory has been able to clone some of the genes that control that process, and he hopes, in the long term, to move those genes into species such as rice or wheat. "If we could create unisexual flowers, we could create hybrid seeds in those crops." That could, he says, increase productivity in crops that feed an enormous number of people worldwide.

Dr. Jerry Yang, head of UConn's Transgenic Animal Facility, made headlines in 1999 when he and his team of researchers successfully used non-reproductive cell DNA (epidermal cells from the ear of donor cow Aspen, left) to clone daughter-twin Amy, right. Researchers hope that Amy will inherit Aspen's prodigious milk productivity, which at 35,000 pounds a year, is more than double the amount produced by an average cow. (Photos: J. Yang)

Plant, animal systems very similar

But the implications of Dellaporta's work extend beyond crop yield. His research on sex determination and cell death is funded, he explains, through the National Institutes of Health. "The reason is because cell death is a very relevant process to human health." There are, he says, many similarities between human and plant cell death. "Plant cells are programmed to die, and animal cells are programmed to die. The fact that the sex determination pathway in plants uses certain signals such as steroid type molecules to signal this process is similar in plants and animals." It's too early, he says, to understand what these connections mean, but they could prove useful for researchers. In plants, he says "we have a system that's highly amenable to genetic analysis. We can create mutants and study genes and do things in our model plant systems that are not really very easy to do in animal systems."

Dr. Gerald Berkowitz, who heads UConn's Department of Plant Science, also takes advantage of the similarities between plant and animal systems. Berkowitz studies potassium ion channels: pores in the cell membrane that permit signals to enter the cell. These structures direct the cells to perform various functions: they are, for example, connected with signal transduction and plant cell movement.

Recently, Berkowitz has begun using ion channels to study pain. "The reason I'm working on pain receptors," he explains, "is because pain receptors are ion channels." Plant ion channels are very similar to animal ion channels, he says.

Scientists have cloned, for the first time, a mammalian pain receptor: a gene that codes for a protein that senses pain stimuli. This means, he said, that we can study how various compounds block pain without causing it. "We don't need to have dogs and give them electric shocks. We don't need pain. We just need the gene expressed in bacteria or cells."

Berkowitz hopes to find new pharmacologically active compounds. A few months ago, he visited the rain forest of the Virgin Islands, where he met with bush doctors who use native plants as anesthetics. "I brought some material back," he said, "and now we can test whether there are compounds in the plants that interact with pain receptors."

At UConn, transgenic animals

Some of the state's most significant agricultural biotechnology advances result from research involving animals. Dr. Xiangzhong "Jerry" Yang, head of UConn's Transgenic Animal Facility, has this past year made headlines with a series of cloning breakthroughs. Yang's laboratory was the first to clone a large farm animal from non-reproductive cell DNA. (Yang used epidermal cells from the ear of a 14-year-old cow named Aspen.) Most recently, Yang announced that, in conjunction with Japanese workers, he has cloned six calves from cells taken from Kamitakafuku, a 17-year-old Japanese bull. In an impressive and unprecedented feat, Yang and his colleagues were able to clone these cells even after they had been kept alive *in vitro* for several months.

Yang's advances have important implications for the agricultural industry. Aspen, for example, the cow whose genes were echoed in her daughter-twin Amy, can produce 35,000 pounds of milk annually, more than double the amount given by an average cow. Through cloning, it may be possible to more sure-handedly create a herd of cows with Aspen's productive efficiency—an obvious boon for farmers.

But Yang's work with Kamitakafuku opens up possibilities that reach even farther. By showing that it was possible to clone cells that had been cultured for long periods of time, Yang has opened the door for gene targeting research. Scientists will be able to take a cell,

(see Ag Biotech, page 13)

IN BRIEF

IN BRIEF

Communication

FASTER INTERNET… Digital subscriber line (DSL) service will be available to some **SNET** customers as early as March 2000. These high-speed connections allow voice calls and Internet service to share the same standard copper phone line, and will provide Internet connections that are about 30 times faster than those transferred by a 56K modem. The service, which will probably cost individual consumers between $39 and $159 per month, depending on the features chosen, is part of a $6 billion SNET initiative which includes upgrading its communications network with fiber optic lines. Although the service will probably be offered first in large urban areas as well as in **Waterbury, New Haven**, and **Bristol**, where SNET has been testing the program, the company hopes to offer the service to 80% of SNET customers by 2002.

… AND MORE. Another, more unique attempt to capture the burgeoning market for high speed Internet access is being made by the Hartford-based company **Gemini Networks**, headed by businessman **Arnold Chase**. The company plans to deliver the service through its own network of coaxial cables, which are the same type of lines that carry cable TV. Unlike conventional plans, consumers would not pay for a Gemini connection. Instead, the costs would be paid by companies using Gemini lines to deliver service. Gemini will offer a way for any company to offer Internet access, local phone service, or long distance phone service, without needing to negotiate for access with competing firms. Building an open network for use by other service providers has never been tried before, said Chase. The company has already obtained permission to build a pilot project in **West Hartford**, **Avon**, and **Farmington**.

HAPPY TALK. By teaching toddlers made-up words, **University of Connecticut** psychology professor **Letitia Naigles** hopes to be able to find out when the youngsters become able to use language as adults do: in ways that they haven't heard before. The psychologist has developed a test that measures the toddlers' word comprehension rather than their word production. The youngsters learn the made-up words by playing with a toy seesaw that either "lorps" (squishes) a ball or "krazzes" it (knocks it back and forth). Once they understand the sounds, they are asked to choose a TV screen showing a specific activity, for example, an animal "lorping" the ball. This shows whether the children can match verb to action, even if the sentence containing the verb is new to them. The researchers expect that the youngsters become able to use language creatively at around age two or two-and-a-half.

NERVE REGROWTH. Hearing loss caused by damage to the inner ear can also alter the nerve cells in the brain, according to research conducted by **Steven Potashner**, professor of anatomy at the **University of Connecticut Health Center**. When damage to the cochlea or middle ear bones occurred, he found, certain nerve cells in the cochlear nucleus of the brain lost some of the contacts that enabled them to transfer acoustic information from the cochlea. Potashner expected this loss to be permanent, but, interestingly, he found evidence that, after about six months, the empty contact sites became reoccupied, implying that the nerve cells were able to grow new contacts. This regrowth, his work suggests, may be related to some cases of tinnitus, or ringing in the ears.

Education & Cognition

CONCENTRATION IN SCIENCE. Nearly forty tenth graders in the **Greater Hartford** area are participating in a unique course, a prototype science and math program that anticipates the opening next fall of a $50 million state-financed **Science, Math, and Technology Resource Center**. The new regional magnet high school, located in the Learning Corridor next to **Trinity College**, is expected to serve the increasing number of high school students who want a rigorous science and technology education. "All courses in this school will be taught from a problem-based, inquiry-based proposition. Students are going to learn science as scientists conduct science," said **Jeffrey L. Osborne**, the Center's director. The school's 300 students will be chosen by lottery from the dozen participating area towns.

TRIARCHIC TEACHING TESTS. **Yale** scientists have received a $3 million National Science Foundation grant to test triarchic instruction in reading, math, and science in grades 1-4 in rural, suburban, and urban schools across the nation. The triarchic system, developed by Yale professor **Robert Sternberg**, focuses on children's creative and practical strengths rather than their academic skills; these strengths, says Sternberg, are key to success in life and in jobs. Triarchic teaching allows children to capitalize on their natural strengths, and enables them to correct or compensate for weaknesses. Results of earlier studies show that high school students who are taught in a way that at least partially fits their pattern of triarchic strengths outperform students who are not, even if, says Sternberg, their achievement is evaluated only by conventional memory-based assessments.

BIG SWITCH. **Yale** researchers have, for the first time, identified a receptor "switch" that controls the ability of neurons to grow. The ability of the Notch receptor to start and stop the growth of neurons could, according to neurobiology professor and CASE member **Pasko Rakic**, who headed the study, be used to repair spinal cord injuries, or, possibly, treat Alzheimer's Disease, which has been connected with Notch receptor malfunctions. Typically, brain cells continue to grow until adolescence. But as they do, activity in the Notch signaling pathway increases, gradually preventing, and stabilizing, the growth of neurites. As stabilization occurs, long-term memory is acquired. Rakic's team found that when Notch receptors are inhibited, the static cells resume growth. If neurons start to grow again, said Rakic, connections between nerve cells are destroyed, along with the memories that they store.

TECHNICAL SUPPORT. A special keyboard designed by **University of Connecticut (UConn)** engineering student **Jeremy Shattuck** will help nine-year-old **Bianca Brown** of Hamden learn her colors, letters, and numbers. The device, tailored to the needs of the child, who has physical and cognitive disabilities, uses flash cards, music, and a talking Tigger head to motivate Bianca and keep her attention. Development of the 20-inch-long by 10-inch-high device was funded through a National Science Foundation program called Bioengineering and Research to Aid the Disabled, which links people with disabilities, who may require technical devices with expensive custom modifications, with engineering students who must earn design credits to graduate. UConn's electrical and systems engineering department received a grant from the program that will pay for supplies, equipment, and fabrication costs for 25 projects a year for five years.

MORE ADVENTURES IN SCIENCE. The **Phoenix Home Life Mutual Insurance Company** has renewed its support for the Adventures in Science Program at **St. Joseph College** through the year 2003. Under the program, directed by chemistry professor

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IN BRIEF

Peter Markow, students from the sixth grade of **Wish School** in Hartford come to the college several times each semester to participate in inquiry-based science explorations. The program was initiated in 1987 for selected young girls from elementary schools of West Hartford, who also continue to participate.

Energy

LIGHT WORK. As part of an effort to upgrade street lights and improve customer service, **Connecticut Light and Power (CL&P)** is replacing older bulbs with new energy-efficient sodium bulbs and photocells in cities throughout the state. The bulbs, which are expected to last up to six years, contain less lead and mercury than current bulbs, making them more environmentally sound, and, according to CL&P, cheaper to maintain. They also eliminate "cycling," the process by which a bulb turns itself on and off every few minutes as it is dying. The upgrade includes safety inspections, repairs, and the cleaning of lenses and reflectors.

POWER UP. Construction of a major generating plant began early last fall in **Killingly**. The 792-megawatt natural gas-fueled plant, expected to open in 2001, will be one of the largest in the state, able to generate electricity for about 800,000 homes. Slightly smaller than the 870-megawatt Millstone 2 nuclear power station, the facility is owned by **PG&E Generating**. It will operate as a merchant plant, selling electricity at the wholesale level, with no guaranteed customer base.

DIVERSITY IN ENERGY. In an attempt to prepare consumers for electric deregulation, the state **Department of Public Utility Control (DPUC)** has mailed the first 500,000 copies of *Electric Choice Consumer Guide*, a 10-page booklet explaining the changes that customers can expect under the new system. The information was sent to the 24 communities in which deregulation was scheduled to begin with the new year; deregulation will be phased into the rest of the state starting July 1. The guide contains a worksheet that can aid consumers in comparing the different companies. DPUC commissioner **John Betkoski**, is overseeing the agency's electric deregulation public education efforts.

EFFICIENCY REBATES. The **University of Connecticut** has earned a $246,000 rebate from the **Connecticut Light and Power Company** for its participation in an energy efficient program that decreased its electricity usage by two million kilowatt hours. The rebate helps pay for energy efficient equipment installed at South Campus, the central chiller plants, and the chemistry building. The university has also secured $500,000 from **Connecticut Natural Gas**, in a program that recognizes the installation of energy-efficient equipment at the chiller plants.

Environment

WEST NILE VIRUS. The suspicion that what was believed to be St. Louis encephalitis in Fairfield and New Haven counties was actually West Nile Virus has been confirmed by scientists from **The Connecticut Agricultural Experiment Station, Yale,** and the **University of Connecticut**. Isolation of the virus from mosquitoes and dead birds in the two counties, and then sequencing and analysis of its genome, established its identify as the West Nile virus. It is very similar to a strain isolated in Romania in 1996. The danger of the new arrival, sometimes fatal to both people and birds, has caused the Station to enhance its ongoing monitoring of the entire state for eastern equine encephalitis. The enhanced survey will include trapping mosquitoes and examining dead birds for the West Nile virus in Fairfield and New Haven counties during the year 2000.

HOME AGAIN. Taking a pair of youngsters to the ocean can be tricky—especially when the youngsters are pilot whales. The two mammals, found beached on Cape Cod during the summer, were nursed back to health at **Mystic Aquarium**; their return to the ocean in October took several weeks to plan. The animals were transported from the aquarium to the **University of Connecticut's** new research vessel, the *Connecticut*, in two huge plywood crates lined with vinyl and partially filled with water. Specially designed canvas stretchers placed in the top of the crates kept the whales partially submerged as a truck carried them to the ship. The ship's crane lifted each one-ton box off the truck and onto the deck. The whales were released in an area frequented by pilot whales, and carried special devices that allowed them to be tracked by satellite for three months. Their travels can be viewed at www.mysticaquarium.org.

NASA ON EARTH. As part of a three-year, NASA-funded project, **University of Connecticut (UConn)** researchers are tracking the impact of urban sprawl on water resources and forest fragmentation in the Northeast. The effort, known as NAUTILUS (Northeast Access to Useable Technology in Land Use Planning for Urban Sprawl), is part of an ongoing space agency effort to apply NASA research results to practical, societal problems. The Connecticut scientists will use remote sensing technology, including satellites, to collect data on land cover—type, elevation, stresses on vegetation, moisture, flooding, and temperature. NAUTILUS staff are also developing web- and CD-based tools that will enable land use planners to use this data to visualize changes in their communities and anticipate future scenarios; UConn has acquired data from as far back as the 1970s, providing a way to determine shifts in the Connecticut landscape over the past 30 years.

SEA THIS. Meteorologists continuously monitor shifting conditions in the Earth's atmosphere. Now, researchers at the **University of Connecticut (UConn)** are developing a technology that can provide the same detailed scrutiny of the coastal ocean. The new system will use both satellite imagery and underwater sensors to track currents, temperature, salinity, and plankton concentrations; researchers will combine that data with computer models to forecast ocean behavior. The benefits of ocean forecasting range from facilitating oil spill cleanups, to helping fishermen find the best places to catch their quotas. The research project, headed by UConn oceanographer **Philip Bogden**, will be conducted in collaboration with scientists from MIT and the Woods Hole Oceanographic Institute; it will be funded by a $4 million federal grant from the National Oceanographic Partnership Program.

TOXIC OR NONTOXIC? Not all the mercury debris deposited in the ocean degenerates into its toxic form, and, with a $592,000 grant from the federal Environmental Protection Agency, **University of Connecticut** marine scientist **William Fitzgerald** hopes to find out why. While the inorganic form of the metal is converted to poisonous methylmercury by microorganisms, this happens only under certain, still unknown conditions. "Most people believe that methylmercury is most prominent in the western Sound, which is polluted by New York's sewage treatment plants. But we believe that we'll discover that methylmercury production occurs at variable rates and in variable amounts throughout the Sound," said Fitzgerald. The researcher believes that much elemental mercury is produced in Long Island Sound, and vaporizes back into the atmosphere; preliminary work suggests that interactions between freshwater, seawater, and wastewater determine the fate of the metal.

Food & Agriculture

KILLER AMOEBAS. The **Connecticut Department of Environmental Protection (DEP)** believes that it has isolated the

cause of lobster deaths in **Long Island Sound**. Based on tests performed during the fall, state workers have concluded that the problem results from infestation by a protozoan parasite known as a paramoeba. While the parasite does not affect humans, Long Island lobstermen have reported crustacean death rates of up to 50%. The DEP cautioned that, although the parasite may be the cause of the deaths, it could be a secondary infection in animals already weakened by another as yet undocumented cause. Changes in ecological conditions need to be studied, according to the DEP.

NEW AND IMPROVED. A mutant apple discovered in an orchard in **Ashford** could restore the declining popularity of the Macintosh in New England, according to apple grower **Michael Janket**. Owned by **Dick and Elaine Crooke,** of **Crooke Orchard**, the tentatively-named Miracle Mac outperforms traditional Macintoshes in several ways. It has a longer growing season, it remains firmer when it is stored, and it doesn't fall from the tree before it is fully ripe. Its flavor, according to Janket, is comparable to the Macoun, one of the market's most popular snack apples. Janket and the Crookes hope to market the tree as a proprietary variety.

LEARNING TO ABSORB POLLUTANTS. Natural organic matter is the main component of soils and sediments that take up such organic pollutants as leak from landfills or are left from pesticide applications. **Joseph Pignatello** and co-workers at **The Connecticut Agricultural Experiment Station** have found that the uptake of pollutants by the organic matter proceeds as if the organic matter were a hard, glassy polymer. Glassy polymers have "dissolution" and "hole-filling" domains. Imagine a solid plastic in which air bubbles are dispersed. The bulk phase takes up pollutants like a pollutant dissolving in an ordinary household liquid. The tiny bubbles, on the other hand, represent the holes that serve as condensation sites for the pollutants. As concentration increases, the holes first fill up, and then pressure on the walls enlarges the holes. High concentrations of warmth favor polymer relaxation, allow the holes to expand, and encourage uptake. Sine the polymer relaxes slowly, more pollutant is absorbed during a second uptake cycle. Hence, the organic matter seems to learn to absorb more pollutant, especially when pollutants are concentrated and the soil is warm.

NUTTY PLAN. Japanese chestnut trees, imported in the late 1880s, carried the blight that destroyed their American cousins. Now, through a project managed by scientists **Phil Gordon** and **Sandra Anagnostakis** of **The Connecticut Agricultural Experiment Station**, there may be a way to use these blighted trees for nut production. By using pruning techniques developed in Japan, the researchers will create small chestnut bushes that yield American chestnuts. The hope is that Connecticut can use these methods, along with planting the blight resistant hybrids developed by the Station, to produce a cash crop, reintroducing the nut to consumers who have not eaten it for an entire generation.

Health

CALL ME IN THE MORNING. An aspirin a day, taken alone, is as effective in treating heart attack patients as aspirin taken with a powerful anti-clotting drug, according to a **Yale** study. The six-year trial, one of the largest of its kind, included 5,059 subjects. Half of the group received aspirin, while the other half was given aspirin and Coumadin, a leading blood-thinning medication. "There was no difference in the two groups in terms of total mortality, cardiovascular mortality, non-fatal myocardial infarction, and non-fatal stroke," said Yale professor **Michael Ezekowitz**. The study recommends aspirin be used alone: it's cheaper, and, unlike Coumadin, does not require monitoring to regulate the dosage. Ezekowitz says that further analyses will be performed to determine if there are subgroups of heart attack patients who may benefit from the drug combination. (Patients should, of course, check with their physicians before changing any medication.)

KEEP IT SHORT. A team which includes **Yale** professor **Sandra L. Wolin** has discovered that an enzyme enabling cancer cells to reproduce is similar to a much-studied RNA-protein complex. Normally, as cells divide, the ends of the chromosomes shorten, causing the cells eventually to die. The enzyme, telomerase, which is present in cancer cells, maintains the ends of the chromosomes, so the cells can continue to multiply. The researchers, said Wolin, found that the enzyme telomerase assembles using a pathway that is already very well known to researchers. "Telomerase is thought to be an incredibly important enzyme because it is part of what makes a cancer cell a cancer cell," says Wolin.

LEAKY VESSEL. Although scientists have been able to grow new blood vessels in damaged hearts, those new vessels tend to leak. Now, **Timothy Hla**, director of the center for vascular biology at the **University of Connecticut Health Center**, has described a way to attack this problem. According to Hla, adding the molecule SPP (a platelet-derived bioactive lipid) to angiogenetic agents, which induce blood vessel formation, can bolster the final result. The process described by Hla may generate stronger blood vessels that could be used to treat heart disease in "natural bypass" operations. SPP is also used by cancer cells, which must create blood vessels to bring them the nutrients they require for their rapid growth. Hla suggests that finding a way to block SPP's action could lead to a new method of treating cancer.

BONING UP. Excess salt intake could exacerbate the loss of bone mass connected with osteoporosis, believes **University of Connecticut** professor **Jasminka Illich-Ernst.** Illich-Ernst recently began a three-year study to examine this idea. "What we are sure of so far, in animals and in humans, is that the more sodium in the diet, the more calcium will be excreted in the urine," she says. The two minerals compete for reabsorption in the kidneys, and when more sodium is present, less calcium is reabsorbed. Illich-Ernst is concerned about the source of the urinary calcium; she believes that it is being drawn from the bones. Her study will track 60 women a year, half of whom will shrink their sodium intake to 1,500 mg daily (compared to an average of more than 3,500 mg).

PAIN KILLERS. Pain is the number one reason for unplanned hospital admissions after outpatient surgery, according to **Richard B. Lilly, Jr.**, director of anesthesiology at **Hartford Hospital.** Now, Lilly and his colleagues have developed a portable pump that continuously delivers a pain-killing medication into the surgical site for 48 hours after the patient goes home. Currently used primarily for orthopedic surgeries, the device, which includes a tube inserted into the wound, appears to shorten recovery room stays by eliminating in some patients the need for narcotic medications. It also speeds up healing, by making patients comfortable enough to begin rehabilitative exercises immediately after surgery.

High Technology

SMALL CHANGES. With biotechnological analyses performed at the **Yale Cancer Center's (YCC)** new DNA microarray sequencing facility, researchers will be able to tell which genes in a cancer cell are actively producing proteins; this information is critical to determining the molecular causes of the disease. DNA microarrays, a powerful and rapidly evolving technology, allow scientists to assess expression levels in human genes on a scale unattainable by other methods. A preliminary set of DNA arrays have been been completed; for more information, see http://info.med.yale.edu/ycc/array.html.

IN BRIEF

BRAIN WATCH. Through functional magnetic resonance imaging (FMRI), **Yale** autism researchers **Ami J. Klin** and **Robert T. Schultz** hope to observe physical differences in the brain functioning of those with autism and those without. The researchers have identified the region in the cortex that controls social functioning: it's at the front of the brain, and is connected to the limbic system, which is associated with emotions. The next step involves showing study participants a video of interacting geometric shapes. Most observers tend to see the shapes as "people" and can easily convert their interactions into a story. But those with autism, who do not relate to other people, see the shapes only in terms of physical forces. For example, if one shape approaches another, an autistic child might credit magnetism, rather than friendship. This suggests, according to Schultz, that the brain is wired differently in people with autism.

ELECTRIFYING MEMORIES. Using the large nerve cells of squid, researchers at **Yale** have developed a new technique for recording the electrical activities within living cells. For the first time, they've been able to observe the activity of mitochondria, the organelles that produce a cell's energy. The new technique, which reveals mitochondrial activity within a neuron's synaptic terminal, has already led to insights into the way changes inside neurons may underlie learning and memory. "We were surprised to find that very brief stimulation of a neuron caused electrical behavior of the mitochondria to increase 60-fold," said **Elizabeth A. Jonas,** an investigator on the study who developed the technique. Although the neuron was stimulated for only one or two seconds, Jonas said, the mitochondria seemed to "remember" the stimulus for thirty seconds or more. This finding suggests that mitochrondria enable neurons to know whether they've been stimulated previously, which allows the neurons to respond to a signal properly.

SOUND IMAGE. Connecticut marine explorer **Robert D. Ballard** , founder and head of the **Institute for Exploration** at **Mystic Aquarium**, has found evidence of what may be the historical basis of the Biblical flood. Using sonar, Ballard, who located the remains of the *Titanic*, was able to obtain the first images of an ancient coastline lurking 550 feet below the surface of the Black Sea. His findings help confirm a recently proposed theory that the Black Sea was created when water from melting glaciers breached a natural dam and flooded thousands of square miles of dry land; shells collected by Ballard's team date the flood to between 7,500 and 6,900 years ago. Ballard believes that it may be possible to find evidence of flood plain settlements that were destroyed by the inundation.

SETTING LIMITS. Ongoing improvements in computers and other electronics over the past three decades have resulted largely from the steadily diminishing circuit size. Now, a limit may have been reached. For the first time, a **Yale** research team has identified the smallest possible reversible electronic switch—the size of a single large molecule. "The ultimate for shrinking the size of a switch is the molecular level, which this study demonstrates," said CASE member **Mark Reed**, chair of electrical engineering at Yale. The devices show a thousand-fold on/off ratio, which is comparable to or exceeds conventional types of electronic devices.

Industry

MORE THAN ASPIRIN. Construction began last fall on a 125,000-square-foot research building, the first of two major expansions planned in **West Haven** by the **Bayer Corporation**. The new facilities include a $53 million chemistry research building and a High Throughput Screening Facility. The structures will accommodate 160 scientists, who will work on developing drugs to treat cancer, osteoporosis, diabetes, and obesity. Additional upgrades include transforming a 10,000-square-foot manufacturing center into a testing facility. Bayer expects to employ more than 500 scientists by 2003.

DATA ON-LINE. The state's massive database of business records went on-line early last fall, and is available free at www.state.ct.us/sots. The new system, Concord, is available from 7 a.m. to 11 p.m. daily, and provides state records on corporations, limited partnerships and limited liability companies, Uniform Commercial Code filings, and federal, state, and local tax liens. It could be used to learn, for example, whether a home improvement contractor is registered to do business in the state. Other state databases currently on the web include the Judicial Department's docket of pending civil lawsuits, a state telephone directory, and a database of laws and bills maintained by the state legislature.

SICK IDEA. A reduction in mental health services at a large Connecticut corporation led to added costs for the company, according to a **Yale** study. The research showed that although the company was able to decrease its mental health costs by over one-third, employees who used the trimmed program expanded their use of non-mental health services by 37%. The study found that these employees also took significantly more sick days. "This is the first study to show that there exists a point where reducing mental health dollars can be bad for both employees and employers," said Yale psychiatry professor **Dr. Robert Rosenheck**.

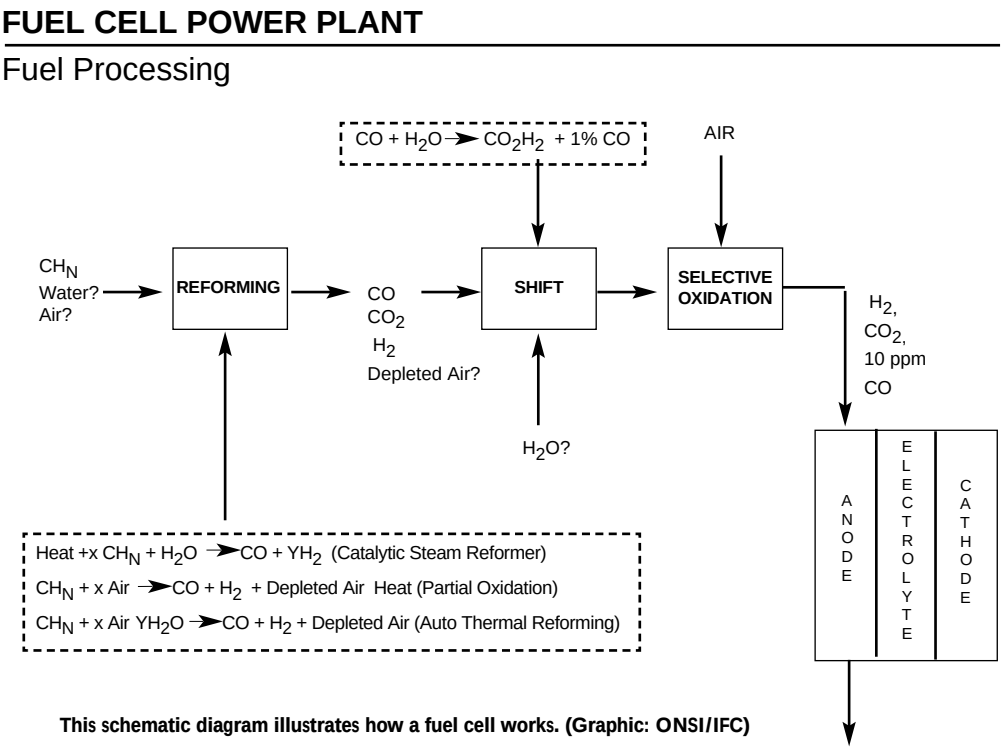
Transportation

AIR CONTROL. Replacing an antiquated facility in a 1950s-era terminal, the new control tower at **Bradley International Airport** offers the latest technology, including fiber optic cables that link radar and other systems to the $8.5 million building; the base of the tower houses a 14,500-square-foot radar room. The tower, completed last fall, rises 165 feet into the air. Tower controllers gain about 80 feet in altitude, for a much better view of the airfield, said air traffic manager **Paul G. Johnston**. Controllers at the Windsor Locks airport guide planes to Bradley and twelve other regional airports, managing air traffic as far as 50 miles away.

MOVING RIGHT ALONG. With a $2.6 million National Science Foundation grant, electrical engineers at **Yale** hope to learn how groups of animals like birds or fish organize their movements. "We hope to discover underlying concepts upon which the coordination of group motion might depend," said grant recipient **A. Stephen Morse**. The researchers will develop models by analyzing the motions of actual schools of fish; they will test the models using robotic vehicles able to function autonomously, without remote control. The results of the study could be used to develop man-made autonomous vehicles that can move in perfect tandem; the project is part of a $50 million initiative that will focus on information technology research.

FLYING HIGH. Planes flying over Connecticut could soon be switched from land-based to satellite-based guidance systems. The change is part of a Federal Aviation Administration (FAA) effort that should mitigate the severe airspace congestion over New York, Connecticut, and New Jersey. Under the current system, VOR (very high frequency, omnidirectional radar) stations direct the planes, sending out radar beams that the pilots can home in on, and transferring control of the plane from one station to another as the plane travels. This process can lead to inefficient, zig-zag routes, especially in the Northeast, where VOR stations are comparatively close together. The FAA hopes to develop a navigation approach in which planes rely on the global positioning system of 24 communications satellites. The new procedures should reduce delays, save fuel, and diminish aircraft noise over residential neighborhoods.

— Compiled and edited by Karen Miller



This schematic diagram illustrates how a fuel cell works. (Graphic: ONSI/IFC)

a fuel cell power plant is always running, there's no "spooling up" time such as one finds with conventional generators. It's always on line.

Fuel cells are about 25% cheaper to run than conventional power generators. With fewer moving parts, maintenance is much easier. They are whisper-quiet, don't vibrate, and operate for years without major servicing. Fuel cells also are environmentally friendly, since they can run on renewable energy sources and their exhaust essentially consists of steam, potable water, oxygen, and heat. They are even exempt from California's stringent emissions laws.

The main disadvantage of today's fuel cells is the initial cost and installation costs, which can be $3,000 to $5,000 per kilowatt in today's market. Operating costs and efficiency will back that down, and will eventually recoup the initial cost. Weight is also a problem; current fuel cell power plants are heavy. In some configurations, however, the fuel cells and ancillary equipment weigh about the same as the alternate solution. Both the cost and weight are being reduced and within ten years, both should be considerably less.

How a Fuel Cell Works

The electrochemical principle basic to fuel cell technology was first proposed in 1839 by the British physicist Sir William R. Grove, from his experimental data on the electrolysis of water. He reasoned that if one combined hydrogen with oxygen, one could obtain electricity. The term "fuel cell" was coined fifty years later by the team of Ludwig Mond and Charles Langer, who also attempted to build a crude fuel cell. Sir Francis Bacon, a talented British engineer of the early 20th century, was instrumental in building the first successful fuel cell based on his 1932 inventions and on the work of Mond and Langer. That unit, a 5-kilowatt nickel electrode/alkaline electrolyte system, made its debut in 1959, and could power one welding machine.

A typical fuel cell using hydrogen as fuel consists of an anode layer, which strips electrons from hydrogen atoms and exports these electrons as electricity; an electrolyte layer, which passes the hydrogen protons to the other side of the cell; and a cathode layer, which accepts the protons and mates them with returning electrons and oxygen from the air to form water. The electrons which have been sent out by the anode as electricity perform work, such as powering computers, and then return to the cathode. These cells are stacked like a pile of dishes, with an end-plate on the top and bottom of the pile. At each corner, the end-plates are connected to tie rods which clamp the cells in position. Manifolds and intake tubes sprout along the sides of this stack like legs on a centipede. The entire fuel cell stack is encased in a fitted insulation jacket somewhat like a high-tech tea cosy in order to conserve heat.

The first stage of a fuel cell power plant (except direct or regenerative fuel cells) consists of a fuel processor in which an organic, hydrogen-rich fuel **(**such as natural gas, propane, methane, methyl alcohol, naphtha, or gasoline**)** is combined with air, water, or other oxygen sources. There are three main types of processors: catalytic steam reformer, partial oxidation reformer, and auto thermal reformer. After the fuel is reformed, it has been broken down into carbon monoxide, depleted air (i.e., stripped of some of its oxygen), and hydrogen gas. Next, those components enter a "shift" step, followed by a selective oxidation step. In the shift step, carbon monoxide and water are converted to carbon dioxide, gaseous hydrogen, and 1% carbon monoxide. Air is added during the selective oxidation step, to produce hydrogen gas, carbon dioxide, and 10 parts per million (ppm) carbon monoxide. It is this hydrogen-rich gas which enters the anode of the fuel cell. If one has a source of pure hydrogen gas, then the other steps may be omitted.

Fuel cells can operate over a wide range of temperatures. Those which operate at higher temperatures are usually more fuel efficient, and the kinetics of electrode reactions are improved. They can also tolerate much higher levels of carbon monoxide than units which operate at lower temperatures.

(See Fuel Cells, page 10)

Types of Fuel Cells

Phosphoric Acid (PAFC): This is the most commonly used type of fuel cell for stationary commercial sites such as hospitals, hotels, and office buildings. The electrolyte is concentrated phosphoric acid, and it operates at about 200º C. It is highly efficient: it can generate energy at up to 85% (40% as electricity and another 45% if the heat given off is also used in combined heat and power applications). ONSI Corporation, a United Technologies subsidiary, is a leading R&D facility, as well as a manufacturer, of this type of fuel cell.

Proton Exchange Membrane (PEM): These cells use a perfluorinated ionomer polymer membrane electrolyte which passes protons from the anode to the cathode. They operate at a relatively low temperature (70-85º C.), and are especially notable for their rapid start time. These are being intensively developed for use in transportation applications, where a quick start is needed. As costs drop, we may see tiny units installed in cell phones and other small electronic devices. United Technologies subsidiary International Fuel Cells (IFC) and Proton Energy Systems are actively engaged in R&D as well as manufacture of this type.

Molten Carbonate (MCFC): These operate at about 600º C. They would be effective in continuously operating facilities, and can consume coal-based or marine diesel fuels. FuelCell Energy is known worldwide for its R&D on this type.

Solid Oxide (SOFC): These also may find a niche in industrial and large-scale applications. Temperatures may reach 950º-1,000º C, which gives this type of fuel cell a power efficiency of up to 60%. They are slow to start up, but once running, provide high grade waste heat which can be used to heat buildings. Georgia-based Siemens-Westinghouse is one of the leading R&D facilities for this type.

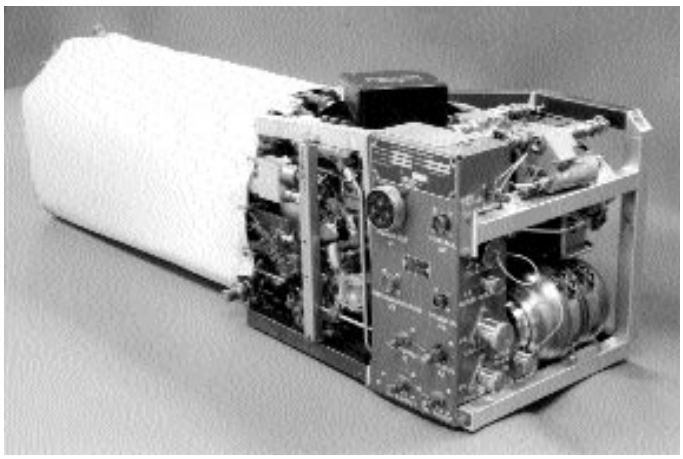
Alkaline (AFC): These are used by NASA on the manned space missions, and operate well at about 200º C. By using alkaline potassium hydroxide as the electrolyte, these can generate electricity at up to 70% efficiency. A disadvantage of this system is that it is restricted to fuels and oxidants which contain no carbon dioxide. AFCs were originally developed from the Bacon cells by Pratt & Whitney Aircraft, and are now produced and serviced by IFC and ONSI.

Direct Methanol (DMFC): These are relatively new to the fuel cell family. They take their hydrogen directly from liquid methanol (methyl alcohol), which is oxidized at the anode. Like PEMs, these also use a membrane electrolyte, and operate at similar temperatures. FuelCell Energy is actively working with this type, which is still in the research stage.

Regenerative (RFC): These are closed-loop generators. A solar-powered electrolyzer separates water into hydrogen and oxygen, which are then used by the fuel cell to produce electricity and exhaust (water). That water can then be recycled into the solar-powered electrolyzer for another go-around, ad infinitum. Proton Energy Systems is developing this type.

Connecticut Fuel Cell Companies

Connecticut-based Pratt & Whitney, now part of United Technologies Corporation (UTC), received the rights to Bacon's fuel cell patent in 1959. Just about that time, a relatively new and unknown government agency called the National Aeronautics and Space Administration (NASA) was beginning to look for a compact electricity generator for America's upcoming manned space missions. Fuel cell research units at United Technologies Corporations—predecessors of the company's current subsidiaries ONSI Corporation and International Fuel Cells (IFC), both located in South Windsor—began making fuel cells for the Apollo program in 1966. United Technologies subsidiaries have been solely responsible for the manufacture and maintenance of the fuel cells used in every US manned launch since then; ONSI and IFC are also very active in R&D on stationary and vehicle fuel cell plants.



A fuel cell built for the US space shuttle program. (Photo: IFC)

The first space-going fuel cells were carried aloft in the Gemini capsules. In the early 1960s, Connecticut-based units of United Technologies got the contract for 54 fuel cell units for the Apollo program, and then, about 25 years ago, for 25 units for the space shuttle. Three of these were lost with the Challenger, but the remaining 22 are still in service.

The first fuel cell-based commercial power plant, IFC's 200 kW PC25™, began operation in 1992. In 1993, the US government and the Big Three automakers (Chrysler, Ford, and General Motors) formed the Partnership for New Generation of Vehicles (PNGV), with the goal of producing a mid-sized automobile equipped with a fuel cell plant that can get 80 mpg or more. The recently-formed DaimlerChrysler company also is working with FuelCell Energy, Inc. of Danbury, CT, on stationary fuel cell power plants.

"Both of these are huge applications, major markets," said IFC's Joseph King, in a recent interview:

"In order to put fuel cells in automobiles, you've got to show that there's a big advantage, more than just emissions and efficiency. It's hard to make a fuel cell lightweight and small, but the auto market and industry interests are really pushing us in that direction. We also have to address the availability of suitable fueling infrastructure. Hydrogen has a heating value of 50,000 BTU's a pound, compared with gasoline, which has a heating value of 18,500 BTU's a pound. But it would take 20 or more times the weight of hydrogen to store it. That takes it down to 2,500 BTU's a pound, which is a 6-to-1 disadvantage compared to gasoline. That's why we're looking at a fuel cell that can run on gasoline, or something that's sufficiently compatible with gasoline that it can be used by either the internal combustion engine or the fuel cell. The average car is started, operated for about 15 minutes, and is then is turned off. It is serviced every 100 operating hours (3,000 miles). A fuel cell unit has the potential of a 4,000 hour service interval (200,000 miles).

"In ground-based stationary applications, the desirable goal is that the single fuel-cell power plant will have a lifetime of 40,000-80,000 operational hours (5-10 years) without overhaul and with minimal servicing. The unit would power a single factory or building complex. Commercial buildings average 5-10kW per 1,000 square feet, and our PC25 puts out 200kW. This means that one PC25 could provide power for a 20,000 square foot building at the minimum, and maybe structures up to 40,000 or more square feet, depending on power requirements. The PC25 is shipped ready to install. All you need is a concrete pad, hookups from the fuel source such as natural gas, and steam/heat pipes and electrical connections leading into the building. In a few years, this footprint should be reduced from three standard parking spaces to that of a single compact parking space."

ONSI fuel cell plants survived the recent earthquakes in Kobe, Japan and the Northridge area of Los Angeles without so much as a quaver in their electrical output.

Sure Power Corporation, located in Danbury, incorporates ONSI fuel cell power plants in its reliable stationary power plants. It is a dynamic, innovative young company specializing in power plants for use in hospitals, computer facilities, and financial establishments.

Fuel cells have a rapid transient response, but cannot handle large increase step changes in power. They can handle step changes and fault current to a point, but the maximum step load and maximum overload capacity of a specific fuel cell is defined early in its design. In order to provide capability beyond the design limits of the standard PC25 fuel cell power plant, Sure Power has linked an ONSI fuel cell power plant with a large flywheel and a special rotary generator set. Coupling the fuel cell with this source of rotary power ensures that if a step load is suddenly required, energy is there. The flywheel stores sufficient energy to carry the load and then gradually transfers the additional load to the fuel cell power plant. This "Motor Generator" also gives the Sure Power installation the ability to provide fault-clearing current. A patent is pending on this power delivery system, which has been installed in the First National Bank of Omaha (Omaha, Nebraska), a processor of credit card transactions from all over the world operating 24 hours a day, 7 days a week. An outage of 8 or more milliseconds might require 10 to 14 hours to get the system back up, which would mean a loss of about 6 million dollars an hour. The Sure Power fuel cell generator eliminates this hazard.

FuelCell Energy, Inc., also located in Danbury, was formerly known as Energy Research Corporation. This company concentrates on natural and synthetic gas-powered fuel cells.

Proton Energy Systems, Inc, located in Rocky Hill, CT, specializes in unitized regenerative fuel cells (URFC) and proton exchange membranes (PEM) for use in hydrogen generators and fuel cells. It has been awarded a NASA Phase II Small Business Innovation Research (SBIR) contract for a zero-gravity PEM URFC energy storage system.

Future Applications

When asked "Where will we be five years from now?" IFC's Joseph King gets a faraway look in his eyes:

"Well, I think five years from now, we will have a much broader application of stationary fuel cell power plants, because that power plant's going to shrink in size by a factor of 3 or 4 for the same power rating. We'll also be able to make the power plant start very quickly, so we can use the fuel cell in what I would call a "peak-shaving" duty, so we'd start it up in the afternoon when the air conditioner goes on "high," and shut it off in the evening when the power's not needed. This will help the utility by not requiring it to provide additional distribution lines. You don't need to operate the unit during the times of the day when the utilities can really provide low-cost power and the distribution lines are perfectly adequate. Generation in the right place is needed… and what the fuel cell does is allow you to put the power generation in exactly the right place.

"In the ten-year range, we should start to see fuel cells penetrating the automobile market much more heavily. We should also see fuel cell plants used in rural electrification in developing areas of the world, as well as powering condominium and office complexes. We will certainly see them more heavily used where computer-grade power is essential."

William Cratty, president of Sure Power, added that hospitals would also be major users of fuel cell-powered plants.

"We're working with the Clean Energy Group out of Vermont under a PEW Foundation grant with Harvard

(See Fuel Cells, page 12)

Fuel Cells *(from page 11)*

> *Medical School, to assess the power quality needs of the medical industry. All the hospitals, the research medical industries today, have diesel engine emergency generators which may go back 40-50 years. If any of these institutions suffers an outage of 8 milliseconds or more, research instruments will fail, data will be corrupted. If that outage lasts for an hour, then you begin to see other experiments with other temperature controls beginning to be affected. This past summer, Providence Hospital in Rhode Island experienced a prolonged power outage during Hurricane Floyd. Not only their computers, but their respirators failed, and they had to hand-operate the respirators, and one patient died. The things that make a hospital run, the actual patient care, dialysis, diagnostic imaging, NMR, MRI, CAT scans, computer-operated as well as other electrical instrumentation, all of those are vulnerable.*

Joseph King added:

> *"The main reasons that the fuel cell industry is important to Connecticut are that right now this state is the world leader in fuel cells: the space application comes from Connecticut and the commercial applications come from Connecticut. We have competition, but we are still number one. In addition, Connecticut is in the energy-poor part of the United States. If you wander around the state and look at all the dams and all the sites where we had mills, we used to be the energy capitol of the United States thanks to water power. Now, we're the country's energy consumer. We also have a body of highly skilled and trainable workers in Connecticut. If you're going to have a high-tech industry, then that industry is going to require very reliable power, so that's another reason to nurture the fuel cell industry. …Connecticut's trying to attract are the kinds of industries that need the fuel cell."*

According to a recent article in the November 1, 1999 *US News & World Report,* one of the 21 hottest career tracks for the next century is that of as a fuel cell engineer. We may find portable units such as Proton Energy Systems' PEM fuel cells or FuelCell Energy's Direct FuelCells™ placed at landfills that are emitting large amounts of methane gas. These gases are now simply vented to the atmosphere. Why not place a small unit right there and scavenge that gas as a fuel to produce electricity? Then, when the gas emitted by the landfill is no longer produced in commercially viable quantities, the unit could be picked up and relocated to another active methane source.

There are also huge amounts of methane (solid crystal) bound in deep-sea water ice. These deposits, which are probably twice as large as those for the remaining fossil fuels on earth, may provide a significant source of fuel for the future. A deep-sea mining dome, equipped with hydrogen scavengers and/or fuel cells capable of using that methane, could export electricity and/or carbon monoxide and hydrogen gas to the surface.

National Medal of Science Awarded to Mathematician Ronald Coifman

Yale mathematician and CASE member Ronald Coifman has been awarded the nation's highest scientific award, the National Medal of Science. Dr. Coifman, Phillips Professor of Mathematics at Yale, received the honor for his fundamental contributions to the field of harmonic analysis, and for adapting that field to the capabilities of the digital computer to produce a family of fast, robust computational tools that have substantially benefitted science and technology. Coifman is considered a world leader in the field of harmonic analysis.

"He introduced tools powerful enough to solve key problems in pure mathematics, yet sufficiently simple and flexible to become the basis for new, fast algorithms to handle the problems of wave propagation, data storage, denoising, and medical imaging," reads the presidential award. "As Coifman moved to applied mathematics, his work in the development of wavelet analysis had a revolutionary impact."

Coifman was elected to CASE in 1995, and received the Connecticut State Medal of Science in 1996.

The National Medal of Science, established by Congress in 1959 and administered by the National Science Foundation, honors individuals for contributions to the present state of knowledge across a variety of science frontiers.

Fossil fuels are a non-renewable finite energy source, and while they are at present still plentifully available, they will eventually dwindle to commercially insignificant amounts.

Mankind has demonstrated an insatiable appetite for electricity. North America, Europe, and Japan consume most of the electricity produced on Earth. As burgeoning global demand for power consumes remaining fossil fuel sources, devices such as fuel cells, which can use alternate. renewable energy sources, will become increasingly vital to the future of industrialized, technology-based societies. Connecticut, home to the world's leaders in fuel cell development and manufacture, is well positioned to play a central role in the growth of this critical technology.***—Jane T. Sibley, science writer***

For more information about Connecticut fuel cell and fuel cell-based power plant manufacturers, go to www.internationalfuelcells.com (IFC), www.onsicorp.com (ONSI), www.hi-availability.com (Sure Power), www.fuelcellenergy.com (FuelCell Technology), and www.protonenergy.com (Proton Energy Systems, Inc.)

knock out or insert or replace a gene, and then clone/grow an animal from that genetically modified cell.

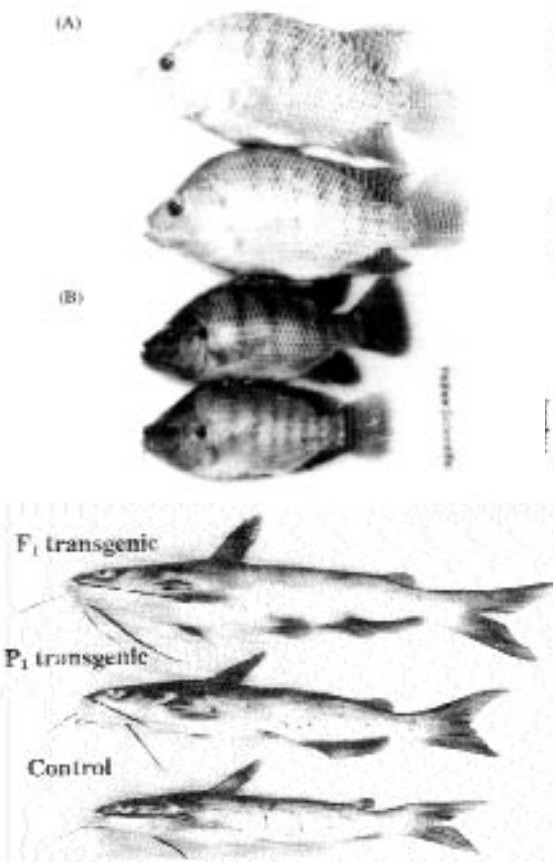
Now, in order to create transgenic animals, a modifying gene must be injected into the cells of an already developing embryo. With luck, some of the embryo's cells will incorporate the extra DNA into their own nuclear material, and those altered cells will then develop into a gonad, producing transgenic sperm or eggs. "Then, in the next generation, you get what you need." But the possibility, opened up by Yang's success with Kamitakafuku, of altering and then cloning a cell, will allow transgenic animals to be produced in just one step.

Transgenic animals have many uses. They can be designed, for example, as bioreactors, which produce pharmaceuticals. In an earlier project, Yang used cell injection to create genetically modified rabbits whose milk contains an enzyme needed to treat victims of Pompe's Disease, a fatal genetic disorder. And, in a project currently underway, he is developing transgenic pigs whose organs can be used for human transplants. Using microinjection, he's been able to develop pigs that produce a protein that delays the recipient's rejection of the organ. But Yang hopes to prevent the rejection process completely, and for this, he says, he needs to get the cloning process working in pigs, then create a transgenic pig with the right genes, and then "still be able to clone those genetically modified donor cells." It's a very difficult project, he says.

Dr. Chen also conducts research with implications stretching from agricultural to biomedical, and beyond. Chen's laboratory, for example, has developed transgenic fish that can serve as markers for pollution. By fusing a gene coding sequence that produces GFP—green fluorescense protein—to a promoter that activates in the presence of endocrin disrupters, which come in part from industrial wastes, Chen has created a gene that, quite simply, turns fish green when they swim in polluted water.

Some of his recent work has evolved from his interest in fish growth hormones. In earlier projects, aimed at aiding the aquaculture industry, Chen developed transgenic fish that grew from 20–59% larger than their unmodified siblings. And, he says, he began to study the structure and function of one of the growth factors. Strangely, the initial form of the growth factor is about twice as large as its mature, functioning form. In other words, to make the mature insulin-like growth factor, a large chunk, known as the E-peptide, was just thrown away.

Chen wondered why. "People believed this E-peptide to be without use. But my feeling was, this is too costly." He did not believe that a cell would go through the effort of making a 70-amino acid peptide just to get rid of it. "So we have spent our time studying this. Recently we have found out several things." First, he says, the E-peptide itself can promote cell division. Second, "and this is the part that becomes very interesting," the E-peptide is able to change the morphology of cancer cells. Normal cells, Chen explains, are "anchorage dependent": they must attach to something. "If you don't let them attach, they will not grow." But cancer cells are anchorage independent. They need not attach to something in order to thrive." The E-peptide, explains Chen, can change cancer cells from anchorage independent to anchorage dependent behavior. Effectively, it turns cancer cells into normal ones.



UConn's Thomas Chen developed transgenic fish that grew 20-59% larger than nontransgenic controls. At top, fish labeled (A) are transgenic *Oreochromis nilocticus, or* Nile Tilapia, while (B) are nontransgenic controls. Pictured below are transgenic and nontransgenic *Ictalurus punctatus,* or channel catfish.

Photos: T. Chen

Currently, Chen is in the process of conducting experiments to test the implications of this discovery. Eventually, he believes, he and his colleagues will develop a chemotherapeutic agent from this E-peptide.

In the drive to create a vibrant Connecticut economy, research at state universities holds the key. Discoveries made by Li, Chen, Dellaporta and their colleagues provide the crucial foundation for the startup companies that most believe Connecticut sorely needs. "Research," says Dr. Yang, "generates the knowledge. It's like a source, a water source." With the breadth and depth of research underway at the state's universities, it seems, encouragingly, that Connecticut's knowledge reservoirs are well supplied. ***— Karen Miller, science writer***

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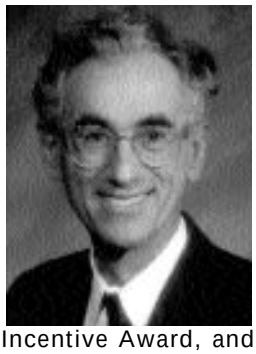
NEW MEMBERS OF CASE

The following individuals were elected to the Connecticut Academy of Science and Engineering in 1999



RAYMOND A. FIRESTONE

Highly Distinguished Scientific Fellow, Boehringer Ingelheim Pharmaceuticals, Inc. Dr. Firestone is a Fellow of the Royal Society of Chemistry. He has served on editorial advisory boards of *Chemical Reviews and Heteroatom Chemistry,* and is currently on the editorial board of *Bioconjugate Chemistry.* He is a recipient of the Merck Director's Award and the Merck Management Incentive Award, and chaired the 1978 Gordon Research Conference on Heterocyclic Chemistry. His research interests include drug research (anti-tumor, anti-inflammatory, anti-infective, vitamin synthesis) and organic reaction mechanisms.

HARRY A. FRANK

Professor of Chemistry, University of Connecticut. Dr. Frank is a member of the American Chemical Society, the Biophysical Society, the American Society for Photobiology, and the International Carotenoid Society, of which he is currently president-elect. He is the recipient of the 1999 University of Connecticut Alumni Association Faculty Excellence Award in Research, and is chairman-elect of the Gordon Research Conference on Carotenoids, 2004. From 1994 to 1995, Dr. Frank was a J. William Fulbright Scholar. His research interests include biophysical chemistry, molecular spectroscopy, magnetic resonance, energy and electron transfer in photosynthesis and the structure and function of carotenoids.

NANCY M. HAEGEL

Professor of Physics, Fairfield University. Dr. Haegel is the recipient of numerous awards, including a Packard Fellowship in 1988, the TRW Innovative Teaching Award at (UCLA) in 1990, Teacher of the Year (Fairfield University) in 1997, and a Humboldt Fellowship in 1999. She is a member of the American Physical Society and has served on the National Science Foundation's Graduate Fellowship Panel. She is a member of the board of trustees of the University of Notre Dame. Her research interests include semiconductor characterization and transport, with emphasis on high resistivity transport, and micro-characterization and infrared detectors.

ROBERT H. HOBBS

Director, Research Operations, United Technologies Research Center. Dr. Hobbs is a member of the American Physical Society, the Institute of Electrical and Electronic Engineers (IEEE), and the Optical Society of America. A competitive sailor, he currently chairs the US Olympic Sailing Committee, and is preparing to send a team to the 2000 Olympic Games in Sydney, Australia. Dr. Hobbs was elected to CASE on the basis of his contributions to the field of kinetics and electron transport. His interests include the management of technology with a focus on industrial research management effectiveness.

PIERRE C. HOHENBERG

Deputy Provost for Science and Technology, Yale University. Dr. Hohenberg is a Fellow of the American Physical Society, the American Academy of Arts and Sciences, the New York Academy of Sciences and the American Association for the Advancement of Science. A member of the National Academy of Sciences, he was the recipient of the Fritz London Low Temperature Prize in 1990, and the Max Planck Medaille in 1999. He currently serves on the editorial board of the *Proceedings* of the National Academy of Sciences as well as the board of directors of the Brookhaven Science Associates. He chairs the US Liaison Committee of the International Union of Pure and Applied Physics. Dr. Hohenberg's research interests include statistical physics, condensed matter theory, and higher education administration.

Gabor Huszar

Senior Research Scientist, Department of Obstetrics and Gynecology, Yale University School of Medicine. Dr. Huszar was elected as a foreign member to the Hungarian National Academy of Sciences, and was invited speaker at a Nobel Conference at the Karolinska Institute in Stockholm, Sweden. He received the 1998 Male Infertility Prize at the World Congress of International Societies of Infertility. A member of numerous professional societies, Dr. Huszar served on the Reproductive Biology Study Section at the National Institutes of Health. His research interests include male infertility, assisted reproduction, sperm function, and environmental toxicology.

EDWARD C. MONAHAN

Professor of Maritime Sciences, University of Connecticut and Director, Connecticut Sea Grant College Program. Dr. Monahan is a Fellow of the American Meteorological Society, the Accoustical Society of America, and the Royal Meteorological Society. He is a member of the American Geophysical Union, the American Society of Limnology and Oceanography, the International Association of Theoretical and Applied Limnology, the Irish Meteorological Society, the Irish Marine Science Association, the European Geophysical Society and is a charter life member of The Oceanography Society. He currently serves on the Public Information Advisory Committee of the American Institute of Physics; the Board on Oceans and Atmosphere of the National Association of State Universities and Land Grant Colleges; the Board of Directors of the Sea Grant Association; and the Management Committee of the Environmental Protection Agency's Long Island

Sound Study. His research interests include bubble-mediated air-sea exchange of moisture, heat, and matter; marine aerosol production; marine remote sensing; and marine environmental sciences.

ERIC J. NESTLER

Elizabeth Mears and House Jameson Professor of Psychiatry, Pharmacology and Neurobiology, Yale University School of Medicine. Dr. Nestler is a member of the Institute of Medicine, the Society for Neuroscience, and the American College of Neuropsychopharmacology (ACNP). He is the recipient of numerous awards, including the Pfizer Scholar Award, the Sloan Research Fellowship, the McKnight Scholar Award, the Efron Award of the ACNP, the Marsh Award of Texas Tech University, and the Pasarow Award. Dr. Nestler has conducted groundbreaking studies in the biology of addiction, unraveling the function of certain genes in the mesolimbic dopamine system. His research interests include the molecular neurobiology of drug addiction and other neuropsychiatric disorders.

SALLY E. SHAYWITZ

Professor of Pediatrics, Yale University School of Medicine. Dr. Shaywitz is the founder and director of the Learning Disorders Unit at the Yale University School of Medicine, and co-directs the school's Center for the Study of Learning and Attention. She is a member of the Institute of Medicine, as well as numerous professional societies, including the American Academy of Pediatrics, the American Association for the Advancement of Science, the American Educational Research Association, the International Dyslexia Association, the Society for Pediatric Research, and the Society for Research in Child Development. She currently serves on the editorial boards of the *Journal of Learning Disabilities,* the *Learning Disability Quarterly,* the *Journal of Women's Health, Section on Gender-Based Biology,* and *Brain and Mind.* In 1995, Dr. Shaywitz was awarded the Distinguished Alumnus Award from the Albert Einstein College of Medicine, and in 1998 received the Achievement Award in Women's Health Research from the Society for the Advancement of Women's Health Research. She was the recipient of the 1999 Kingsbury Center 60th Anniversary Award and the 1999 LD Access Distinguished Research Award. Her research interests include the neurobiology of reading and dyslexia.

JOHN F. TALLMAN

Executive Vice President and Scientific Director, Neurogen Corporation and Adjunct Professor, Yale University School of Medicine. Dr. Tallman is a member of the American Society for Biochemistry and Molecular Biology, the American Society for Pharmacology and Experimental Therapeutics, the Society for Neuroscience, the American College of Neuropsychopharmacology, and the Collegium Internationale Neuro-Psychopharmacoloqium. He received the NIMH Merit Award (1988-1999) and the Klingestein Senior Fellowship in Neuroscience. He serves on numerous editorial boards and is currently the senior editor of *Neuropsychopharmacology.* He served as a section chief at the National Institute of Mental Health and as an associate professor of psychiatry and pharmacology at the Yale University School of Medicine. A co-founder of the Neurogen Corporation, his research interests include neurochemistry, neuropharmacology, drug discovery and development, ligand gated channels, and receptor proteins.

SANDRA K. WELLER

Professor of Microbiology, University of Connecticut Health Center. Dr. Weller is a member of the American Society for Microbiology and the American Society for Virology. She serves on the editorial board of the *Journal of Virology* and is a past member of the National Institutes of Health study section on Experimental Virology. She chaired the 1998 FASEB conference on viral assembly. She is the recipient of several awards, including the American Cancer Society's Junior Faculty Research Award, the Established Investigator Award from the American Heart Association, the Stuart Wilson Young Faculty Award from the University of Connecticut Health Center, and the Merit Award from the NIAID. She was recently elected chair of the Division on DNA Viruses of the American Society of Microbiology. Dr. Weller's research interests include DNA replication, genome maturation and encapsidation of Herpes Simplex Virus type 1.

JERRY M. WOODALL

C. Baldwin Sawyer Professor of Electrical Engineering, Yale University. Dr. Woodall is a member of National Academy of Engineering and currently serves on the Governing Board of the American Institute of Physics. He is a Fellow and former president of both the Electrochemical Society and the American Vacuum Society, and currently chairs the Education Committee of the Electron Devices Society. He also is a member of the Beckman Institute External Advisory Committee, the Advisory Committee for the New York State Center for Advanced Telecommunication Technology, and the Advisory Board of the Jet Propulsion Laboratory Center for Space Microelectronic Technology. Dr. Woodall has received numerous awards, including several IBM Outstanding Invention and Outstanding Innovation awards and 30 IBM Invention Achievement Awards. In 1992, he received an IBM Corporate Award for his invention of the GaAlAs/GaAs heterojunction. He has served as a consultant for the Jet Propulsion Laboratory and Keithly Instruments. His research interests include exploratory compound semiconductor materials and devices and development of niche product electronic and photonic devices.

J. J. KIM WRIGHT

Vice President, Discovery Chemistry, Bristol-Myers Squibb. Dr. Wright is a member of American Chemical Society's Medicinal Chemistry Section, and serves on their Long-Range Planning Committee. He is the author of 32 patents and 56 publications. He was elected to CASE on the basis of his accomplishments as a medicinal chemist and his significant drug discovery efforts. He has been involved in a broad spectrum of discovery programs leading to the advancement of more than 20 novel drugs for human clinical trials for the treatment of diseases such as cancer, neurodegenerative and cardiovascular disorders, bacterial and viral infections. His research interests include organic chemistry, medicinal chemistry, and natural products.

DURACELL
PRESENTS

CPTV's Family Science Expo

Water, Water Everywhere? Exploring our Precious Resource

The Ninth Annual CPTV Family Science Expo, presented by Duracell, will be held March 23-26 in the athletic center of Trinity College in Hartford. Designed for families with children ages 4-14, the Expo provides an opportunity to explore the vital daily impact of water, from the pursuit of clean tapwater to the new technologies allowing undersea exploration to the ever-changing paths of rivers and the multitude of life forms created in them. Open to the public March 25 & 26; admission is $5 for adults, $4 for children. The Expo offers free admission to school groups with advance reservations on March 23 and 24. For more information, contact CPTV at 860-278-5310 or check their website at www.cpbi.org.

CASE is represented on the Expo's Scientific Advisory Committee again this year by Academy Secretary David M. Wetstone.

From the Academy *(from page 2)*

reduction in emissions standards over the period when the inspection program was introduced made it virtually impossible to determine the effectiveness of the program in the the overall reduction. The CASE study was complicated by the fact that no analysis has been performed of the difference in emissions from vehicles that failed and then passed.

It was determined that newer vehicles, with computer-controlled engines, achieved reduced emissions. Test failure rates showed that new cars have very low failure rates; that the failure rates increase as the vehicles age; and that there was little difference in failure rates among manufacturers. The overall failure rate for the entire fleet was about 6% under the idle test program.

The emissions test was changed from the idle test to the Acceleration Simulation Mode test, ASM2525, in 1998. In this test, the vehicle is placed on a dynamometer and run at 25 miles per hour for 240 seconds. Tailpipe gas concentrations are sampled and the car is deemed to pass when the concentrations of all three gases sampled—carbon monoxide, nitrogen oxide and hydrocarbons—fall below the standard set for the engine size of the vehicle.

There were more than the usual start-up problems with the new test. Failure rates for vehicles tested under the idle test had leveled off at 5-6% of the tested fleet. Initially, the results under the new test procedure were similar. The new test is judged to be more stringent, and more failures were expected. New equipment was placed in service starting in the second half of 1998. System leaks were uncovered and the failure rates increased each quarter from the fourth quarter of 1998 through the third quarter of 1999, rising from just under 5% to over 10% of the tested vehicles. The committee judged that this new measurement program was not in control because the number of failed vehicles increased each quarter. If the vehicle emissions testing procedure was issuing false passes early in the period, then there were excess emissions into the state's atmosphere in 1998 and early 1999.

The CASE committee recommended that vehicles less than four years old be exempt from the emissions test because their failure rate was less than half a percent. Remote testing, which is part of the new state plan for additional emission reduction, was endorsed. Comparison of emissions from failed vehicles to their second test was recommended; however, new Federal Regulations require this analysis after two years of the enhanced test program. Finally, the committee recommended a quality assurance program to stop the errors made in the startup of the enhanced program, and to provide some confidence that the $27,000,000 spent by state residents each year achieves reliable measurements so that reduced emissions are not only realized, but demonstrated. — ***Norman Bowne, Chair***

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