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Energy Studies

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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).

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. Herbert H. Woodson is director.

Editor: Jennifer Evans

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Indirect Evaporative Cooling System May Cut Summer Energy Peaks

Today's version of the swamp cooler shows promise as a way to save energy costs in commercial buildings, according to Conservation and Solar Energy Program researchers.

The swamp cooler is one of many forms of evaporative cooling. Each is based on the fact that air blown across water speeds evaporation, which significantly cools both the air and the water.

Since ancient times, people have exploited the cooling power of evaporating water in hot weather. Egyptian frescoes show slaves fanning large water jars; the surfaces of these jars were presumably porous enough to be wet. Ancient Persians as well as American Indians covered their tents with felt that was then doused with water. Western pioneers kept food in a cool box covered with wet cloth and placed in a breezy window.

In the 1940s and '50s, millions of evaporative coolers were in use in the United States, mostly in dry climate areas. But today less than 5

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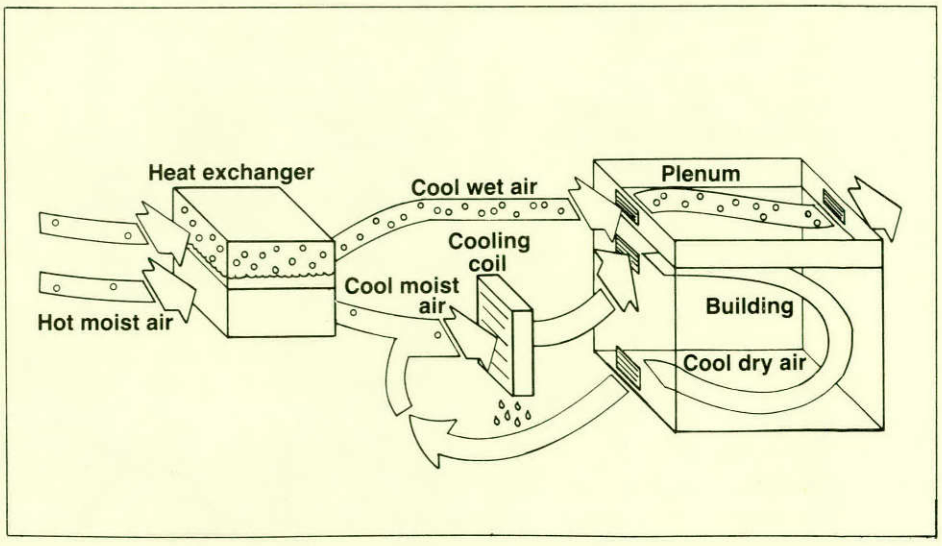

This system combines indirect evaporative cooling with vapor-compression cooling. It cools the interior space and the ceiling plenum in a one-story commercial building.

percent of the cooling in these areas is evaporative. The reason is that vapor compression has taken over as the standard form of cooling.

John Peterson, conservation and solar energy researcher, said that, according to recently completed research, a system combining vapor-compression and indirect evaporative cooling (combined system) seems to have significant advantages over either system alone. (Direct evaporative, indirect evaporative, and vapor-compression cooling are described in the accompanying box.)

Effect on electric peaks. In commercial buildings in most of the United States, the combined system studied could reduce peak summer electric demand and energy bills, he said.

Peterson and Bruce Hunn, manager of the center's Conservation and Solar Energy Program, have done detailed studies of a system incorporating indirect-evaporative and vapor-compression cooling equipment into the air conditioning of a 10,000-square-foot office building (see diagram). Their findings indicate the system could reduce the peak summer demand of such a building by 11 to 16 percent, depending on climate.

"I would encourage utilities to look at the results," Peterson said. "Eleven percent of a building's total demand may not sound like much to a layman, but it is a lot when you consider the potential benefit to an electric utility."

Many utilities agree and have begun offering cash incentives for energy-saving features to be installed in commercial buildings. Frequently they also charge commercial users an expensive premium for occasional high peaks of electricity use, called a "demand rate."

In the study, the researchers modeled a typical one-story office building with a conventional vapor-compression cooling system installed on its flat roof. The system's modeled performance was compared with that of a similar system having an indirect evaporative cooling stage to precool the outside air.

Cooling the plenum. The combined system has an innovative feature: the wet-side air is exhausted through the plenum (the space between the ceiling and the roof). The plenum is quite hot in the summer because it is filled with heat from the sun beating down upon it and the heat from the building's lights. The cool, wet-side air blowing through the plenum counteracts this heat buildup considerably, Peterson said.

The wet-side air is humid, but the 90 percent or so relative humidity of the air that enters the plenum is reduced to about 40 percent by the time it exits. This amount of humidity is not expected to encourage mildew or mold in the plenum, especially since an office building's air conditioning is usually turned off at night, Peterson said.

The savings to utilities were found to be quite high: to build a base-load power plant currently costs $1,500 per kilowatt of capacity. To build and install combined systems (equivalent to deferring a power plant) was calculated to cost only $85 to $340 per peak kilowatt.

The researchers estimated that the combined system would cost about $700 more to install in a new office building than a conventional vapor-compression system. It would pay for itself in utility bill savings in eighteen months or less.

"This is one technology we feel is the cream of the crop," Peterson said.

The reason why peak kilowatts can be saved in this way is that the peak demand on many electric utilities occurs on the hottest summer afternoons. The peak demand of commercial buildings generally occurs then also. Evaporative cooling works best on hot days.

Power plant alternative. The economics of the combined system studied did not vary much among the climate regions, except Houston, Dr. Hunn said. It seems to be cost effective in all regions, even in a muggy climate such as Houston's.

The center study is the first to examine this combined system that integrates plenum cooling. No actual systems of this type have yet been built and tested in operation.

Indirect evaporative cooling may have been overlooked until now because it principally has been considered a way to reduce overall electricity use rather than peak demand. As the cost of new power plants rises and the expense of demand charges increases, the more attractive become systems that reduce commercial peaks. ■

Three Ways to Cool Air

Direct Evaporative Cooling

The concept of direct evaporative cooling is fairly simple: Water sprays or trickles over a mat made of a porous material such as cellulose, spun glass, wood excelsior, or mineral wool. The water thus spreads out over a large surface area. Air is blown directly through the mat. Water evaporates into the air, cooling the air. A fan blows the air, now cool and humid, into the building.

Indirect Evaporative Cooling

In indirect evaporative cooling, the process is mostly the same, except that the final cooled air is kept dry. One stream of air is cooled through direct evaporation (described above). It enters a heat exchanger, made up of plates (or tubes). The heat exchanger plates are stacked in alternation so that maximum heat transfer occurs across each plate, from the stream of outside air (the "dry side") into the stream of evaporatively cooled air (the "wet side"). Thus the outside air is also cooled, but never gets mixed with the wet air. The wet-side air is usually exhausted to the outside. The dry, cooled air goes into the building.

Vapor-Compression Cooling

A vapor-compression air conditioner is the type found in most US homes and offices. It works because of an interesting characteristic of its working fluid: a refrigerant (such as freon) that literally vaporizes, turning from a liquid to a gas, at about −60° F.

In vapor-compression cooling, the liquid refrigerant passes through a valve that reduces pressure. The fluid starts to vaporize. Vaporization causes it to pick up heat from a nearby stream of air (from the building), vaporizing it still further. The air is thus cooled and flows out into the building.

The working fluid is left in a useless state, however—a heated gas under low pressure. To return it to the cooler, higher pressure form, it is first compressed, then cooled and condensed back into a liquid.

Since Three-Mile Island

Engineer Herbert Woodson says nuclear energy has matured since March 28, 1979

(Editor's note: Dr. Herbert H. Woodson, director of the UT Center for Energy Studies, gave a talk October 11 entitled, "Since Three-Mile Island: The Prospects for Nuclear Power in the United States." The article below is Part One of a two-part series excerpted from that talk. Dr. Woodson is a member of the board of directors of the Atomic Industrial Forum and chairman of the Energy Engineering Board of the National Research Council.)

As I read the popular press, I sometimes get the idea that nuclear power is something that we are going to start trying to use sometime in the future. As of the first of January, 1984, there were 76 reactors in commercial operation in the US capable of generating 60,000 megawatts. That is to be compared with the total US installed electric generating capacity of 658,000 megawatts (see table). That is a sizeable fraction of generation, and roughly a $60 billion investment. Conclusion: nuclear power is a reality. It is not something to be tried sometime in the indefinite future.

As of January 1, 1984, nuclear units with construction permits include 39 units more than 50 percent complete, 10 units 25 to 49 percent complete, and 3 less than 25 percent complete (see table). There's a lot of speculation about whether these will be completed. My own guess is somewhere around 40 to 45 of these units will be completed, perhaps more.

The fraction of our energy generated by nuclear power in 1983 was 12.7 percent; in 1984 through June it was 13.4 percent. That amount is comparable to what we generated with hydro or natural gas.

In 1984 through June the state of Vermont was 74.8 percent dependent on nuclear energy for its electricity: South Carolina, 55 percent; Connecticut, 51 percent (see table). Among regions, New England was most dependent, getting a little more than a quarter of its energy from nuclear. The South Atlantic, all the way from Delaware down to Florida, was 23 percent. The Mid-Atlantic, New York, New Jersey, Pennsylvania, almost 19 percent.

Before Three-Mile Island, I think there were three problems with nuclear power: first of all, there was an almost total preoccupation with what is called a design-basis accident. This is the worst imaginable, physically possible accident, but extremely unlikely. Everybody got preoccupied with that catastrophic accident, and didn't worry about the less serious accidents that can cascade into real problems.

Within the utilities, I think there was a lack of appreciation for the complexity of nuclear power plants. And of course there was lack of experience in operation. If TMI hadn't happened, a similar event would have happened somewhere else, as part of the maturing process.

The accident. What actually happened at Three-Mile Island? Well, there was an equipment malfunction with complications. A feedwater pump shut down. As expected and planned for, the pressure in the reactor immediately started increasing. To alleviate that, a pressure relief valve opened. The pressure was relieved and then that valve stuck open when it should have closed.

That was the malfunction. To compound the problem, the indication in the control room was that the valve was closed. There were conflicting indications in the control room as to what was going on. The operators had conflicting signals, they made a rational choice, and it happened to have been the wrong choice. The net result was that the core suffered severe damage. Still, there were no injuries to the people who worked in the plant or to the public.

There tends to be a reaction in some circles to say, "That proved nuclear energy is really a dud and so we better get rid of it." The industry didn't react that way.

The first thing they did, within three weeks of the Three-Mile Island acci-

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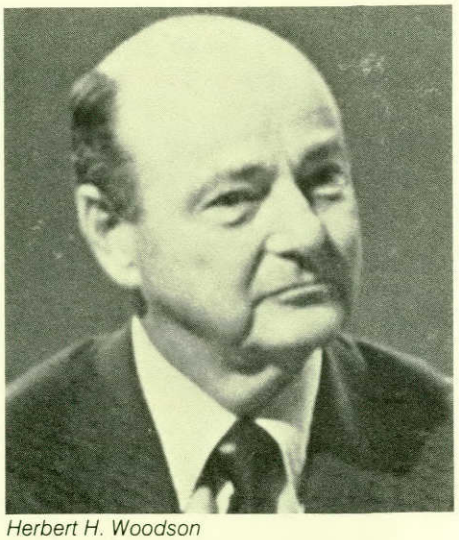

Herbert H. Woodson

Nuclear Reactors Operating in the United States

76	in commercial operation	60,233 Mwe*
3	with full-power operating licenses	3,180 Mwe
3	with low-power operating licenses	3,428 Mwe

Reactors under Construction

39	more than 50% complete
10	25% to 49% complete
3	less than 25% complete

*1 Mwe is 1 megawatt (electric), the same as 1,000 kilowatts of capacity. The country's total installed electric generating capacity is 658,173 Mwe.
(Jan. 1, 1984. Source: Atomic Industrial Forum.)

States Most Dependent on Nuclear Energy

	Nuclear % of Total Generation
Vermont	74.8 %
South Carolina	55.4
Connecticut	51.4
Virginia	49.4
Maine	41.4
Arkansas	38.4
Nebraska	33.8
Minnesota	32.3
Alabama	30.9
Maryland	29.5
Illinois	29.0
North Carolina	27.1
Total US Average	13.4 %

(Jan.-June 1984. Source: US Energy Information Administration)

dent, was to establish the Nuclear Safety Analysis Center. It is headquartered at the Electric Power Research Institute in Palo Alto. The first accomplishment of NSAC was a minute-by-minute reconstruction of what happened at Three-Mile Island. That description to this day has proven to be a very accurate one.

Every time something out of the ordinary happens in a nuclear plant, the operator has to prepare a written report and send it to the Nuclear Regulatory Commission. Utilities in 1981 filed something like 5,000 of these. About 2 to 3 percent of these reports are really significant. The Nuclear Safety Analysis Center takes the ones that appear to have significance and does some simulation anc study of what would be the consequence of something else happening on top of that. The Nuclear Safety Analysis Center runs at something like $10 million a year and continues to study safety issues.

Within about a year of Three-Mile Island, another organization was established, called the Institute of Nuclear Power Operations, headquartered in Atlanta. Its members are all the utilities that operate nuclear power plants in this country plus some foreign utilities. It sets standards for operating nuclear plants and sends auditing teams into nuclear facilities once every year or two to audit operations. It also establishes what operator training should be and accredits training programs. If something unusual happens at one plant that might be of consequence to others, the institute sends that message out quickly.

Less radioactivity released. The operation of nuclear plants now is much better and safer than before TMI. Two other things have happened since Three-Mile Island. One was a realization that the containment might really be breached and release radioactivity, in which case it is necessary to protect the populace in the vicinity. That led to the development of emergency plans and the ten-mile evacuation zones.

But with Three-Mile Island, it was discovered that the breach of containment would not release as much radioactivity as originally expected. Primarily the radioactive iodine is of concern. But the iodine, instead of occurring as a gas, actually occurs as a salt that gets mostly dissolved in water. As a result, the potential for radioactive release is being reevaluated. When those results come out soon, it is expected that nuclear plants will be considered much less potentially harmful, from the viewpoint of release of radioactivity, than they had been before.

The second thing has to do with capacity factors. The capacity factors of nuclear plants have not been as high on average as people expected them to be. There is no fundamental physical or engineering reason why this must be so. A concerted, cooperative effort is underway within the industry to improve the capacity factors of nuclear plants. They are achieving some success. In 1983 there were 13 nuclear units that achieved better than 80 percent capacity factor. ■

(Part Two: Recent cost comparisons, a burst in electricity demand, and decommissioning costs.)

UT Austin Energy

More Field Tests Needed in Hazardous Waste Disposal, Engineering Professor Says

The US Environmental Protection Agency is placing more emphasis on field research as opposed to lab research in hazardous waste sites partly as a result of UT research studies.

Dr. David F. Daniel, UT assistant professor of civil engineering, said that the studies have also influenced states' regulation of hazardous waste sites. The reports in the three-year effort call for development of mechanisms for early warning of leakage at waste sites.

"For years, we've tried to determine how hazardous waste landfills would perform based on laboratory tests, but it's now clear we need larger-scale field tests to make good judgments about whether a disposal site will leak excessively," he said. Early warning would allow easier and cheaper repair of the leak.

Wastes with concentrated chemicals such as methanol, xylene (a paint solvent), trichloreothylene (used in dry cleaning), and acetic acid can destroy the impermeability of clay liners in landfills and should not be buried, one report suggests. Instead such wastes should be solidified before disposal or burned.

Research on compacted, man-made clay, conducted by several graduate students at UT, suggests that clay liners are a more effective barrier when the chemicals they hold are diluted in water. The clay is less likely to crack when a heavy layer of soil or waste is laid over the liner.

UT System to Enhance Recovery from Its Oil Lands

The University of Texas System Board of Regents has approved a $500,000 initial project to enhance oil recovery from reservoirs on university lands in West Texas. The research was proposed by the UT Bureau of Economic Geology.

The University Lands Office in Midland, Texas, and area operators and leaseholders will cooperate in the reservoir characterization project. Approximately $2 million is expected to be spent over four to six years.

About 128 oil reservoirs are currently being produced on university lands. They originally contained an estimated 5.5 billion barrels of oil.

Under present plans, an estimated 1.6 billion barrels of the oil, about 29 percent, will be recovered. The rest is now classified as unrecoverable by conventional means.

Recovering a portion of the remaining oil is a complex task, said Dr. William L. Fisher, director of the bureau. It will depend on future oil prices and on how well the reservoirs can be defined, characterized, and exploited, he said.

The initial effort by the bureau will involve subplay delineation of the reservoirs, ranking of subplays by estimated potential, and selecting reservoirs in top-ranked subplays for more analysis. A subplay is a portion of a play, a family of reservoirs.

Characterization of these selected, representative reservoirs is aimed at establishing geologic and fluid behavior models applicable to other reservoirs.

S. Texas Oil, Gas Activity Linked to Earthquakes

Recent mild earthquakes in South Texas may have been caused by

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CES Update

Office of Director

Dr. Herbert H. Woodson has been appointed to **the advisory council of the Electric Power Research Institute.** The institute was founded by US electric utilities to research improvements in how electric power is produced, distributed, and used.

Dr. Woodson has also been appointed to a subpanel of the federal Energy Research Advisory Board. The subpanel's task, he said, is to examine the infrastructure of energy R&D and make recommendations of needed changes. The subpanel's findings will be used by the Department of Energy in developing a new national plan for long-range energy research.

Conservation and Solar Energy

A computer tool for scrutinizing the **energy efficiency of evaporative cooling towers** has been created and tested by Conservation and Solar Energy researchers.

The tool, a computer program for a microcomputer, can be used in analyzing many different kinds of cooling towers under varying climate conditions. It is most useful to an engineer designing a tower or to a manager seeking to improve an existing tower's performance, according to Dr. Jerold Jones, UT mechanical engineering professor who supervised the project.

Mechanical engineering graduate student Gary Reichelt developed the program. A copy of it and a brief description of how to use it are available from Alice Wilson, Center for Energy Studies, ENS 143, UT Austin, Austin, Texas 78712.

Evaporative cooling towers are prevalent in cooling systems of large buildings such as offices. Refrigeration plants and industries that discharge significant waste heat, such as chemical processing and oil refining, also make use of evaporative cooling towers.

The purpose of an evaporative tower is to cool the condenser water of an air-conditioning (or refrigeration) system. Inside most towers of this type, water trickles over numerous wooden or plastic slats, spreading itself over a wide surface. Air is blown through the slats by fans. By evaporation and air contact, the water is typically cooled 80°F to 85°F.

Dr. Jones said that cooling towers are usually designed to meet the peak cooling required on a hot, humid day, when evaporation rates are poor and the efficiency of the tower is hindered. Less attention is paid to optimizing overall operation. The modeling project revealed that conditions vary significantly throughout the day and throughout the cooling season. These variations create opportunities for energy savings, in both the initial tower design and subsequent operation.

The computer program allows a designer to evaluate changes such as varying the air flow through the tower or varying the condenser water temperature.

"Which is most effective: keeping the fans on and driving the water temperature down as far as possible, or saving energy by reducing the air flow? It depends," Dr. Jones said. The model can compare these kinds of choices realistically. In particular, the important effects of the humidity content of the outdoor air can be examined.

Mr. Reichelt said that the program also revealed that two-speed fans may be more cost effective than other variable-speed fans. Variable-speed drives provide a 30 to 50 percent savings in fan energy with a constant condensing water temperature. However, the designer must also consider the impact on chiller operation. Chiller energy may be re-

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Photovoltaics Course Offered Dec. 3-4

As photovoltaics continue to drop in price, the market for the systems increases daily. Today, more than 6,000 homes in the United States receive all their electricity from the sun. Commercial and industrial installations are at a similar level and increasing. An understanding of photovoltaics is becoming more critical in the design professions.

A two-day course on solar photovoltaics systems will be offered December 3–4 at the Thompson Conference Center at The University of Texas at Austin. The course is organized by the University of Wisconsin Division of Extension and is sponsored by the UT Center for Energy Studies and the City of Austin Electric Department.

Participants in the course will learn how to design and size photovoltaic systems, to specify all components, to do economic analyses, and to install systems. Topics include the basics of photovoltaics, configurations, components, sizing methods, economic analysis, array mounting methods, utility interface issues, and small- and large-scale case studies. Workshop leaders will also discuss the near-term market outlook for photovoltaics.

The workshop leaders are

- Paul Maycock, president of Photovoltaic Energy Systems, Inc., Alexandria, Virginia; editor of *PV News*; and former director of the DOE Photovoltaics Division
- Steven Strong, president of Solar Design Associates, Lincoln, Massachusetts; and cochairman of the Second National Conference on the Application of Photovoltaics (November 1984)

The course is designed for engineers, architects, contractors, utility professionals, and energy managers. The registration fee is $325 and covers a notebook, refreshments, two lunches, and one dinner. To register, contact

Donald R. Schramm
Department of Engineering and Applied Science
University of Wisconsin—Extension
432 North Lake Street
Madison, Wisconsin 53706
608/263-7757

Maycock and Strong will give a more general talk on photovoltaics that is free and open to the public at 7 p.m., December 4, in the Austin Electric Bulding Auditorium, 301 West Avenue. ■

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duced more by operating the tower fans and reducing the condensing water temperature. The program allows the designer to consider these tradeoffs. ■

Center for Energy Studies researchers are helping **evaluate sites and alternative tracking systems** for a solar electric power plant, being considered by the City of Austin. If built, it would be one of only about ten large-scale photovoltaic plants in the nation.

Two studies are being undertaken, according to Dr. Bruce Hunn, manager of the center's Conservation and Solar Energy Program.

The first is a study of microclimatic variations in solar radiation. The researchers want to learn if solar energy patterns vary significantly among different locations near Austin. To accomplish this aim, four portable pyranometers, solar measurement devices, will be set up at locations within 40 miles of Austin.

"If we do not see variation 40 miles away, we do not expect it within 40 miles," Hunn said. By interpolating among monitoring points, researchers can build up a picture of the solar energy patterns of the whole area, including the best power station site.

The second study will compare the performance of two kinds of solar collector arrays. A tracking collector is designed to rotate throughout the day, keeping its face toward the sun. A fixed collector is less expensive to build but can be up to 30 percent less efficient because it does not move to stay faced toward the sun. Which type is more cost effective in the warm but somewhat cloudy Austin climate remains to be seen. ■

A computer **model of electricity supply in Texas** is being developed by a center researcher for the Public Utility Commission of Texas.

Younghan Kwun, PhD candidate in electrical and computer engineering, is working on the model under the supervision of Dr. Martin L. Baughman, center researcher and associate professor of electrical and computer engineering. Baughman returned to the university in September after a one-year leave of absence.

Jay Zarnikau, economic analyst in the Economic Research Division of the Public Utility Commission, said that the model will be used as a research tool in forming the Texas long-term electrical energy plan. The plan, done every two years, will be submitted to Governor Mark White at the end of 1984.

The model will allow the PUC staff "to examine the generation expansion plans of the state's electric utilities, cogeneration, marginal electricity costs, future fuel requirements, and other related issues," Zarnikau said.

Separations Research Program

Two more companies have become industrial participants in the Separations Research Program, bringing the total to 34 companies. The new firms are **Goodyear Tire and Rubber and FMC Corporation.** ■

(Continued from page 4)

activities in nearby oil and gas fields, according to a University of Texas scientist.

Earthquakes of 3.2 and 3.9 on the Richter scale occurred July 23, 1983, near the town of Fashing, and March 2, 1984, near Pleasanton. Oil and gas fields in the vicinity appear to have undergone large-scale depressurization as a result of fluid withdrawal, said Dr. Wayne Pennington of UT's Institute for Geophysics and Department of Geological Sciences.

The occurrences may be the first well-documented evidence of fluid withdrawal causing earthquakes without massive ground subsidence.

"The earthquakes all appear to originate on known faults where these faults form boundaries of an oil or gas field," he said. They represent little hazard to the community.

Production of oil and gas results in the lowering of fluid pressure in the reservoir rock. This, in turn, affects the strength of the rock. The two gas fields were discovered in the late 1940s and 1950s. Unconfirmed reports of earthquakes started in the late 1960s.

"What we think is happening is that the faults that are present have been moving naturally but without earthquakes until fluid pressure along them was decreased to a point where the faults would stick and slip in jerky motions, producing earthquakes," Dr. Pennington said.

The possibility of a large earthquake is remote, he said. ■