Defense Intelligence Agency

Defense Analysis Report

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Technology Forecast: Worldwide Research on Low-Energy Nuclear Reactions Increasing and Gaining Acceptance

Scientists worldwide have been quietly investigating low-energy nuclear reactions (LENR) for the past 20 years. Researchers in this controversial field are now claiming paradigm-shifting results, including generation of large amounts of excess heat, nuclear activity and transmutation of elements.[1,2,3] Although no current theory exists to explain all the reported phenomena, some scientists now believe quantum-level nuclear reactions may be occurring. DIA assesses with high confidence that if LENR can produce nuclear-origin energy at room temperatures, this disruptive technology could revolutionize energy production and storage, since nuclear reactions release millions of times more energy per unit mass than do any known chemical fuel.[4,5]

Background

In 1989, Martin Fleischmann and Stanley Pons announced that their electrochemical experiments had produced excess energy under standard temperature and pressure conditions.[6] Because they could not explain this physical phenomenon based on known chemical reactions, they suggested the excess heat could be nuclear in origin. However, their experiments did not show the radiation or radioactivity expected from a nuclear reaction. Many researchers attempted to replicate the results and failed. As a result, the physics community disparaged their work as lacking credibility, and the press mistakenly dubbed it "cold fusion." Related research also suffered from the negative publicity of cold fusion for the past 20 years, but many scientists believed something important was occurring and continued their research with little or no visibility. For years, scientists were intrigued by the possibility of producing large amounts of clean energy through LENR, and now this research has begun to be accepted in the scientific community as reproducible and legitimate.

Source Summary Statement

This assessment is based on analysis of a wide body of intelligence reporting, most of which is open source information including scientific briefings, peer-reviewed technical journals, international scientific conference proceedings, interviews with scientific experts and technical media. While there is little classified data on this topic due to the S&T nature of the information and the lack of collection, DIA judges that these open sources generally provide the most reliable intelligence available on this topic. The information in this report has been corroborated and reviewed by U.S. technology experts who are familiar with the data and the international scientists involved in this work.

Although much skepticism remains, LENR programs are receiving increased support worldwide, including state sponsorship and funding from major corporations.[7,8,9,10] DIA assesses that Japan and Italy are leaders in the field, although Russia, China, Israel, and India[11] are devoting significant resources to this work in the hope of finding a new clean

energy source. Scientists worldwide have been reporting anomalous excess heat production, as well as evidence of nuclear particles[12, 13, 14] and transmutation.[15, 16, 17]

- Y. Iwamura[18] at Japan's Mitsubishi Heavy Industries first detected transmutation of elements when permeating deuterium through palladium metal in 2002.

- Researchers led by Y. Arata at Osaka University in Japan[19] and a team led by V.Violante at ENEA in Italy (the Italian National Agency for New Technologies, Energy, and the Environment—the equivalent to the U.S. Department of Energy)[20] also made transmutation claims.

- Additional indications of transmutation have been reported in China, Russia, France, Ukraine, and the United States.[21, 22]

- Researchers in Japan, Italy, Israel, and the United States have all reported detecting evidence of nuclear particle emissions.[23, 24]

- Chinese researchers described LENR experiments in 1991 that generated so much heat that they caused an explosion that was not believed to be chemical in origin.[25]

- Japanese, French, and U.S. scientists also have reported rapid, high-energy LENR releases leading to laboratory explosions, according to scientific journal articles from 1992 to 2009.[26, 27]

- Israeli scientists reported in 2008 that they have applied pulsating electrical currents to their LENR experiments to increase the excess energy production.[28]

- As of January 2008, India was reportedly considering restarting its LENR program after 14 years of dormancy.[29]

U.S. LENR researchers also have reported results that support the phenomena of anomalous heat, nuclear particle production, and transmutation.[30, 31, 32]

- At the March 2009 American Chemical Society annual meeting, researchers at U.S. Navy SPAWAR Pacific reported excess energy,[33] nuclear particles,[34] and transmutation,[35, 36] stating that these effects were probably the result of nuclear reactions.[37]

- A research team at the U.S. company SRI International has been studying the electrochemistry and kinetics of LENR since the early 1990's, reporting excess heat and helium production.[38]

- In May 2002, researchers at JET Thermal in Massachusetts reported excess heat and optimal operating points for LENR manifolds.[39]

- Researchers at the China Lake Naval Air Warfare Center in California first reported anomalous power correlated with Helium-4 production in 1996.[40]

Although no one theory currently exists to explain all the observed LENR phenomena, some scientists now believe these nuclear reactions may be small-scale deuterium fusion occurring in a palladium metal lattice.[41, 42, 43] Some others still believe the heat evolution can be explained by non-nuclear means. Another possibility is that LENR may involve an intricate combination of fusion and fission triggered by unique chemical and physical configurations on a nanoscale level.[44, 45] **This body of research has produced evidence that nuclear reactions may be occurring under conditions not previously believed possible.** Recent results suggest these anomalous LENR phenomena can be triggered by various energetic stimuli (electric and magnetic fields, acoustic waves, infrared, lasers)[46, 47] and may have a variety of operational modes.

Nuclear Fusion

Nuclear fusion as currently understood occurs only in the core of stars, in nuclear weapons, in high temperature plasmas, or in inertially confined high-energy collisions. Scientists for years have attempted to harness nuclear fusion through high-temperature plasma techniques but have been unable to produce more energy output than supplied. Fusion was once thought to be the answer to the world's future clean energy needs, but after 60 years of research still has yet to live up to this promise. "Hot" fusion researchers do not believe fusion can occur at near-room temperatures based on the Coulomb barrier that repels like nuclear charges and have dismissed much of the "cold fusion" research conducted since 1989. As a result, such research has received limited funding and support over the past 20 years.

Potential Applications of LENR: The Technology Surprise Factor

LENR's potential as a future clean energy source is still unknown. However, recent results indicating nuclear activity and transmutation are intriguing and pose the following questions:

- If the excess heat from these experiments could be captured and intensified, could LENR be used as a power source for engines, batteries, or other equipment?

- If nuclear particles could be generated and transmute elements, could LENR be used to mitigate hazardous waste or to neutralize weapons of mass destruction?[48]

- If the various modes of energy production could be identified and optimized, could LENR be used to create designer materials or critical resources that are in short supply or serve as a tailored, "dial-a-mode" power source?

- If rapid, explosive energy output can occur in one or several modes, could LENR serve as a new high-energy-density explosive?

International LENR research was highlighted in April 2009 on a U.S. television program focused on the 20th anniversary of the Fleischman and Pons announcement.[49] Many U.S. researchers are collaborating with foreign scientists, but each team has proprietary aspects of their experiments that are not shared. Because some peer-reviewed journals are reluctant to review or publish LENR data due to past controversies, most results are presented at international conferences, and foreign scientists have access to much of the U.S. data. In addition, U.S. experts have been invited to brief on LENR to nuclear institutes in India,[50] Belgium,[51] and South Korea,[52] and a reciprocal visit by South Koreans to SPAWAR Pacific to initiate collaboration is planned. This relatively free flow of information increases the likelihood of a technology breakthrough—as well as the potential for technology surprise—by an international team, especially those from countries that are devoting more resources to this research than is the United States, and are supported with major corporate funding (Mitsubishi, Toyota, and Honda in Japan; Pirelli in Italy).[53]

The Experiments

Most LENR experiments involve electrodes immersed in solutions of metal salts such as lithium chloride or lithium sulfate, with heavy water substituted for natural water. Electric current is sent through the experimental apparatus, in most instances producing excess heat. This effect occurs over long periods (several hundreds of hours), and many early experimenters achieved negative results because they were unaware of this incubation period. Israeli researchers used pulsating electric fields to increase heat production. The application of magnetic fields has been shown to stimulate increased heat and power. Usually one of the electrodes is palladium, because it has a high ability to adsorb (hold on the surface) and absorb deuterium atoms in its metal matrix. Deuterium is an isotope of hydrogen that undergoes fusion in nuclear weapons at high temperatures and pressures; it also undergoes fusion and is one of the basic building blocks of the heavier elements formed in stars. The Navy SPAWAR experiments used a unique technique to place the palladium atoms in the heavy-water solution and to codeposit palladium and deuterium, which rapidly increases the deuterium "loading" necessary for the LENR phenomena to occur.

A Notional LENR Electrochemical Cell (Left) and a French LENR Apparatus After an Unexplained Explosion (Right)[54]

Who's Hot in Cold Fusion?

The countries with the most advanced LENR programs are Japan, Italy, and Israel. In addition, Russia, France, China, South Korea, and India are spending significant resources on LENR research. The following are among the most notable efforts:

- In Japan, Iwamura at Mitsubishi has been studying transmutation of elements in LENR experiments and multilayer palladium (Pd) complexes. His team includes the Japanese Synchrotron Radiation Research Institute and SPring-8 at Riken. Kitamura and other researchers at Kobe University are investigating Pd nanopowders and Helium-4 ash. Arata at Mitsubishi Heavy Industries has worked on catalysts containing nanopalladium. Yamaguchi at Kobe noted transmutation using multilayered Pd samples. Mizuno at Hokkaido is studying transmutations and heat generation. A team led by Hioki at Toyota is investigating deuterium gas permeation through Pd as well as transmutations. Toriyabe at Tohoku University is developing charged-particle detectors for LENR. Kasagi is looking at electron and ionic screening in LENR effects.

- Vittorio Violante, a leader in the field of Pd metallurgy and the role of surface effects in LENR, heads a team at ENEA, Frascati Rome, (the Italian equivalent to the U.S. Department of Energy) performing LENR experiments. A team led by Francesco Celani at INFN that includes STMicroelectronics and Pirelli labs is studying deuterium migration in nanocoated Pd for fast-loading and anomalous heat effects. The Italian Physical and Chemical Societies are supporting LENR research in Italy.

- Srinivasan in India noted that India is restarting its LENR program; the Bhabha Atomic Research Centre had several groups working on LENR from 1989 to the early 1990s. Sinha at IISc in Bangalore is studying models for fusion in metal deuterides. Lakshmanan at Saveetha College is exploring fusion in sodium metal solutions.

- Andrei Lipson and other researchers at the Russian Academy of Sciences and scientists in Tomsk are studying the emission of charged particles during the use of electron beams to excite palladium/deuterium (Pd/D) and titanium/deuterium (Ti/D) targets. Karabut and others at LUCH also are conducting LENR experiments. A Dubna team led by Gareev is studying nuclear fusion during cavitation and molecular transitions. LUCH's Savvatimova, Dash, Muromtsev, and Artamonov also are conducting LENR experiments. Adamenko and Vysotskii of Kiev are looking for magnetic monopoles in LENR experiments. Kurchatov-based scientist Goryachev is investigating LENR for alternative energy sources and for mitigating radioactive waste.

- Xing Z. Li at Tshinghua University claims 20 institutions in China are investigating LENR with governmental support. Tian's team at Cahnchun University of Science and Technology is investigating laser triggering in Pd/D systems. Zhang and other researchers at the Chinese Academy of Sciences have studied Pd-D kinetics in LENR since 1991.

- Israeli scientists at Energetics in Omer have shown that variations in energy output can be increased using variable frequency or pulsed "superwaves" to stimulate LENR effects.

- The French Atomic Energy Agency had an official LENR program from 1997 to 1999. EDF also had one for several years. Currently, Jean-Paul Biberian from the Universite Marseille and Jacques Dufour at CNAM are working on LENR in France.

- Jan Marwan of Dr. Marwan Chemie in Berlin, Germany, is studying the nanostructure of palladium hydride systems. Huke and others from the Technische Universitat Berlin are working with Czerski in Poland and Ruprecht in Canada on electron screening mechanisms for deuteron fusion.

Outlook and Implications

If nuclear reactions in LENR experiments are real and controllable, DIA assesses that whoever produces the first commercialized LENR power source could revolutionize energy production and storage for the future. The potential applications of this phenomenon, if commercialized, are unlimited. The anomalous LENR effects seen in these metal lattices containing deuterium may also have as-yet undetermined nanotechnology implications. LENR could serve as a power source for batteries that could last for decades, providing power for electricity, sensors, military operations, and other applications in remote areas, including space. LENR could also have medical applications for disease treatment, pacemakers, or other equipment. Because nuclear fusion releases **10 million times more energy per unit mass** than does liquid transportation fuel, the military potential of such high-energy-density power sources is enormous. And since the U.S. military is the largest user of liquid fuel for transportation, LENR power sources could produce the greatest transformation of the battlefield for U.S. forces since the transition from horsepower to gasoline power.

Prepared by: Beverly Barnhart, DIA/DI, Defense Warning Office. With contributions from: Dr. Patrick McDaniel, University of New Mexico; Dr. Pam Mosier-Boss, U.S. Navy SPAWAR/Pacific; Dr. Michael McKubre, SRI International; Mr. Lawrence Forsley, JWK International; and Dr. Louis DeChiaro, NSWC/Dahlgren.

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