Energy Studies

Volume 15 Number 4
March/April 1990

Newsletter of the Center for Energy Studies of The University of Texas at Austin

Energy Studies reports on activities of the Center for Energy Studies and other energy-related news from The University of Texas at Austin. Subscription is free upon request (six issues a year). ISSN: 0743-829X.

The Center for Energy Studies is a multidisciplinary research center, the central liaison for energy research, education, and public service at The University of Texas at Austin. Dr. John R. Howell is director.

Editor: Jennifer Evans

Searching for what to do with nuclear waste

Engineering professor Dale Klein says we should store spent nuclear fuel for the short term in one central place

The Commission on Monitored Retrievable Storage recently reported to Congress its qualified support of a centralized, temporary facility to hold spent nuclear fuel before it goes into a permanent repository.

Dale E. Klein served as one of three members of the commission. He is a mechanical engineering professor with experience in nuclear energy and heat transfer, as well as a researcher with the center and its former deputy director.

As associate dean for research of the College of Engineering at The University of Texas at Austin, Dr. Klein directs the Bureau of Engineering Research and oversees the college's research endeavors, which grew to a level of $50 million last year. Dr. Klein was named Engineer of the Year in February by the Travis Chapter of the Texas Society of Professional Engineers.

In this interview Dr. Klein discusses the vehement national debate over a proposal to store high-level nuclear wastes temporarily at a central site and what the future holds on the issue.

Dale E. Klein

What is the MRS?

The MRS [Monitored Retrievable Storage facility] basically is an interim storage concept for spent nuclear fuel from commercial reactors. The electric utilities are running out of space in their spent fuel pools. Several utilities are having to store spent fuel in metallic casks or in metallic tubes in concrete bunkers above ground.

Is it true that utilities generally store spent fuel rods under water?

(Continued on next page)

Meeting set May 22–23 for companies to explore joining Environmental Solutions Program

An informational meeting for companies and institutions interested in participation in the new Environmental Solutions Program will be held in Austin May 22–23.

The Environmental Solutions Program involves fifteen UT Austin faculty and staff from five engineering disciplines who bring to the program more than $2.3 million in technical

(Continued on next page)

(Dale Klein, continued)

Yes. A fuel rod assembly is a few inches wide and roughly 10 feet long. It has individual rods about the size of your finger in it. The South Texas Nuclear Plant, for example, has about 190 assemblies in the core. A third of those are taken out each year and stored in water to let them cool both thermally and radioactively.

The original intent was that, after the fuel rods had cooled in water for six months, you would take them to a reprocessing plant to get out the good uranium and plutonium and then throw away the true waste. That's what France, Great Britain, and Germany are doing. In this country no one in the industry expected a utility would have to store its spent fuel on site for a long period. The bottom line is, the utilities have run out of space and are having to go to dry storage above ground.

The difficulty with storage at the plant sites is that each utility will do its own thing, and we're going to go back to nonstandardization, just as with the reactors. Then when we start moving this material to the final repository, it's going to be in different packages, it's going to be different weights, it's going to be in different configurations, and it's going to make the high-level waste program more difficult to manage—unless there is a central, standardized facility.

That's what the MRS is: a central standardized dry-storage facility that all the utilities can use, before the waste goes to the permanent geological repository.

> Without an MRS, we will ultimately get to the point of having more than 70 baby MRSs.

What opposition has there been to an MRS?

A comment we heard in our commission hearings from a variety of people with a variety of agendas was that if there is a central storage technique, then there will be no incentive for the government and the utilities to move toward a *permanent* geological repository—and that the MRS then will become a de facto permanent repository. I personally don't believe that. Some individuals want to stop nuclear power, and they see stopping a solution to waste disposal as a means to accomplish that. Some think that an MRS will open up the system for reprocessing. Whether the United States reprocesses commercial spent fuel depends upon a variety of issues, especially economics. The MRS is a simple concept, but a complicated issue.

What are the advantages of one temporary nuclear storage place?

We have more than 70 reactor sites. Without an MRS, we will ultimately get to the point of having more than 70 baby MRSs. Each utility will have to do its own at-reactor dry storage. It would be better to have one standardized facility with trained personnel to deal with the temporary storage of the spent fuel.

Currently the law says spent fuel can't be placed in an MRS until a permanent repository is built. Is that a good idea?

What that linkage of time does is cause all the uncertainties of the permanent solution to be placed on a temporary solution, and it makes the MRS essentially worthless, in my view. All the uncertainty and schedule slippages that will occur on the repository—because of the technologies that need to be developed—are then laid right upon the MRS.

The reason for the time linkage is the fear that the MRS could become a de facto repository. One thing that

(Continued on page 3)

(Environmental Solutions Program, continued)

environmental research already under way. About 50 graduate students work in these projects.

The main categories of the research are

- waste minimization
- treatment of sludges
- air pollution control
- treatment of water
- site remediation
- waste containment and isolation
- environmental assessment
- energy-environment interactions

Companies that join the program will have access to research results 3 to 24 months before publication, nonexclusive license to patents developed by the program, a channel for recruitment, and a variety of related benefits. Sponsors may attend presentations of research results twice a year. By the second year, the program is expected to make available to sponsors 200 published and unpublished reports, articles, theses, computer manuals, and software.

The leveraging aspect of sponsorship is a significant one. For the yearly sponsorship fee, a sponsor will receive access to many times that amount of research, including research funded outside the program.

Raymond C. Loehr was appointed in March as the program's director. Dr. Loehr is a professor of civil engineering and an expert on industrial and hazardous waste treatment, including bioremediation. He chairs the Science Advisory Board of the US Environmental Protection Agency and has been active on the board since 1976.

The new program will be jointly administered by the UT Center for Energy Studies and the Center for Research in Water Resources. ■

To attend the May 22–23 meeting and receive the ESP prospectus

To register for the informational meeting for prospective sponsors or to obtain a prospectus on the Environmental Solutions Program (scheduled for release in April), call Charles Tischler, UT Center for Energy Studies, 512/471-7792. The day-and-a-half meeting is set for May 22–23 in Austin, Texas, and is free.

Those who have questions or wish to discuss the Environmental Solutions Program are welcome to call José Luis Bravo, 512/471-0939.

was interesting on our commission was that the three commissioners had different viewpoints. I think our chairman, Alex Radin, does believe the MRS could become a de facto repository. I just don't believe that, because one is a central, temporary, above-ground storage and the other is a permanent disposal technique. From a technical perspective I don't see the coupling. However, Alex has been involved in policy issues for a number of years and he has a perspective different from mine.

What were the main findings of the commission?

What we tried to do, based on having studied this issue for about two years, was to come up with recommendations to Congress on how to solve this contentious issue.

The public perception of the high-level waste issue is much different from the reality. People tend to view it in terms of a very difficult problem that has no solutions and involves imminent danger. But in reality nuclear waste is just a very small problem of a much bigger chemical waste problem that we have in this country. With nuclear waste the volumes are small, and we have several technical solutions for it.

We don't *have* to have a permanent solution today for nuclear waste. We can in fact store it above ground for several years—hundreds of years, if we need to. The difficulty is the public perception that it's a problem we have to solve today. That's not quite correct. We *should* solve it, but we don't have to bury these wastes in the next five years. In general, the Europeans have come up with a temporary solution to their waste problem much better than we have.

What do the Europeans do?

France and Great Britain have a large facility that reprocesses spent fuel from several countries. After reprocessing they place the waste in glass logs, again standardized, stored in a tube underground. They plan to store the glass logs for at least 50 years, as they march toward a permanent geological solution.

In the United States, it's different. We seem to have to solve the permanent storage problem before we can solve the temporary storage problem. It's just backwards.

Do you think utility workers or the public are endangered by above-ground storage at utility sites?

No. That is one of the commission's findings. You can store the waste safely at reactors and at a central storage site, but in my view central storage is more prudent. The cumulative advantages on several issues add up to make centralized storage better. What Congress wanted was one little flag they could hold up and say, "This is the reason we need to have central interim storage," and there's no one little flag that does that. Economics alone won't justify it; safety alone won't justify it; environmental consequences alone won't justify it. But all together the advantages sum up and weigh toward having a central facility.

> Nuclear waste is just a very small part of a much bigger chemical waste problem that we have.

The thing that's amazing to me when we look at the issue is that it's not primarily a technical issue. We know how to do interim storage. The technologies are relatively benign. The spent fuel is in a passive mode. It's not like a working reactor. You just put it in a strong container and it sits there. But yet it arouses a lot of emotions. It's safe, it's clean, the risks are well understood and much lower than other risks we routinely undertake. The public policy tail is wagging the scientific dog.

As you see the delay for the permanent storage stretched further and further into the future, it argues, I think, more and more for the need for central interim storage. If we don't do that, we're going to have more than 70 baby MRS sites.

My view is that there has to be some kind of linkage with the permanent repository other than time; otherwise, the MRS could end up being a de facto repository. The linkage may be tonnage, financial—there are a variety of linkages possible. We tried to say very clearly in our recommendations that a time linkage tying the central interim storage to the permanent repository is not a valid linkage. It puts all the uncertainty of the geological solution on the interim solution, and that's just inappropriate. It's very impractical and not logical.

How would a tonnage linkage work?

Only a certain number of tons of spent fuel could be stored at a central storage facility and no more, until a permanent repository was built.

What do you think is going to happen on the MRS issue?

If you ask ten different people that question, you'll get ten different answers. It's a political problem more than a technical problem. DOE is currently looking at a way to get the linkages removed, as the commission recommended. People have dug in their heels on both sides in Congress.

It seems that in general the Senate has favored central storage and in general the House has opposed it, perhaps somewhat because of the different ways they're elected. The law, as it stands now, links the permanent and interim measures in time and tonnage. This being an election year, I don't see any significant legislation coming through soon—but I've been surprised before.

Has this experience as a federal advisor affected what you teach young engineers?

The most important concept that I try to convey now to my students is that they need to come up with sound, logical technical assessments. But their job is only beginning. They need to communicate to the public why that technical solution is needed. Engineers typically are the infamous quiet, shy, and bashful type. They need to go to Rotary groups, their churches, their neighborhood associations. As engineers, we need to give the public more correct information and a more balanced view than what they get from the media. My classroom now is not just the engineering students in my classes. It includes the general public as well. ■

CES Update

Building Energy Systems

Building Energy Systems researcher John L. Peterson has been appointed to a nine-member committee of ASHRAE that will update **ASHRAE'S energy policy** and make recommendations on the National Energy Strategy being formulated by the US Department of Energy. ASHRAE is the American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

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Jerold H. Jones, Building Energy Systems researcher and professor of mechanical engineering, has been awarded the Faculty Excellence Award of the UT Austin Department of Mechanical Engineering.

Electric Power

W. Mack Grady will teach two short courses at UT Austin: **"Power System Harmonics,"** June 4–6, and **"Fundamentals of Electric Power System Engineering,"** June 11–15. Dr. Grady is a center researcher and an associate professor of electrical and computer engineering.

For further information, contact Continuing Engineering Studies, The University of Texas at Austin, Austin, Texas 78712 (512/471-3506).

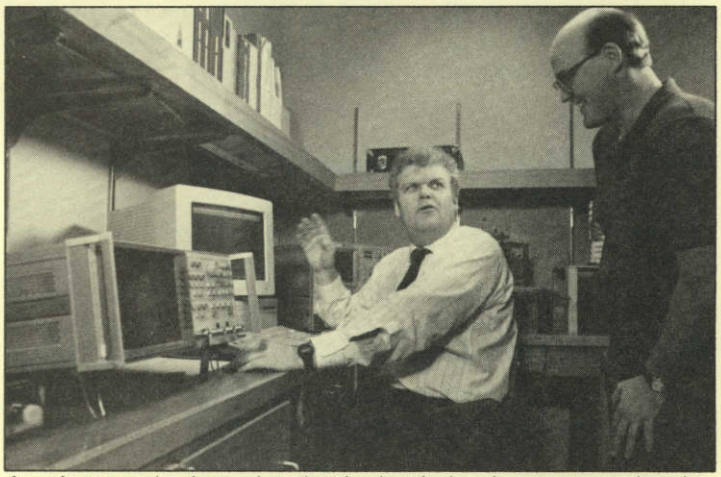
Process Energetics

Uneven heating is a common problem in microwave and radio-frequency ovens, both the small home units and the huge industrial-scale ovens. Process Energetics researchers have demonstrated that the shape of an object heated with microwaves can be a major cause of uneven heating.

Hot spots are undesirable because they can damage the microwaved material or require that the heating be done more slowly.

It has generally been thought that uneven microwave heating is caused by interference zones where the microwaves intersect inside the oven and that the problem can be fixed by improving oven design.

John A. Pearce disagrees. Dr. Pearce is a UT associate professor of electrical and computer engineering who, with doctoral student Sung-il Yang, recently completed a study of uneven microwave heating. The research was funded by the Electric Power Research Institute, the National Science Foundation, and the Energy Research in Applications Program of the state of Texas.



A professor and a doctoral student in electrical and computer engineering, John Pearce (left) and Dwight Munk, use an array of computer-controlled devices to explore the dielectric properties of microwave and radio-frequency heating.

"One may spend a great deal of time designing the oven cavity," he said, "but if you have an oddly shaped object, you'll have hot spots in the object, even if there is no resonance effect in it."

Strong interference patterns should not be present in large industrial ovens because a device called a mode stirrer rotates and reflects the microwaves in all directions. Thus the microwaves, on average, intersect fairly evenly throughout the oven.

Yet some objects develop hot spots even when the microwaves seem to be well distributed. The researchers' experimentation and modeling showed that conditions at the boundary between the air and the surface of the material engender the hot spots.

In the experiments the researchers suspended a sphere in the middle of the center's 6-kilowatt microwave oven and, through thermographic measurements, found it heated evenly. When rectangular and cylindrical test objects were treated the same way, however, they heated unevenly. For example, with one rectangular sample of polysaccharide (a water-saturated polymer), the middle of a side heated to 21° C, the edges to 35° C, and the corners to 37° C.

"Microwave heating is much more intense at the corner than at the edge, and much more intense at the edge than at the center of the surface," Dr. Pearce said.

The geometry of the object affects its microwave absorption in two ways, the group has discovered. First, because of their shape, edge areas can absorb microwaves from two directions, and corners can absorb them from three directions. Second, microwaves bend as they leave the air and enter an object. The more complex the geometry of the boundary—an edge or a corner versus a flat plane surface—the more the heat is concentrated.

The experimentation was simple compared to the computer modeling of the phenomenon, Dr. Pearce said.

Dr. Yang, who received his PhD in August, created a model of microwave heating of three shapes: a rectangular block, a wedge, and a cylinder. The model divided each object into 400 parts and solved 1,200 simultaneous equations to derive the spatial distribution of power density. A Cray supercomputer was used because of the complexity of the calculations. The results of the modeling conformed well to the experimental data.

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The **Texas Drying Research Consortium,** a joint effort of the

(Continued on page 5)

Process Energetics Program and researchers at Texas A&M University, has formed an advisory council. The purpose of the consortium is to investigate improvements in industrial drying processes. The advisory council will help guide the research and widen its applicability to industry.

Texas Drying Research Consortium Members: Wilfred Bourg, Frito-Lay, Inc.; Charles Moyers, Jr., Union Carbide Corp.; Tom Blackwood, Monsanto Chemical Co.; Edward Kelleher, Champion International Corp.; Wing Seto, International Paper Corp.; Ron Yeske, Institute for Paper Science and Technology, Inc.; Dick Alescio, Brown & Root USA, Inc.; Jeff Pulkowski, Beloit Corp.; James Kelly, Aeroglide Corp.

Invited Observers: Dan Wiley, Office of Industrial Programs, US Department of Energy; Ammi Ammernath, Electric Power Research Institute; Les Donaldson, Gas Research Institute; William Hazard, Texas Higher Education Coordinating Board.

Separations

Separations researchers have discovered a way to **separate a paraffin-olefin mixture by means of adsorption.**

Paraffin-olefin separations are an important step in the making of raw materials for most plastics. The leading commercial process, a type of high-pressure distillation, is expensive and difficult because of the molecular similarity between the two hydrocarbons, according to José Luis Bravo, manager of the center's Separations Research Program.

Adsorption has never been used commercially for separating paraffins and olefins, and most experts have thought the idea was not possible, said Mr. Bravo. In adsorption, a gas or liquid mixture is put through a bed of solid particles (such as activated carbon or synthetic zeolite) that contain microscopic pores. One kind of molecule in the mixture adsorbs (adheres) inside the adsorbent's pores more strongly than others. These molecules are thus separated from the mixture. Eventually the adsorbent becomes saturated, but usually can be emptied and used again.

Finnish researcher Harri Järvelin and others are separating propane from propylene with adsorption under low pressure.

One of the primary reasons that certain molecules remain in a conventional adsorbent while others do not is that the adsorbent's pore openings are a certain size. Larger molecules are excluded, while smaller molecules do pass inside and adsorb. For this reason synthetic zeolites are called molecular sieves.

Paraffins and olefins having the same number of carbon atoms are about the same size, however, and thus do not seem to be good candidates for separation by adsorption.

In experiments conducted by Harri Järvelin, visiting researcher from Neste Oy in Finland, six commercially available adsorbents were tested for their ability to separate propane (a paraffin) from propylene (an olefin) in nitrogen under low pressure.

In the experiments two synthetic zeolites of types X and A performed well as adsorbents. (Activated carbon, alumina, one other zeolite, and silica gel performed poorly.)

The performance of the X and A zeolites surprised the researchers. Another odd fact is that propane and propylene are both known to be small enough to fit through the zeolites' pores, Mr. Järvelin said. Yet only propylene was adsorbed in large amounts. Therefore the cause of the separation did not seem to be size differences nor diffusion rate differences, which are size related.

The researchers said one possible explanation is that propylene has more chemical affinity than propane for the zeolites.

"What is the chemical at the bottom of the pore? Not only their pore geometry but also their chemical composition can affect the performance of zeolites," Mr. Bravo said.

"Nobody believed you could do it," Mr. Järvelin said. "This project shows you how much is unknown in adsorption. It's still a little bit mysterious."

Although the experiments demonstrate that paraffin and olefin can be separated by adsorption, the process has a long way to go before commercial viability. Mr. Bravo said that the separation would be more useful to industry if it could be modified so that the paraffin rather than the olefin was adsorbed onto the zeolite. In a chemical plant such mixtures are usually processed under high pressure, and separation of paraffins and olefins by adsorption has yet to be demonstrated at high pressure.

The investigation has been a synergistic project, drawing on the experience of the program's membrane experts, as well as being the group's first venture into development of an adsorption process, according to Mr. Bravo. Other participants in the study were Susan M. Jordan, postdoctoral fellow, and James R. Fair, program head.

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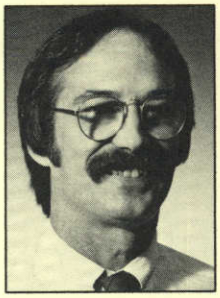
The Separations Research Program has scheduled **two conferences** to present research results to its sponsors: the first April 10–11 in Austin and the second May 16–17 at the facilities of Dow Benelux in Terneuzen, the Netherlands. ■



Ronald D. Matthews

Matthew Hall

Correction: The photographs of Ronald D. Matthews and Matthew Hall were mistakenly switched in the previous issue. Dr. Matthews is an associate professor of mechanical engineering. Dr. Hall is a new research fellow with the Combustion Research Group.

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UT Austin Energy

Mark and Fisher appointed to top DOE advisory board

Two energy experts from The University of Texas have been appointed to a new high-level board of the US Department of Energy, the Secretary of Energy's Advisory Board.

The two are Hans Mark, chancellor of The University of Texas System, and William L. Fisher, director of the UT Austin Bureau of Economic Geology and chairman of the Department of Geological Sciences. The appointments must be approved by the UT System Board of Regents.

Bush spokesman points to new foreign markets for US energy firms

A tremendous increase in opportunities abroad for US energy companies lies ahead in the 1990s, predicted Thad Grundy, Jr., deputy assistant secretary for international affairs for the US Department of Energy.

Mr. Grundy spoke February 10 at a symposium on international energy trade and regulation sponsored by the *Texas International Law Journal* and the UT Austin School of Law.

He said the Bush administration and the US Department of Energy (DOE) are launching a major export initiative in international markets that is expected to help the domestic oil and gas industry compete abroad. They are also preparing a national energy strategy to be unveiled April 1 and presented to Congress.

The export initiative calls for the federal government to increase its aggressiveness in representing US energy companies selling abroad.

"The United States has the best-trained petroleum service sector in the world," Mr. Grundy said.

He identified four areas of the world as holding the greatest promise for US companies: the Soviet Union and Eastern Europe, the Middle East, the Pacific Rim, and the Western Hemisphere.

The Soviet Union and Eastern Europe represent the biggest opportunity, according to Mr. Grundy, because they are a large market unable to meet their own demand because of glaring inefficiencies in the Soviet Union oil and gas industry.

Soviet oil production fell 240,000 barrels a day in the first few months of 1989, as compared with 1988, he said. By 1995 DOE predicts Soviet production to drop by 2 million barrels a day from the 1988 levels. "The Soviets are using technology discarded by the United States oil and gas industry in the 1930s and 40s," said Mr. Grundy.

The Soviet Union is expected to severely curtail exports to Eastern Europe and raise prices on what remains. Mr. Grundy said that pressure to bolster the industry will increase because sale of oil and gas is the main way the Soviet Union can obtain hard currency to buy consumer goods demanded by its populace.

He reported that the first energy trade meeting in ten years between US and Soviet officials occurred recently, and a spring meeting in Moscow is planned.

Mr. Grundy cautioned, however, that 30,000 Soviets stood in line to receive their first MacDonald's hamburger. Monumental delay and bureaucratic inefficiency are accepted as a fact of life in the Soviet Union and are bound to hamper business development.

In the Middle East, demand for oil is projected to increase. Opportunities for American oil service and equipment companies are likely to arise when the Middle East is forced to call on outside help to increase its production.

With its economic boom, the Pacific Rim is experiencing rapid growth in energy consumption and is growing as a market for refinery and service equipment.

Within the Western Hemisphere, Mr. Grundy said, the best opportunities exist in Mexico, which has made major strides in opening its economy; Venezuela, which is seeking private partners in certain areas of its government-controlled oil industry; Argentina, now privatizing its oil industry; and Chile, the most open and dynamic economy in South America in many ways. ■