Low Energy Nuclear Reactions:
Exciting New Science
Potential Clean Energy

David J. Nagel
The George Washington University
Washington DC 20052

Kamron Fazel
The Pennsylvania State University
University Park PA 16802

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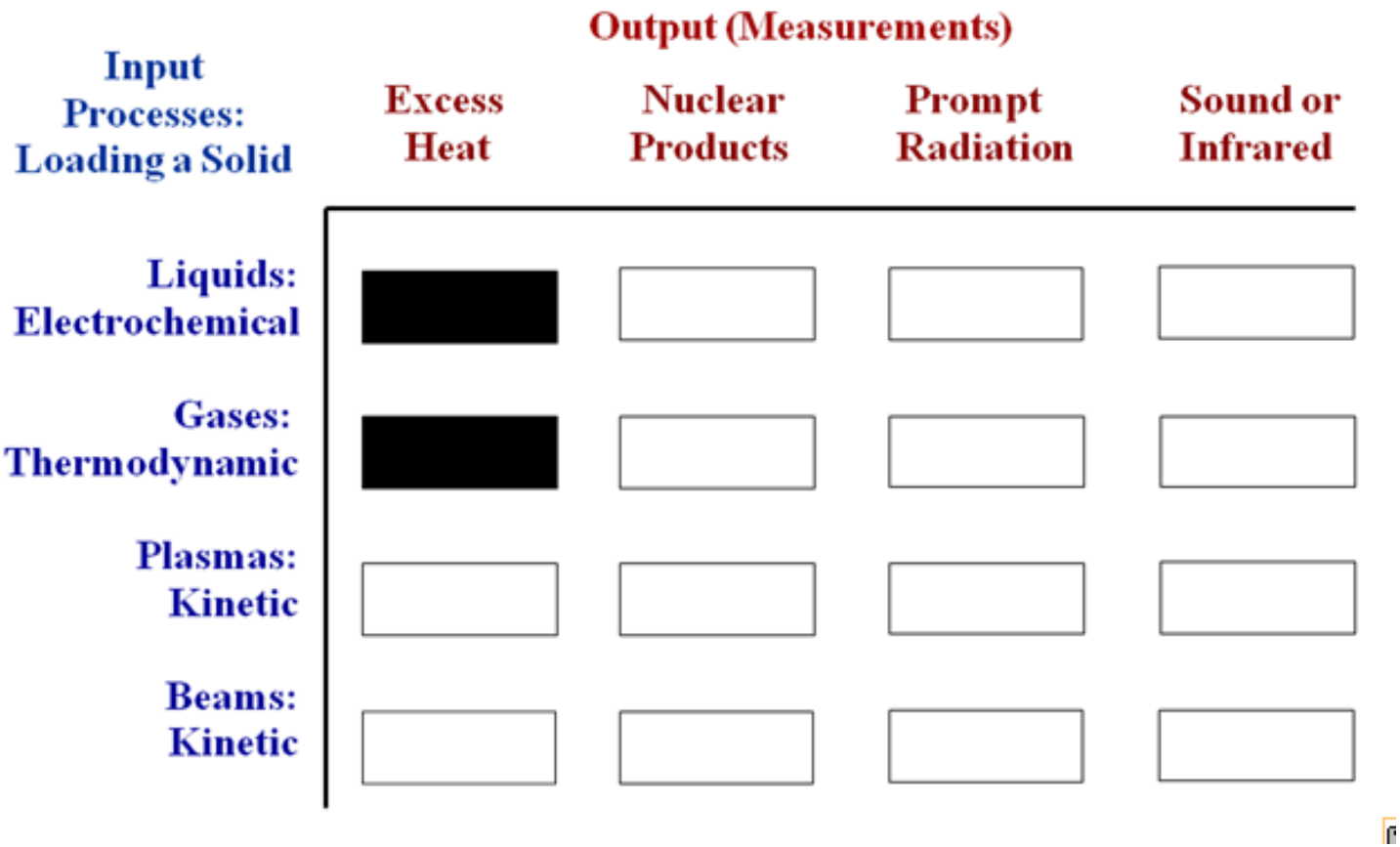
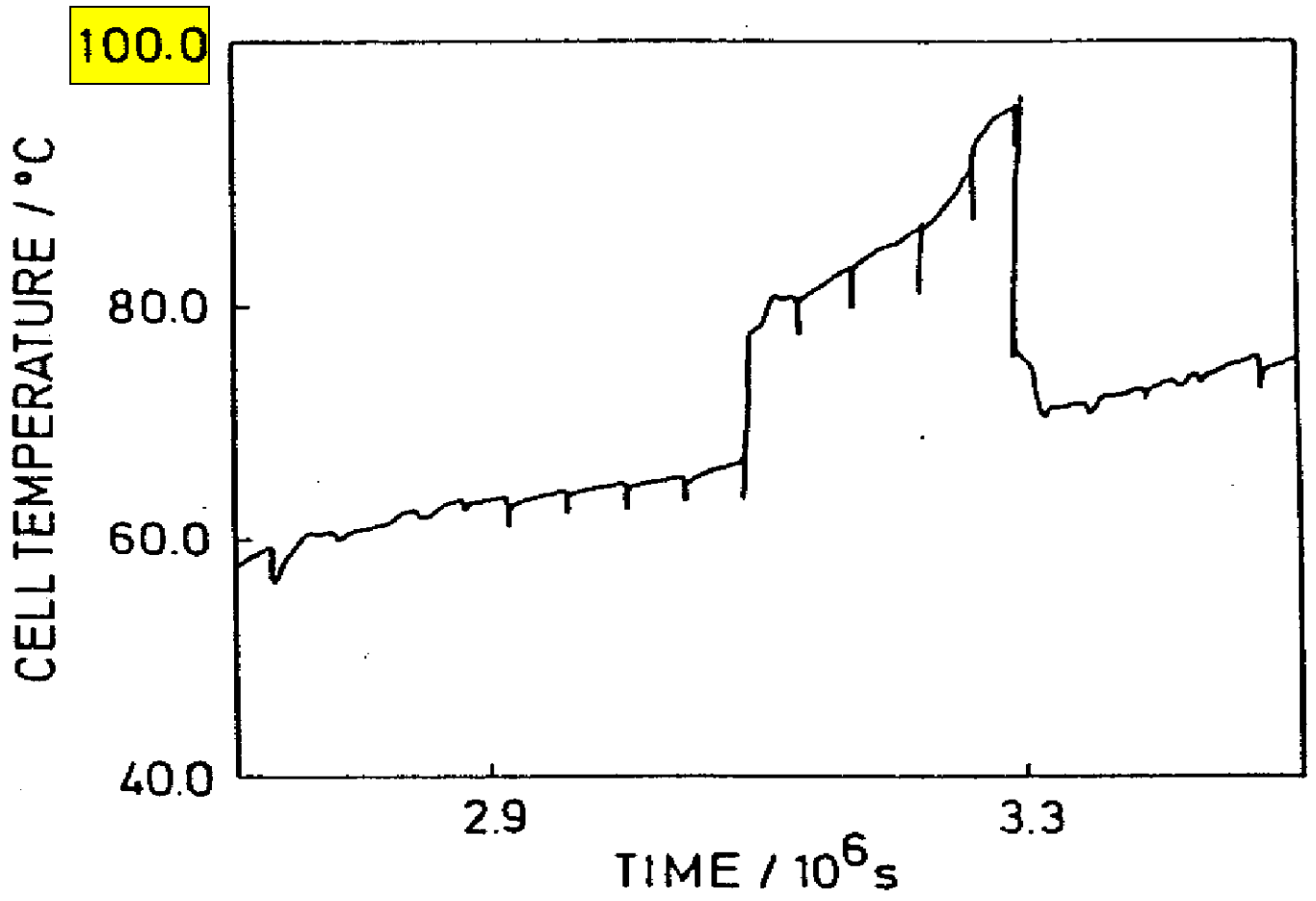
Low Energy Nuclear Reactions

- It is now well established experimentally that
  it is possible to induce nuclear reactions at low energies.
- The scientific case for LENR is based on several types of data,
  and the accumulation of data is large and robust.

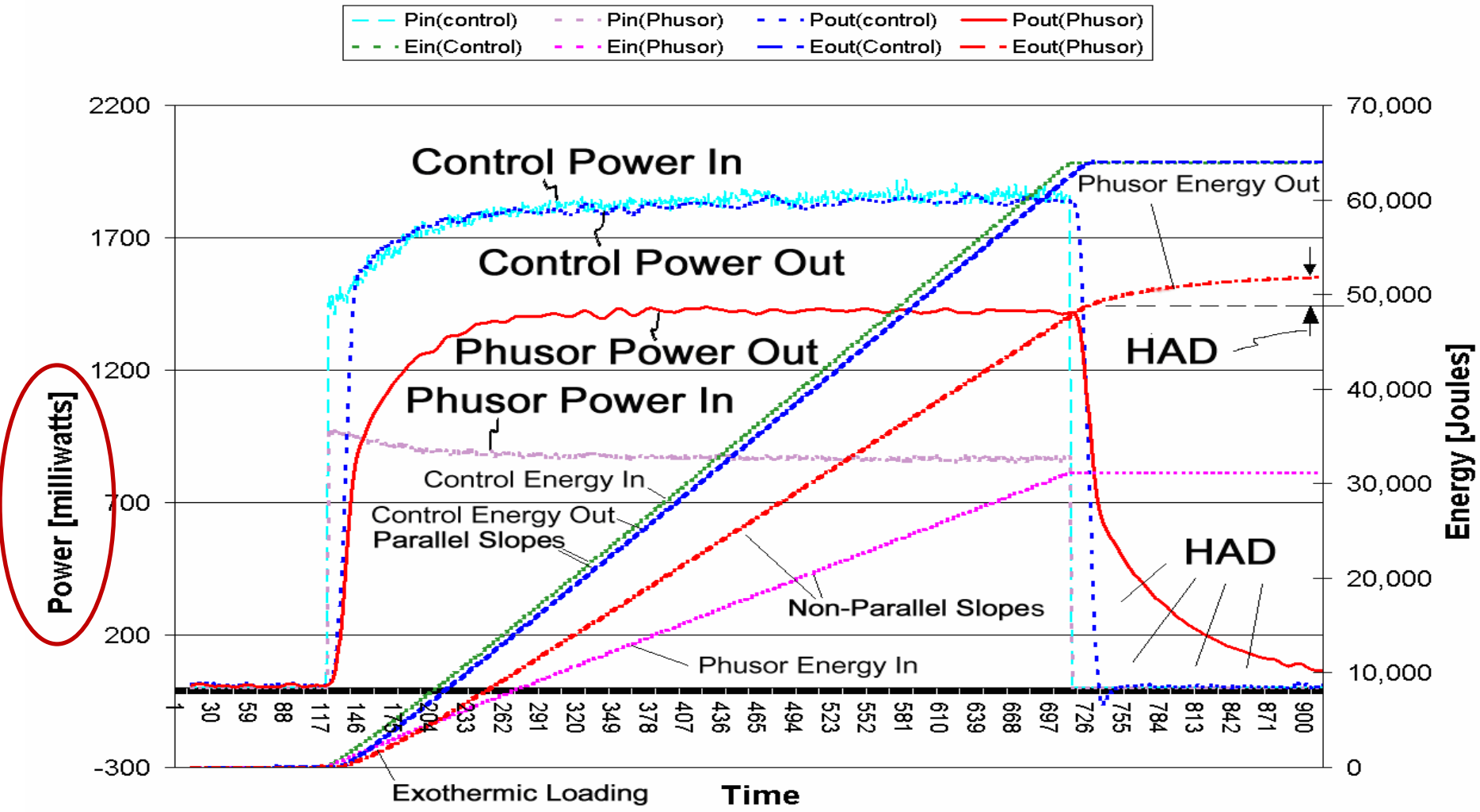


Early Data on Cell Temperature



S. Pons, M. Fleischmann, C. Walling and J. Simpson
International Patent Publication No. 90/10935 (1990)

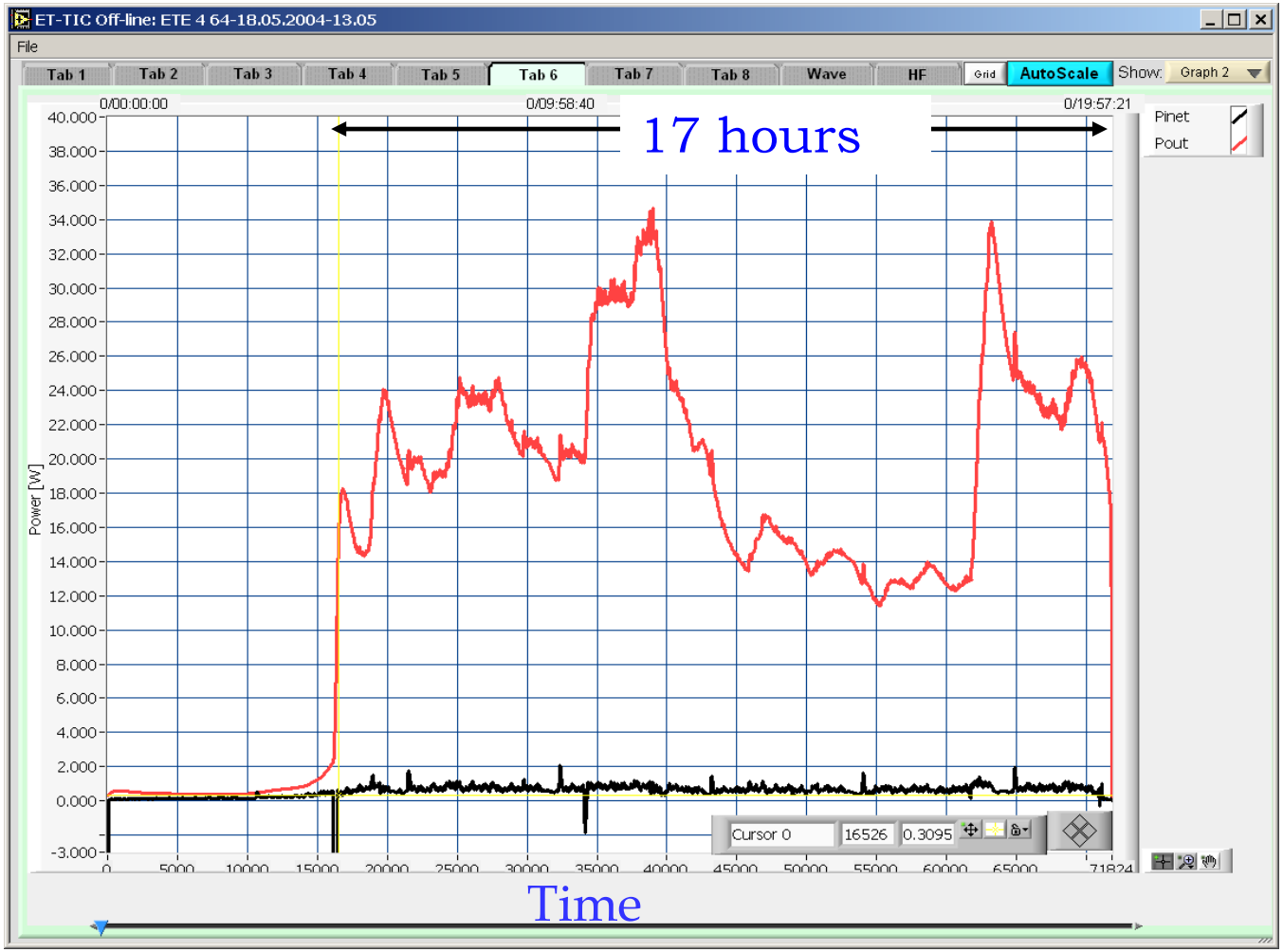
Determination of Excess Thermal Power using Inactive (Control) and Active Cells



M. Swartz and G. Verner, Dual Ohmic Controls Improve Understanding of "Heat after Death", Transactions, American Nuclear Society, Vol. 93, 891-892 (2005).

Energetics Technologies Ltd.

Average P_{out} ≈ 21 Watts & Energy Amplification = 1.144 MJ/0.044 MJ = 26



I. Dardik at al, ICCF-11 (2004)

Two Approaches and Two Material Systems

- The original work on "cold fusion" and most later studies used electrochemical loading of D into Pd to stimulate LENR
- But, many scientists over the past two decades have studied gas loading of H into Ni at elevated temperatures and pressures.

Italian Work on Gas Loading for LENR

- Francesco Piantelli (Department of Physics of the University of Siena) and his colleagues have performed H + Ni experiments since 1989.
- Their work resulted in one patent and one patent application:

F. Piantelli, *Energy Generation and Generator by Means of Anharmonic Stimulated Fusion*. Patent EP 0767962 B1 (1995).

S. Piantelli and F. Piantelli, WO 2010058288 A1: Method for Producing Energy and Apparatus Therefor. 2010-05-27.

- In the early 1990s, Sergio Focardi from the University of Bologna teamed with F. Piantelli. They announced a 40-50 watt source (1994).

S. Focardi , R. Habel and F. Piantelli , "Anomalous Heat Production in Ni-H Systems," Nuovo Cimento, Vol. 107A, p. 163-167 (1994)

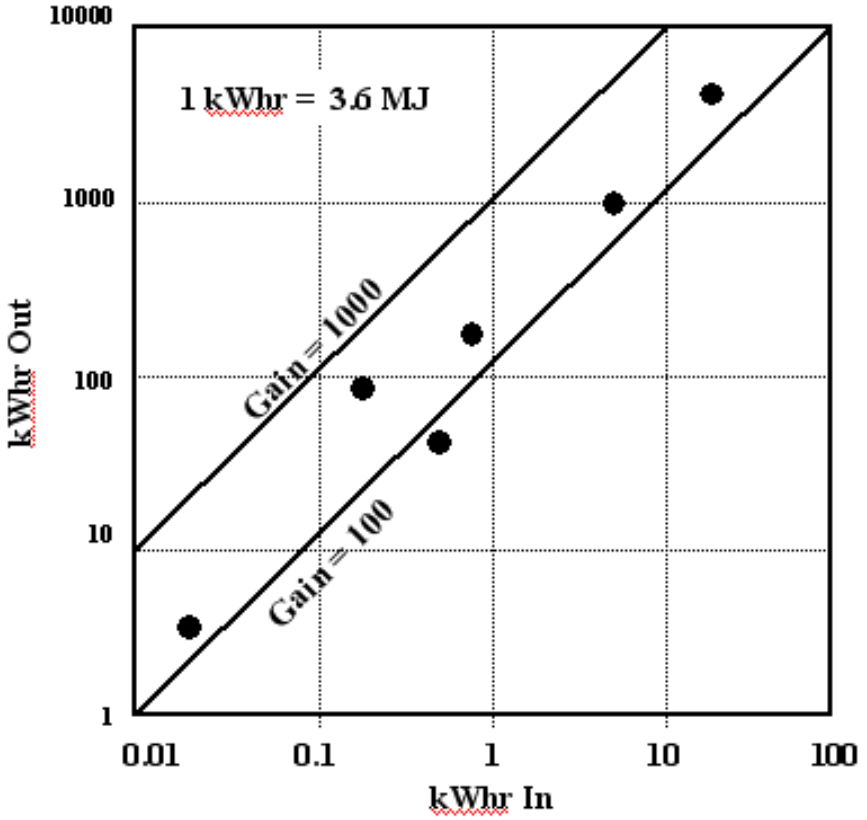
- Andrea Rossi, owner of an Italian company, hired S. Focardi as a consultant in 2007.

Rossi and Focardi

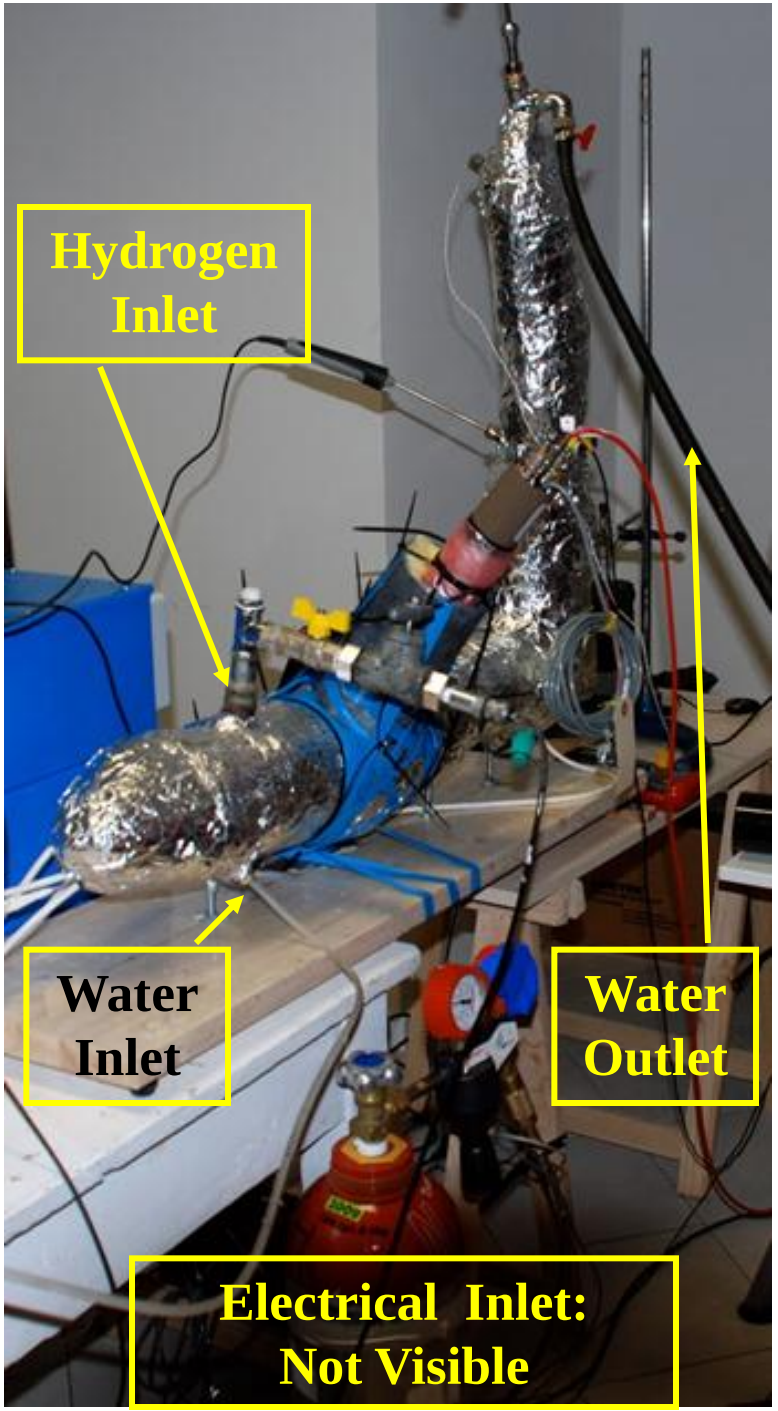
- For the past two years, Rossi, Focardi and others have performed tests and demonstrations of an energy generator called the E-Cat.
- The term E-Cat stands for Energy Catalyzer, but nuclear reactions are not subject to catalysis in the usual sense of the word.
- It is possible that some substance in the E-Cat produces (catalyzes) an environment in which LENR can and do occur.
- The materials in the E-Cat, other than Ni and H, are a closely-guarded secret, and were not disclosed in a patent application.

- In March 2010, Focardi and Rossi posted a paper on the web. It reported immense energy gains: **80 to 415 !!**

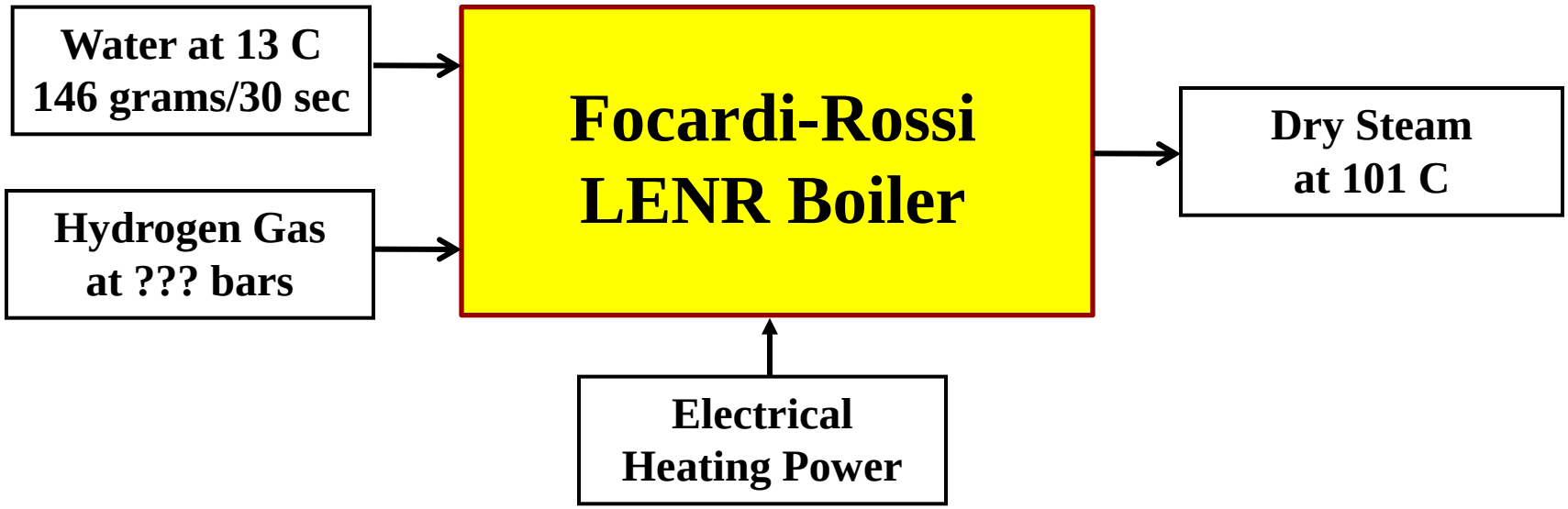
- Note: 1.55 GJ is the maximum energy produced by Tokamak hot fusion (TFTR)



14 January 2011 Demonstration by Rossi and Focardi



Quantitative Performance of Demonstration Device On 14 January 2011



Note: H consumption is said to be very small (< 1 gm)
Water Volume in 1 hour: 146 gm/30sec = 17.52 kg/hour

Heating to Boiling: [100 – 13] deg x 17.52 kg x 4.18 (kJ/kg deg) = 6371 kJ
Vaporization: 1752 kg x 2257 kJ/kg = 39,543 kJ
Total Energy Out: 6372 kJ + 39,543 kJ = 45,914 kJ

Input Energy Profile: 1000 W to 400 W over 30 minutes, and then 400 W for 30 minutes.
1st half hour: 700 W x 1800 sec = 1260 kJ
2nd half hour: 400 W x 1800 sec = 720 kJ, so Total Energy Input = 1980 kJ

Energy Gain = 45, 914/1980 = 23

Photos by G. Levi of Rossi Apparatus from 29 March Test

Photograph of three bare and one insulated E-Cat Devices

Close-up of the section of the E-Cat which is heated by a clamp-on resistive heater.

Swedish physicists Sven Kullander and Hanno Essén observed the test and stated:
"Any chemical process should be ruled out for producing 25 kW from whatever is in a 50 cubic centimeter container.
The only alternative explanation is that there is some kind of a nuclear process that gives rise to the measured energy production."

Synopsis of Rossi E-Cat Tests in 2011

Date	Duration	Power Level	Energy Gain
14 Jan	1 hour	10 kW	23
11 Feb	18 hours	16 kW	135
29 Mar	6 hours	4.4 kW	15
28 Apr	3 hours	2.3 kW	8

http://www.angewandtebiologischeneuemedizin.com/en/index.php?title=Focardi-Rossi_Energy-Catalyzer
http://en.wikipedia.org/wiki/Energy_Catalyzer

Stated concerns about the Recent E-Cat Tests:
None of the tests was as fully instrumented as desired by scientists and engineers who have worked on LENR.

How to Perform Robust Validation Tests

1. **The tests should be designed, conducted and analyzed so rigorously that they will withstand all anticipated questions and criticisms.**

2. **Persons experienced in the types of measurements and instrumentation employed should participate in all three phases of the tests (design, performance and analysis).**

3. **Redundant, well-calibrated sensors and systems will be employed to measure all known streams of energy and matter entering and coming from the device being tested.**

4. **Signal-to-noise ratios of ten or more are required for all measurements to**
   - **(a) exclude the possibility of cumulative errors leading to wrong conclusions and**
   - **(b) insure detection of new effects, specifically nuclear reactions at low energies.**

5. **The test should be repeated at least three times, with each conducted for a continuous period of sufficient duration to strongly exclude the possibility of the measured exit energy being from chemicals stored within the device and then releasing energy.**

6. **A thorough statistical data analysis should be conducted in order to make the error bars associated with each measurement and compute an overall uncertainty in the energy gain.**

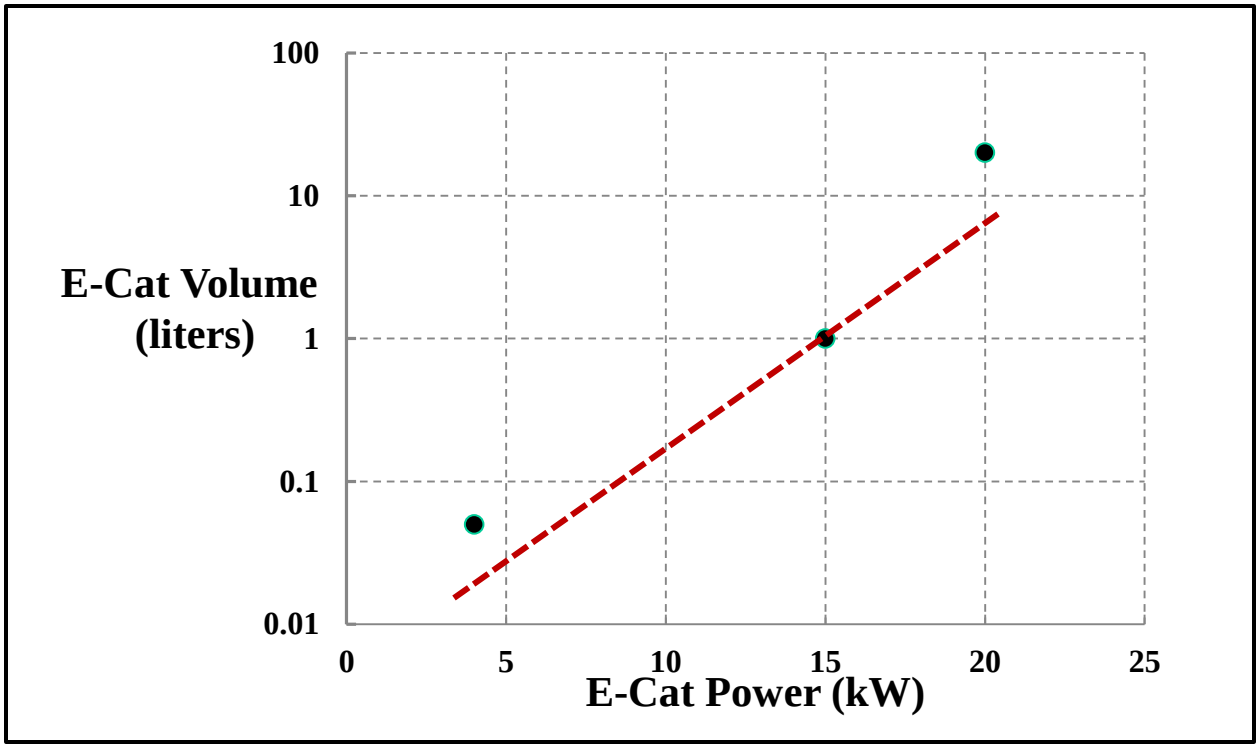
7. **The tests should be fully documented in a report containing all the key aspects of tests, including full calibration data and all raw data, and the report should be publicly available soon after the tests.**

8. **A red team of persons experienced in related laboratory measurements should be used to critique the design & execution of the tests, and the analysis of the measured results, plus the report with all relevant details.**

"Robust Performance Validation of LENR Energy Generators", K.S. Grabowski, D.L. Knies, M.E. Melich, A.E. Moser & D.J. Nagel, ICCF-16, Chennai, India, 6-11 Feb 2011 and http://www.lenr-canr.org/acrobat/Nagel DJchecklist.pdf

Additional Information from Rossi

A practical embodiment of the inventive apparatus, installed on October 16, 2007, was operating 24 hours per day, and provided an amount of energy sufficient to heat the factory of the Company EON. There was a 90% savings on electricity bills over a period of six months.



A 10 kW unit would consume 100 mg of Ni & 10 mg of H_2 in 6 months.

Rossi wrote on 28 April that he had 97 devices operating in four countries.

What Rossi is Doing Commercially NOW

Rossi has a contract to deliver a 1 MW system to the Greek company Defkalion in the fall of this year. 300 4kW units will be manufactured & tested in the US before delivery to Greece.

Pending stable & controllable operation of the promised system, there are normal engineering questions about the industrial E-Cat units, which include:

Adaptability
Compatibility
Durability
Operability
Predictability
Reliability
Stability

Availability
Dependability
Maintainability
Portability
Recoverability
Scalability
Usability

The Current Overall Situation for LENR

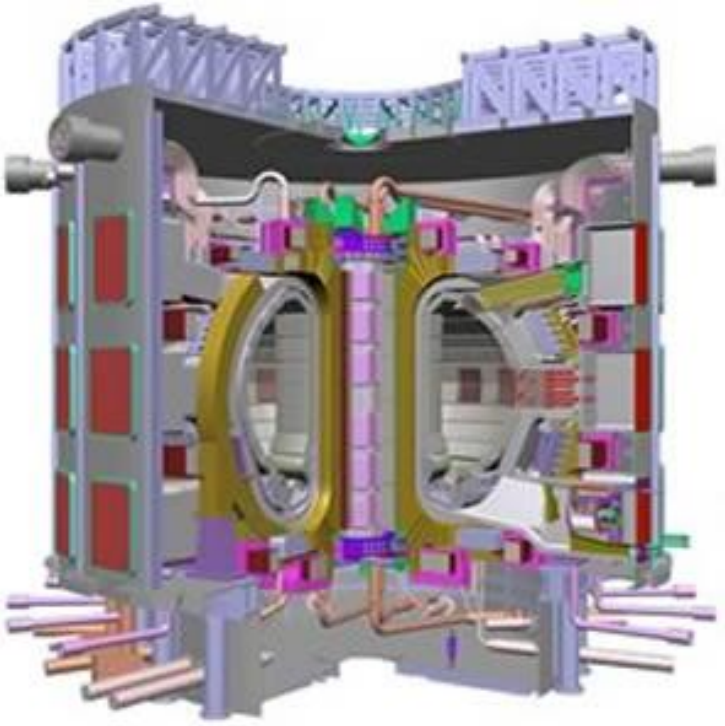
Nuclear reactions are occurring in the LENR experiments
It is possible to initiate nuclear reactions with chemical energies.
The reactions yield significant power for noteworthy times.

Current Major Scientific Problems:
- **Full Reproducibility and Controllability**
- **Lack of Quantitative Understanding**

Exciting (Historic) Possibilities
- **Distributed nuclear power sources**
- **Negligible Prompt Radiation**
- **Negligible Radioactive Waste**

Many Potential Applications
- **Clean water from rivers and the sea**
- **Home heating and maybe electricity**
- **Portable power for electronics**

Hot and "Cold" Fusion Systems



ITER
500 MW
Capital Cost > $10B
> $20/W

Rossi E-Cat Device
4 kW
Capital Cost < $10K
< $2/W

Centralized

Distributed

Comparison of Hot and "Cold" Fusion Histories

	Hot Fusion		LENR
	Magnetic	**Inertial**	
Approximate Years of Research	60	40	20
Estimated Total Spent on Research	> $20B	> $4B	< $0.2B
Rate of Research Funding ($M/year)	333	100	10

Contrasts of Hot and "Cold" Fusion

	Hot Fusion	**"Cold" Fusion**
Size of Sources	Large Plants	Small & Distributed
Operational Environment	High Radiation Levels	Low Radiation Levels
Safety	Possibly Very Good	
Residual Radioactivity	Significant	Very Small
Cost per kW-hr	Unknown	
Time to Market	40 years	Less than 10 years

Responsible US Government Agencies

Department of Energy	**Developing Sources of Energy** **No support of LENR R and D**
Department of Defense	**Major Federal User of Energy** **Now funds limited research on LENR**
National Science Foundation	**Scientific Research** **No funding (or Apparent Awareness)**
Environmental Protection Agency	**Clean Energy and Climate Change** **No funding (or Apparent Awareness)**
Department of Commerce	**Protection of Intellectual Property** **US PTO rejects LENR patent applications**

US agencies responsible for funding research, development and applications of new energy sources, and associated IP protection, are generally ignoring LENR.

Apparent Advantages of LENR Energy Sources

Radiation Safe:	**Little prompt radiation**
Non-Radioactive:	**No radioactive waste problem**
Green:	**No greenhouse gases**
Small:	**Maybe even for portable electronics**
Distributed:	**Less load for the grid**

Urgent Needs within the US

Study by the National Research Council
Funding of Research and Development
Protection of Intellectual Property

Wonderful Scientific Challenge
Potentially Very Important Energy Source