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Enhancement of Excess Thermal Power in Interaction of Nano-Metal and H(D)-Gas

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Abstract Significant enhancement of excess thermal power by the anomalous heat effect (AHE) has been attained by our latest experiments on interaction of binary nano-composite metal powders and H (or D) gas at elevated temperature of 300-400 °C. Observed excess thermal power levels in average were 10, 86 and 186 W/kg-sample for PNZ10, PNZ10r and PNZ10rr, respectively with deuterium-gas. In addition, levels in average were 11, 117 and 226 W/kg-sample for CNZ7, CNZ7r and CNZ7rr, respectively with light hydrogen gas. Generation of excess thermal power was very reproducible by week cycle runs of heating power on/off mode, and was steady for several days in each elevated temperature run.

Key words: anomalous heat, enhancement, Ni-based, nano-composite-metals, hydrogen gas, elevated temperature, 200 W/kg, excess thermal power, repeated re-calcination, several weeks run

I. INTRODUCTION

The anomalous heat effect (AHE) by the interaction of hydrogen-isotope-gas and nickel-based nano-composite samples as Pd-Ni/zirconia (PNZ) and Cu-Ni/zirconia (CNZ) powder samples at elevated temperatures around 300 °C has been studied intensively [1,2] under the NEDO-MHE project in 2015-2017 [3], for verifying the existing of the phenomenon and finding conditions of excess power generation in controllable way. As reviewed in ref. [4], the 8 year-long (2008-2015) series of study on AHE by interaction of metal nanoparticles and D(H)-gas under the collaboration of Technova Inc. and Kobe University has become the basis for the collaborative research of NEDO-MHE. The AHE phenomenon has been replicated by independent experiments at Tohoku University as well as at Kobe University under the collaboration study of the NEDO-MHE project [5, 6, 7]. Observed excess thermal power level of AHE were on the level of 3-20 W, and more enhancement was required for industrial application.

To scale up the AHE power level, study has been extended [8, 9] independently at Kobe University as the collaboration project with Technova Inc., after the 2015-2017 NEDO-MHE project. We have found that the re-calcination of used metal composite powder sample was very effective to enhance excess thermal power by the succeeding hydrogen charging runs at elevated temperature as reported in our ICCF22 presentation [10] and paper [11].

In this paper, we report that further significant enhancement of excess thermal power has been obtained by using the third re-calcined samples as PNZ10rr (Pd_1Ni_{10}/zirconia) and CNZ7rr (Cu_1Ni_7/zirconia). The gas-turbulence effect by large local AHE has been observed in all elevated temperature runs, in which we observed generation of over 50 W excess thermal powers with rather steady continuation for

weeks. We summarize results of AHE in comparison of excess thermal power data by the first calcined sample (PNZ10 or CNZ7), the second calcined sample (PNZ10r or CNZ7r) and the third calcined sample (PNZ10rr or CNZ7rr). We used deuterium gas for PNZ-type samples, while light hydrogen gas for CNZ-type samples. We have observed similar levels of excess thermal power for either deuterium or light-hydrogen gas, by some reasons in underlying mechanisms to be elucidated in future.

These observations must be circumstantial evidences of some nuclear reactions for underlying mechanisms of the AHE, as predicted by the condensed cluster fusion theory (CCF/TSC theory) by Akito Takahashi (see many papers downloadable at Research Gate [12]). For an introduction of CCF/TSC theories, the review papers [13, 14, 15] are recommendable.

The series of our study on AHE is a kind of spin-off subjective which has been developed after the about 20 years research of "cold fusion" started by the notorious F-P announcement in 1989[16]. A dream of potential clean portable nuclear energy, which would save the world global warming problem by CO_2 accumulation, was a hope by the "cold fusion" (CF) phenomenon in 1990s, if really existing. However, the so called reproducibility problem has blocked the extension of researches by the original method of heavy water electrolysis with Pd cathode, although worldwide efforts by limited number of continuing researchers have gradually accumulated experimental results and theoretical aspects [17, 18, 19, 20, 21]. People have conceived that the difficulty of reproducibility arises by the material problem, although the CF occurrence might be on/near surface of Pd (or some other metals) from the consequences of many research works [20, 21]. Microscopic material condition at surface of metal electrode of electrolysis is too complex to control the optimum CF generating conditions. The hydrogen-gas (D or H gas) loading methods, especially the method using Pd nano-powder [22] was a kind of spin-off approach to realize reproducible results of AHE. The gas loading method has been greatly extended by the NEDO-MHE works [3], toward works using metal nano-composite samples with H(or D)-gas interactions at elevated temperatures [1-7] to report enhanced level of sustainable AHE. In Japan, the Tohoku University & Clean Planet collaboration, Nissan Motors group, Kyushu University, Iwate University, Technova & Kobe University collaboration and other groups are active now in the MHE (nano-Metal Hydrogen Energy) study based on the gas loading method [23, 24]. In the world, the INFN/Frascati group, Russian groups, French groups, USA groups are making active research efforts based on some kinds of gas-loading method. See related papers in recent JCMNS publications [21] in 2015-2020. The extending studies by the nano-metal composite samples and H(D)-gas interaction may look like passing through a breakthrough for the development of eco-friendly hard-radiation less energy sources. The results of present work may provide a step to that way.

II. EXPERIMENTAL METHODS AND PROCEDURE

The fabrication procedures of Pd-Ni/zirconia and Cu-Ni/zirconia for nano-composite samples were described in our previous papers [1-9, 11]. The outline is 1) making thin (ca. 10 micron) amorphous metal ribbons of $Pd_xNi_yZr_z$ or $Cu_xNi_yZr_z$ metal composite alloys by the melt-spun method, 2) calcination in electric oven at ca. 450 °C for 120-180 hours, and 3) making ca. 0.1mm size powders by automatic mortaring machine. The atomic ratios of x/y/z are from 1/10/20 to 1/7/14, approximately. In the present work, we used $Pd_1/Ni_{10}/Zr_{20}$ and $Cu_1/Ni_7/Zr_{14}$ for PNZ10 and CNZ7 samples, respectively. After the first H(or D) gas charging and elevating temperature runs (#M-N, N=1,2,3), we took out the sample from RC (reaction chamber) to make re-calcination in electric oven in ambient air with ca. 450 °C for ca. 180 hours. Then we reused for the second H(D)-charging and temperature-elevation runs (#M-N, N=1,2,3).

Between M=1 and 2 or M=2 and 3, we made so called baking treatment with 250-450 °C RC average temperature under vacuum-evacuation to meet the final RC pressure of less than 1 Pa. The second and third re-calcined samples are renamed with suffix r, as PNZ10r (or CNZ7r) and PNZ10rr (or CNZ7rr). The C system schematics for AHE calorimetry at Kobe University has been many times shown [1, 2, 4 -9, 11].

Calorimetry calibration data are given in [8] for TC1-TC6, TC2-TC6, and RTDav-TC6, by using blank sample of 1mm diameter zirconia beads (ca. 1.4 kg), for oil flow rate 18.4 ccm. For heating up RC, we used constant power supply units by Keithley Co., so that we did not need any correction for input heater power variation for [W1, W2]= [120, 80] W and [140, 95] W ET (elevated temperature) runs.

H (or D) gas was initially filled in Gas Cylinder having volume of 4 litters (for H-gas) and 2 litters (for D-gas), and fed to RC through Super Needle Valve. Initial pressure of Gas Cylinder was 0.4 to 1.0 MPa. By adjusting the SNV path size, we set gas flow rate as it took about 60 min to reach the equilibrium pressures at Ps and Pr [1-9], for the case of blank calorimetry runs. Here Ps is pressure of source gas cylinder, and Pr is pressure of RC. When we had the AHE of significant amount, evolution data of Pr and Ps were changed significantly from the blank runs. From the variation of Ps and Pr, we could calculate rate of H (or D) gas molars (or number of atoms) transferred by the runs. For present works, H-gas was used for CNZ7rr runs, and D-gas was used for PNZ10rr runs.

Typical patterns of the AHE experiments are as follows;

0) baking the sample (#1-0, #2-0),

1) H (or D) gas charging to RC at room temperature (RT) (heaters: [0, 0], #1-1, #2-1),

2) elevate RC temperature (heaters: [120, 80], #1-2, #2-2), run from Monday to Friday

3) cool RC to RT (heaters: [0, 0], #1-3, #2-3), from Friday to Monday

4) elevate RC temperature (heaters: [140, 95], #1-4, #2-4), from Monday to Friday

Actual run-tables are given in Table-1 and 2, respectively for PNZ10rr and CNZ7rr.

Table-1: Run table of PNZ10rr (438g PNZ10rr sample + 498g zirconia filler)

Run Number ID	W1, W2 (W)	Gas Fill Ps Pressure	Starting Time	RTD4 max (deg C)	Wex max (W) by RTDav
PNZ10rr #1-0	140, 40	Baking	2019/8/23		
PNZ10rr #1-1	0, 0	0.468 D2 MPa	2019/8/26	28.5	1
PNZ10rr #1-2	120, 80		2019/8/26	288.3	75.2
PNZ10rr #1-3	0, 0		2019/8/30		0
PNZ10rr #1-4	140, 95		2019/9/2	326.5	86.5
PNZ10rr #1-5	0, 0		2019/9/6		
PNZ10rr #1-6	140, 95		2019/9/18	327.4	87.1
PNZ10rr #1-7	0, 0		2019/9/20		
PNZ10rr #2-0	140, 40	Baking	2019/9/25		
PNZ10rr #2-1	0, 0	0.468 D2 MPa	2019/9/30	26.7	0.2
PNZ10rr #2-2	120, 80		2019/9/30	288.5	79.4
PNZ10rr #2-3	0, 0		2019/10/4		0
PNZ10rr #2-4	140, 95		2019/10/7	326.20	87
PNZ10rr #3-0	140, 40	Baking	2019/10/16		
PNZ10rr #3-1	0, 0		2019/10/21	26.8	0.2
PNZ10rr #3-2	120, 80		2019/10/21	288.6	77.5
PNZ10rr #3-3	0, 0		2019/10/25		
PNZ10rr #-3-4	140, 95		2019/10/28	326	86.5

Table 2: Run Table of CNZ7rr (340g CNZ7rr sample + 1011g zirconia beads filler)

Run Number ID	W1, W2 (W)	Gas Fill Ps Pressure or	Starting Time	RTD4 max (deg C)	Wex max (W) by RTDav
CNZ7rr #1-0	140, 40	Baking under Evac.	2019/11/6		
CNZ7rr #1-1	0, 0	Ps=0.564 MPa	2019/11/11	27	0.3
CNZ7rr #1-2-1	120, 80		2019/11/11	284.6	73.1
CNZ7rr #1-2-0	0, 0		2019/11/11		
CNZ7rr #1-2-2	120, 80		2019/11/12	284.8	75.5
CNZ7rr #1-3	0, 0		2019/11/15		
CNZ7rr #1-4	140, 95		2019/11/18	324	83.2
CNZ7rr #2-0	140, 40	Baking under Evac.	2019/11/25		
CNZ7rr #2-1	0, 0	Ps=0.560 MPa	2019/11/27	31	3
CNZ7rr #2-2	120, 80		2019/11/27	285.6	72.6
CNZ7rr #2-3	0, 0		2019/11/28		
CNZ7rr #2-4	140, 95	Not done			

3. RESULTS AND DISCUSSIONS

3.1 Heat Generation by PNZ10rr and D-Gas

We show a typical example of on-line data display (by NI Lab-View) in a rise-up phase of ET (elevated temperature) run of PNZ10rr #1-4, in Fig.1.

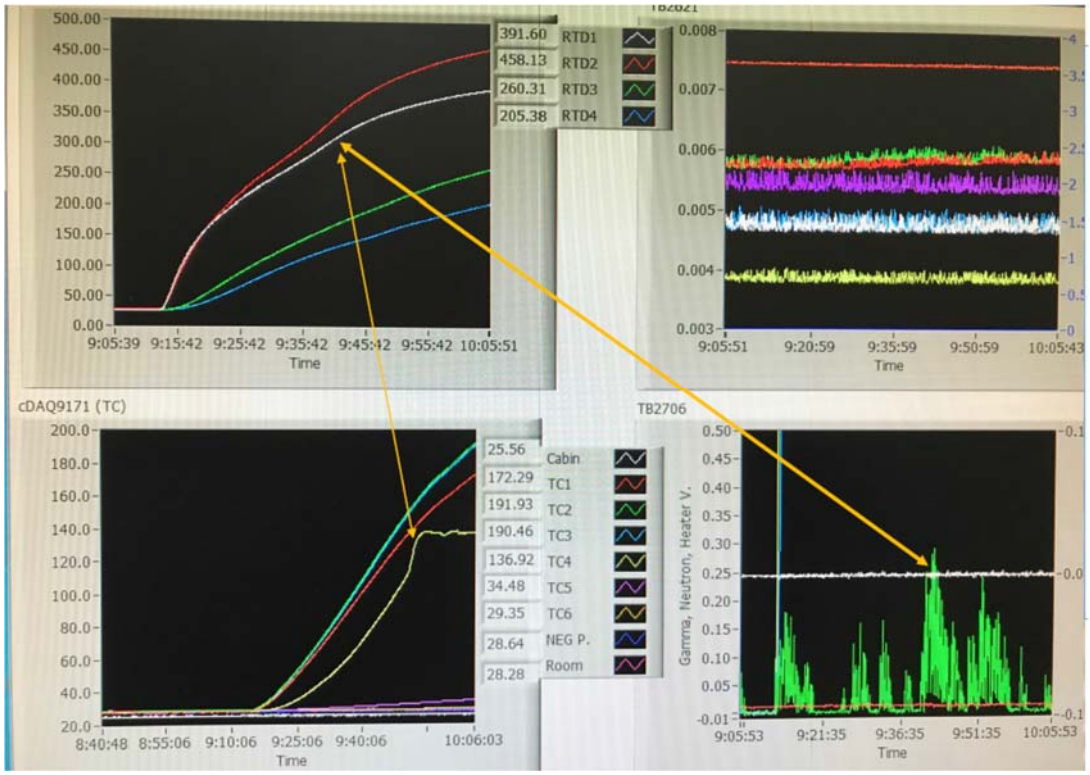

Fig.1: Typical rise-up time-evolution of RC (reaction chamber) temperatures (RTD1-4; upper left), oil outlet (TC1, TC2, TC3), inlet (TC6) and upper flange center (TC4) temperatures (lower left), pressures (upper right) and neutron rate (green; lower right), for PNZ10rr #1-4 [140, 95] run

We see start of anomalous excess temperatures rise of RTD1 and RTD2 (3 and 6 cm from bottom of RC (reaction chamber)), after temperatures exceeded ca. 300 °C (see upper left display), deviating upward from the indicial response (1.0 minus exponential saturating curve with calorimeter time constant) of calibration run with pure zirconia beads. An apparent neutron count increase (green in lower right display) looks correlating to the excess temperature rise of RTD1, 2, although neutron yield is close to natural background level. Very strangely, temperature at upper flange center by TC4 (outside of the hydrogen gas inlet/outlet tube) rises up steeply and suddenly becomes "flat" (see lower left display). We have reported already that gas-turbulence inside RC happens during strong local AHE [10, 11] which made underestimation of oil flow calorimetry by TC1, 2, 3 temperatures (as you see downward distortion; lower left display and see also Fig.2). As shown in Fig.2, strange evolution of TC4 temperature continues. Obviously, oil-outlet temperature monitors (TC1, 2 and 3) are distorted downward correspondingly, although temperatures (by RTD1, 2, 3, 4) in RC are increasing smoothly (upper left display).

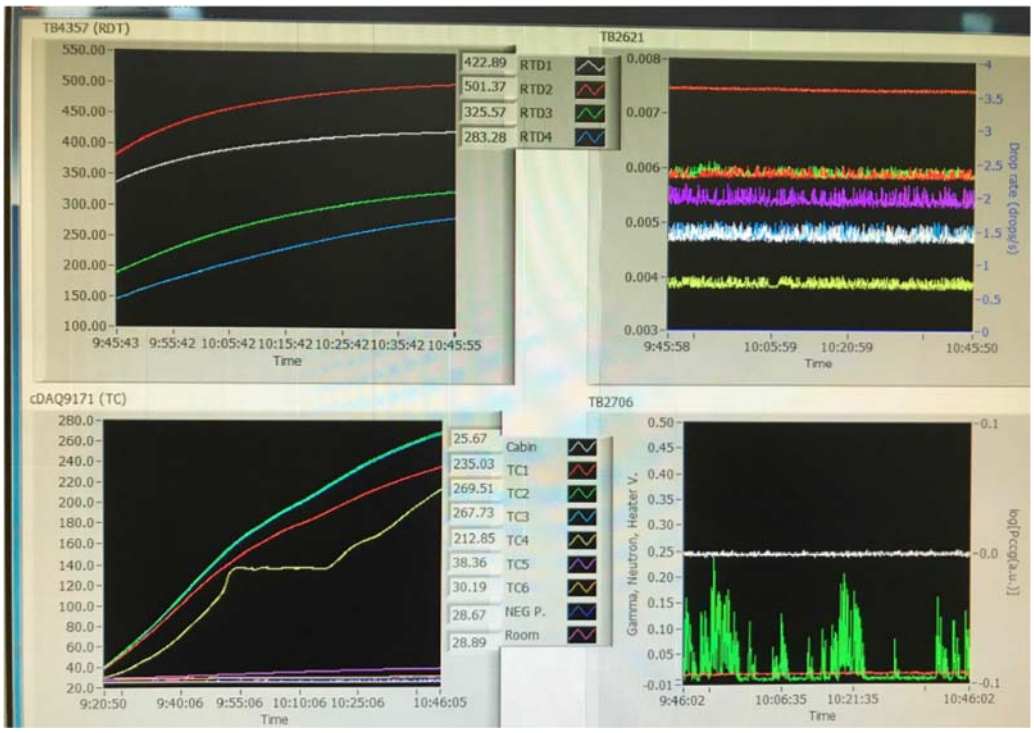

Fig.2; Rise-up data display-2 for PNZ10rr #1-4 run

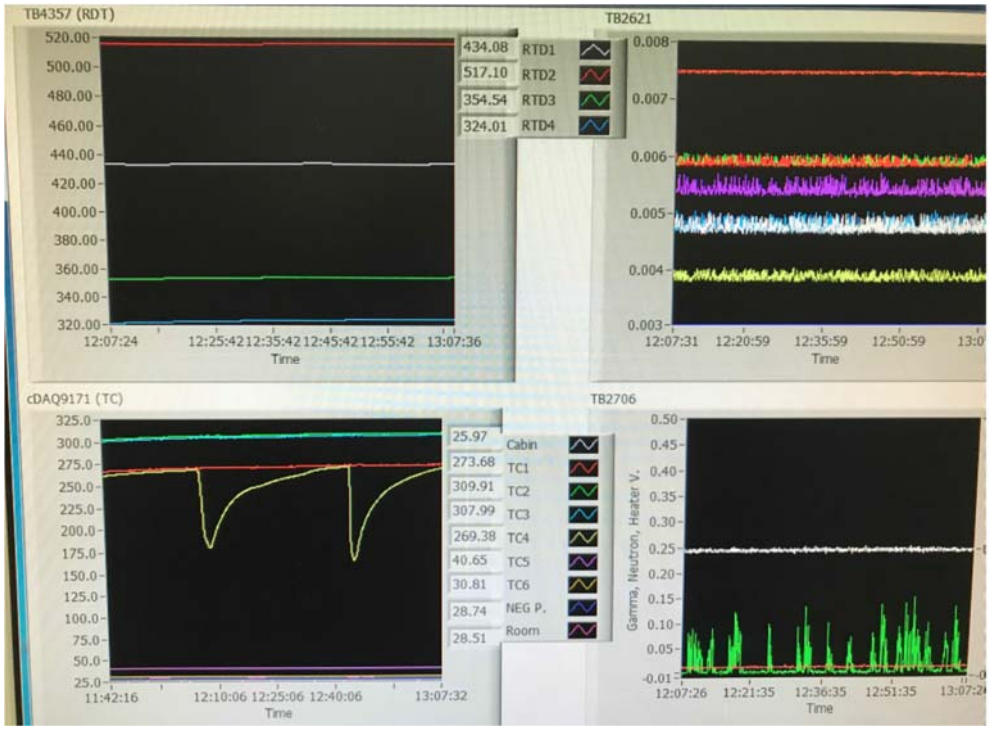

Fig.3 Rise-up data-3 for PNZ10rr #1-4 run

After that, RC temperatures have reached at some equilibrium state as seen in Fig.3. However, to our surprise, TC4 temperature suddenly decreased with ca. 100 °C negative spikes. In our conclusion by discussions [11], lower temperature hydrogen (D) gas in lower peripheral region of RC near oil-inlet would have blown up suddenly to make up-stream of colder convection gas flow. In the 4th day of PNZ10rr #1-4 run, TC4 temperature drew chaotic oscillation with smaller negative spikes and higher repetition as shown in Fig.4.

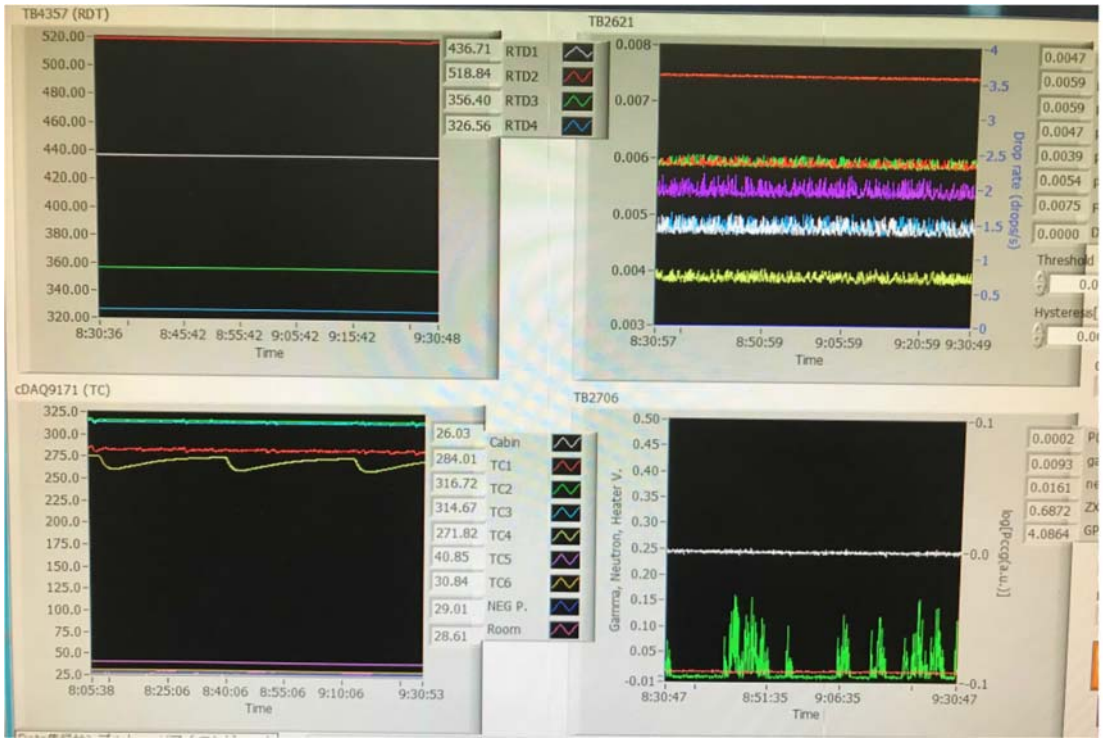

Fig.4; Evolution of data in the 4th day of PNZ10rr #1-4 run.

Inside temperatures in RC (upper left display) evolved very flat with average RC temperature of ca. 410 °C. The equilibrium temperature by the zirconia beads calibration run with [140, 95] W heater input was 322 °C. Excess thermal power is estimated as 86.6 W. Because of H(D)-gas turbulence effect under strong local AHE, excess thermal power levels have been underestimated by TC1, 2, 3 temperatures, but fortunately calorimetry by RTDav values was not visibly distorted [10, 11]. In this work, we have adopted excess thermal power data by RTDav (average RC temperature). In Fig.5, we show example of comparison of excess thermal power data between RTDav and TC1 adoptions. Because of the downward distortion of TC1 temperature correlating to TC4 chaotic oscillation, excess thermal powers by TC1 (TC1-TC6 was used) draw around 40 W, while excess thermal powers by RTDav draw over 80 W that is reliable. Data by TC1 fluctuated around 40W, while data by RTDav increased up smoothly to saturated value over 80 W and continued for 5 days run (Monday to Friday).

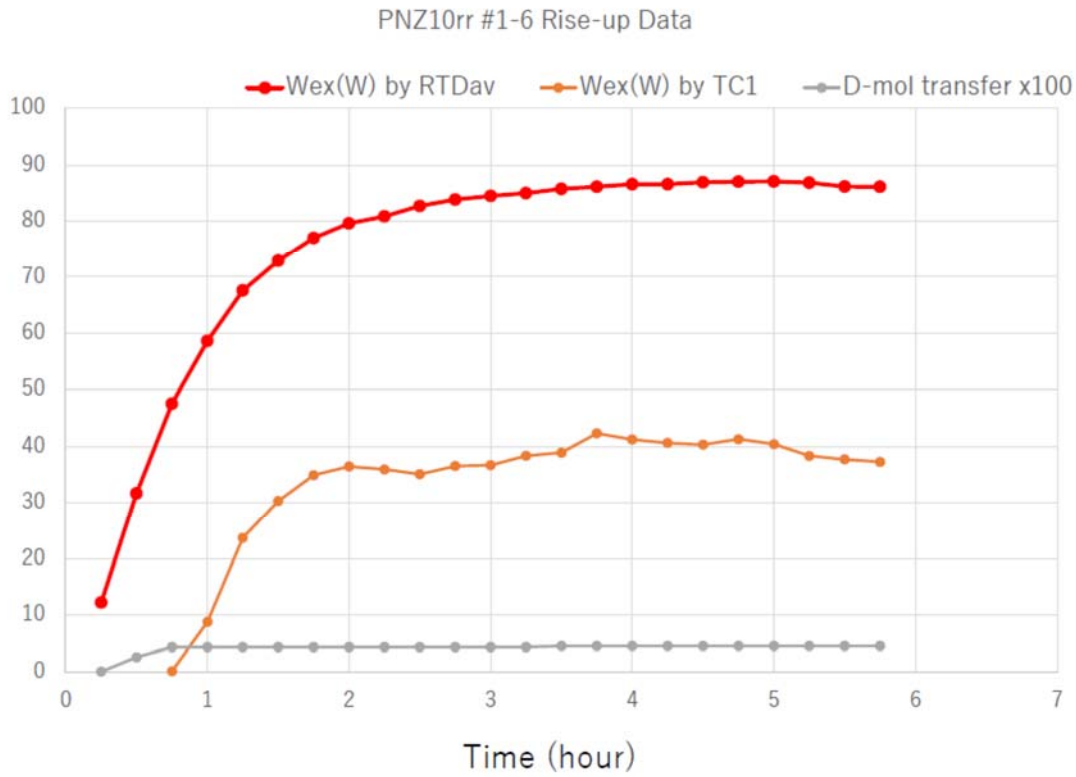

Fig.5; Comparison of rise-up data of excess thermal powers by RTDav and TC1 for PNZ10rr #1-6 run

Bwteen ET (elevated temperature) runs, we turned off heaters [W1, W2] in the period of Friday to Monday. In every ET runs from Monday, we have observed generation of significant excess thermal power rise-up and similar TC4 chaotic oascillations. The AHE phenomenon is now very repeatable/reproducible, both for PNZ10-type with D-gas and CNZ7-type with H-gas (as shown later). Generated excess thermal power levels were near steady for several days, and switched on/off by heater on/off in controlable way. We show detail in the following.

To show the significant enhancement of AHE (anomalous heat effect) by the re-calcination treatment of PNZ10r sample, data of PNZ10r #1-2 run [120, 80] (10, 11) is copied in Fig.6. Please remark on excess thermal power by RTDav. In rise-up, peak power exceeds 30 W but it decreases to rather flat value of ca. 16 W. By heating with [120, 80] watts, D-gas was desorbed to saturate at ca. 0.5 D-mol. Heat hump happened under larger D-desorption rate. Since large positive heat generation by desorption cannot be conceived by known chemical reactions, this data is already anomalous.

To be compared with it, we show data by PNZ10rr #1-2 run [120, 80] in Fig.7. Near 75 W steady excess thermal power was generated by this third calcined sample. Comparing with the cae of PNZ10r #1-2 run, we have got 4.7 times enhancement of excess thermal power level by the PNZ10rr #1-2 run. It is interesting to see that AHE of PNZ10rr #1-2 happened under D-absorption mode (saturating to ca. 0.2 D-mol absorption), which was endothermic D-absorption under heating up. Initial D-

absorption runs at RT (room temperature), PNZ10r absorbed more D-mol than PNZ10rr, by unknown change of nano-composite Pd-Ni islands to be studied further.

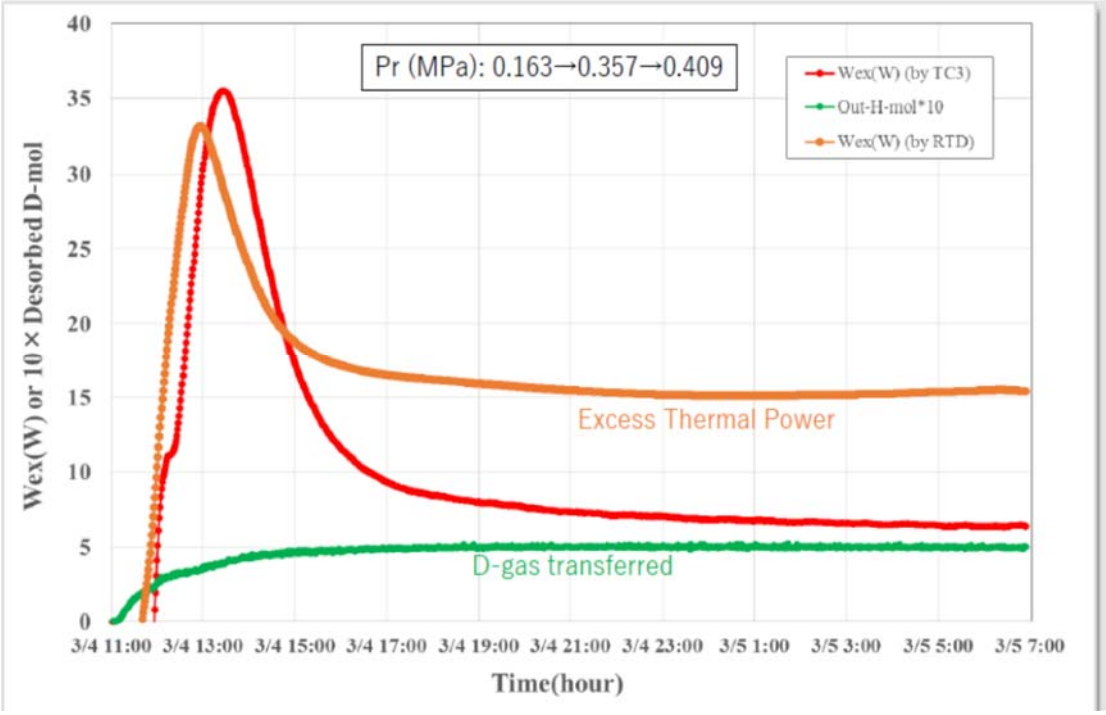

Fig.6; Copy of rise-up data of PNZ10r #1-2 run [10, 11]

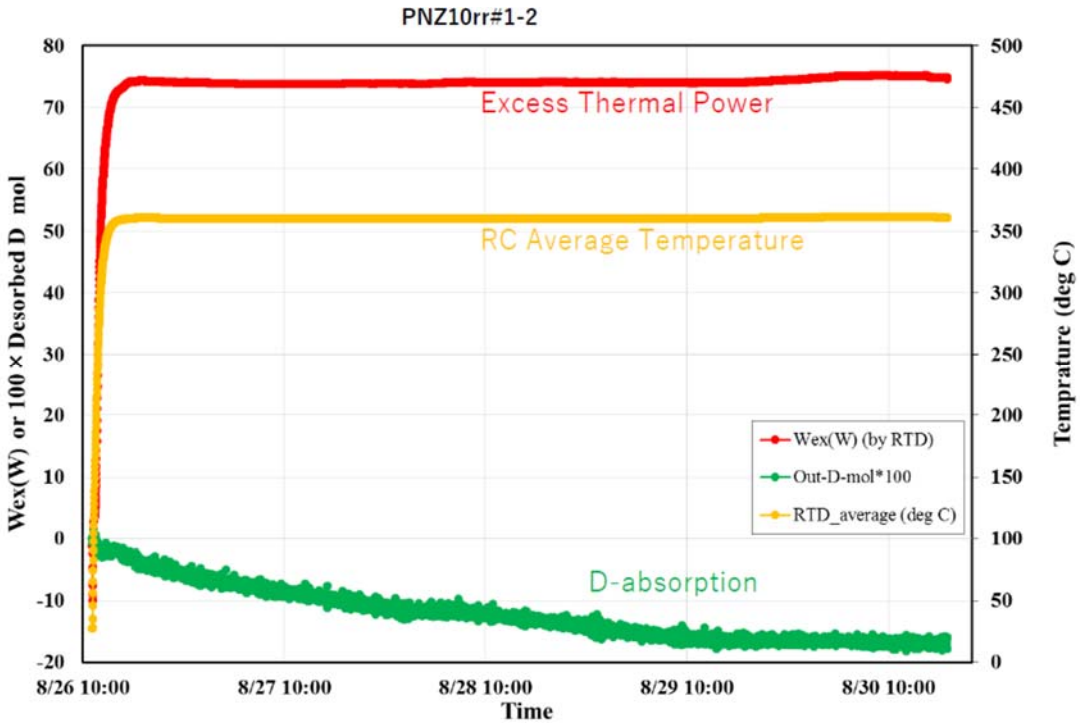

Fig.7; Rise-up data of PNZ10rr #1-2 run (nominal) with [120, 80]

In Fig.8, generation of steady excess thermal power of 85 W level is shown by the succeeding ET runs with [140, 95] heating condition.

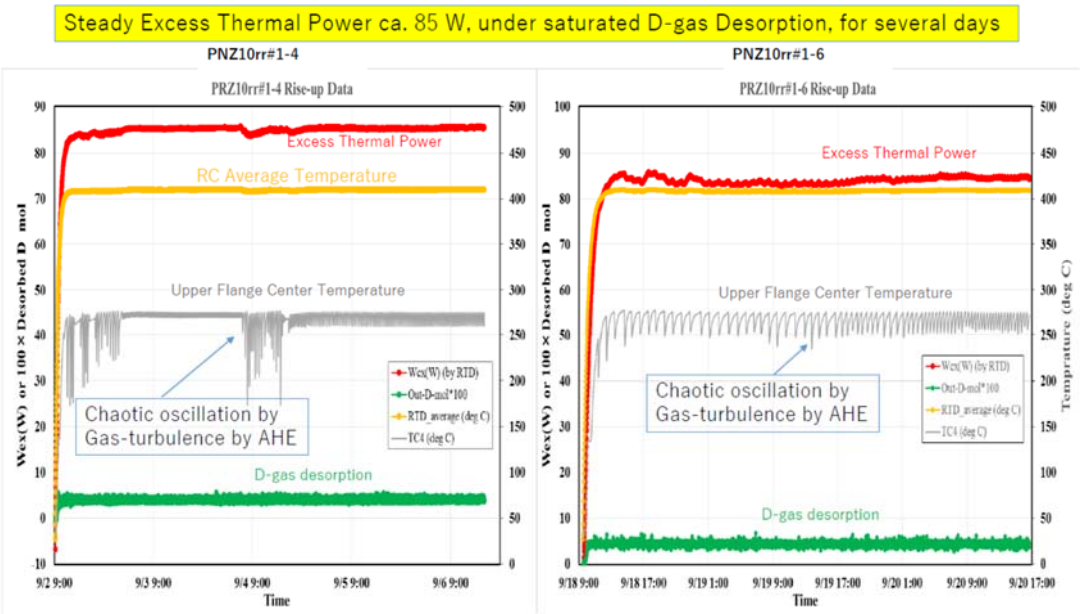

Fig.8; Repeatable and steady generation of excess thermal power by PNZ10rr sample

Average RC temperature made very steady evolution with ca. 410 °C, while TC4 temperature at central position of upper flange of RC made sporadic/chaotic oscillations by the gas turbulence effect. We may recognize that the chaotic TC4 oscillation is an indication of strong AHE in RC. Excess thermal powers were generated under the saturation state of D-desorption (ca. 0.05 D-mol).

In Fig.9, we show steady generation of excess thermal power for PNZ10rr sample after the second baking [10, 11] treatment.

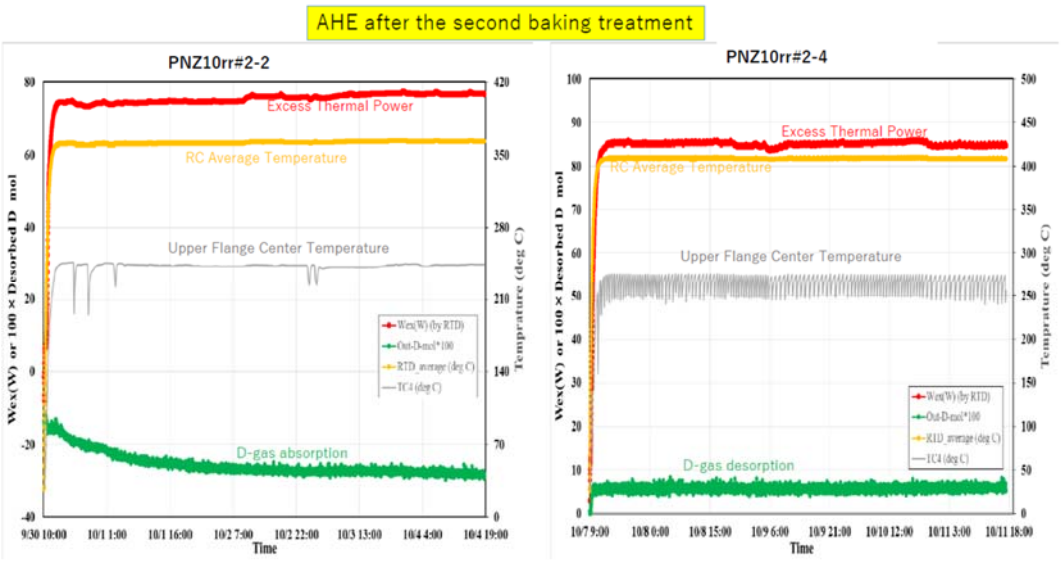

Fig.9; Generation of excess thermal power for PNZ10rr #2-2 and #2-4 runs

AHE happened under slow D-absorption mode, in the case of PNZ10rr #2-2, and level of excess thermal power over 70 W increased slowly according to the decrement of D-absorption rate (due to endothermic absorption). AHE by PNZ10rr #2-4 generated steady excess thermal power of ca. 84 W. We found that the baking treatment did not make significant enhancement of excess thermal power, although it was effective for PNZ10r cases [10, 11]. Chaotic oscillation of TC4 temperature was taking place.

In Table-3, we summarize data of excess thermal power and RC average temperature by PNZ10, PNZ10r and PNZ10rr runs.

Table-3; Summary results of AHE enhancement for PNZ10-type samples with D-gas

Run ID: Nominal	Heater Input (W)	Wex (W/kg); PNZ10	Wex (W/kg); PNZ10r	Wex (W/kg); PNZ10rr	RC Av-Temp (° C); PNZ10	RC Av-Temp (° C); PNZ10r	RC Av-Temp (° C); PNZ10rr
#1-2	[120, 80]	5	47.3	168	280	301.3	360
#1-4	[140, 95]	4	95	198	310	366	409
#2-2	[120, 80]	10		175	306		362
#2-4	[140, 95]	14	77	200	342	357	410
#3-2	[120, 80]	8		177	298		362
#3-4	[140, 95]	18	124	196	348	379	408
		sample weight: 1kg	sample weight: 0.45 kg	sample weight: 0.438 kg			

Observed excess thermal power levels in average were 10, 86 and 186 W/kg-sample for PNZ10, PNZ10r and PNZ10rr, respectively with deuterium-gas. The enhancement of AHE power was largest by the second calcination, and was still large by the third calcination. We need to try the forth calcination to see further trend of AHE enhancement. Accordingly, average RC temperatures increased by the calcination and baking treatments. The effect of baking looks saturating for the third calcination sample runs. The AHE power level reached at 200 W/kg-sample level.

We have repeatedly reported [1-11] that observed level of excess thermal power was too large to be explained by chemical reactions which happens by exchange of atomic and molecular orbital electrons with small energy (less than a few eV per hydrogen or other atom, for instance). In this work, we have also obtained data of specific reaction energy per D-atom transfer as shown in Fig.10. Under long-lasting excess thermal power of near 90 W for nearly a month (190 MJ of total heat), we observed evolution of specific reaction energy reaching 100 keV/D-transfer at maximum.

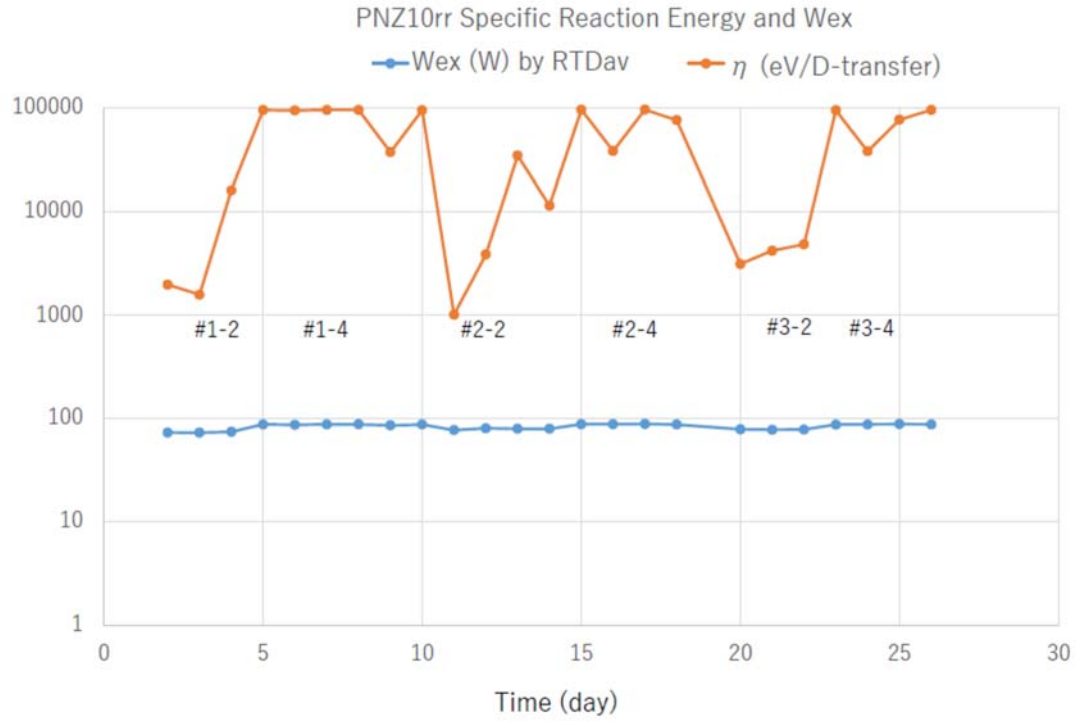

Fig.10; Evolution of data of specific reaction energy per D-atom by PNZ10rr ET runs

We conceive that only a portion of transferred D-atoms was attributed to some unknown new condensed matter nuclear reactions (theoretical candidate is the CCF/TSC model [13, 14, 15]). Therefore, real specific reaction energy must be much larger to be over several MeV/D level as nuclear reaction level. As excess thermal power is taking place under flat D-transferred state (after saturation of either absorption or desorption of D-gas), we have conceived that 4D/TSC or 4H/TSC like cluster formation rate on surface catalytic sites of binary metal nano-islands is of key factor to enhance the effect.

3-2 Heat Generation by CNZ7rr and H-Gas

We used 340g of third calcined sample of CNZ7rr plus 1011 g of filler zirconia beads to set up in RC. Oxidation rate by re-calcination was only 1.9%, but color of powder changed from grey to light brown by the re-calcination. Light hydrogen gas (H-gas) was used for AHE generation experiments, in similar way as PNZ10rr runs.

In Fig.11 we show the first ET run CNZ7rr #1-2-1 with [120, 80] W heating. About 70 W excess thermal power was obtained after saturation of H-absorption (0.4 H-mol). The chaotic oscillation of TC4 temperature happened similarly as the cases of PNZ10rr runs. We did only one day operation for CNZ7rr #1-2-1 run, and cooled to RT by making [0, 0] heating. Next day we started to run CNZ7rr #1-2-2 with [120, 80] W heating. The rise-up data of CNZ7rr #1-2-2 is shown Fig.11. We obtained excess thermal power level of ca. 70 W, namely same with that by CNZ7rr #1-2-1. AHE level is quite repeatable/reproducible, while AHE happened under the state after H-

desorption saturated. From these results, we can conceive that AHE reactions are taking place on surface reaction sites.

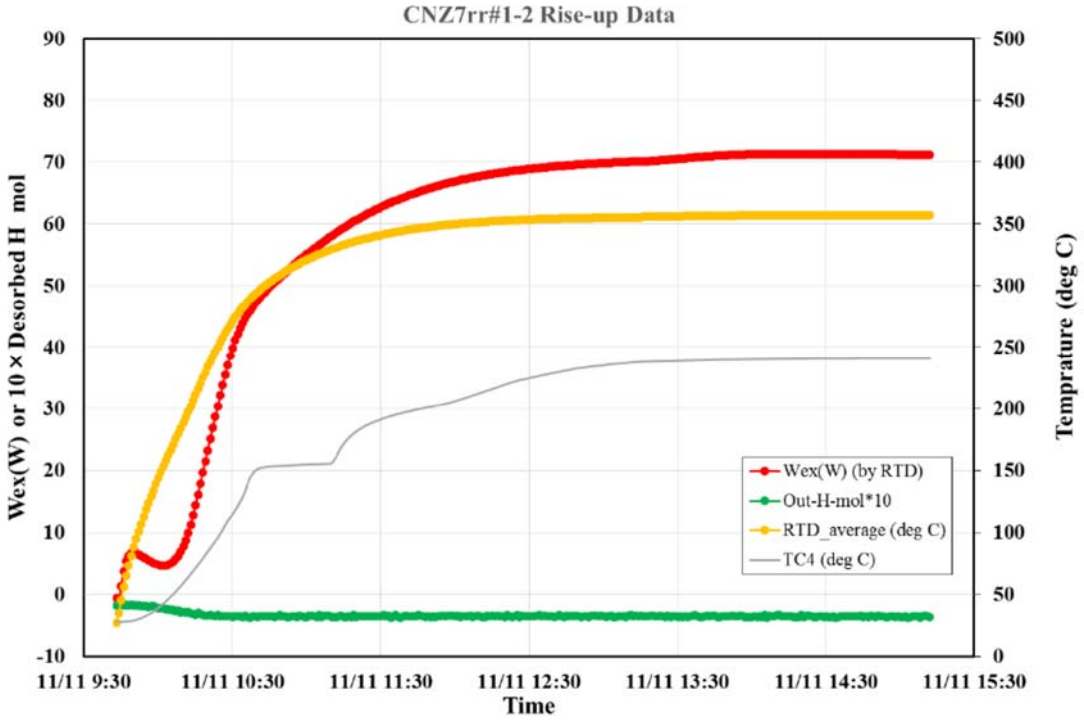

Fig.10; Initial ET run of CNZ7rr #1-2-1

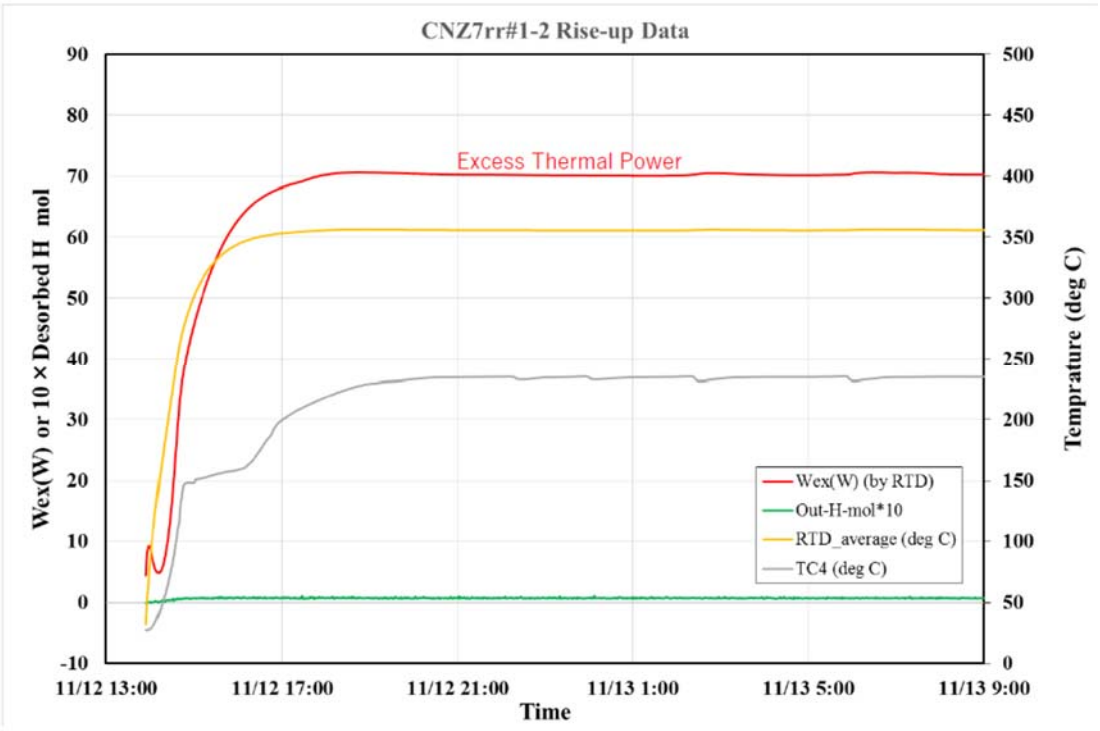

Fig.11; ET run by one day after the initial ET run, CNZ7rr #1-2-2

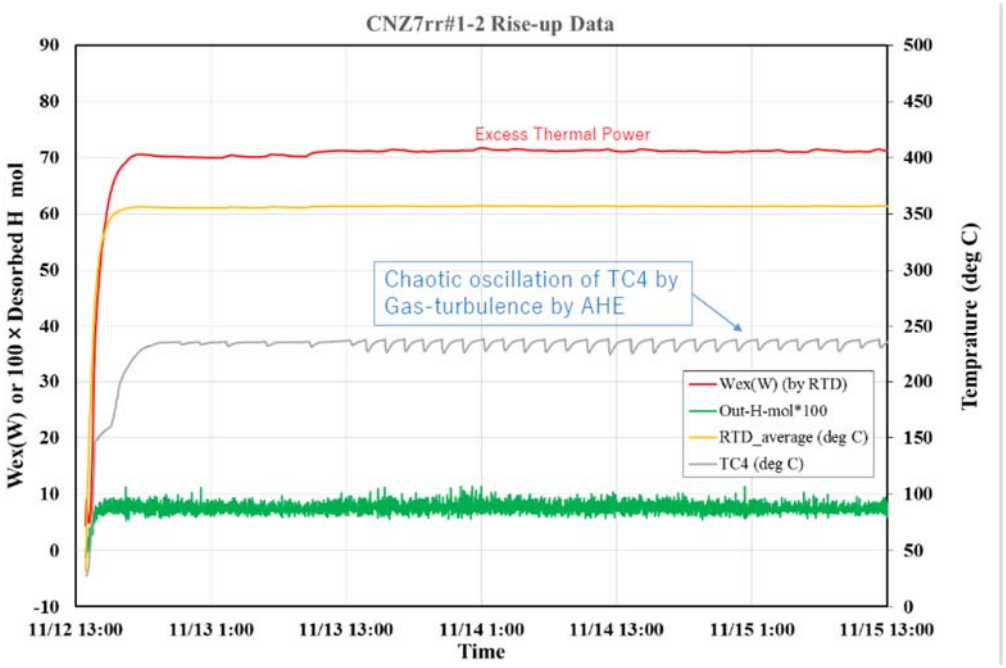

Fig.12; One week data of AHE by CNZ7rr #1-2-2 run

In Fig.12, we show AHE data for 4 days run of CNZ7rr #1-2-2. Evolution of ca. 70 W excess thermal power is very steady. Chaotic oscillation of TC4 temperature evolved sporadically. The AHE continued after H-desorption saturated at the level of 0.07 H-mol. We are discussing that small fluctuation (in one minute averaged data plot) of desorbed H-gas level might have important information of frequent small change of H-gas in/out on surface of Cu-Ni nano-islands as mesoscopic catalyst sites where TSC formation is thought [13, 14]. We need precise and accurate measurement of gas pressure for that end.

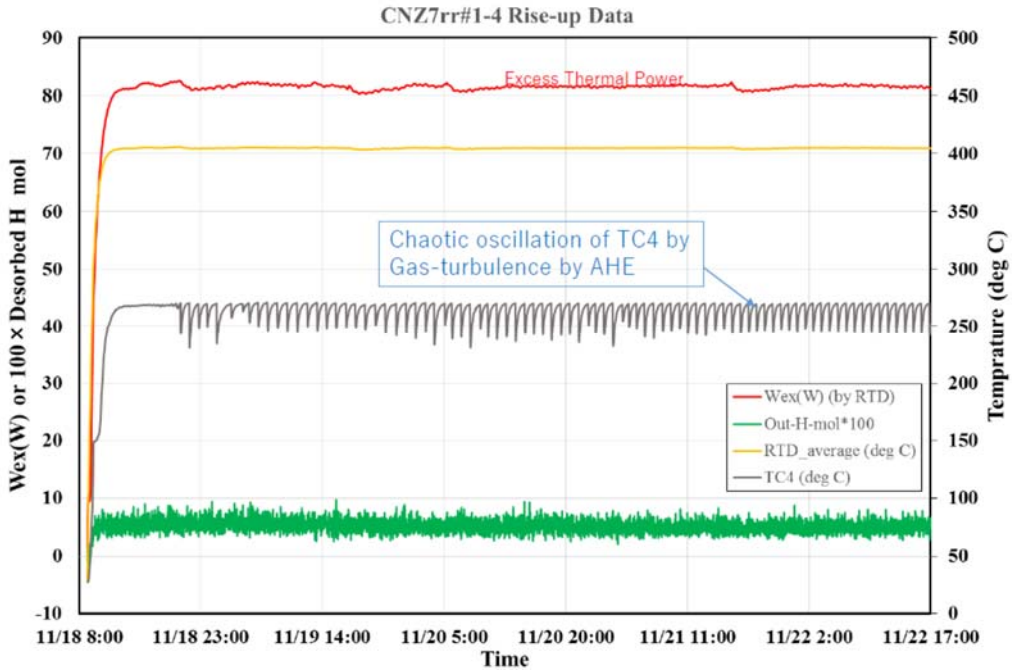

FIG.13; 5 days long run of CNZ7rr #1-4 with [140, 95] W heating

In Fig.13, we show AHE data by 5 days long run of CNZ7rr #1-4.
Steady excess thermal power level over 80 W was observed under the H-gas desorption-saturated mode. Averaged RC temperature exceeded 400 °C. TC4 oscillation was sporadic as seen in other cases.

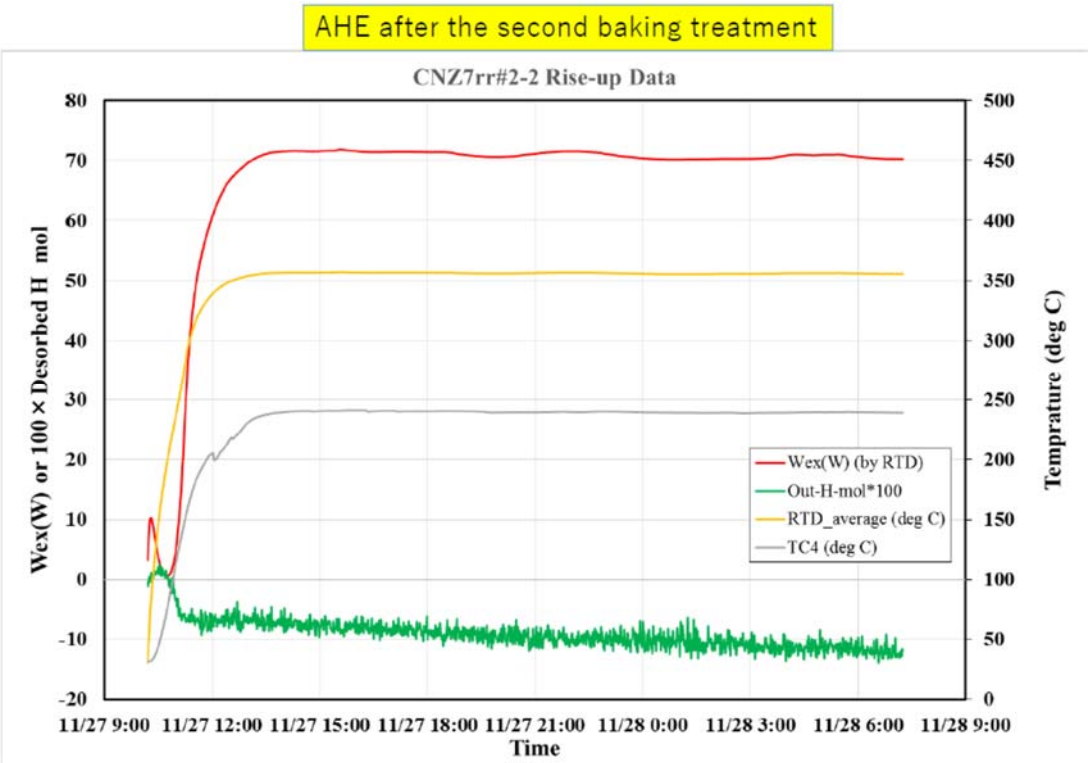

Fig.14; CNZ7rr #2-2 run, after the second baking treatment

In Fig.14, we show AHE data by CNZ7rr #2-2 run, after the second baking of sample. Similar level of ca. 70 W excess thermal power was obtained, comparing with the case of CNZ7rr #1-2-2. However, AHE took place under slow H-absorption mode, in this case. We compare results of rise-up data between CNZ7rr #1-2-1 and CNZ7rr #2-2, in Fig. 15. Rise-up of excess thermal power appeared with about 30 min delay for CNZ7rr #2-2, while the rise-up was faster for CNA7rr #1-2-1. Probably, larger endothermic H-absorption by CNZ7rr #2-2 is attributable to the slower excess power rise-up.
Finally, we show a baking data for CNZ7rr in Fig.16. Before baking, CNZ7rr sample retained ca. 0.76 H-mol, which corresponds to 0.5 H/Ni loading ratio. As we know 1.0 (full O-sites occupation)-3.0 (full O+T sites occupation) may be attained in Ni-core Pd (or Cu)-incomplete shell nano-islands [4] at RT, present observation of AHE excess thermal power evolution in rather steady level is considered to have been taking place under the non-saturation state of H-loading in Ni core at ET runs. We may conceive that optimum dynamic H-gas in/out flux on surface of binary nano-islands is of good condition for sustaining enhanced excess thermal power generation.
Summary table of enhancement effect of excess thermal power by re-calcination and baking treatments for CNZ7, CNZ7r and CNZ7rr samples is given in Table-4.

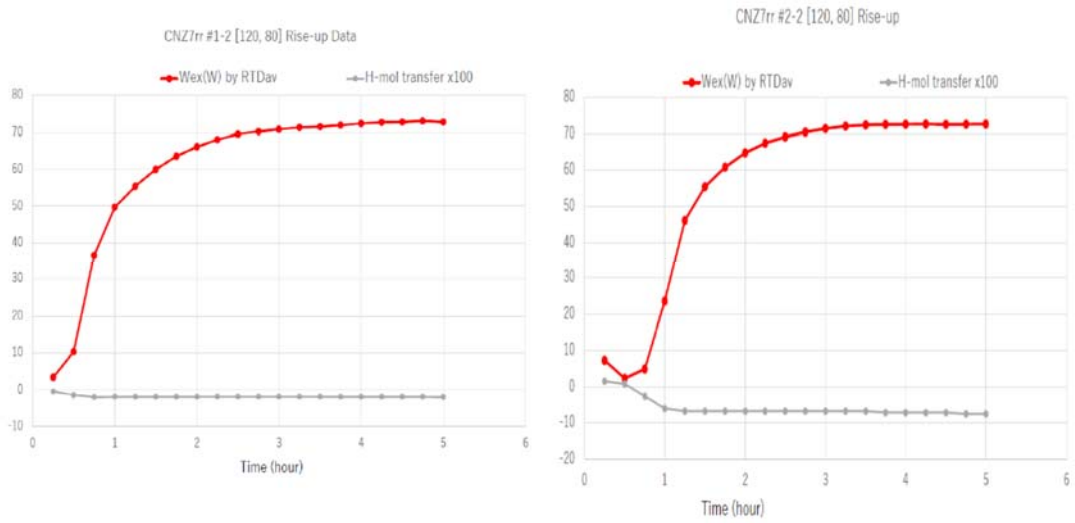

Fig.15; Comparison of rise-up data between CNZ7rr #2-2 run, after the second baking treatment, and CNZ7rr #1-2-1

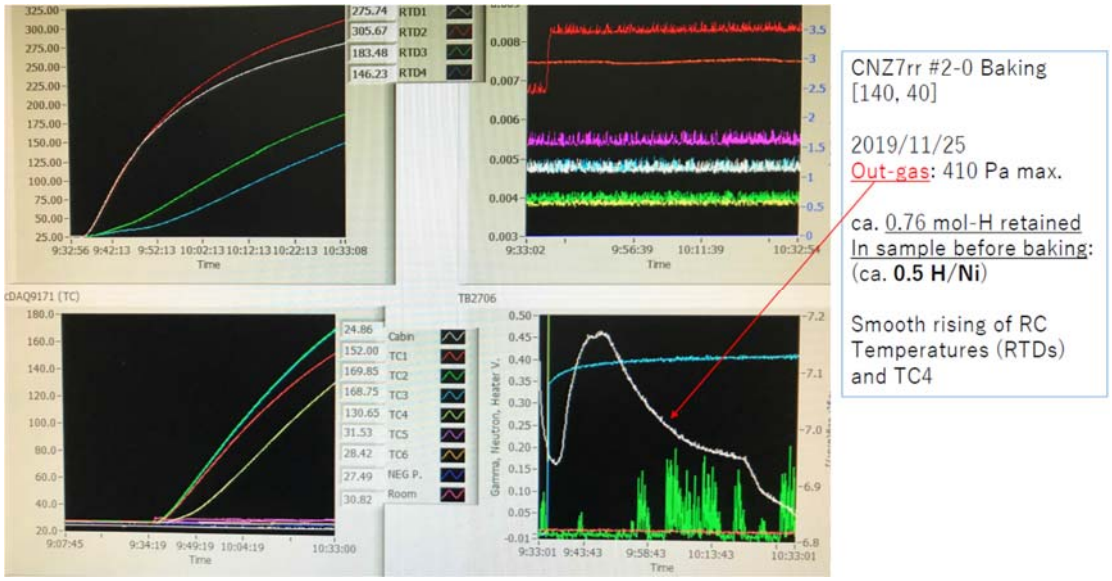

Fig.16; Display of rise-up data for baking treatment of CNZ7rr #2-0

Enhanced feature of excess thermal powers by re-calcination is in average, 11, 117 and 226 W/kg-sample for CNZ7, CNZ7r and CNZ7rr, respectively with light hydrogen gas. The enhancement was slightly larger for CNZ7-type sample with H-gas than that of PNZ10-type samples with D-gas. The reason will be elucidated in future studies. Over 200 W/kg level and weeks lasting excess heat generation is now possible by using less expensive materials of Cu and Ni with conventional hydrogen gas with modest H-gas pressure (0.1-0.5 MPa) as 300-400 °C of RC temperature. It is very encouraging data source towards our target of industrial products development by the MHE energy [1-4] as radiation-less, high energy density and portable energy generation source.

Table-4; Summary results of AHE enhancement for CNZ7-type samples with H-gas

Run ID: Nominal	Input W)	Wex (W/kg); CNZ7	Wex (W/kg); CNZ7r	Wex (W/kg); CNZ7rr	RC Temp (° C); CNZ7	RC Temp (° C); CNZ7r	RC Temp (° C); CNZ7rr
#1-2	[120, 80]	(152) (short burst)	96	219	(382 at burst)	336	358
#1-4	[140, 95]	12	110	245	336	383	405
#2-2	[120, 80]	6.8	118	214	295	346	357
#2-4	[140, 95]	14	126		359	392	
#3-2	[120, 80]	8.6	115		298	345	
#3-4	[140, 95]	13	137		349	392	
		sample weight: 1kg	sample weight: 0.505 kg	sample weight: 0.34 kg			

VI SUMMARY AND CONCLUDING REMARKS

Repeated re-calcination is effective to enhance sustainable excess thermal power by the interaction of Ni-based binary nano-composite metal powder with H (or D)-gas.

Baking treatment between elevated temperature runs is effective to enhance excess thermal power for the second re-calcination, but the enhancement has saturated for the third re-calcination.

To eliminate the gas turbulence effect for calorimetry, condition of homogeneous temperature in sample region will be tested to enhance more AHE.

Excess thermal power reached at the level of 200 W/kg-sample continuing for several weeks or more, by the elevated temperature interaction of either D-gas or H-gas and Ni-based binary nano-composite powders supported in zirconia flakes.

Further extension study towards application of industrial clean portable primary thermal energy source is encouraging.

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