cal discussions, and will give major presentations at Massachusetts Institute of Technology and Texas A&M, on his experiments. There is every reason to hope that, as laboratories around the world become able to replicate Takahashi's experiment, it will no longer be possible for the enemies of cold fusion to suppress this extraordinary new science. With this in mind, I hope that even less technically versed readers will want to follow the story of Takahashi's experiments.

Takahashi runs the experiment in six-hour cycles, alternating between low- and high-current input. Low-current input at .25 amperes typically generates excess heat in the range of 50 watts. He typically gets excess power densities of over 150 watts/cm^3, when the current is raised to 4.2 amperes.

Unlike in most other experiments, Takahashi is able to detect neutrons while also measuring high excess heats. He has taken some samples for tritium, but these have yet to be analyzed. Takahashi believes that his statistics show that the amount of neutrons and tritium increases with time up to a maximum at which heat generation really begins to take off; when, he claims, the neutron and tritium production decreases while excess heat generation increases. On several occasions, however, when he experienced large heat bursts, he also noted high neutron bursts.

There is a generally positive climate in Japan toward scientific research, which includes investigation of cold fusion—even though perhaps the majority of scientists in Japan still retain a certain skepticism about the phenomenon reported by Fleischmann and Pons. Their critical attitude, however, is tolerant toward those who wish to go off the beaten path to explore new hypotheses, unlike the situation in western Europe and the United States, where there has been a veritable witchhunt against scientists who dared to work on cold fusion experiments—especially if they reported positive results. Whereas in the United States and, albeit to a lesser degree, in Europe as well, Fleischmann, Pons, and their supporters have been treated as almost common criminals by the leading scientific and popular press, the opposite is the case in Japan. In fact, it is a widely circulated rumor that the two cold fusion pioneers, who are now living in Europe, are receiving financial support from the Japanese, so that they can continue their research in a less pressured environment.

The leading programs in the world today—aside from the ongoing work of the two cold fusion pioneers—are those in Japan and the research work in the United States supported at Stanford Research Institute (SRI) by the Electric Power and Research Institute (EPRI). EPRI is reported to have a $12 million fund available to it over the next four years—during which it hopes to develop a prototype cold fusion generator. Because this is a commercial venture, and because of the generally aversive climate toward cold fusion in the United States today, EPRI has maintained a high level of secrecy in the programs which they sponsor. (This situation has only been made worse by the recent tragic accident which occurred at SRI, in which cold fusion experimenter Andrew Riley was killed when a cell which he was removing from a calorimeter blew up [see box].)

What varies between these programs is the protocol of the loading, the configuration of the structure of the electrodes, and the metallurgical treatment of the palladium or its particular alloys. These are the aspects on which research efforts are being concentrated, with results which are increas-

Some issues of the accident at SRI

Chemist Andrew Riley was killed when the cold fusion cell he was holding exploded Jan. 2 at the Stanford Research Institute (SRI) in California. Riley was working on the SRI cold fusion team led by Michael McKubre. Others present during the accident suffered minor injuries, and a portion of the ceiling in the laboratory was damaged. Although there is as yet no official report about the accident, some details have emerged that raise a question as to the nature of the explosion. The cell involved was 6 inches high and 4 inches in diameter. It was designed as a high-pressure closed cell, and therefore had a half-inch thick steel wall. A portion of the steel container split off during the explosion, striking Riley's face and then denting the laboratory ceiling.

Originally it was supposed that this cell was operating at 30-100 atmospheres, the typical pressure for SRI cold fusion experiments. But this was not the case. This particular experiment, designed to test a new configuration of the electrodes, was working at just above atmospheric pressure. According to one unconfirmed account, the electrode was 1 cc in volume, compared to a typical 0.1 cc and had a plate-shaped geometry. Although the cell was closed, two leaks had developed. This would give the cell something like the conformation of Takahashi's latest experiment.

At high pressures, hydrogen (or deuterium) gas can combine explosively with atmospheric oxygen, particularly if they come into contact with metal, which will act as a catalyst. Here the use of a metal-containing wall may be relevant, although usually the metal wall will be shielded by the formation of steam. Furthermore, such cells routinely contain recombiners, which are made of finely ground palladium and carbon. These recombiners control the rate of recombination, in order to prevent an explosion from occurring. In the cell that exploded, it is known that the sensor attached to the recombiner was out ingly reproducible. A palladium cathode and a platinum anode can, and frequently do, produce excess heat, as well as other products, such as tritium, helium-3, and helium-4, results that indicate some sort of nuclear reaction—although not a traditional hot fusion reaction conducted under vacuum conditions. In future research, the emphasis will be to understand and control what is actually going on, rather than merely to establish that cold fusion does exist.

In Japan there are over 100 researchers who are working at universities, as well as more secret programs being supported by industrial consortia. Like SRI, these commercially oriented research programs deliberately maintain a low profile. The university groups are interdisciplinary and are organized into 20 working groups that are independent of each other, but collaborate in sharing information. The group leaders meet together every few months to review the ongoing work in a friendly but searchingly critical environment, as I saw at the meeting which I attended. The program is coordi-

of order. The recombiner from that cell has decomposed into small spherical balls containing bits of platinum. This would indicate the violence of the explosion, but nothing about the functioning of the recombiner beforehand.

Although the cell was certainly open to the atmosphere, which would argue against a sharp rise in the pressure of the hydrogen and water, perhaps the holes were not sufficiently large to act as adequate vents. The containing steel wall had a bulge at the bottom, which may indicate a slow buildup of pressure inside. Yet, even assuming—for ease of calcuation—that at the time of the accident the canister was three-quarters full of hydrogen (thus overestimating the hydrogen content, since oxygen would have been present and would be needed for a recombination to occur), the force of such an explosion would appear to be at least an order of magnitude too low to account for the damage. This calculation does not assume the buildup of high pressure inside the cell. In the near future, estimates should be available of the dynamite equivalent of the explosion.

Apparently Andrew Riley had disconnected the cell from the current, and was removing it from the water bath in which it was contained during electrolysis. Within a minute, as he was moving to place it upon a work bench, the cell exploded in his hands and a steam cloud erupted. Thus, the explosion occurred *after* the cell was turned off. This suggests that the heating occurred within the electrode rather than in the solution. The experiment had been going on for some time over 1,000 hours. Sensing devices which were functioning during the accident should provide more indication of what caused the explosion.

Stopping electrolysis affects the ability of the solution to transfer heat from the electrode through the solution, and can allow a steam buildup to occur around the overheated electrode. If, in fact, a very high-temperature fusion event had been occurring, inability to vent the heat may have caused the explosion. Here the scale-up of the size of the electrode would be relevant. Another contributing factor could be the deloading of the electrode as it cooled, which could have caused phase-shift oscillations and created an unstable, runaway fusion reaction. If this was a fusion reaction, neither neutrons nor radiation appear to have been detected.

From their first public announcement of cold fusion in 1989, Martin Fleischmann and Stanley Pons have warned of the danger of a runaway fusion event. They have urged that strict safety protocols be followed. Fleischmann and Pons have recommended the use of very thin electrodes, under 1 cc in volume, designed in a symmetrical configuration. Another recommended precaution is to reduce the electric current gradually, thus deloading the electrode gradually and allowing maximum heat transfer as the electrode cools. They have preferred working with open cells in order to allow a slow boil-out of the solution to occur.

Another possibility, one actually tried in some SRI experiments, is to use a deuterium fuel cell anode. In this case there would be no decomposition of the water and thus no oxygen collected at the anode. Deuterium would be fed in at the anode and travel to the cathode, where it would be absorbed within the palladium. In a closed cell, recombination could not occur. Whatever happened at SRI, it is certainly true that the direction of research at present is toward closed cells at high pressure. This implies using sensing devices—as was done at SRI—and monitoring any accumulation of hydrogen in the laboratory. Some researchers have already begun introducing extra shielding into their laboratories and protective gear for laboratory workers.

It is clear that a no-holds-barred review of the accident must be conducted by top researchers in the field in order to reach a consensus on new safety protocols. This implies that concern for safety should override considerations of proprietary interests, which have otherwise hampered scientific cooperation. In any case, this will improve the conditions for more rapid scientific progress. Andrew Riley was young—34 years old—but he had already achieved an impressive record as a chemist specializing in materials science at the University of Utah National Cold Fusion Institute and the Materials Science Department. His death is a painful loss to us all.—*Carol White*