

Cold Fusion: A Changing Landscape?

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WHAT IS COLD FUSION?

**WHAT DO I MEAN BY
“CHANGING LANDSCAPE”?**

Cold Fusion Is...

- A hypothesized type of nuclear reaction
- Believed to produce “excess energy”
 - At much lower temperatures than “hot fusion” (e.g., the sun, hydrogen bombs)
- A potential major source of energy
- Difficult to achieve and reproduce
- In a rejected and highly marginalized status
- Still VERY controversial!

Main Elements (Examples)

- Methods
 - Electrolytic cell
 - Gas loading
 - Gas discharge
- Materials
 - Pd, Ni, H, D
- Signatures
 - Excess heat
 - Radiation
 - Nuclear products



Electrolytic Cell



Gas Loading Cell

http://en.wikiversity.org/wiki/Cold_fusion/Electrolytic_cell_fusion

<http://www.extremetech.com>

Potential Benefits

- Heat production (water purification, cooking)
- Electricity generation (boilers, direct conversion)
- No emissions or effluents
- Radiation only at levels of detection in apparatus
- Central or distributed deployment (scalable)
- Ease of operation & maintenance
- Fail safe (no runaway)
- Potential new area of science

Nagel, 2012

CHANGING LANDSCAPE?

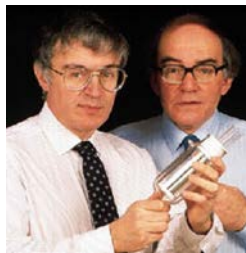
**Much Has Happened Since It
Was Announced and Rejected**

What Do I Mean by “Changing Landscape”?

- Announcement and rejection, 1989
- Continued research
- Accumulated body of evidence
- Advances in explanation
- Recent developments
- Policy opportunities
 - Realizing benefits
 - Mitigating impacts

ANNOUNCEMENT AND REJECTION

Stanley Pons



Martin Fleischmann

1989 Announcement

- Martin Fleischmann & Stanley Pons
- Press Conference, University of Utah
- Motivation: competition with BYU in Provo
- Professional paper several weeks later
- High level of professional and public interest
- Many attempts to replicate based on little information



May 8, 1989

Swift Rejection

- CF remarkably difficult to achieve
- Many replication attempts; few successes
- Absence of evidence used as evidence of absence
- Seaborg meeting with Bush in May
 - *"You are going to have to create a high level panel that will study it for six months and then they will come out and tell you it's not valid. And that's what he did."*
- U.S. DoE report, 1989
- Sociology of science perspectives



CONTINUED RESEARCH

Investigators
Conferences
Agencies
Private Labs

Investigators and Venues: Indicators

- Countries
 - U.S.
 - Italy
 - Japan
 - India
 - South Korea
 - Russia
 - China
 - Sweden
 - Others
- Investigators
 - Hard to pin down
 - CMNS Google group: 300
 - Storms & Grimshaw, 2010: 57 worldwide
 - ICCF Conferences: ~150-250 attendees
 - National agencies
 - Several private laboratories

ICCF Conferences

- Approximately annually
- 18 since 1990 worldwide
 - ICCF-14, 2008, Washington, DC
 - ICCF-15, 2009, Rome
 - ICCF-16, 2011, Chennai, India
 - ICCF-17, 2012, Daejeon, South Korea
 - ICCF-18, 2013, University of Missouri
- ICCF-19, April 2015, Padua, Italy
- ~150-250 attendees in recent years



U.S. Agencies Having CF Interests

- U.S. NASA, Langley Research Center
- U.S. Navy
 - Naval Research Laboratory, Washington, DC
 - Naval Postgraduate School, Monterrey, CA
 - SPAWAR, San Diego, CA
 - Air Weapons Station, China Lake, CA
- Defense Intelligence Agency



Italian Research Laboratories, Frascati

- ENEA
 - National Agency for New Technologies, Energy and Sustainable Economic Development
 - Vittorio Violante, lead
 - Electrolytic cell research
- INFN
 - National Institute of Nuclear Physics
 - Francesco Celani, lead
 - Constantan wire cells



Tom Claytor's Private LENR Lab, Los Alamos, NM



Experiment Setup

Outside View

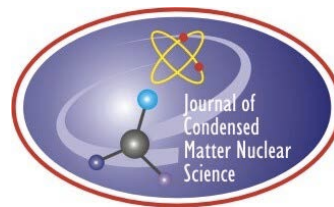


ACCUMULATED EVIDENCE

Examples

Journal of ISCMNS

- International Society of Condensed Matter Nuclear Science
 - “Ardeat nec consumitur”
 - Mission: Promote the understanding, development and application of CMNS for the benefit of the public.
 - 224 members, 5 countries
- Volumes 1-13, 2007-2014
- 199 titles as of September 2014



LENR-CANR Website

- LENR: Low Energy Nuclear Reactions
- CANR: Chemically Assisted Nuclear Reactions
- Over 1,200 original scientific papers
- Bibliography of more than 3,500 items
 - Journal papers
 - News articles
 - Books
- 3,000,000 downloads as of June 2014
- Jed Rothwell, Librarian

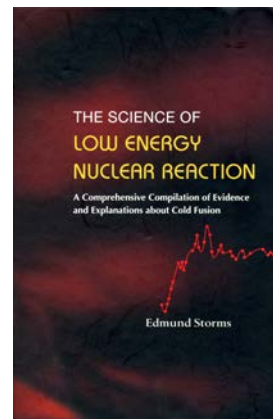


<http://news.newenergytimes.net/2011/page/26/>

Reports of Positive Experiments

- Storms, 2007
- Period 1989 to 2004

● Excess heat	184
● Radiation	55
● Transmutation	80
● Tritium production	61
● Helium production	6
● Total Reports	386



Bayesian Network Analysis Early Verifications, 1989-90

- Cravens and Letts, 2008

- 6 papers selected
- Excess heat: all successful
- $P_s = 0.1$
- After BNA, $P_p = 0.99$

$$P(A | B) = \frac{P(B | A)P(A)}{P(B)}$$

Bayes' Theorem

- Johnson and Melich, 2008

- 8 papers selected
- Excess heat: 5 successful, 3 not
- $P_s = 0.5$
- After BNA, $P_p = 0.91$

P_s : Starting Probability
 P_p : Posterior Probability

- Both outcomes: $P > 90\%$

Cold Fusion: Science or Pseudoscience?

- Criteria for science from three established sources

- Langmuir, 1989
- Sagan, 1995
- Shermer, 2001

Symptoms of Pathological Science

▷The maximum effect that is observed is produced by a causative agent of barely detectable intensity, and the magnitude of the effect is substantially independent of the intensity of the cause.
▷The effect is of a magnitude that remains close to the limit of detectability or, many measurements are necessary because of the very low statistical significance of the results.
▷There are claims of great accuracy.
▷Fantastic theories contrary to experience are suggested.
▷Criticisms are met by *ad hoc* excuses thought up on the spur of the moment.
▷The ratio of supporters to critics rises up to somewhere near 50% and then falls gradually to oblivion.

Langmuir's "Symptoms"

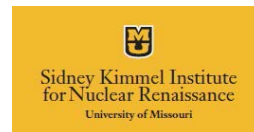
- 27 total criteria
- Found that all criteria are met
- Conclusion: Cold fusion is science, not pseudoscience
- Storms and Grimshaw, 2010

RECENT DEVELOPMENTS

**Major University
Major Corporation
Empirical Devices**

University of Missouri

- SKINR Established 2012
- Grant from philanthropist Sidney Kimmel
- Objectives (anomalous heat effect, AHE)
 - Reveal AHE mechanism
 - Improve reproducibility
- Director: Graham Hubler
(former Naval Research Lab)
- Roots in Energetics Technologies; Superwave stimulation
- ICCF-18 host



National Instruments

- Long-term opportunity for instrumentation and control
- Interest in CF by James Truchard, CEO
- Hosted meeting of major CF players in 2012
- Supported Celani Constantan cell demonstrations
- Presentations at ICCF conferences (2013 keynote)
- Supported University of Texas policy research



<http://www.ni.com/company/our-vision/leadership/truchard.htm>

Empirical Devices: Examples

Rossi	E-Cat	Leonardo Corp
Celani	Constantan	INFN, Italy
Miley	LENR-Gen	Univ of Illinois
Swartz	Nanor, Phusor	JET Energy
Godes	CECR Device	Brillouin
Stringham	Sonofusion	First Gate Energies
Mills	CIHT*	Blacklight Power

*None are verified or offered in commercial units.
But considered in aggregate...*

*May not be cold fusion

Andrea Rossi's E-Cat (Energy Catalyzer)

- Demonstration October 28, 2011, Bologna, Italy
- Multi-reactor assembly in shipping container
- Steam generation with manifold system
- Reported about 479 kW for 5.5 hours
- 2635 kWh total energy – equivalent to 72 gal of gasoline



http://www.nyteknik.se/nyheter/energi_miljo/energi/article3264361.ece

http://peswiki.com/index.php/News:October_28,_2011_Test_of_the_One_Megawatt_E-Cat

Independent Tests of E-Cat

- Two reports, led by Giuseppe Levi, Bologna University
- High temp E-Cat – “Hot-Cat”
- Report of 2013 test
 - 1st: 195 kWh, 96 hr
 - 2nd: 95 kWh, 116 hr
- Report of 2014 test
 - 1.4 MWh, 32 da
- Many criticisms of both tests
- Future tests not announced



Device in First Test



Device in Second Test

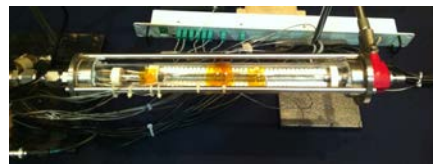
Industrial Heat E-Cat Interest

- Acquired North American E-Cat rights
- Reportedly for \$11 million, early 2014
- Backed by Cherokee Investment Fund
- \$2 billion currently under management
- Motivation: curb air pollution from coal
- Supported two independent tests by Levi et al.
- Contacts with officials in China
- Interest also in other CF investigations



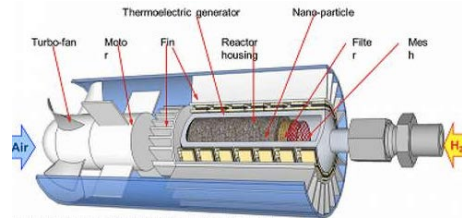
Celani's Constantan Cell

- Treated (heated) Constantan (Cu-Ni) wire
- Hydrogen or deuterium gas
- Dissipative calorimeter (Stefan-Boltzman)
- Input power: 57 W
- Two demos in 2012
 - 1st: COP = 1.2
 - 2nd: COP = 1.1
- Demos supported by National Instruments
- Francesco Celani, Italy's INFN



Miley's LENR-Gen Module

- "Electrode cell"
- Nickel nanoparticles
- Hydrogen gas
- 10 kW units
- May be set up in series or parallel
- Lenuco, LLC
- George Miley, professor emeritus
- University of Illinois, Urbana-Champaign



<http://www.21stcentech.com/energy-update-lenr-no-commercial-product/>

Swartz's Nanor and Phusor

- Phusor
 - Aqueous solution
 - Pd and Ni
- Nanor
 - Nonaqueous
 - Pd, Ni, Zr
 - Nanoparticles
- JET Energy, Massachusetts
- Mitchell Swartz, owner & operator
- Collaboration with MIT, Hagelstein



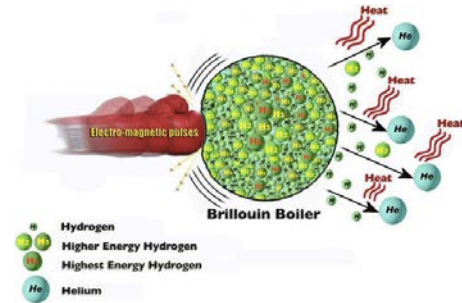
Phusor Electrode with Electrolysis Bubbles



http://peswiki.com/index.php/Directory:JET_Thermal_Products

Brillouin's CECR Technology

- Ni-H reactions
- Stimulation with Controlled Electron Capture Reaction (CECR) process
- Conversion to He with energy release
- Heat absorbed by metal for beneficial use
- Robert Godes, President
- Located in Berkeley, CA



ADVANCES IN EXPLANATION

Two Leading Examples

Peter Hagelstein

Edmund Storms

Peter Hagelstein: MIT Faculty



- Associate Professor, Electrical Engineering & Computer Science
- Ph.D., Electrical Engineering, MIT
- Pioneering X-ray laser work, Lawrence Livermore Laboratory
- 1984 Lawrence Award, Innovation & Creativity
- Returned to MIT, conducts CF theory research
- Textbook: Introductory Applied Quantum and Statistical Mechanics

Hagelstein: Reactions in the Lattice

- Hypothesis in framework of nuclear physics & condensed matter physics
- Deal with “silence” of CF reactions (no emissions)
- Method of energy transfer from nuclear to vibrational (heat)
- Steady work over a decade; “graveyard” of >300 models
- Current (2014): Inverse Fractionation model + new Fundamental Hamiltonian
- Significant progress, still some distance to go

Fundamental Hamiltonian

$$\hat{H} = \sum_j (M c^2 + \mathbf{a} \cdot c \hat{\mathbf{P}}_j) + \sum_{\langle i, j \rangle} \frac{Z_i Z_j e^2}{|\mathbf{R}_i - \mathbf{R}_j|} + E_n(\{\mathbf{R}\}) - \int \frac{\hat{H}(E)}{2}$$

Edmund Storms: Los Alamos National Lab

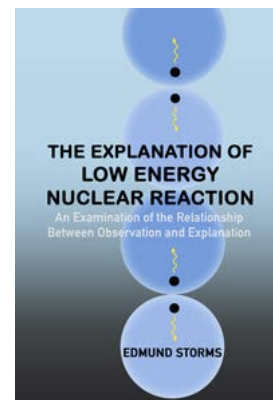
- Cold fusion research while at LANL
- Continued at private lab, Santa Fe, NM
- Privately-owned scanning electron microscope
- Nearly all CF methods and signatures
- More than 100 technical papers
- Two books, 2007 & 2014
- Complete CF private library: 4,600 items
- Ph.D., Radiochemistry, Washington Univ



SEM with EDX

Storms: Reactions at the Material Surface

- CF reactions in stress-induced nanocracks
- Hydrogen or deuterium forms linear structures (“hydroton”) in cracks
- Resonance of hydroton results in fusion and gradual energy release
- Emitted photons absorbed in lattice – excess energy
- New (expanded) explanations in physics required



Storms, 2014

SUMMARY

Is There A Changing Landscape?

Cold Fusion Is...

- Potentially very beneficial
- Difficult to achieve and replicate
- A topic of research in many venues
- Supported by a large body of research
- Indicated by several recent developments
- Getting closer to a satisfactory explanation
- Apparently a real phenomenon
- Likely to have many secondary impacts
- Still VERY controversial!

Two Primary (Related) Challenges

- Adequate Explanation
- Reliable Reproducibility

What's Needed?

1. Research for stronger experimental evidence (large parameter space)
2. Support for improved hypotheses
3. Experiments designed to test hypotheses (follow the scientific method)
4. Utilization of empirical device findings for scientific understanding
5. Parallel development of energy production applications

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QUESTIONS?