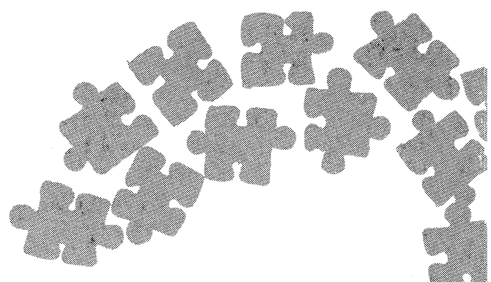
Cold ConFusion



Despite ridicule from their colleagues, a few scientists struggle to verify a hotly contested claim

By ELIZABETH PENNISI

A few weeks ago, physicist Frank E. Close visited Los Alamos (N.M.) National Laboratory to promote his book, *Too Hot To Handle*, which pans the discovery of so-called cold fusion. Yet even as he spoke, a handful of researchers were hard at work in one of the lab's tunnels trying to decipher just what cold fusion is really all about.

Like dozens of others in the United States, and perhaps hundreds across the globe, these investigators refuse to trash the notion of cold fusion. They continue to seek evidence of the controversial phenomenon, two years after the first round of follow-up studies failed to support claims that a new kind of nuclear reaction had emerged in bench-top experiments at the University of Utah (SN: 4/1/89, p.196).

And with each suggestive new finding, these researchers grow increasingly confident. They insist that their observations are rooted in real measurements, not experimental artifacts — despite the ridicule of their fellow scientists, who dismiss such results as sloppy science, unrecognized error, wishful thinking or even fraud.

"I think it is inappropriate for people to say we don't know how to run our experiments," argues Charles D. Scott, a chemist who has investigated cold fusion at Oak Ridge (Tenn.) National Laboratory. "There are enough people who have seen these results. It is absolutely real."

Nonetheless, the tone of next week's Second Annual Conference on Cold Fusion will likely be far from triumphant. Most of the 200 investigators expected to converge at this international meeting in Como, Italy, will swap tales of frustration. They have seen, and in some cases continue to see, signs of excess heat or nuclear events in their experiments. But they still cannot guarantee that anyone — including the experimenters themselves — can reproduce those results, because they still do not know what triggers the odd reactions (SN: 4/7/90, p.212).

This business of sparking fusion in a bottle sounded incredibly easy as originally described by chemists B. Stanley Pons and Martin Fleischmann. But the experimental setup has proved incredibly complex, requiring a mix of expertise seldom found in any one person or even in any one institution.

"If Pons and Fleischmann exaggerated, then the worst exaggeration they made is that this was a simple experiment," contends Edmund K. Storms, a materials scientist pursuing cold fusion at Los Alamos. "It's one of the most chemically complex environments that I have had to deal with."

Cold fusion setups require finesse in metallurgy, chemistry and physics. Results, if any, usually take days or weeks to appear, and then do so sporadically and unpredictably. "After a period of time, something in your experiment changes and you no longer have the same results," says physicist Edward Cecil of the Colorado School of Mines in Golden.

Moreover, cold fusion's dramatic implications — both for science and for society — can color interpretations of results. A widely accepted confirmation of the phenomenon could drastically upset conventional nuclear physics. At the same time, it would hold out the seductive prospect of producing enormous quantities of "clean" energy, not to mention riches and fame for those who harness the process. With so much at stake, researchers have trouble objectively evaluating experimental findings.

Nevertheless, groups in the United States, Italy, India, Spain, the Soviet Union, Japan and China plod forward, attempting to create cold fusion through a variety of techniques. In general, they all try to load as much deuterium (a hydrogen isotope) into a metal, usually titanium or palladium, and then look for evidence that something unusual has occurred.

Some have detected heat, as measured by calorimeters. Others have detected neutrons, charged nuclear particles, helium (SN: 3/23/91, p.180) or tritium, the triple-heavy hydrogen isotope. All of these observations suggest that some kind of interaction occurs among the deuterium nuclei, asserts Bombay physicist M. Srinivasan in his review of cold fusion experiments, which appears in the April 25 CURRENT SCIENCE, a journal published in India.

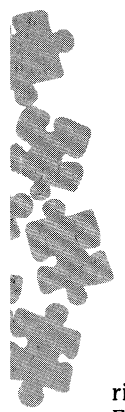
No one is sure whether that interaction is really fusion in the conventional sense, however. So for now, the researchers simply continue with their experiments, improving their faith in the validity of the results, as they strive to develop a formula for consistently triggering cold fusion events.

"Until you have a recipe for doing it reproducibly, there will always be justifiable criticism," says Bruce E. Liebert, a materials scientist at the University of Hawaii at Manoa. "Until you do that, you can't do good science. That's the single most important question to address in this field right now."

Yet the investigators insist they are making progress. At a conference this spring in the USSR, for instance, Soviet scientists presented 80 papers, more than half of which described experimental results "that roughly mimicked results reported around the rest of the world," says David H. Worledge, a program manager in the nuclear power division of the industry-funded Electric Power Research Institute (EPRI) in Palo Alto, Calif. None of this work proves that cold fusion occurs, Worledge says, but the data make that possibility more difficult to ignore. "All are inconclusive, but a fairly substantial weight of evidence is building," he maintains.

At next week's meeting in Italy, organizers expect scientists to present some 100 papers, most of them detailing new experimental results. And this month, the American Institute of Physics will publish 70 papers in the proceedings of last October's conference, "Anomalous Nuclear Effects in Deuterium/Solid Systems," held in Provo, Utah.

From the recent work, researchers have gleaned several insights about what they must do in their experiments. They now realize that the way deuterium gets into the palladium — as well as how rapidly and to what degree it does so — can be critical to their success. EPRI-funded researchers stress the need to load the palladium with almost as many deuterium atoms as palladium atoms. Joseph Santucci, a nuclear engineer and program manager at EPRI, surmises that many investigators may have trouble getting their experiments to work because they lack the ability to measure the number of deuterium atoms present and thus cannot be sure they have achieved a high enough ratio. Other scientists suggest that loading the deuterium too rapidly or too slowly decreases the chances of sparking the elusive reaction.



In addition, many investigators have improved the purity of their starting materials and experimental apparatus. Others have shown that the amount of electrical current used or the way it is delivered can be critical. A few think cold fusion depends on somehow jolting the materials into a state of disequilibrium. Fleischmann, working at the University of Southamptom in England, now focuses on deciphering the chemical events on the palladium surface, which he thinks may play a crucial role in cold fusion.

While some data suggest that the phenomenon does involve interactions between deuterium nuclei, the products of these apparent interactions do not conform to the standard notions of nuclear physics. According to those principles, fusion of deuterium nuclei should lead to any of three pairs of products: a helium isotope and a neutron; a proton and a tritium nucleus; or helium and gamma rays, which have such high energy they should escape without generating excess heat. In cold fusion experiments, these products appear — but not in the right proportions.

For example, the yields of neutrons or tritium seen by several groups are too low to account for the excess heat measured, and they seem unrelated to whatever generates the heat. This has led investigators to suggest that cold fusion may be several reactions, reports Storms in a review article scheduled for the September FUSION TECHNOLOGY.

"The connection may only be that all these phenomena are taking place in the solid lattice," adds Fleischmann. "I think that is what makes the problem so fiendishly difficult."

The challenge of putting together this puzzle whose pieces don't quite fit has attracted a number of theorists. All have their own ideas about what might allow deuterium nuclei to get close enough to interact. However, says Worledge, "there are so many theories, we don't get much guidance from them."

He and most other cold fusion investigators focus instead on real-world results, looking for measurable fusion products such as excess heat, charged particles, tritium and neutrons.

Srinivasan's review paper tallies at least a dozen reports of excess power of 25 to 30 percent. Pons and Fleischmann and a separate team of EPRI scientists reportedly have achieved even higher energy-production rates, but neither group will discuss its results.

Others are more willing to share their data — and their frustrations.

At Oak Ridge, for example, Scott set up a closed system in which he ran experiments for hundreds, and in some cases thousands, of hours. At times during those 10 tests, he saw what seemed to be bursts of 5 to 10 percent excess power. "What we found with some tests is that when we went through perturbations, then we got the energy bursts," he explains. In one cell, his team induced excess energy and even neutron emission by decreasing the temperature of the solutions used. But Scott says he stopped working on cold fusion last January for lack of research funds.

At the University of Hawaii, Liebert and materials scientist Bor Yann Liaw obtained suggestive results last year from a different type of cold fusion experiment. They made a molten-salt electrolytic cell by heating lithium and potassium salts to nearly 400°C; the cell also contained a lithium-deuterium compound and a small palladium electrode. The researchers passed a low electrical current through the apparatus for several days and found that the cell yielded more energy, in the form of heat, than they put into it, Liebert says. When they boosted the density of the current, the excess power increased and lasted almost four days, until no more lithium-deuteride remained in the molten-salt solution.

The team has since tried the experiment several more times, Liaw says, but only one of those attempts yielded excess heat, which lasted for a day.

Several researchers report encouraging — though transient — observations of charged particles. At the Colorado School of Mines, Cecil detected low-energy charged particles emitted from thin titanium foils. He used high pressure to force deuterium into the titanium, then dunked the foil into liquid nitrogen to cool it. After several hours, his particle detector registered about 1,000 particles per second for up to two hours, then stopped. He repeated this procedure more than 25 times and saw positively charged tritium nuclei at some point in about half of the experiments.

For the past nine months, he has seen nothing at all and he's not sure why. "You have to be careful that you are not getting spurious electrical signals," he admits.

Nevertheless, Cecil says his control experiments convince him that what he saw was real, and he takes heart from some still-unpublished findings by George P. Chambers and his colleagues at the Naval Research Laboratory in Washington, D.C. "They have similar results under different experimental conditions," he says. According to Srinivasan, Cecil's data also fit with findings by Japanese researchers.

As for tritium, Los Alamos physicist Thomas N. Claytor got results by forcing palladium to absorb deuterium under high pressure, then pulsing a very high current at a moderate voltage through the apparatus. He found that this led to a higher tritium count than a low-current, high-voltage pulse. In another study, Storms' team at Los Alamos deliberately inserted tritium into a metal lattice and watched its behavior to learn what to expect from a palladium or titanium sample contaminated with tritium, which could give the false impression of tritium production.

Scientists looking for tritium as evidence of cold fusion find that this triple isotope seems to arise from very fine "hairs" that sometimes build up on the palladium surface. The voltage may concentrate there, providing the extra bit of energy to trigger fusion. But researchers don't know what controls the formation of these fine structures. "No one has the courage to stop [an electrolytic cell] while it is producing tritium [to look at the hairs]," Storms explains.

And by the time the tritium production stops, the palladium or titanium surface lies buried under a layer of crud. "So until we get this more reproducibly, you won't have a good idea of what's going on," says Storms.

Meanwhile, reports of tritium detection trickle in from many parts of the world, including India, Spain and Italy. In some cases, these scientists have detected neutron emissions along with the tritium.

Observations of neutrons also seem to be fairly consistent from one team to the next, although the experimental reaction yields low quantities of these nuclear components. "In general, the results on neutrons are the kind of results that start looking like truth," says Worledge. "They have turned up in the same way in several different detectors at the same time in different laboratories, even down in deep mines."

Cold fusion has remained true to its seemingly fickle nature in an experiment set up this spring at Japan's Kamiokande neutrino detector. The detector came up empty-handed in its initial neutron searches, suggesting the reaction simply wasn't happening. However, the project still has several months to go.

The scientific community continues to deride such pursuits, and the antipathy has taken its toll. On June 30, the National Cold Fusion Institute, set up in Salt Lake City almost two years ago with $5 million from the State of Utah, will close its doors for lack of money.

But a few die-hards still refuse to give up. "To write [cold fusion] off at this stage, I think, would be a mistake," says Santucci. "Right now, the most important thing is to continue the work in a low-key, low-profile way." □