—or they can vibrate in a combination of these three. The problem has been to determine in advance what is likely to happen, and to correct any fault by adjusting the design.

The blades must not be allowed to vibrate at their natural or resonant frequency, for should this happen the stresses on them might be increased tenfold, disastrously, as a wine glass can be shattered by vibrating it at its natural frequency.

The turbine design engineer is well aware of the stresses induced by vibration, and can calculate them fairly accurately. Alternatively he can test selected stages of the turbine in full-scale models.

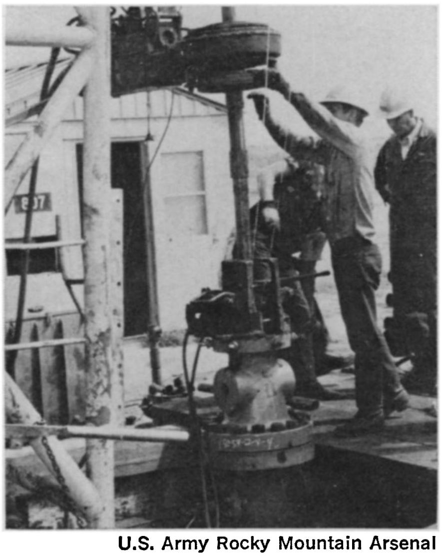
But calculation is complex and testing at full-scale is prohibitively expensive—unless 100 or so turbines are to be made to the same design. In the Queen only two turbines were required, so the ship had to provide its own test bed. This was one of the main reasons for trials before Cunard accepted the ship.

It was in the trials that the design fault showed up in the liner. The fact that the same row of blades became damaged in each turbine alerted the designers, Parsons and Marine Engineering Turbine Research and Development Association, and the builders of the turbines, John Brown Engineering, to look at vibration as the possible cause.

Until they are able to find the fault and remedy it the ship will remain at her anchorage at Southampton, used only for social functions and sightseeing.

QUAKE PREVENTION

Messing with the mousetrap



U.S. Army Rocky Mountain Arsenal

Pressure measurements at Denver.

California is sitting on a geological time bomb, overdue to explode. The bomb is the notorious San Andreas fault, a 600-mile-long fracture in the earth's crust starting 100 miles north of San Francisco, running southeast parallel to the coast and splitting into branches that run to the Imperial Valley and the Gulf of California.

It was 63 years ago that a horizontal slippage averaging 10 feet in the fault triggered events that destroyed San Francisco and killed 700 people. Geologists are certain another major quake will hit the fault region (SN: 6/10/67, p. 550), and probably within the next 30 years. Despite this certainty, California blissfully goes on constructing large housing developments and major engineering projects astride the fault, as well as selling sites for nuclear power plants.

The Federal Council for Science and Technology, in a recent proposal, recommends a 10-year national earthquake research program to find ways to predict when and where quakes will strike and how to minimize loss of lives and property (SN: 2/1, p. 113).

Unobtrusively listed at the end of six primary objectives of the program and couched in modest language is a phrase that is actually a plan to defuse and prevent earthquakes, or at least modify them.

Basically, the idea is simple: Inject fluid into underground rock, release the strain and produce a gradual series of tiny earthquakes or tremors instead of one violent jolt.

Ironically, the idea came about as a result of what looks like man-made earthquakes which themselves raised a storm of opposition: In 1962, the Army began pumping liquid chemical wastes into the ground near Denver, Colo. (SN: 5/4, p. 434). Soon tremors shook the area. The tremors continued through 1965, their number coinciding with pumping rate. As geologists reconstruct it, the rock at the Colorado dumping site was filled with vertical, parallel fractures or cracks, and was nonporous so it couldn't absorb the liquid. The liquid filled the cracks, widening them and reducing the friction between rock surfaces. The rocks, already under stress from internal forces, began slipping, producing the Denver quakes.

Three years before the first Denver quake, in 1959, geologists Drs. M. King Hubbert and William W. Rubey had already described the mechanics of the effects of fluid pressure on fault displacement. The Hubbert-Rubey theory states that rock strength is inversely related to pore pressure, the pressure of fluids in the rock spaces. As the pore pressure increases, rock strength decreases.

Geologists and geophysicists at the National Center for Earthquake Research in Menlo Park, Calif., are considering testing the theory, with an eye to its application in earthquake control. Right now, they are at the data-gathering stage, but within three to four years, they hope to complete field experiments.

One factor favoring the fluid injection method is the nature of West Coast earthquakes. Most of the world's earthquake activity takes place at relatively deep levels, but on the West Coast it is shallow enough to put it within reach of standard drills.

"We are excited about it," says Dr. John H. Healy, geophysicist with the U.S. Geological Survey at Menlo Park. "There is a remote chance that it might be used in the San Andreas fault and a fairly good chance we might try it in a remote section."

There is some evidence that the method can work. At the Rangely oil fields in western Colorado, one of the ways to get oil out of the ground is to pump water into the margins of the oil fields and remove the oil from the center. Seismic activity, in the form of small earthquakes, has been detected.

Dr. Hubbert is very cautious about the method. He feels that the consequences of employing a fluid pressure mechanism could go either way. "The increase of fluid pressure could set off a San Francisco earthquake," he warns, adding that it depends on the amount of stress on the rocks. "If there were little stress build-up, then it could work."

He compares the stress situation to that of a giant mousetrap: "A small act can release the trap. Fluid injection could produce a series of small jolts or set off a big one. Injections should occur at a minimum of stress. If you're going to mess with a mousetrap, mess with it when it's not set."

One other earthquake control idea being considered is the use of explosives to relieve the stress. However, that is not being seriously considered. The scheme would be to place large numbers of explosives in a region under stress. Theoretically, the explosions could break the weak points in the rock, thereby shaking the fault loose a little bit at a time.

But such a method requires extremely precise control; it is very likely to trigger a quake. The magnitude of the explosions required could cause as much damage as the quake. Explosion effects at the Atomic Energy Commission's Nevada test site are being checked to test the method.

HINDSIGHT REVISITED

Payoffs from research

The electron microscope magnifies objects to more than 100,000 times their real size. Studies of viruses, cancer cells and high-strength alloys for spacecraft depend on it. The electron microscope and its related instruments today constitute a $200 million industry. But the machine is not really new; its origins go back to 1858 when cathode rays were discovered and a theory of kinetic mixing of gases was proposed.

Birth control pills, first marketed only nine years ago, trace their heritage to 1849 and the discovery of a hormone. Now they are the base of a $100 million business; millions of women take them regularly.

Applied advances in science, a National Science Foundation study shows, almost invariably depend on a solid base of fundamental knowledge acquired years before ideas for its application are conceived. The study, initiated by NSF in 1967 and carried out by the Illinois Institute of Technology Research Institute, was designed to test scientists' long-held hypothesis that without basic, undirected research there is no progress in applied research.

This study, says NSF director Dr. Leland J. Haworth, "demonstrates the need for a broad base of scientific knowledge to underpin technological progress." The hypothesis backing basic research, he believes, is proved.

Undertaken to provide a systematic evaluation of the role of research in the process of technological innovation —a process that according to NSF cost the nation $24 billion in 1968—NSF and IITRI scientists chose five important advances with major social or economic impact on society and traced their lineage from the first bit of knowledge to ultimate development.

The five are:

- The electron microscope.
- Oral contraceptives.
- The video recorder that gives high quality images and instant replay ability to television.
- Magnetic ferrites, a class of engineering materials used in computers, and television transformers.
- Matrix isolation, a technique for stopping chemical reactions for observation.

Of the key events identified in the life-cycle of each of these developments, approximately 70 percent were nonmission research, "completed without insight into the conception and innovation to which it will ultimately contribute," the report states.

Further, it says, more than three-quarters of that basic work is carried out in universities and colleges, where