them and overloading still other generators in a cascading effect. The operator, faced with a thousand meters and dials, had to decide in a matter of minutes whether to turn off power to a limited area or risk a much larger blackout.

At MIT's Electric Power Systems Engineering Laboratory, Professors Gerald L. Wilson, Fred C. Schweppe and David N. Wormley and their students are developing an emergency state control system under the sponsorship of the Energy Research and Development Administration (ERDA).

This system will help avoid crises at two levels: At the local power plant, it will govern the power output so as not to put too much mechanical strain on the generator. At the regional "nerve center," it will advise the human operator as to what to do and will take some automatic action in case of a power outage.

The MIT project has two parts. One is the computer control system. The other is a miniature electric power grid on which to test it.

How does the computer "know" how to avert disaster?

The computer is programmed with a mathematical model of the network of power plants it is to control. The model predicts the future values of variables—such as currents, voltages and boiler temperatures—fed into the computer by remote sensors. Every so often the machine updates these values by receiving new sensory inputs, thereby improving its short-term mathematical extrapolation. This also allows the machine to perceive unexpected changes and begin extrapolating from the new state of affairs.

When an emergency arises, the computer advises the operator to react in such a way as to push the system away from the condition of emergency. Sometimes the computer controls these variables automatically—e.g., by directly governing the output of a generator.

What variables are important in assessing a state of emergency? One might think that only the fast electrical changes are important, but slow changes are also significant. In particular, one has to watch the boiler variables when there is a power drain, for it takes time to heat new steam in a boiler. Sensing these important slow variables is a big problem, for not many sensors can survive the inside of a boiler.

Within the next few months, the MIT group will begin testing the control system on a miniature power grid developed over the last eight years by Professor Wilson and Dr. S. D. Umans (see Reports on Research, Dec., 1974). The network of four 900-watt generators will be connected with circuit simulations of boilers. By simulating an emergency on a millionfold-reduced scale, the group hopes to test the control system's ability to cope with the crisis and minimize the power outage.

Although this test is only a steppingstone to trying out the system in an actual emergency, it is far superior to the common expedient of coupling a control system to a digital simulation of the situation to be controlled. A digital simulation oversimplifies the physical variables. Professor Wilson has said, "It is easier to design a digital system that controls a digital simulation than to design one that controls the real world."

—*Michael H. Brill*

Ultrasound Safe

MIT researchers have made important progress in demonstrating that ultrasound—high-pitched sound above the range of human hearing—will be safe when used in two newly-developed applications: destroying cancer tumors and identifying heart damage.

A group led by Dr. Padmakar P. Lele, director of MIT's Laboratory for Medical Ultrasonics, has determined that anchored tissues, such as brain and liver, can safely withstand the levels of ultrasound needed for these new applications.

The feasibility of using ultrasound to destroy tumors or to detect myocardial infarctions—patches of dead tissue in the heart muscle—has been demonstrated in previous studies by Dr. Lele, who is also professor of experimental medicine in the MIT Department of Mechanical Engineering.

In order to determine whether these uses of ultrasound will be safe, the researchers have examined three potentially damaging effects of ultrasound on tissue—cavitation, streaming, and heating.

Cavitation refers to the formation of tiny bubbles in tissue as a result of irradiation with ultrasound. These bubbles oscillate in the tissue, grow in size, and eventually collapse, causing local stress and releasing large amounts of heat at the points of collapse.

To examine the extent of cavitation in anchored tissues, Dr. Lele and research associate Dr. Nagabhusan Senapati irradiated samples of tissue with ultrasound while sending a second detecting beam of ultrasound through the tissues. Any cavitation in the tissue would scatter the detecting beam. Furthermore, the oscillating bubbles would generate ultrasound at half the frequency of the incoming beam, and the collapse of the bubbles would result in bursts of ultrasonic energy over a wide band of frequencies.

The researchers found that no cavitation occurred in anchored tissues until the ultrasound reached intensities hundreds of times higher than necessary for it to be effective.

Streaming occurs when the ultrasonic radiation differs in intensity at different points within the tissue. This can be due to an ultrasonic field with large intensity variations, or to the gradual loss of energy by the ultrasound as it passes through the tissue. The cells in the tissue will tend to move toward the areas of lowest intensity, placing a strain on the tissue, and possibly damaging it.

In order to determine if streaming could damage anchored tissues, Dr. Lele studied the effects of ultrasound on a sensitive physiological function—the conduction of nerve impulses. Ultrasonic radiation designed to maximize the occurrence of streaming was directed at the tissue. The results showed that streaming, alone, did not alter nerve conduction in any way.

The researchers then examined the effects of ultrasonic heating on tissues. They heated samples of tissue with bursts of ultrasound of different intensities and durations. They discovered that the tissues would be damaged only if they were heated past certain threshold temperatures and durations, which could be experimentally determined.

As a control, the experimenters heated samples of tissue directly, using electric heating elements, and they got results identical to those obtained with ultrasonic heating.

"We are confident, on the basis of our tests, that carefully controlled ultrasound can be used safely on anchored tissues," Dr. Lele said.

Continuing studies will determine the effects of ultrasound on unanchored tissues, such as blood and other body fluids.

—*PMR*

Hip Stresses

A group of MIT engineers have made important new measurements of the pressures inside the human hip joint in an attempt to discover the causes of a widespread form of arthritis.

The engineers are using a newly-developed hip simulation machine, and it has led them to quite unexpected results.

"The usual assumption has been that the pressure exerted by the thigh bone against the hip socket was uniform at all points in the socket, axisymmetrical, or at least well-behaved," said Dr. Robert W. Mann, leader of the investigation, "but our measurements indicate that the pressures are distributed in an irregular way, even in hip joints that seem absolutely normal."

A study of these irregularities, Dr. Mann speculates, many show that they are caused by minor abnormalities in the geometry of the joint, and the presence of these abnormalities may be related to the development of osteoarthritis, a degenera-