Lattice Energy LLC

LENRs are disruptive new source of safe, radiation-free nuclear energy

Japan’s NEDO-sponsored LENR device project released more info at Technova seminar in Tokyo on March 2, 2018

METI
Ministry of Economy, Trade and Industry

Japan's Energy

NEDO

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NAGOYA UNIVERSITY

KOBE UNIVERSITY

KYUSHU UNIVERSITY

Japan's government targeting commercialization of LENRs

NEDO organized and funded LENR project with industry and academia

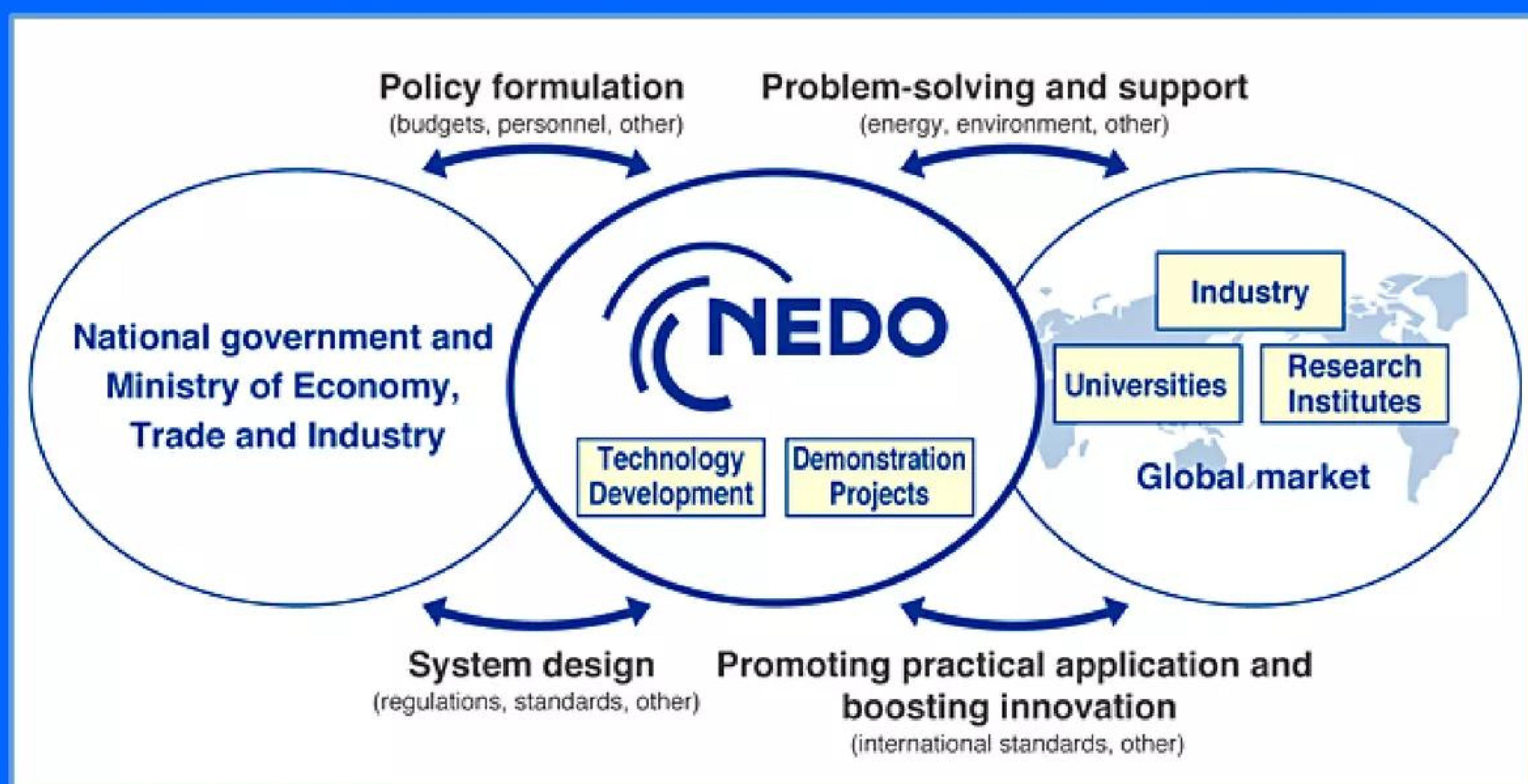
NEDO New Energy and Industrial Technology Development Organization

Combining the efforts of industry, government and academia and leveraging established international research networks, NEDO is committed to contributing to the resolution of energy and global environmental problems and further enhancing Japan's industrial competitiveness

http://www.nedo.go.jp/english/

NEDO's mode of operation – graphic copied from home page of NEDO website

経済産業省 Ministry of Economy, Trade and Industry



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Lattice, Mitsubishi Heavy Industries, Toyota, and Nissan are all developing new type of nuclear power generation technology that could be much better than fission or fusion because it would be hard-radiation-free and produce negligible long-lived radioactive wastes. While still in very early stage of commercial development, ultralow energy neutron reactions (LENRs) offer great promise as a new future source of affordable CO_2-free green energy.

LENRs are green: no energetic radiation or radwastes

Lack of hard radiation obviates need for shielding and containment

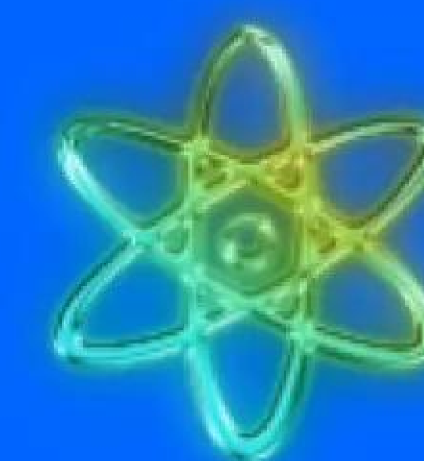
Major opportunity to develop broad range of competitive LENR power sources

Fission and fusion processes both emit deadly MeV-energy neutron and gamma radiation

Fission reactors need 1 foot of steel and 3 feet of concrete to protect human beings from dangerous hard radiation and wastes emitted by reactor; systems intrinsically large and heavy

LENRs could enable future development of small, portable battery-like power sources that are very safe and disposable

Revolution in green nuclear technology



Much larger LENR systems based on dusty plasma embodiments could potentially scale-up to megawatts

Haber-Bosch process used globally to produce Ammonia

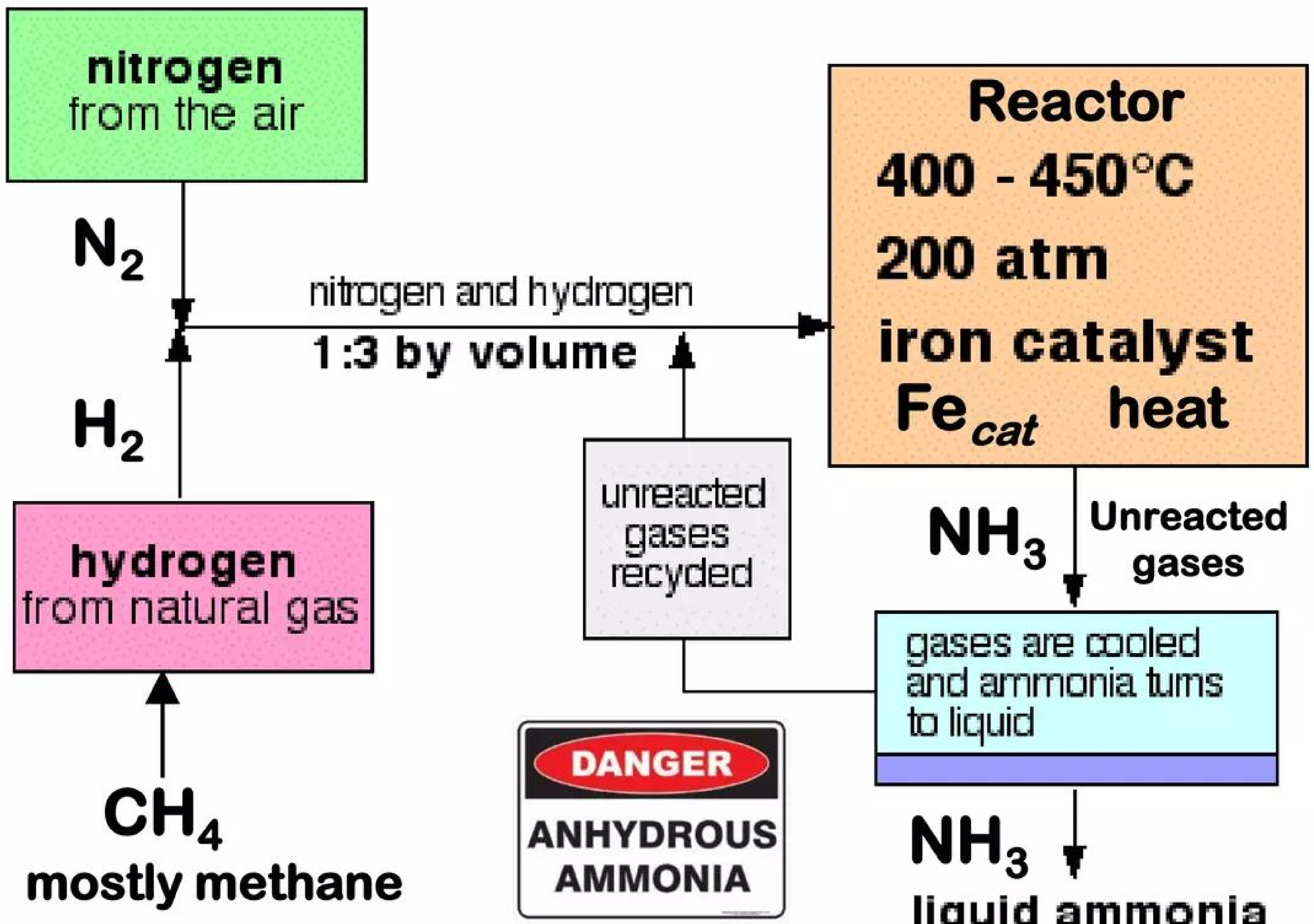
Chemical reactions need temps of 400 - 450^{o} C and pressures of 200 atm.

Nitrogen and Hydrogen reacted with Fe catalyst to make usable ammonia

Chemical reactions in Haber-Bosch process are:

(natural gas) $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$ followed by $N_2 + 3H_2 \rightarrow 2NH_3$ (ammonia)

Fritz Haber



Carl Bosch

Adapted from source: http://www.chemguide.co.uk/physical/equilibria/haber.html

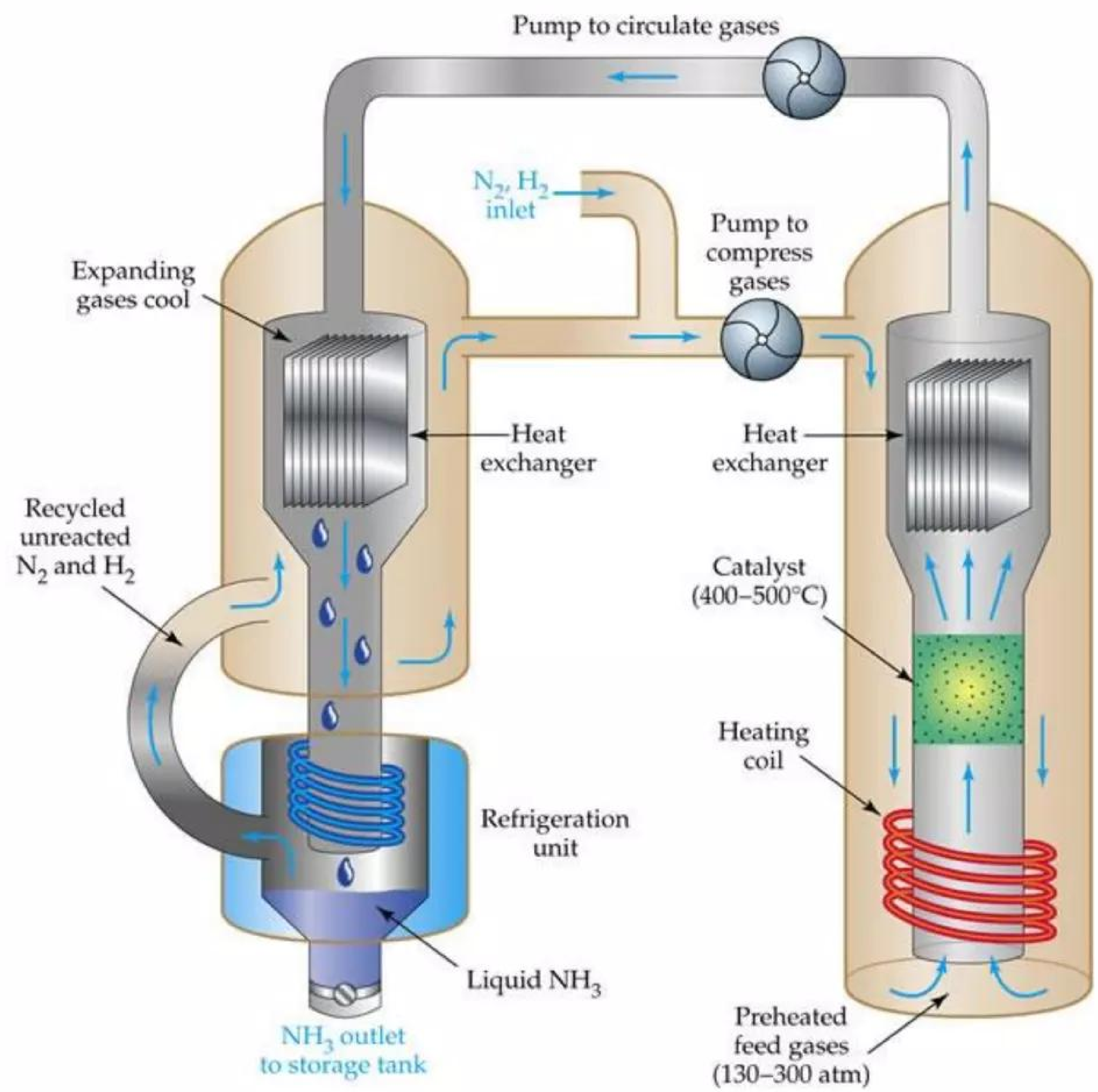
LENRs occur at lower temps & pressures than Haber-Bosch

LENRs are hard-radiation-free → do not require shielding or containment

Assaleyuh ammonia plant (Iran)
Operates at ~ 450º C and 200 atm.

Reactor on left ~100 feet tall

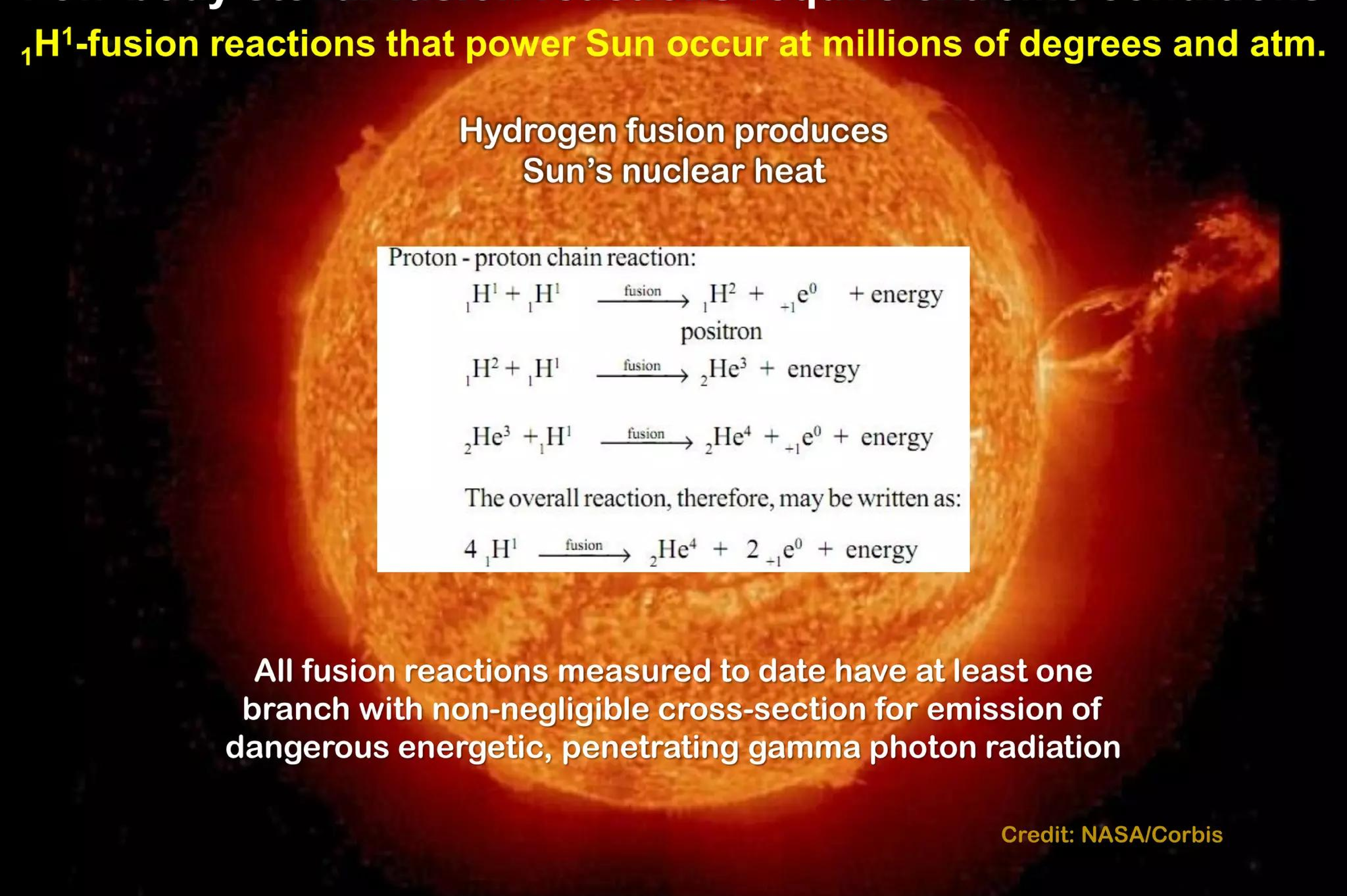
Haber-Bosch process uses Iron (Fe) catalyst to fix gaseous N_2



Graphic source: quarkology.com

Few-body stellar fusion reactions require extreme conditions

${}_1H^1$-fusion reactions that power Sun occur at millions of degrees and atm.



Hydrogen fusion produces Sun's nuclear heat

Proton - proton chain reaction:

$${}_1H^1 + {}_1H^1 \xrightarrow{\text{fusion}} {}_1H^2 + {}_{+1}e^0 + \text{energy}$$

positron

$${}_1H^2 + {}_1H^1 \xrightarrow{\text{fusion}} {}_2He^3 + \text{energy}$$

$${}_2He^3 + {}_1H^1 \xrightarrow{\text{fusion}} {}_2He^4 + {}_{+1}e^0 + \text{energy}$$

The overall reaction, therefore, may be written as:

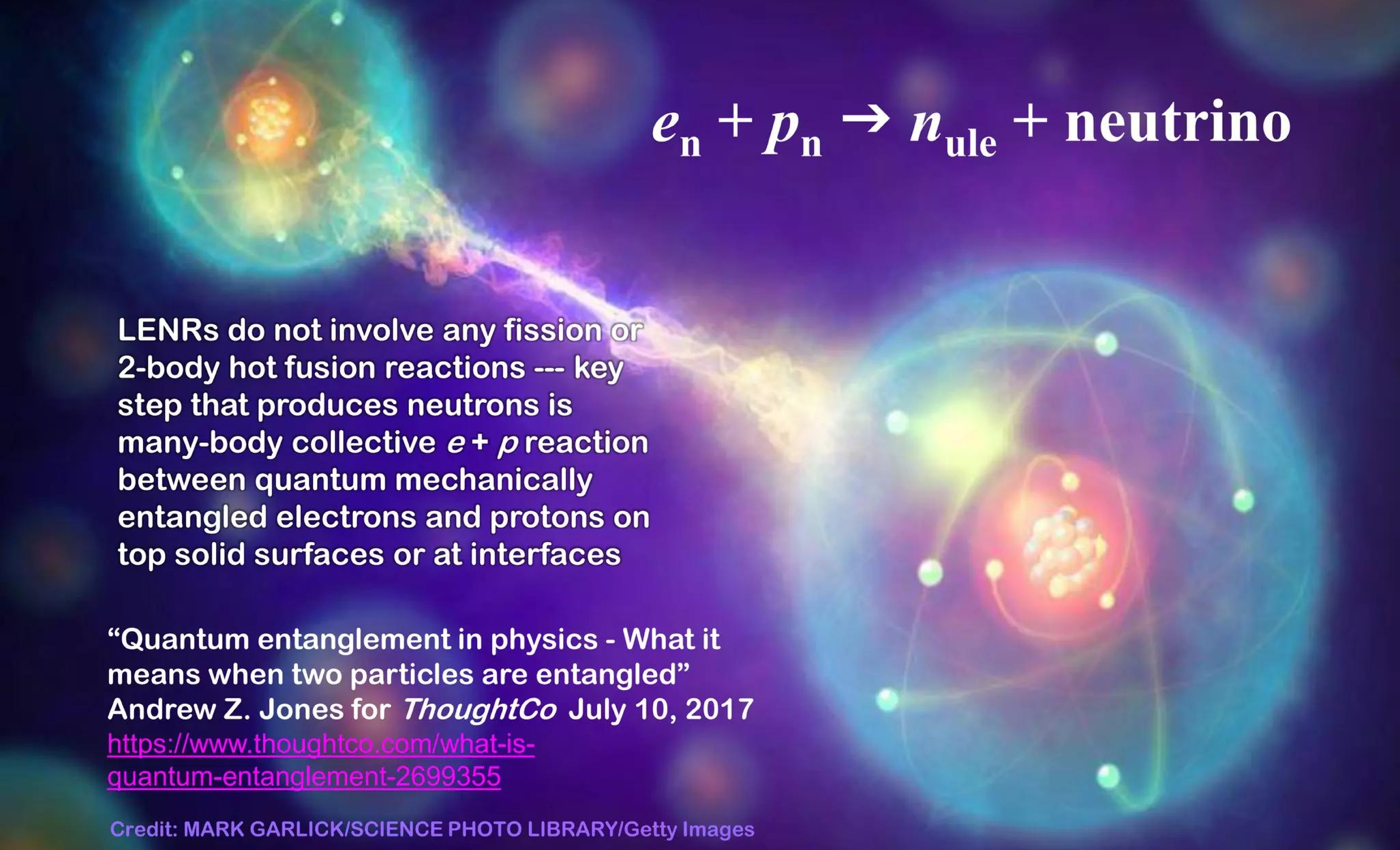
$$4\,{}_1H^1 \xrightarrow{\text{fusion}} {}_2He^4 + 2\,{}_{+1}e^0 + \text{energy}$$

All fusion reactions measured to date have at least one branch with non-negligible cross-section for emission of dangerous energetic, penetrating gamma photon radiation

Credit: NASA/Corbis

Many-body collective quantum effects are crucial for LENRs

Enable heat-producing nuclear reactions at moderate temps/pressures



$$e_{\mathrm{n}} + p_{\mathrm{n}} \rightarrow n_{\mathrm{ule}} + \textbf{neutrino}$$

LENRs do not involve any fission or 2-body hot fusion reactions --- key step that produces neutrons is many-body collective *e* + *p* reaction between quantum mechanically entangled electrons and protons on top solid surfaces or at interfaces

"Quantum entanglement in physics - What it means when two particles are entangled" Andrew Z. Jones for *ThoughtCo* July 10, 2017 https://www.thoughtco.com/what-is-quantum-entanglement-2699355

Credit: MARK GARLICK/SCIENCE PHOTO LIBRARY/Getty Images

Technova Inc. had project seminar in Tokyo on March 2, 2018

Discussed status and recent progress in NEDO LENR device R&D project

Technova Seminar 2018/3/2

常温核融合研究の現状

高橋　亮人　（Takahashi, Akito）

(大阪大学名誉教授: Prof. Emeritus Osaka U.）

(テクノバ、シニアアドバイザー: Senior Advisor, Technova Inc.）

For Technova Seminar 2018-3-2, Tokyo Japan

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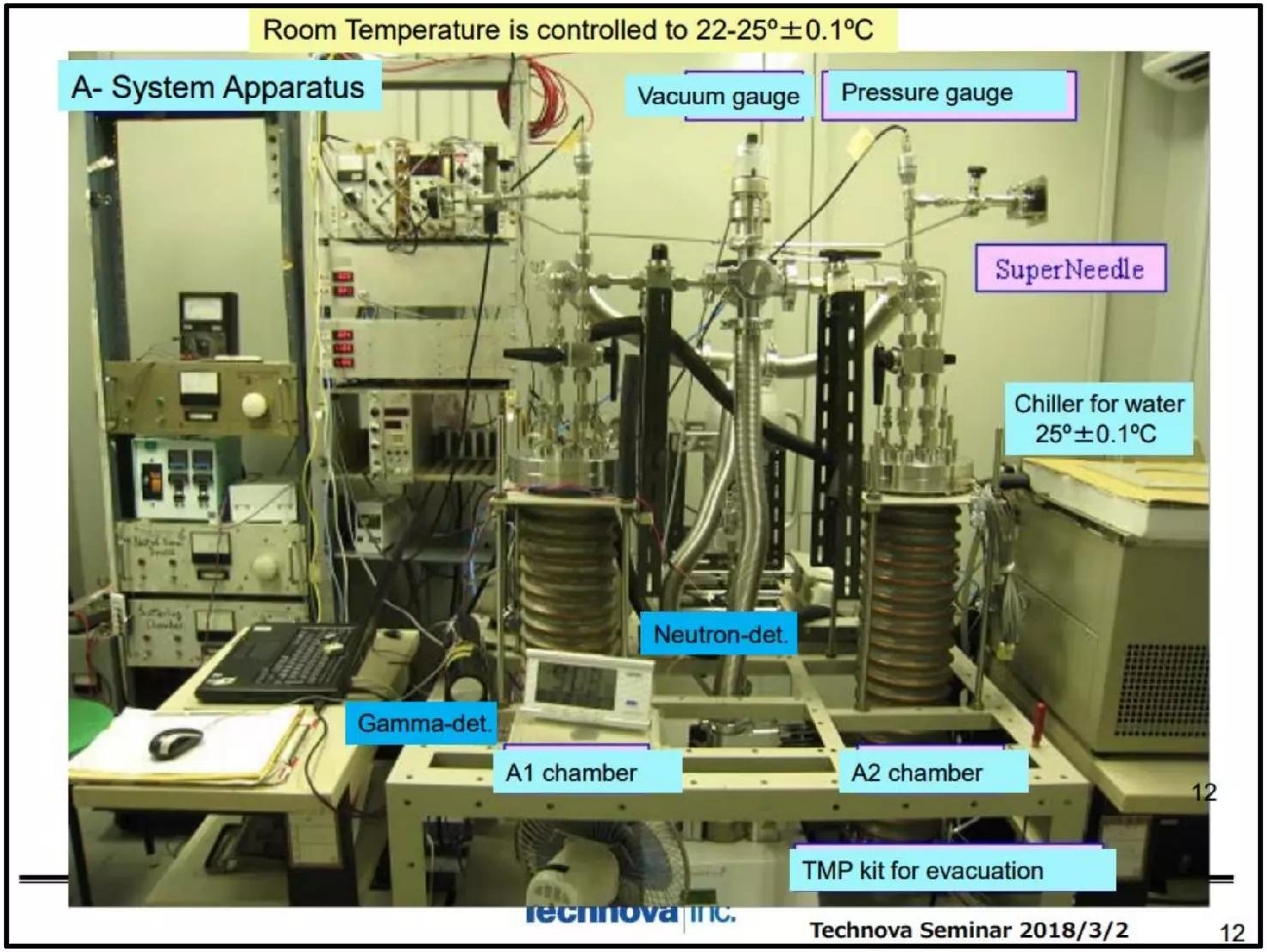
https://www.researchgate.net/publication/323600178_Present_Status_of_Cold_Fusion_Research

Unshielded apparatus for NEDO LENR device experiments

Gamma & neutron detectors confirm deadly energetic radiation is absent



Unshielded apparatus for NEDO LENR device experiments

Accurate, sensitive calorimetry used to measure excess heat production

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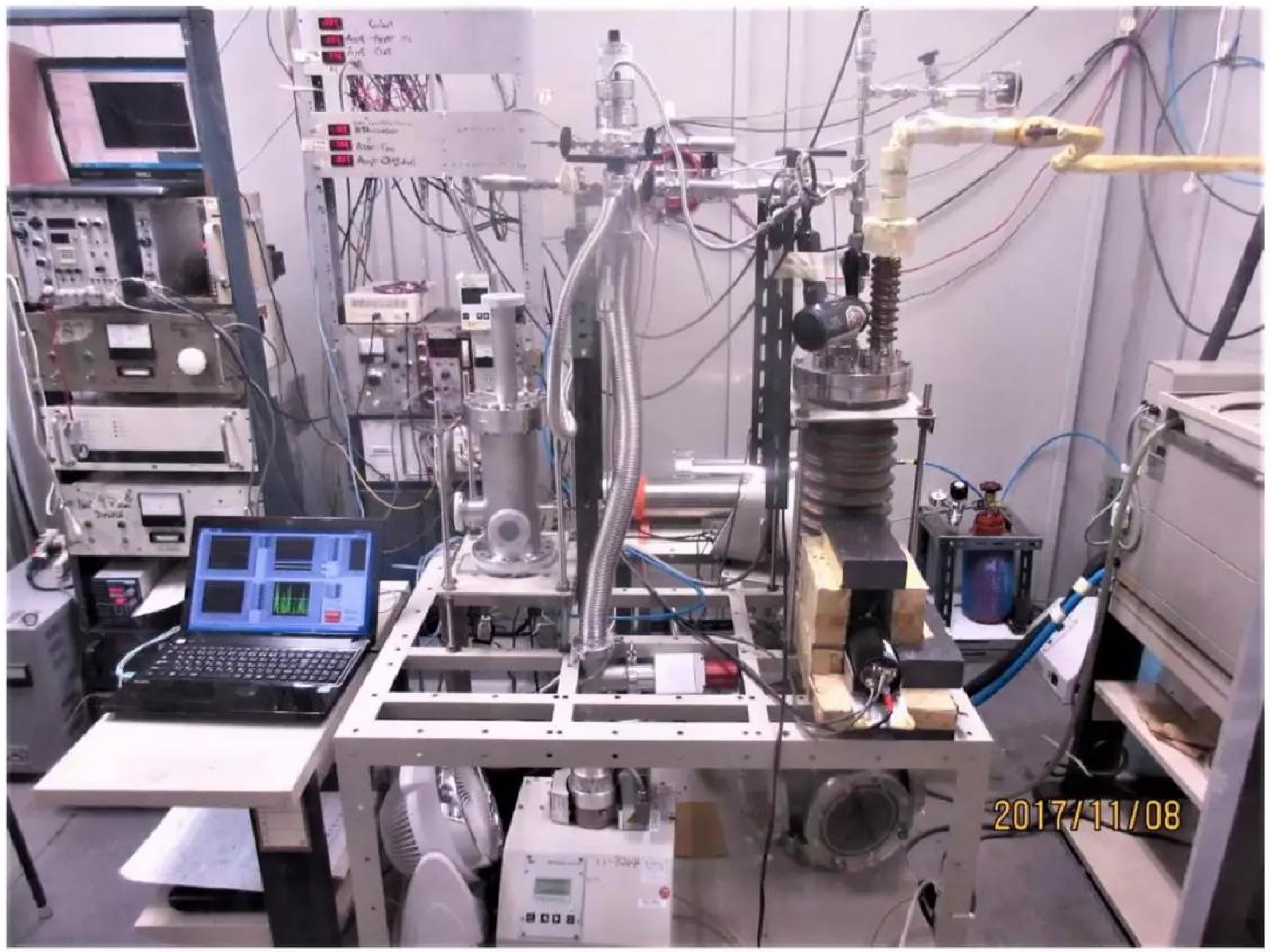
神戸大MHE装置の主要部

MHE Calorimetry Test System at Kobe University, since 2012



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Unshielded apparatus for NEDO LENR device experiments

Schematic diagram at left describes details of experimental apparatus

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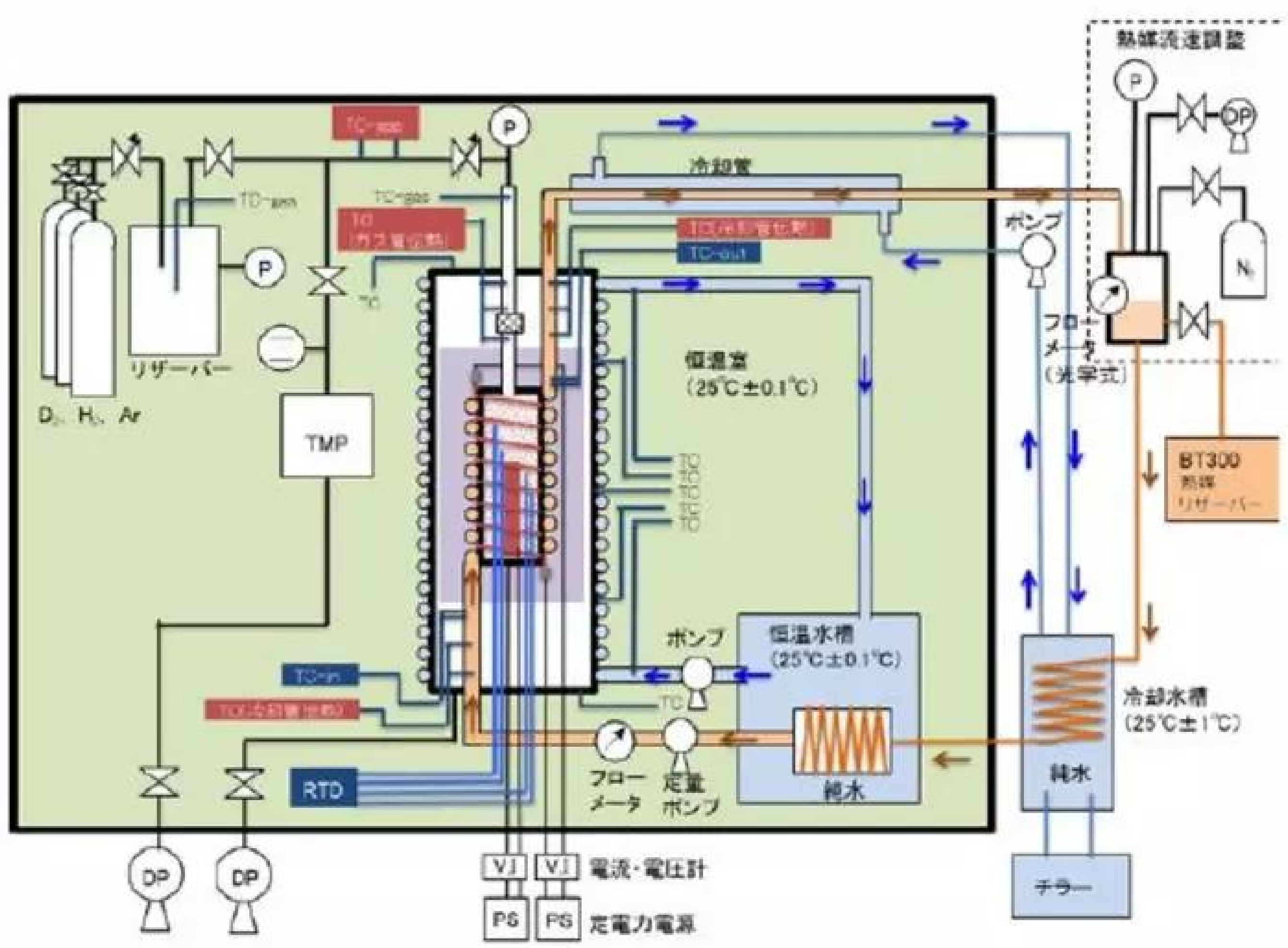
新規高精度熱評価装置（東北大学ELPH）を設計・製造・組み立てし、発熱試験に成功：共同実験



装置構成
Schematics of facility

東北大MHE装置外観
Main part of Tohoku MHE facility

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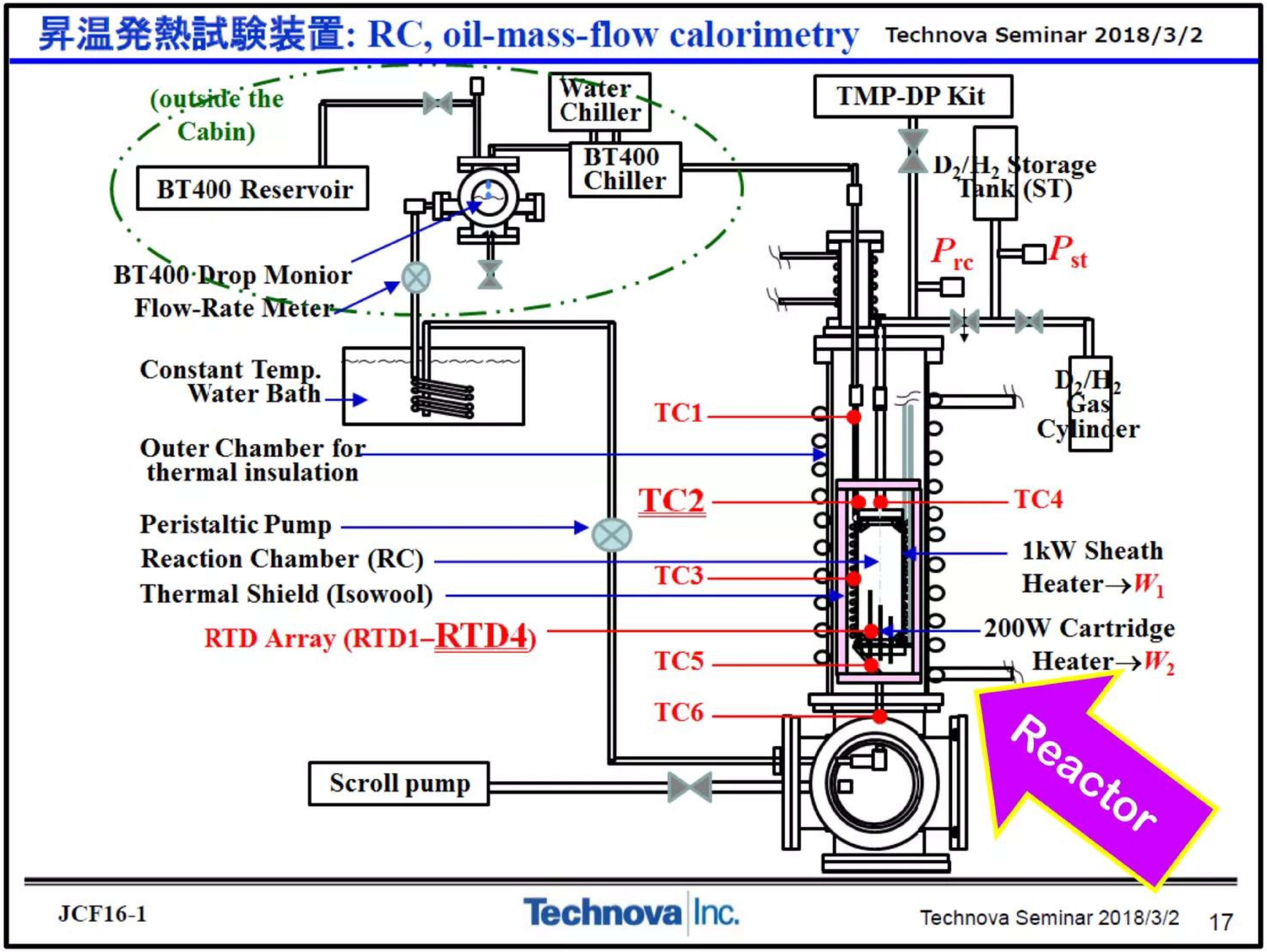
Unshielded apparatus for NEDO LENR device experiments

Volume of reaction chamber = 500 cc; LENR samples & filler placed inside

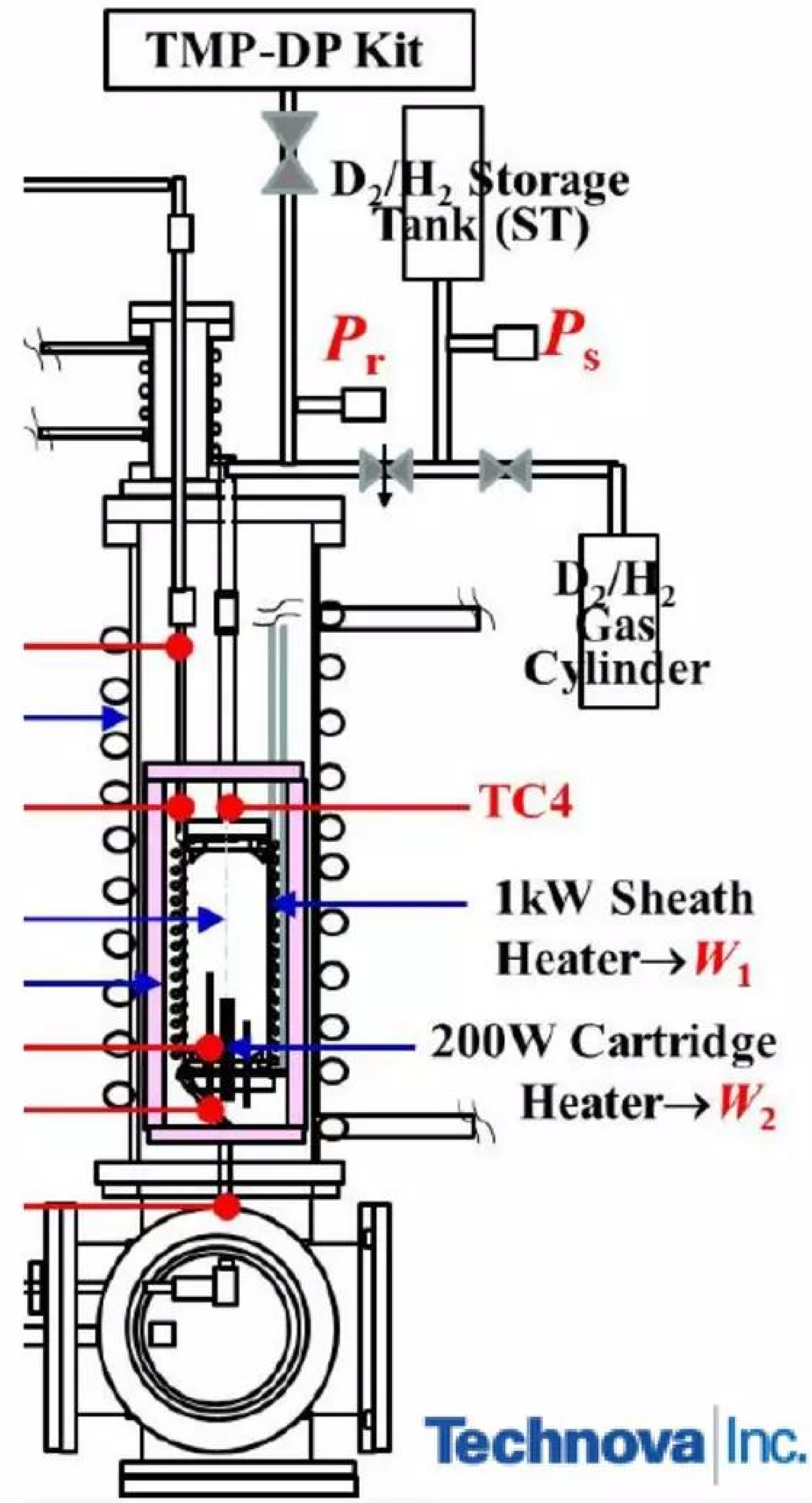


NEDO project utilizes standardized experimental methods

Apparatus designed to accurately measure excess heat production in RC

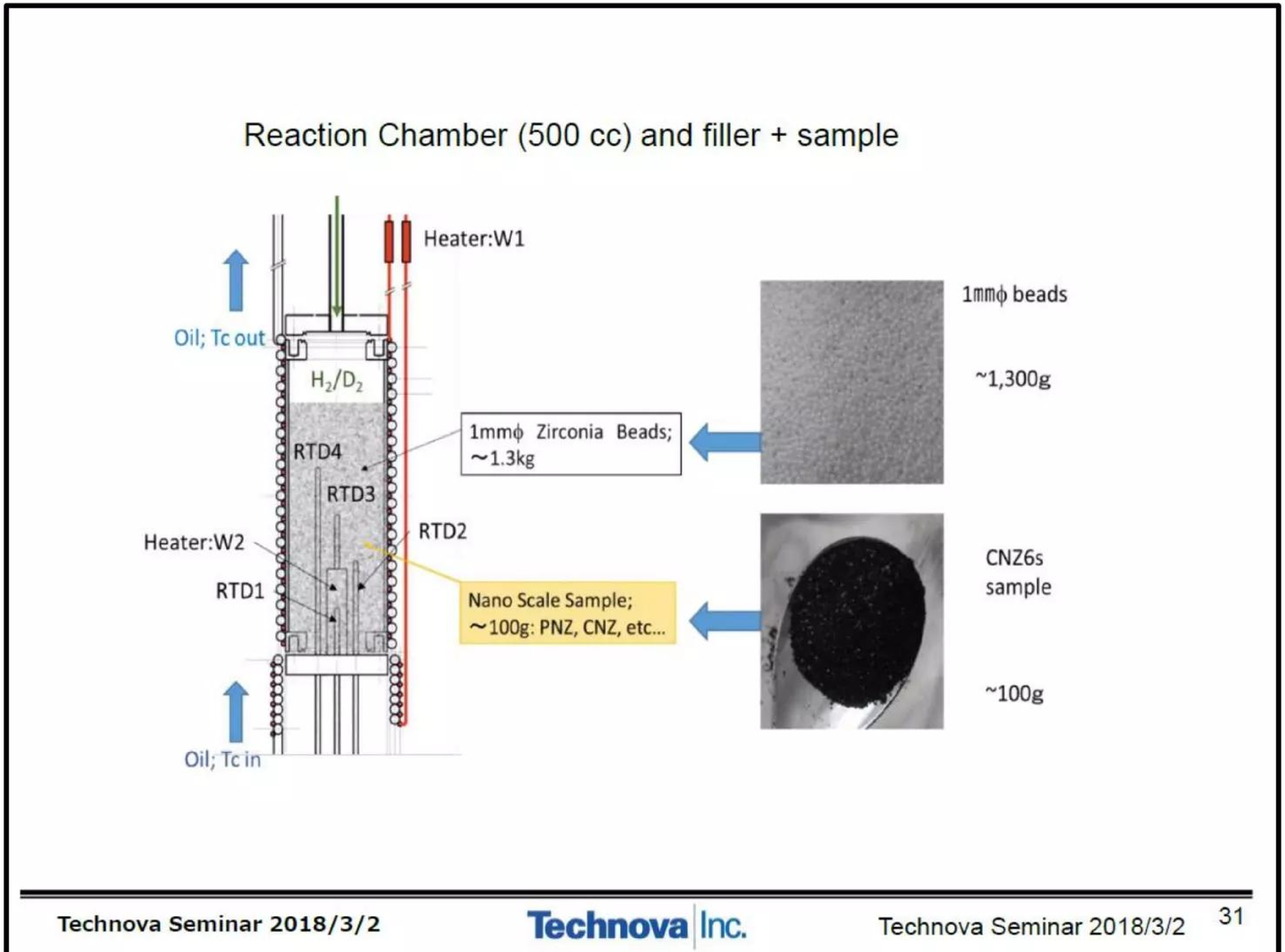
Generic overview of experimental run after LENR device materials fabrication

- Non-destructively characterize LENR device materials
- Place LENR device materials in reaction chamber (RC)
- Open valve: admit either 99^{+}%-pure D_2 or H_2 gas into reaction chamber at ~1 atm pressure and room temp; then close valve (RC is sealed); measure excess heat production via calorimetry (tiny values @ room temp)
- Use external heaters to heat reaction chamber up to desired initial working temperature and pressure
- Conduct experimental run for planned period of time: continuously measure excess heat production inside RC via calorimetry (excess heat ≈ measured total thermal output from RC minus total thermal input into RC) for remaining duration of given experimental run
- Stop experiment; remove device materials from RC
- Post-experiment: analyze LENR test device materials



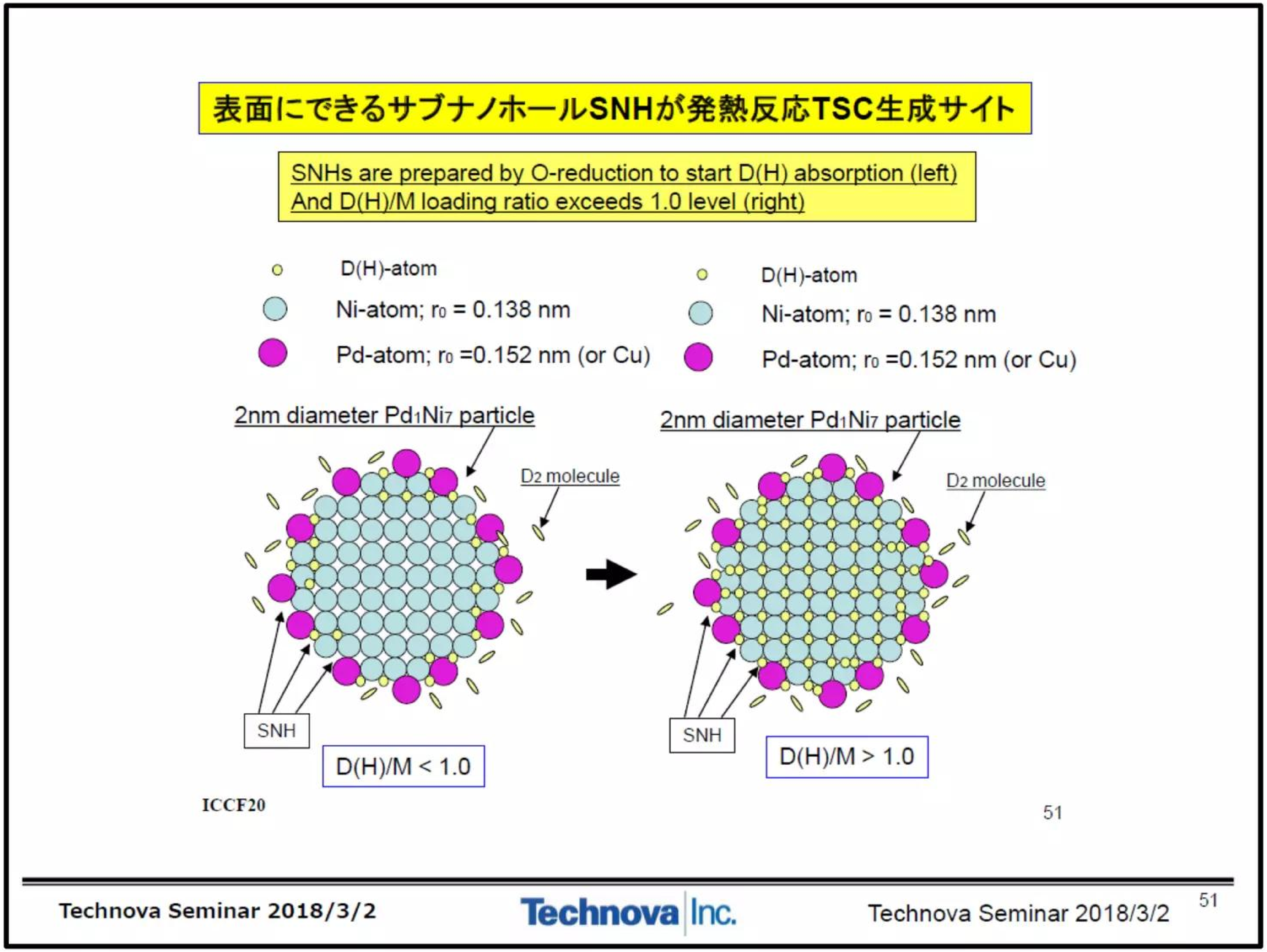
Nanocomposite LENR samples and filler in reaction chamber

~100 g LENR device materials dispersed in 1,300 g of Zirconia filler beads



Model for structure of Pd_1/Ni_7 nanoparticle loading with D(H)

D(H)/metal-atom ratio must be > 0.80 for LENRs to be triggered on surface

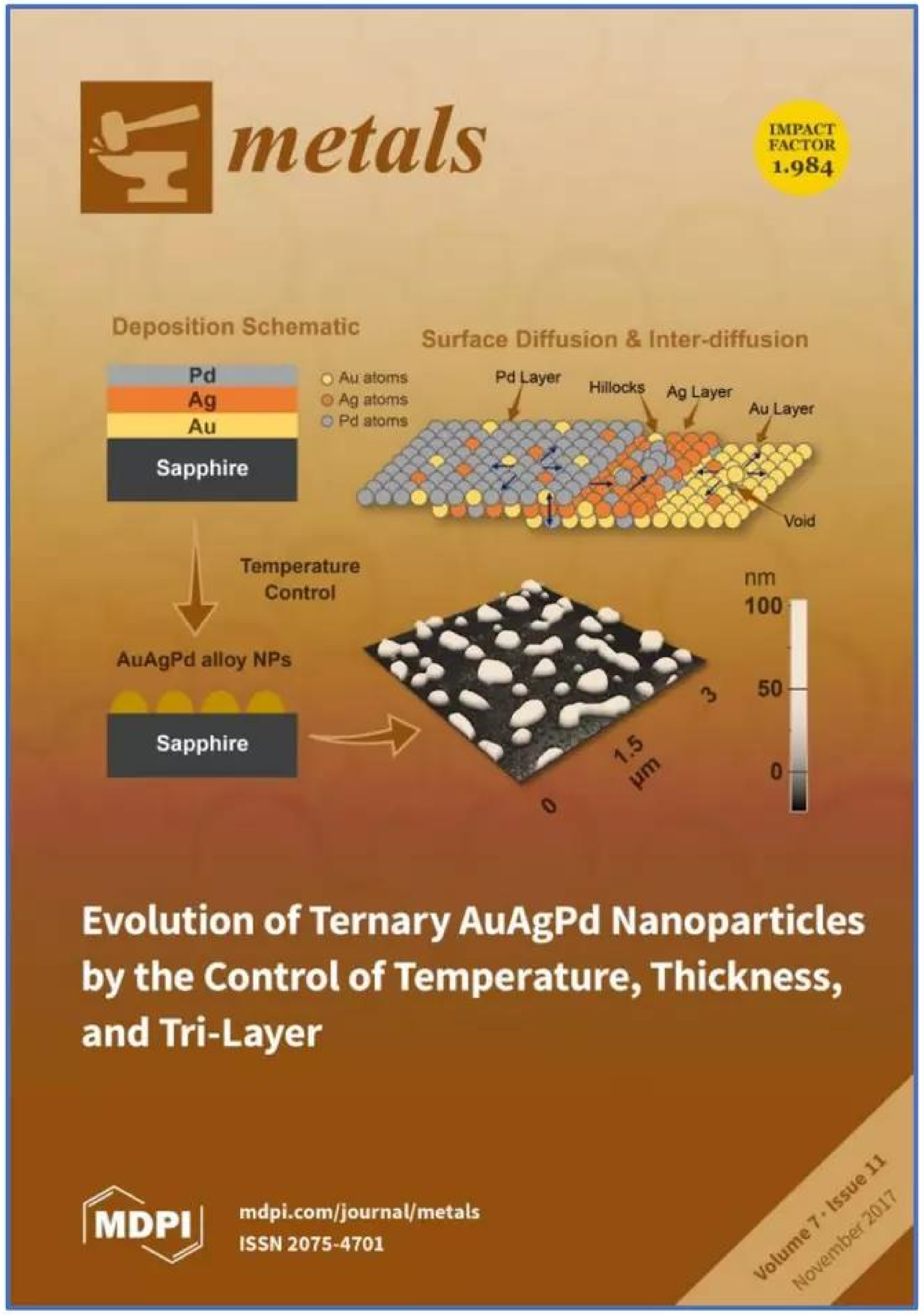


NEDO project utilizes standardized experimental methods

LENR test devices: nanocomposite structures with varied compositions

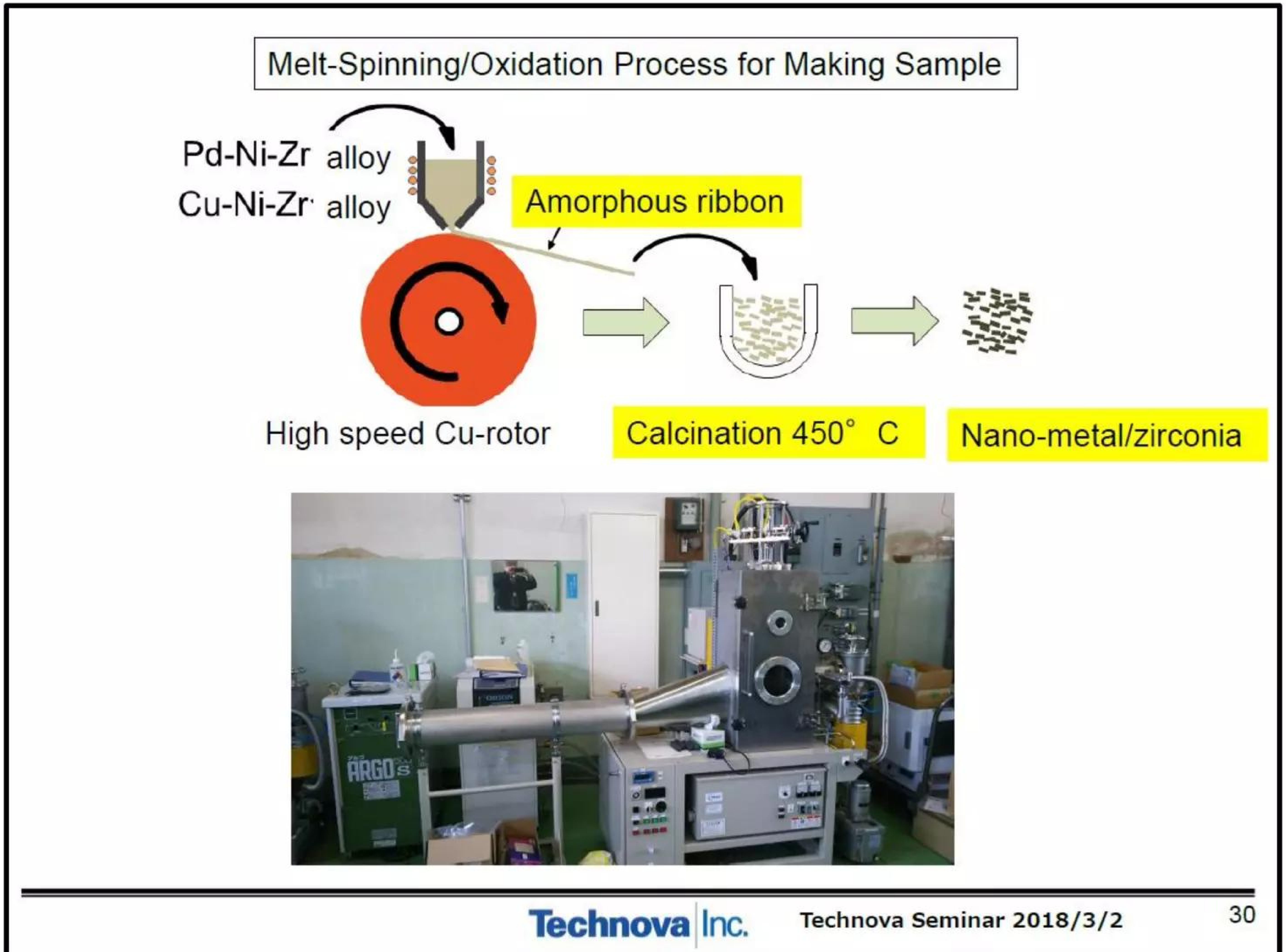
Overview of NEDO project LENR device materials composition and fabrication

- **Designed multi-metallic, nanocomposite LENR test devices comprising alloys of metallic Ni, Pd, Zr, and Cu, with metal-oxide support substrates; fabricated via several well-established methods**
- **Solid-state LENR devices were amorphous. Had nanometer-scale domains consisting of alloyed metals with various molar ratios. Ni, Pd, Zr will form good hydrides when exposed to Hydrogen**
- **LENR device types tested: PS (Pd-SiO_2), CNS (Cu-Ni-SiO_2), PNZ (Pd-Ni-Zr), or CNZ (Cu-Ni-Zr) used with either SiO_2 or ZrO_2 filler substrates**
- **LENR test devices were carefully analyzed and characterized before-and-after experimental runs with some or all of following techniques: XRD, SOR-XRD, SOR-XAFS, TEM, STEM/EDS, ERDA, and ICP-MS, among others**



Several methods used to fabricate nanocomposite samples

Melt-spinning and oxidation at 450^{o} C utilized for some nanoparticulates



Details about chemical composition of LENR device samples

Nickel (Ni) fortuitously added to mixture based on educated guesswork

Atomic composition for Pd_1Ni_{10}/ZrO_2 (PNZ6, PNZ6r) and Pd_1Ni_7/ZrO_2 (PNZ7k)

今後試料量増大とナノ構造をそろえることが期待される
To increase sample and control nm size is key.

16 cc in volume

Sample	Mass (g)	Molar ratio				ZrO_2 filler mass (g)
		Ni	Pd	Zr	O	
PNZ6	124.2	**0.318**	**0.032**	**0.650**	0.240	1377
calcined at 450°C·60h		10 : 1				
PNZ6r	131.9	**0.318**	**0.032**	**0.650**	1.03	1378
recalcined at 450°C·60h		10 : 1				
PNZ7k	99.8	**0.306**	**0.044**	**0.650**	0.274	1531
calcined at 450°C·60h		7 : 1				

95% of 500-cc RC was filled with ZrO_2 filler

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Summary of experimental results for NEDO LENR project

Reactors typically operated at 200 - 350^{o} C; excess heat up to 25 Watts

6機関参加の共同試験実施状況・発熱データ概要

回	試験日	場所	試料	水素	炉内温度	最大出力、積算発熱量 （積算発熱量目標値：360kJ/mol-D（H））
1	H28.01.13-22	神戸大	PS3 (Pd/SiO2)	D	室温 200-300℃	室温 23W、35kJ/mol-D 昇温 ゼロ
2	H28.03.07-18	神戸大	PNZ3 (PdNi7/ZrO2)	D	室温 200-300℃	室温 2.5W、73kJ/mol-D(＃1), 48kJ/mol-D(＃2) 昇温 10W、7,700kJ/mol-D
3	H28.05.09-18	神戸大	PNZ3r (再酸化)	H	室温 200-300℃	室温 0.6W、 95kJ/mol-H 昇温 8W、2MJ/mol-H
4	H28.06.10-20	神戸大	CNZ5 (CuNi7/ZrO2)	H	室温 200-300℃	室温 0.3W、 50kJ/mol-H 昇温 3.3W、3.6MJ/mol-H
5	H28.07.04-22	東北大	PNZ4s (PdNi7/ZrO2)	D	室温 160-300℃	室温 10W、 55kJ/mol-D 昇温 3.3W、1.4MJ/mol-D
6	H28.08.05-19	東北大	CNZ5s (CuNi7/ZrO2)	H	室温 160-250℃	室温 実施せず 昇温 5W、6.5MJ/mol-H
7	H28.9.15-11.4	神戸大	PSf1 (Pd/SiO2$_{-covered}$)	D	室温 200-300℃	室温 2.5W、49kJ/mol-D(＃1）,18kJ/mol-D(＃2～) 昇温 ゼロ
8	H28.10.20 -11.16	東北大	PSn1 (Pd/meso-Si)	D	室温 200-300℃	室温 4.2W、106kJ/mol-D(＃1）,24kJ/mol-D(＃2) 昇温 ゼロ
9	H28.11.21 -H29. 1.23	神戸大	CNS3 (CuNi10/SiO2)	H	室温 200-400℃	室温 0.1W、56kJ/mol-H(＃1）,56kJ/mol-H(＃2) 昇温 4.4W、67 MJ/mol-H
10	H28.12.21 -H29.2.4	東北大	CNS3s (CuNi10/SiO2)	H	室温 150-300℃	室温 実施せず 昇温 4.2W、11MJ/mol-H
11	H29.2.6-3.16	神戸大	PNZ5 (PdNi7/ZrO2)	D	室温 250-350℃	室温 8W、63kJ/mol-D(＃1）,40kJ/mol-D(＃2) 昇温 4.2W, 7.6MJ/mol-D
12	H29.3.1-4.16	東北大	CNZ6 s (CuNi7/ZrO2)	H	室温 150-300℃	室温 実施せず 昇温 2.1W、5.3MJ/mol-H
13	H29.5.22	九州大	PNZ3	H	RT-450℃	DSC、TPR測定
14	H29.5.24-6.30	神戸大	PNZ6 (PdNi10/ZrO2)	D	室温 250-350℃	室温 7.5W、58kJ/mol-D）(＃1）,37kJ/mol-D(＃2) 昇温 25W, 200MJ/mol-D

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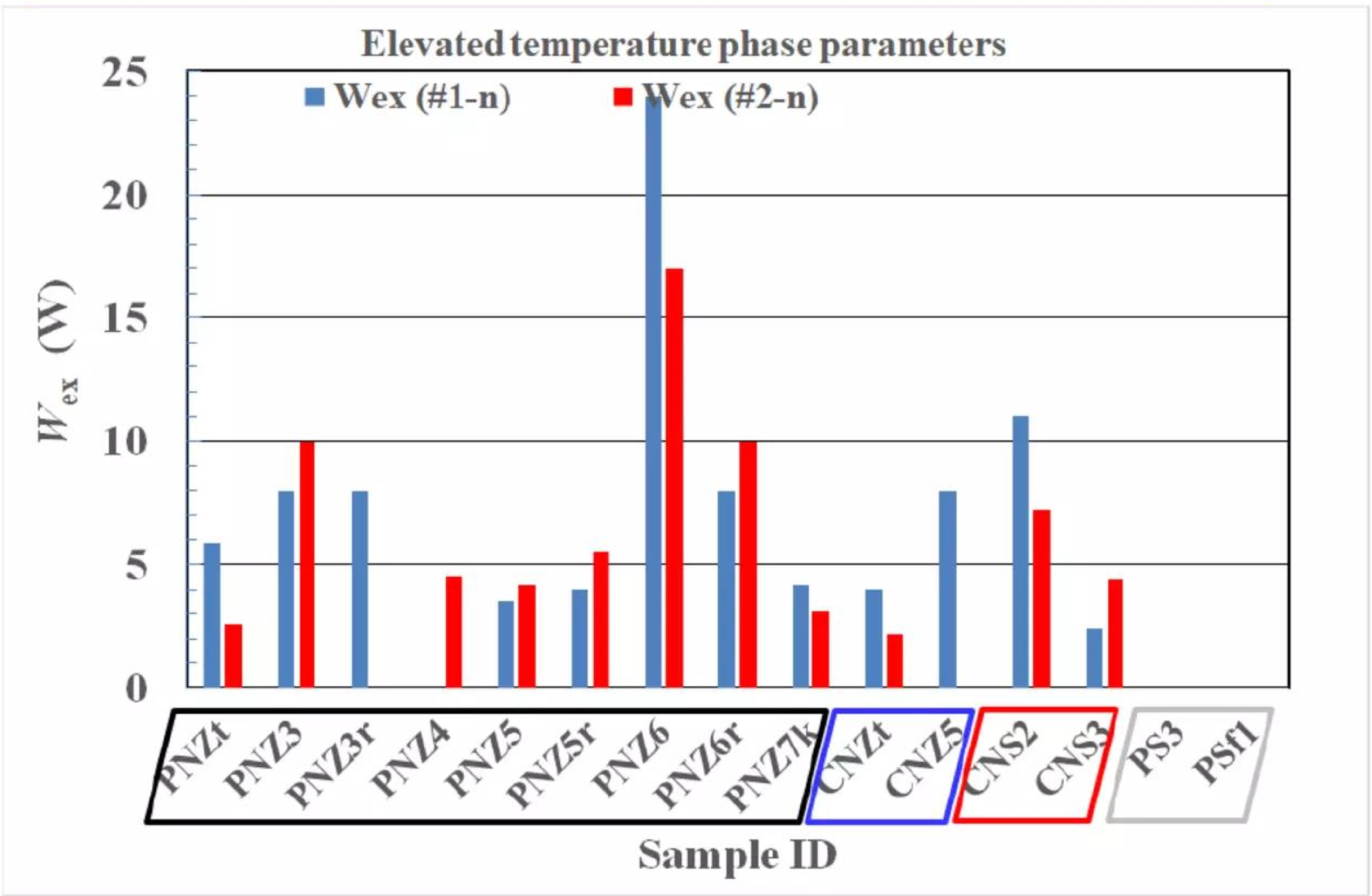
Summary of experimental results for NEDO LENR project

Reproducibility for Watt-levels of excess heat was an excellent ~ 70 - 80%

Largest excess power was observed by PNZ6 (Pd_1Ni_{10}/ZrO_2) 120g



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24 - 25 Watt heat source can boil cup of tea in about an hour

Excess heat in certain NEDO experiments enough to boil a cup of tea

0.0826 megajoules (MJ) of thermal energy is required to boil a single cup of tea

Typical tea or coffee cup holds ~ 250 ml of water. Starting with cup of water at room temperature (~ 21^{o} C), it must be heated-up by 79^{o} to reach water's boiling point of 100^{o} C. Total amount of thermal input energy required to heat one cup of water up to its boiling point in order to make tea is calculated as follows:

Water specific heat = 4.184 Joules/gram ^{o}C   Watt = 1 Joule/sec

1 ml water weight = 1 gram … so 250 ml weighs 250 grams

4.184 x 250 x 79 = 82,634 joules (82.6 kJ = 0.0826 MJ)

24 Watt heat source can provide ~ 83 kJ of thermal energy by operating for 3,443 seconds (57.4 minutes or ~ 1 hour)

Results validate commercial potential of LENRs for energy

NEDO project has demonstrated Watt-level reproducibility of excess heat

- Seminar discussed experimental results for NEDO LENR project: clearly demonstrated that a critical step in commercialization of LENRs for power generation now technically feasible: better fabrication methods for LENR device materials that can reproducibly create Watt-levels of excess heat
- Technical evaluation of summary project report dated January 2018 and related earlier project reports released by Technova Inc. on ResearchGate revealed project achieved Watt-level heat outputs for nontrivial durations with good 70 - 80% success rate using specially fabricated nanocomposite LENR device materials comprising nano-alloys of Ni, Pd, and Zr metals. Demonstrated long-sought experimental reproducibility of excess heat but methods *still* rely on spontaneous *random* formation of LENR active sites
- Widom-Larsen theory posits that LENRs occur in microscopic nanometer to micron-sized active sites located on surfaces or at interfaces. No doubt that present levels of NEDO device performance can be further improved with better fabrication methods and yet-to-be-tested materials. However, Lattice believes vast improvements in device reproducibility and scale-up of excess heating power will require mastery of design, fabrication, and emplacement of purpose-built nanostructures that are precursors to W-L LENR active sites. Once achieved, enables scale-up to kilowatt heat output

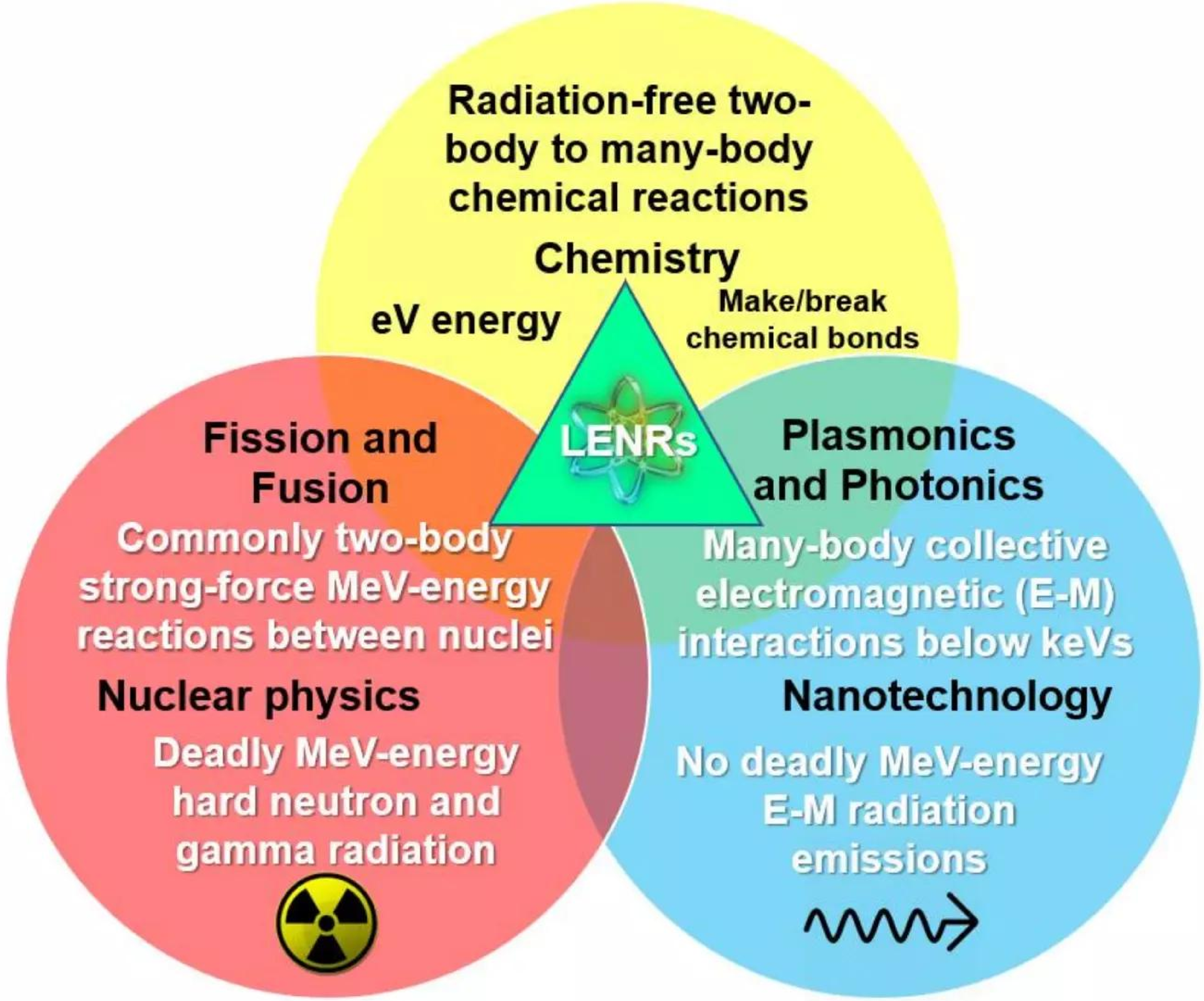
No reason why LENR heat output can't be scaled-up greatly

Nanotechnology can be leveraged to accelerate LENR commercialization

- Some might scoff at NEDO project's achieving only Watt-levels of excess heat, given that automotive applications would require on order of at least 60 kilowatts to successfully power full-sized motor vehicles. Skeptics would be wise to recall that world's first Uranium nuclear fission reactor, Fermi's CP-1 at University of Chicago in 1942, weighed 400 tons and only produced 0.5 Watts of excess heat; today's commercial reactors produce > 10^9 Watts. Including mass of reaction vessels, NEDO's primitive LENR reactor devices only weigh tens of kilograms and already produce more heat than did CP-1
- Unlike Uranium fission reactors, again verified by NEDO results, LENRs do not produce deadly energetic gamma and neutron radiation or long-lived radioactive wastes. Consequently, if future commercial LENR reactors with sufficiently scaled-up power outputs can be developed they would not require heavy, expensive radiation shielding and containment systems for safe operation. That would enable LENR power systems to be vastly less expensive than fission or fusion reactors and light-enough to be utilized in unshielded propulsion systems for motor vehicles, aircraft, and spacecraft
- Lattice believes that LENRs and nanotechnology are intimately interrelated. NEDO project's excellent results with nanocomposites support idea that nanotech can be leveraged to greatly accelerate LENR commercialization

Chemistry interconnected with LENR physics and nanotech

Nanotechnology can be leveraged to accelerate LENR commercialization



NEDO project has demonstrated that LENRs can produce non-trivial amounts of excess heat from nanocomposite multi-metal devices without emission of deadly fluxes of energetic neutron or gamma radiation --- safe nuclear technology

Next steps: further nanotech engineering, optimization of device materials, and scale-up of excess heat output and useful operating lifetimes

Credit: Getty Images

Comparison of LENRs to fission and fusion

Fission, fusion, and LENRs all involve controlled release of nuclear binding energy (heat) for power generation: no CO_2 emissions; scale of energy release is MeVs (nuclear regime) > 1,000,000x energy density of chemical energy power sources

Heavy element fission: involves shattering heavy nuclei to release stored nuclear binding energy; requires massive shielding and containment structures to handle radiation; major radioactive waste clean-up issues and costs; limited sources of fuel: today, almost entirely Uranium; Thorium-based fuel cycles now under development; heavy element U-235 (fissile isotope fuel) + neutrons → complex array of lower-mass fission products (some are very long-lived radioisotopes) + energetic gamma radiation + energetic neutron radiation + heat

Fusion of light nuclei: involves smashing light nuclei together to release stored nuclear binding energy; present multi-billion $ development efforts (e.g., ITER, NIF, other Tokamaks) focusing mainly on D+T fusion reaction; requires massive shielding/containment structures to handle 14 MeV neutron radiation; minor radioactive waste clean-up $ costs vs. fission

Two key sources of fuel: Deuterium and Tritium (both are heavy isotopes of Hydrogen)

Most likely to be developed commercial fusion reaction involves the following:

D + T → He-4 (helium) + neutron + heat (total energy yield 17.6 MeV; ~14.1 MeV in neutron)

Ultralow energy neutron reactions (LENRs): distinguishing feature is neutron production via electroweak reaction; neutron capture on fuel + gamma conversion to IR + decays [β^-, α] releases nuclear binding energy; early-stage technology; no emission of energetic neutron or gamma radiation and no long-lived radioactive waste products; LENR systems would not require massive, expensive radiation shielding or containment structures → much lower $$$ cost; many possible fuels --- any element/isotope that can capture LENR neutrons; involves neutron-catalyzed transmutation of fuels into heavier stable elements; process creates heat

Revolutionary ultralow energy neutron reactions (LENRs)

Radiation-free LENRs transmute stable elements to other stable elements

Fission and fusion → Evolution of nuclear technology → Safe green LENRs

Laura 13

No deadly MeV-energy gamma radiation

No dangerous energetic neutron radiation

Insignificant production of radioactive waste

Vastly higher energies vs. chemical processes

Revolutionary, no CO_2 , and environmentally green

Is fully explained by physics of Widom-Larsen theory

Image credit: co-author Domenico Pacifici
From: "Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing"
J. Feng et al., *Nano Letters* pp. 602 - 609 (2012)

Further info re Japanese NEDO project and LENR technology

Purplish hyperlinks below are ‘live’ as well as in SlideShare PowerPoints

“Small, primitive nanocomposite LENR devices fabricated in NEDO project produced enough cumulative excess heat to boil cup of tea for up to 45 days”

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-nedo-industryacademiagovernment-project-nanocomposite-lenr-devices-produce-enough-heat-to-boil-cup-of-tea-feb-7-2018

“Japan’s NEDO industry-academia-government R&D program’s recent experimental results technically validated potential for LENRs to become major future energy source”

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-nedo-lenr-project-reported-reasonably-reproducible-wattlevel-excess-heat-production-feb-4-2018

“January 2018: project report released - summarized progress in Japanese government-funded NEDO R&D in LENRs for Oct. 2015 thru Oct. 2017. Project scientists reported good progress in developing nanocomposite LENR devices for use as powerful heat sources”

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-nedo-lenr-project-reported-good-progress-in-excess-heat-production-and-device-fabrication-jan-27-2018

“March 1, 2018 – Putin announced nuclear-powered Russian cruise missile”

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-russia-announces-nuclear-fissionpowered-cruise-missile-perhaps-lenr-powered-in-future-march-3-2018

Key publications about Widom-Larsen theory of LENRs

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen (author's copy)
European Physical Journal C - Particles and Fields 46 pp. 107 - 112 (2006)
http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen (author's copy)
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http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

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L. Larsen c.v.: http://www.slideshare.net/lewisglarsen/lewis-g-larsen-cv-june-2013

- We believe Lattice is the world-leader in proprietary knowledge about LENR device engineering required to develop high-performance, long lived, scalable power sources. Our published peer-reviewed theoretical papers rigorously explain the breakthrough device physics of LENR processes, including the absence of dangerous energetic neutron or gamma radiation and lack of long-lived radioactive waste production
- Lattice welcomes inquiries from large, established organizations that have an interest in discussing the possibility of becoming Lattice's strategic capital and/or technology development partner
- Lewis Larsen also independently engages in consulting on variety of subject areas that include: Lithium-ion battery safety issues; long-term electricity grid reliability and resilience; and evaluating potential future impact of LENRs from a long-term investment risk management perspective for large CAPEX projects in the oil & gas, petrochemicals, transportation, utility, and aerospace industries

