How Cold Fusion Happened—Twice!

The inside story of how two little-known electrochemists achieved the breakthrough, or the disappointment, of the decade—and how it may all have been discovered before

IT WAS A STARTLING RESULT. The researcher placed palladium electrodes in water and ran a current across them, and the cell produced heat and helium. Convinced that he had found a way to fuse hydrogen into helium, the scientist applied for a patent.

Sound familiar? It's not what you think. The year was 1927, not 1989, and the researcher was Swedish scientist John Tandberg, not Stanley Pons or Martin Fleischmann. Fission had not even been discovered, and yet a Swedish scientist seemed to have stumbled across fusion!

This 60-year-old fusion claim is just one of many surprising twists and turns in the saga that has been unfolding ever since Stanley Pons and Martin Fleischmann claimed they had found a way to produce fusion at room temperatures. This is not science as usual. And as such, the process of science is at least as interesting as the science itself—perhaps more interesting, since no one really knows how important the science will eventually turn out to be.

The main protagonists of the tale are, of course, electrochemists Fleischmann and Pons. Born in Czechoslovakia in 1927, Fleischmann came to England in the 1930s. Educated at Imperial College in London, he eventually wound up at the University of Southampton, where he was Professor of Electrochemistry from 1967 to 1983. And there he met Stanley Pons.

Pons, born in 1943 in Valdese, North Carolina, went to school at Wake Forest. A former professor recommended Pons to Fleischmann, who then helped Pons get into the graduate program at Southampton. Although Fleischmann did not serve as Pons's adviser, the two became good friends and close collaborators. They have written 32 papers together.

The two men came to the collaboration along very different paths. Fleischmann advanced steadily through the ranks of academia. As a graduate student in the late 1940s, he was part of a group of young scientists, several of whom went on to become leaders in electrochemistry.

Fleischmann is described as a brilliant, incredibly creative thinker. "He is one of the brightest people that I know," said Robert Jansson, a Monsanto Co. chemist who worked with him at Southampton. "He is very quick to comprehend new ideas that are put to him." Among colleagues, Fleischmann has a reputation for coming up with many ideas, testing them "quick and dirty" to see if they lead anywhere, and then letting other people refine them.

Pons did not move as easily into science as did Fleischmann. In 1965, after graduating from Wake Forest University, he entered the University of Michigan. As a graduate student in chemistry, he published two papers, including one that was a "real breakthrough," according to his former adviser, Harry Mark. Reviewers of the paper were very skeptical and negative, Mark said, but the paper was eventually accepted and later proved to be correct. Said Mark, "Pons has a history of doing things that people thought were insane."

But the things Mark admired didn't lead to a doctorate—not immediately. When Pons was about 6 months from a Ph.D., family problems forced him to leave school to work in the family textile business. Nearly 10 years later, as Mark remembered it, Pons called him up and said he wanted to return to science. Mark arranged through Fleischmann for Pons to go to Southampton, where he would not have to repeat all his course work again. Pons had kept current with the field, and in the 2 years it took him to complete his doctorate he wrote half a dozen papers.

Pons's strength, Mark said, is that he can conceive of ideas that other people would never consider or would dismiss as nonsense. He is also a very careful, meticulous experimenter, in contrast with Fleischmann. The two scientists feed on each other's creativity "like a circular feedback loop."

That interaction led to probably the craziest idea either of them had ever had—that one could create a sustained room-temperature fusion reaction in a palladium electrode sitting in a jar of heavy water. The two have

"Utah Effect" Strikes Again?

Back in 1972 three University of Utah scientists reported that they had created an x-ray laser. While the impact of such an achievement hardly rivaled the proposition that fusion had been achieved in a test tube, the announcement made headlines because researchers had tried unsuccessfully for years to develop a laser that used x-rays instead of infrared or visible light.

The purported laser had been developed by John Kepros, a postdoc working under chemistry professor Edward Eyring. Kepros focused a beam from a conventional infrared laser onto a copper gel "sandwich"—a copper sulfate solution mixed with gelatin and placed between two glass slides. About 90% of the times the researchers fired the laser at the sandwich, nothing happened. But one time out of ten, the sandwich would shatter and, Kepros claimed, the gel would emit a thin beam of coherent x-rays that left their trace on photographic film.

Because there was no known physical process that would explain the effect and because the scientists involved were not laser scientists, the claim was greeted with skepticism. Few labs could reproduce the results. A few researchers did report hints of confirmation, however, and several scientists offered theoretical explanations.

Eventually, skepticism won out. The spots on the films, it turned out, were caused not by coherent x-rays but by some sporadic effect produced by the high-energy beam hitting the gelatin target. The unfortunate postdoc, John Kepros, got a job somewhere else and dropped the work on the x-ray laser. His legacy was something physicists outside state borders came to dub the "Utah effect." Few may remember it today, but every now and then someone from cross-state rival Brigham Young University still tells that old tale.

Still, if the current cold fusion claims are confirmed, the joke will be on them. But if cold fusion fizzles, the Utah effect will have struck again. ■ R.P.

said that the idea sprang from anomalous effects each had seen in studies involving electrodes, and it took shape in discussions they held over the years. Eventually, they decided to test their ideas. They were lucky in that one of their earliest experiments showed an unmistakable effect—it blew up. With that encouragement, they performed a series of tests, eventually spending $100,000 of their own money.

Last fall, they decided they had seen enough to apply for a Department of Energy grant, and there the story took its first plot twist. Steven Jones, a Brigham Young University physicist who was acting as a reviewer for the grant, decided in December to approach them about a collaboration because his own work overlapped significantly with theirs.

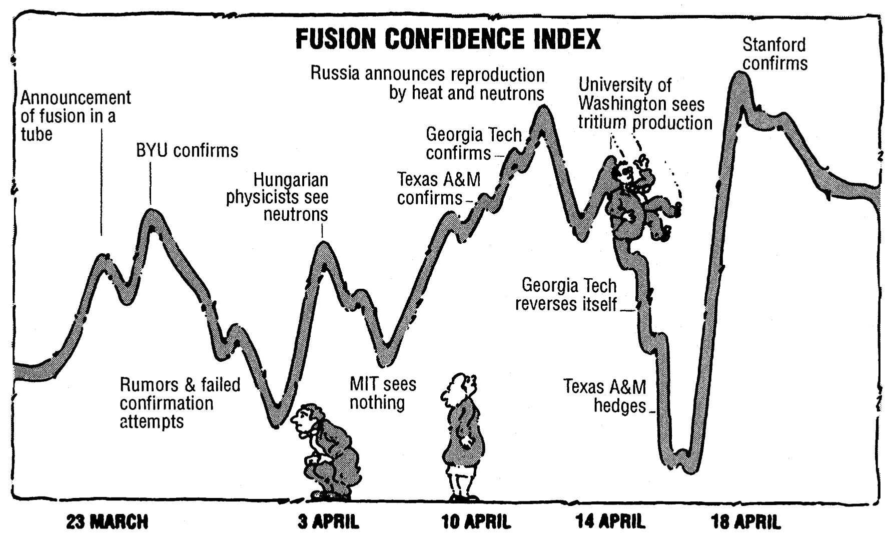
Jones's proposal presented a problem. Although he was not measuring the large amounts of heat that Pons and Fleischmann reported—in fact, Jones is still skeptical of their heat measurements—he did claim to detect fusion in metal electrodes, and used careful neutron measurements as evidence. Furthermore, he decided in early February that he was ready to publish his results.

Pons and Fleischmann were not ready to publish. They have said they would have preferred another 18 months of experiments. But they had no choice. After trying unsuccessfully to get Jones to put off announcing his results, they agreed to quickly prepare a manuscript and submit it simultaneously with Jones's manuscript on 24 March to *Nature*. That was 6 March.

Four days later, Ron Fawcett called Pons. Fawcett, a University of California chemistry professor who serves as U.S. editor of the *Journal of Electroanalytical Chemistry*, had called Pons on a personal matter, but the conversation turned to a manuscript Pons said he was preparing: one on cold fusion. Pons and Fleischmann published papers quite regularly in the journal, and Fawcett told Pons that, considering the importance of the paper, he could get the manuscript through the review process quickly. Pons mailed the manuscript the next day, 11 March.

Fawcett got it 2 days later and sent it out quickly. Within a week he had reviewers' comments. He and Pons agreed on revisions, and the revised copy was in Fawcett's hands on 22 March.

Fawcett defends the journal's decision to publish the paper even though it lacked many of the details demanded of most experiments. The referees, he said, thought there was enough evidence to justify publishing it as a "preliminary note" even though there seemed to be no way to explain the results.



Bulls Outpace Bears—for Now!

The cold fusion confidence index was up as *Science* went to press, mostly on the strength of a confirmation report from Stanford University. But it may be down again by the time this issue is in readers' hands.

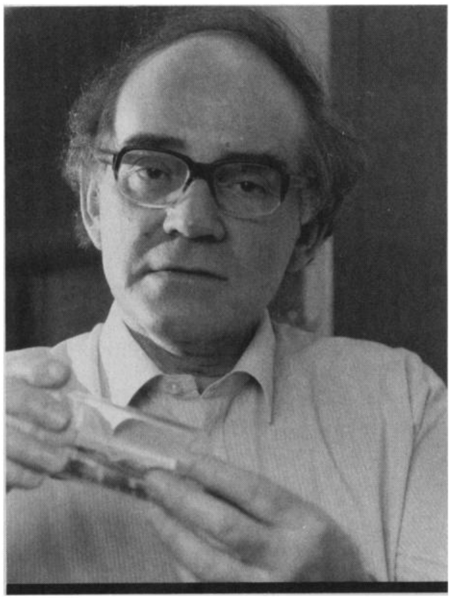
On 18 April, materials scientist Robert Huggins told reporters he had seen more heat than could be explained by a chemical reaction when he passed current through palladium electrodes in jars of heavy water. Most importantly, Huggins said he had run a control experiment with regular water, and that the heavy water version produced significantly more heat than the control. One of the main objections to the "fusion in a jar" experiments done by Stanley Pons and Martin Fleischmann has been that the two scientists did not report any control experiments run with normal water. If Huggins' result holds up, it would be strong evidence for fusion, because if a chemical reaction were heating up the cells, there should be little difference in heat production between heavy and light water.

The Stanford announcement followed a week when stock in the fusion claims had plunged. On 11 April, Georgia Tech researchers retracted an earlier report in which they said they detected neutrons from fusion cells. The scientists discovered that their neutron counters were sensitive to heat, a previously unknown effect that had skewed their measurements. A few days later, Texas A&M University scientists modified their earlier claims to have measured heat from fusion cells. Although the three researchers still insisted that the cells were producing more energy in heat than was being inserted as electrical current, they softened their numbers from a 60% to 80% increase to less than 10%.

On the same day as the Stanford announcement, Italian scientists said they had seen neutron production in deuterium-soaked palladium without any current applied. The researchers at the National Agency for Alternative Energy said they allowed deuterium to diffuse into palladium shavings at low temperature and detected neutrons coming from the palladium as the temperature was varied. The following day, scientists in both Brazil and India reported seeing neutrons from fusion cells similar to the Utah cells.

Many scientists following the fusion story say their attitudes change daily as news arrives via phone, fax, and computer network. They are bullish when they hear of a new confirmation or when a theorist announces some new way to explain cold fusion, but then, if other verification attempts see nothing, or if the seeming impossibility of cold fusion becomes too hard to swallow, they turn into bears.

Indicative of the confusion surrounding the fusion claims was a flipflop by the National Academy of Sciences. The academy had planned a press conference for 25 April to address policy implications of the discovery, but canceled it a few days before it was scheduled. "We were assuming about one and a half weeks ago that there might be some solid decision about cold fusion by now," said spokeswoman Carol Pearson. "But since there has not been, the heads of this place decided that cold fusion is not at the stage where the academy should be making any statements." ■ R.P.



"It's not my normal style of operation."

—Martin Fleischmann

Meanwhile, the University of Utah was gearing up to trumpet the cold fusion results to the world. A press officer conducted interviews of Pons and Fleischmann on Friday, 17 March, and had a press release ready for review by the administration by Monday. On Wednesday, the press office notified reporters that there would be a major announcement the next day.

In another plot twist, the *Financial Times* of London broke the story the morning of the press conference, surprising even the Utah press office. It seems that Fleischmann had contacted an old friend, Richard Cookson, to ask him about the best way to get good coverage in Britain. Cookson, a retired professor of chemistry at Southampton, put Fleischmann in touch with his son Clive Cookson, who writes for the *Financial Times*. Clive Cookson told Fleischmann that since 24 March was Good Friday, a bank holiday in England, the *Financial Times* would not be published on that day. If Cookson had been forced to wait for the 23 March press conference before going into print, he would not have been able to publish the news until the following Monday. Fleischmann, after consulting with Pons (but apparently not the Utah press office), agreed to provide Cookson with the information for publication a day early, and the paper got the story of the year 1 day before anyone else.

The rest has been mostly confusion, with hundreds of scientists trying to reproduce the cold fusion but few of them having success (see box). If the effect exists, it is not particularly easy to reproduce.

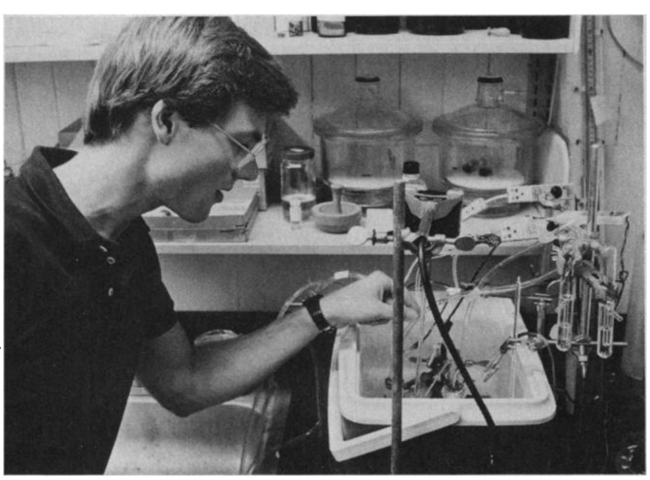
Both Jones and Pons submitted manuscripts to *Nature*, although not simultaneously. Jones submitted his on 23 March after he heard from the press conference that Pons had already submitted a manuscript. Pons submitted his the next day and expressed his irritation with Jones for breaking their agreement and not waiting for the agreed upon date.

Jones's paper will appear in the 27 April *Nature*. Pons withdrew his manuscript after the editors asked him for changes that he said he was now too busy to make.

Many scientists have criticized the way Pons and Fleischmann publicized their result long before they had done all the things one normally does to prepare a result for publication. Fleischmann himself, in a radio interview, indicated he was not happy with the way things were done: "It's not my normal style of operation."

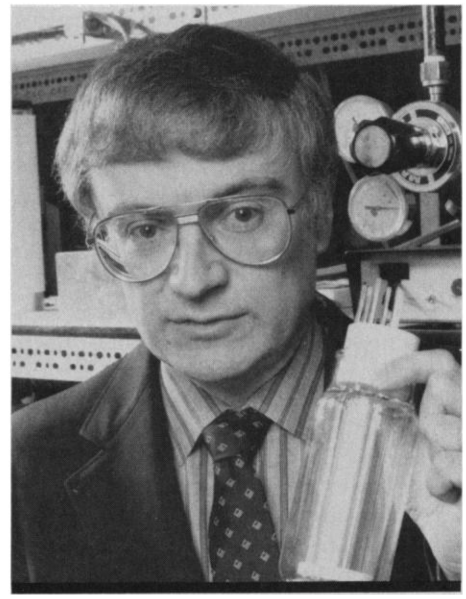
The University of Utah says the decision to go public was made because word of the fusion result was spreading and because Jones was getting ready to publish his paper. James Brophy, the university's vice president for research, said local reporters were aware weeks before the press conference that something big was going on in the chemistry building. None of them, however, were closing in on the fusion news and preparing to publish an article on it, Brophy said.

The deeper reason for the announcement seems to be that the Brigham Young group was preparing to submit an article for publication whose content was unknown to the Utah researchers. "That's one of the issues that convinced Pons and Fleischmann to take the data they had and prepare their own paper," Brophy said.



Stanford University

Fusion in a picnic cooler? *Stanford undergraduate George Lucier adjusts piping in his lab's test of cold fusion.*



"I cannot explain the data by any other means."

—Stanley Pons

Perhaps understandably, the university has played down the second reason for the press conference and has emphasized "rumors, leaks, questions, and false information." One administration official even pointed to the article in the 23 March *Financial Times* as an example of how the press was closing in!

If the fusion results pan out, the University of Utah, the chemistry department, and Pons and Fleischmann all stand to become very rich. Each party gets one-third of the proceedings from the discovery.

For Utah—both the state and the university—the fusion discovery seems like a godsend, for hard economic times and a state citizenry that does not like extra taxes have emptied the coffers. Much of the university faculty has not had a raise in 4 years, and a spokeswoman for the university said average salaries there are 20% less than at comparable institutions. A number of faculty members have left. Many of the ones remaining are like Pons, who says he came to Utah because of the beauty of the area and the skiing in the nearby mountains.

One of the ironies of the cold fusion story is that the University of Southampton—the school where Pons got his start in the field and where Fleischmann has worked for more than 20 years—will get nothing. In 1983, Fleischmann took early retirement under a program by the Thatcher government. Since then, Fleischmann has been a research professor, which means he contin-

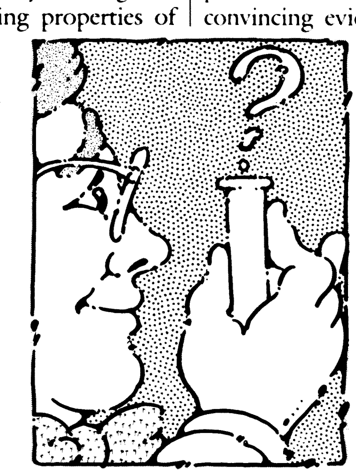
Cold Fusion: Is It Hot Enough to Make Power?

Just suppose for a moment that the claims of Doctors Stanley Pons of the University of Utah and Martin Fleischmann of the University of Southampton turn out to be true: that they've discovered fusion in a test tube. What is in store for the energy production business?

Science put this question to applications-oriented fusion engineers, most of whom were reluctant to speculate. "I would not take seriously any attempt anybody makes to extrapolate to a reactor at this point," says Mohamed A. Abdou, a fusion researcher at the University of California at Los Angeles. Gerald Kulcinski, of University of Wisconsin, is equally cautious: "The heat has us all baffled," he told *Science*. "Until we know where it is coming from it is hard to project out to a reactor."

This cool response is not for lack of imagination. Kulcinski, after all, is the author of many ambitious schemes in the quest for harnessing fusion—such as going to the moon for exotic reactor fuel. But in this case Kulcinski and others are frustrated by the scant amount of information surrounding Pons and Fleischmann's experiments. Pressed to look beyond the data dearth, however, fusion engineers quickly point to a whole list of formidable practical problems.

One critical issue that must be addressed here, says Kulcinski, is sensitivity of heat production to increases in the operating temperature of the palladium electrode. "You could be talking about something that is really uneconomic," he says, noting that there is a tendency for the hydrogen-absorbing properties of materials such as palladium, titanium, and nickel to deteriorate as temperatures increase. With palladium, absorption declines sharply as heat levels rise above room temperature (20°C). At 90°C, adds Kulcinski, the crystal lattice absorbs 12 times less deuterium than it does at room temperature. This falloff accelerates as temperatures rise.



But even if these technical problems can be overcome, there is the difficulty of obtaining enough palladium, a scarce and expensive metal. How much palladium a power reactor would require is hard to estimate, says Kulcinski. But, in one rough swipe at shaping a design for a 1000-megawatt reactor, he estimates that something in excess of 300 tons would be needed to operate one reactor. At the metal's current market rate—$4 million per ton—that would put the price tag of just the palladium for one cold fusion reactor at $1.5 billion. Not only is the price daunting, but many nations may not wish to rely on South Africa and the Soviet Union, which in 1988 supplied 98% of the world's palladium. More problematic, the world has only a small amount of known recoverable reserves of palladium.

Fortunately, there appear to be a host of potential hydrogen-hungry substitutes, including titanium, nickel, tantalum, and vanadium. The first has been the most discussed to date for several reasons. The United States has a large titanium production capability, and worldwide there are large dispersed deposits of the material. Furthermore, says UCLA's Abdou, titanium is a well-characterized metal and is affected less by neutrons. In fact, it has even been used in an experiment: Brigham Young University researcher Steven E. Jones reported signs of low levels of fusion occurring in an electrolysis experiment using titanium electrodes—but he saw no heat.

Quandaries over the eventual choice of a metal to run a cold fusion reactor pale before the intricacies of turning the "fusion in a jar" into an electricity producer capable of, say, lighting a neighborhood. The key question is, can the process eventually produce electricity? Kulcinski doubts this, saying "There is no convincing evidence" that it can. Pons and Fleischmann have asserted that their electrolysis experiments using palladium electrodes and heavy water have yielded as much as 10 watts of heat per cubic centimeter. This exceeds the 1 watt used to power the reaction, but it "is far removed from the conditions we are talking about for a pressurized water reactor," says Peter Murray of Westinghouse Electric Corp.

For a reasonably efficient steam-driven generating cycle, says Murray, temperatures of around 315°C will have to be produced. Electrodes and the reactor cell, he adds, will have to be able to withstand those higher temperatures.

■ **Mark Crawford**

ues to use a lab at the university but is not paid by the university. "We are not getting any money out of this," said Southampton spokesman Mike Chamey. "What we are getting is the kudos. It is impossible to put a value on that."

Even more ironic is the discovery that several researchers in the late 1920s were pursuing a line of research very similar to the cold fusion experiments being done now. In 1926, two German researchers published a paper in *Die Naturwissenschaften* in which they report what appeared to be hydrogen fusion in palladium. The researchers placed palladium in a hydrogen atmosphere, so that hydrogen atoms were absorbed into the palladium metal. After 12 hours, the scientists checked the palladium and found a measurable amount of helium-4, as evidenced by spectrographic analysis. As a control, they put the palladium in an oxygen atmosphere for the same amount of time and found only trace amounts of helium-4.

Although fusion was not well understood at that time, the researchers suggested that four hydrogen atoms were combining to form a single helium-4 atom plus extra energy. From their calculated helium-4 production, they determined that the energy production would be too small to detect.

In 1927, Swedish scientist John Tandberg extended the results of the Germans. He used electrolysis of water to get hydrogen into a palladium electrode and increase the reaction efficiency. Tandberg applied for a Swedish patent for "a method to produce helium and useful reaction energy." After the discovery of deuterium in 1932, Tandberg continued his work with heavy water.

The whole thing came apart when the German researchers discovered helium-4 contamination of their apparatus. They retracted their paper, and Tandberg's patent application was subsequently denied.

Tandberg's process sounds quite similar to the Utah method for cold fusion, and the original German results sound much like an experiment done recently by Italian researchers in which they claim to see fusion in deuterium-filled palladium without an electric current. Whether cold fusion will turn out to be a 60-year-old scientific breakthrough or a 60-year-old mistake is still not clear. Stay tuned. ■ **Robert Pool**