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Industrial Heat
Raleigh, NC
USA

NEW PRODUCTION TECHNOLOGIES OF ENERGY

E-CAT MW1

HOT CAT:

COLLECTION OF TEST REPORTS

Ferrara, April 29 – May 2, 2013

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CHAPTER 1:
E-CAT MW1 ENERGY PLANT
COEFFICIENT OF PERFORMANCE (COP) EVALUATION TEST

The following report illustrates the results of the COP evaluation tests on the E-CAT MW1 ENERGY PLANT

1. Foreword

On 30 April 2013, in Ferrara, in Via del Commercio 34/36, have been carried out tests for assessing the COP of the E-CAT MW1 ENERGY PLANT, designed by the company Leonardo Corporation, 1331 Lincoln road, S.te #601, Beach Miami, Florida (USA)

They take part in the tests:

for Industrial Heat
Mr T. Barker Dameron
Mr J. Compton
Mr T. Darden
Mr J. Vaughn

for Leonardo Corporation
Mr F. Fabiani
Mr A. Rossi

Mr F. Penon ERV

2. Device

The system under test consists of 107 units, each of which absorbs a power of about 1.1 kW
Each unit consists of a reaction chamber, where the nickel powder reacts with the hydrogen in the presence of a catalyst, covered by industrial secret.
The electric heaters, fed by the current generator and the power of which is regulated by the power panel, heat the reaction chamber and trigger the reaction between nickel and hydrogen.
The energy produced is removed by the cooling fluid, water, sent to inside of the module from the pump (model Prominent Gamma for the units on the roof of the container, model Prominent Concept plus for the other units), associated to the unit itself
The control of the reaction is performed by means of probes, which detect the temperature of water in entry of the plant and the steam to output
The flow rate of the cooling fluid is manually set to start of operations

3. Test set up

3.1 List of components

n. 1 Generator	(300 Kw)
n. 2 Water pump	(model EEM, Tellarini pompe, 0,37 Kw)
n. 107 E-Cat units	
n. 24 Water pump	(model Prominent Gamma, 23 w,)
n. 56 Water pump	(model Prominent Concept plus, 15w)
n. 2 Heat sinks	
n.2 Water tank	(1 cubic meter capacity each)

3.2 Measurement instrumentation

n. 2 Flowmeter

n.1 Manometer

n. 4 Instrument with probe / sensor for temperature measurement by immersion

n. 1 Multifunction Calibrator

n. 1 Power analyzer

4. Operation of the test device

The water contained in the two tanks, placed at the sides of the shenker, is conveyed by pumps in the units E-Cat, where it is heated to vaporize. The steam is collected in the two tubes of the steam line, which convey it to the outside of the shelter, where flow together in a single tube.
The vapor is then passed through two heat sinks to its condensation
The water thus obtained is conveyed into the reservoir, positioned inside of the shelter and from here conveyed to the two external tanks by the two pumps on the sides of the reservoir, (See also diagram in Annex 1)

The generator powers the heating elements of the E-Cat units, the pumps for the water, the internal services to the shelter and the control panel. Heat sinks (fans) are connected to the public electric grid

5. History of the test

In order to comply with the Italian law the trial was conducted by activating only 18 E-Cat units

30/04/2013

h 12.25 Activation of the generator
h 12.57 Start recording automatically exit temperatures of steam and temperatures of water in tank 1
h 13.30 Beginning of the test

01/05/2013

h 13.00 End of the test
Activate shutdown procedure
h 13.16 End of the temperature recording

6. Calculation of COP

COP = energy produced (E_P) / energy absorbed (E_A)

6.1 Calculation of the energy produced (E_P)

The energy produced by 18 reactors is given by the sum of the heat of heating of water, heat of vaporization of water and heat of superheating the steam.

$E_p = E_R + E_V + E_S$

E_R (energy of heating of water up to100 ℃) =
$M_{W1} \times C_{sw} \times (T_{ev} - T_{iw1}) + M_{W2} \times C_{sw} \times (T_{ev} - T_{iw2})$

M_{W1} = mass of water vaporized during the whole test, coming from tank 1
T_{iW1} = inlet temperature of the water, coming from tank 2
M_{W2} = mass of water vaporized during the whole test, coming from tank 2
T_{W2} = inlet temperature of the water, coming from tank 2
C_{sw}= specific heat of water = 1,14 Wh/(kg°K)
T_{vw} = vaporization temperature of the water = 100 ℃

E_V = (energy of vaporization of water) = $\lambda \times (M_{W1} + M_{W2})$
λ = (latent energy of vaporization) = 627,5 Wh/kg
E_S (heating energy of steam) = $M_s \times C_{ps} \times (T_{os} - T_{vw})$
M_s = mass of steam produced during the whole test
C_{ps} =specific heat of steam at constant pressure = 0,542 Wh/kg
T_{os} = outlet temperature of the steam
T_{vw} = vaporization temperature of the water

Note: Throughout the test the temperatures of steam measured by the two probes have always been the same or very similar to each other.
Throughout the test the pressure of the steam was always equal to atmospheric pressure

In order to be conservative:
- it has not been taken into account the heating energy of steam
- the temperature of the inlet water has always been considered equal to the maximum value of the same measured during the whole test
- the uncertainty of measurement of the mass of water heated all were considered against. Consequently, the total mass of water transited during the trial period has been reduced by 10%.

6.2 Calculation of the energy absorbed (E_a)

The absorbed energy is generated by the generator set
In order to be conservative:
- all the energy, produced by the generator, is supposed to be absorbed by the 18 reactors

In reality a part of this energy feeds the pumps, which convey the water from the internal reservoir to the two external tanks and pumps, which convey the water from the tanks external to the reactors. This energy then would not have gone to feed the reactors
- all the energy produced by the generator since its activation has been taken into account in the context of the test

6.3 Calculation of the COP

The COP has been considered only during the period, in which the E-Cat was operating, namely when the temperature of the steam at ambient pressure was higher than 101 °C
The COP has not been considered during the phases of activation and de-activation

At the beginning of the test, the following values were measured:

M_{W1b} = 1050 kg
M_{W2b} = 2100 kg
T_{iW1} = 21.6 °C
T_{iW2} = 22.4 °C
T_{os} = 121,3 °C
Energy produced by generator set = 8.98 KWh
At the end of the operational period, the following values were measured:

M_{W1e} = 1750 kg
M_{W2e} = 3900 kg
T_{iW1} = 54.4 °C
T_{iW2} = 46.8 °C
T_{os} = 139,7 °C
Energy produced by generator set = 140,7 KWh

$E_R = M_{W1} \times C_{sw} \times (T_{ev} – T_{iw1}) + M_{W2} \times C_{sw} \times (T_{ev} – T_{iw2})$

$M_{W1} = (M_{W1e} - M_{W1b})$ = 1750 – 1050 = 700 kg
$M_{W2} = (M_{W2e} – M_{W2b})$ = 3900 – 2100 = 1800 kg

and reducing by 10%

M_{W1} = 630 kg
M_{W2} = 1620 kg

During the test the highest value of T_{iW1} is equal to 54,9 ℃, the highest value of T_{iW2} is equal to 55,2 ℃
Substituting the values we get then

E_R = 630 x 1.14 x (100–54,9) + 1620 x 1.14 x (100–55,2) = 32391 + 82737 = 115128 wh

E_V = λ x (M_{W1} + M_{W2}) = 627,5 x (630 + 1620) = 627,5 x 2250 = 1411875 wh

E_S = M_s x C_{ps} x (T_{os} – T_{vw}) = not taken into account

E_a = 140.70 – 8,98 = 131,72 Kwh

We take into account

E_a = 140.70 kwh = 140700 wh

$$COP = \frac{(115128 + 1411875)}{140700} = \frac{1527003}{140700} = 10{,}85$$

Throughout the test the temperature of the outlet steam was always significantly higher than 100 °C

Abano Terme, 07/05/2013

Fabio Penon M. Eng.

Annex 1. Test facility diagram

CHAPTER 2:
E-CAT MW1 ENERGY PLANT
COP REPEATABILITY TEST

The following report illustrates the results of the COP repeatability test on the E-CAT MW1 ENERGY PLANT

1. Foreword

On 30/04/2013 in Ferrara, in via del Commercio 34/36 have been carried out tests for assessing the COP of the E-CAT MW1 ENERGY PLANT, designed by the company Leonardo Corporation, 1331 Lincoln road, S.te #601, Beach Miami, Florida (USA)
Later it was decided to conduct further testing with two objectives
- check the value of the COP, obtained by activating another 18 E-Cat units, but different from those used in the previous test
- verify that the value of the COP is consistent with that obtained in the previous test
On 02/05/2013 the test was carried out

They take part in the tests:

for Industrial Heat
Mr T. Barker Dameron
Mr T. Darden
Mr J. Vaughn

for Leonardo Corporation
Mr F. Fabiani
Mr A. Rossi

Mr F. Penon (consultant)

2. Device

The system under test consists of 107 units, each of which absorbs a power of about 1.1 kW
Each unit consists of a reaction chamber, where the nickel powder reacts with the hydrogen in the presence of a catalyst, covered by industrial secret.
The electric heaters, fed by the current generator and the power of which is regulated by the power panel, heat the reaction chamber and trigger the reaction between nickel and hydrogen.

The energy produced is removed by the cooling fluid, water, sent to inside of the module from the pump (model Prominent Gamma for the units on the roof of the container, model Prominent Concept plus for the other units), associated to the unit itself
The control of the reaction is performed by means of probes, which detect the temperature of water in entry of the plant and the steam to output
The flow rate of the cooling fluid is manually set to start of operations

3. Test set up

3.1 List of components

n. 1 Generator	(300 Kw)
n. 2 Water pump	(model EEM, Tellarini pompe, 0,37 Kw)
n. 107 E-Cat units	
n. 24 Water pump	(model Prominent Gamma, 23 w,)
n. 56 Water pump	(model Prominent Concept plus, 15w)
n. 2 Heat sinks	
n.2 Water tank	(1 cubic meter capacity each)

3.2 Measurement instrumentation

n. 2 Flowmeter

n.1 Manometer

n. 4 Instrument with probe / sensor for temperature measurement by immersion

n. 1 Multifunction Calibrator

n. 1 Power analyzer

4. Operation of the test device

The water contained in the two tanks, placed at the sides of the shenker, is conveyed by pumps in the units E-Cat, where it is heated to vaporize. The steam is collected in the two tubes of the steam line, which convey it to the outside of the shelter, where flow together in a single tube.
The vapor is then passed through two heat sinks to its condensation
The water thus obtained is conveyed into the reservoir, positioned inside of the shelter and from here conveyed to the two external tanks by the two pumps on the sides of the reservoir, (See also diagram in Annex 1)
The generator powers the heating elements of the E-Cat units, the pumps for the water, the internal services to the shelter and the control panel. Heat sinks (fans) are connected to the public electric grid

5. History of the test

In order to comply with the Italian law the trial was conducted by activating only 18 E-Cat units, but different from those used in the previous test

02/05/2013

h 15.30	Activation of the generator
h 16.00	Start recording automatically exit temperatures of steam and temperatures of water in tank 1
h 17.30	Beginning of the test
h 18.45	End of the test Activate shutdown procedure
h 18.54	End of the temperature recording

6. Calculation of COP

$$COP = \frac{\text{energy produced } (E_P)}{\text{energy absorbed } (E_A)}$$

6.1 Calculation of the energy produced (E_P)

The energy produced by 18 reactors is given by the sum of the heat of heating of water, heat of vaporization of water and heat of superheating the steam.

$E_p = E_R + E_V + E_S$

E_R (energy of heating of water up to100 ℃) =
$M_{W1} \times C_{sw} \times (T_{ev} - T_{iw1}) + M_{W2} \times C_{sw} \times (T_{ev} - T_{iw2})$
M_{W1} = mass of water vaporized during the whole test, coming from tank 1
T_{iW1} = inlet temperature of the water, coming from tank 2
M_{W2} = mass of water vaporized during the whole test, coming from tank 2
T_{W2} = inlet temperature of the water, coming from tank 2
C_{sw}= specific heat of water = 1,14 Wh/(kg°K)
T_{vw} = vaporization temperature of the water = 100 ℃

E_V = (energy of vaporization of water) = $\lambda \times (M_{W1} + M_{W2})$
λ = (latent energy of vaporization) = 627,5 Wh/kg

E_S (heating energy of steam) = $M_s \times C_{ps} \times (T_{os} - T_{vw})$
M_s = mass of steam produced during the whole test
C_{ps} =specific heat of steam at constant pressure = 0,542 Wh/kg
T_{os} = outlet temperature of the steam
T_{vw} = vaporization temperature of the water

Note: Throughout the test the temperatures of steam measured by the two probes have always been the same or very similar to each other.
Throughout the test the pressure of the steam was always equal to atmospheric pressure

In order to be conservative:

- it has not been taken into account the heating energy of steam
- the temperature of the inlet water has always been considered equal to the maximum value of the same measured during the whole test
- the uncertainty of measurement of the mass of water heated all were considered against. Consequently, the total mass of water transited during the trial period has been reduced by 10%.

6.2 Calculation of the energy absorbed (E_a)

The absorbed energy is generated by the generator set
In order to be conservative:
- all the energy, produced by the generator, is supposed to be absorbed by the 18 reactors

In reality a part of this energy feeds the pumps, which convey the water from the internal reservoir to the two external tanks and pumps, which convey the water from the tanks external to the reactors. This energy then would not have gone to feed the reactors
- all the energy produced by the generator since its activation has been taken into account in the context of the test

6.3 Calculation of the COP

The COP has been considered only during the period, in which the E-Cat was operating, namely when the temperature of the steam at ambient pressure was higher than 101 °C
The COP has not been considered during the phases of activation and de-activation

At the beginning of the test, the following values were measured:

M_{W1b} = 1900 kg
M_{W2b} = 3950 kg
T_{iW1} = 30.9 °C
T_{iW2} = 29.0 °C
T_{os} = 130,2 °C
Energy produced by generator set = 14.22 KWh

At the end of the operational period, the following values were measured:

M_{W1e} = 2100 kg
M_{W2e} = 4100 kg
T_{iW1} = 31.8 °C
T_{iW2} = 29.9 °C
T_{os} = 124,9 °C
Energy produced by generator set = 23,31 KWh

$E_R = M_{W1} \times C_{sw} \times (T_{ev} - T_{iw1}) + M_{W2} \times C_{sw} \times (T_{ev} - T_{iw2})$

$M_{W1} = (M_{W1e} - M_{W1b}) = 2100 - 1900 = 200$ kg
$M_{W2} = (M_{W2e} - M_{W2b}) = 4100 - 3950 = 150$ kg

and reducing by 10%
M_{W1} = 180 kg
M_{W2} = 135 kg

During the test the highest value of T_{iW1} is equal to 33,0 ℃, the highest value of T_{iW2} is equal to 31,9 ℃
Substituting the values we get then

E_R = 180 x 1.14 x (100–33,0) + 135 x 1.14 x (100–31.9) = 13748+ 10481 = 24229 wh

E_V = λ x (M_{W1} + M_{W2}) = 627,5 x (180 + 135) = 627,5 x 315 = 197662 wh

E_S = M_s x C_{ps} x (T_{os} – T_{vw}) = not taken into account

E_a = 23.31 – 14.22 = 9.09 Kwh

We take into account

E_a = 23.31 kwh = 23310 wh

$$COP = \frac{(24229 + 197662)}{23310} = \frac{221891}{23310} = 9.5$$

Throughout the test the temperature of the outlet steam was always significantly higher than 100 °C

7. Conclusions

The value of the COP, obtained by activating another 18 E-Cat units, but different from those used in the previous test, and by applying the same conservative criteria of the previous test, is greater than 6 and is comparable with the previous COP

Abano Terme, 11/05/2013

Fabio Penon M. Eng.

CHAPTER 3:
HOT CAT DEVICE
TEST OF THE RELIABILITY AND STABILITY OF OPERATION

The following report illustrates the results of the test of the reliability and stability of operation of the HOT CAT device

1. Foreword

On 01 May 2013, in Ferrara, in Via del Commercio 34/36, has been carried out a test of the reliability and stability of operation of the HOT CAT device, designed by the company Leonardo Corporation, 1331 Lincoln road, S.te #601, Beach Miami, Florida (USA)
It was also calculated the COP of the device

They take part in the tests:

for Industrial Heat
Mr T. Barker Dameron
Mr J. Compton
Mr T. Darden
Mr J. Vaughn

for Leonardo Corporation
Mr F. Fabiani
Mr A. Rossi

Mr F. Penon consultant

2. Device

The test device consists of three coaxial cylinders.

The innermost cylinder is made of steel AISI 316 and contains the powders charge

The intermediate cylinder is made of corundum, houses three resistors, in turn fed through a TRIAC. The TRIAC allows to modulate the power supply interrupting with the frequency determined in advance

The outer cylinder is made of silicon nitride ceramic and is coated by a special aeronautical-industry grade black paint, specifically designed for the Hot-Cat.
The Hot Cat was placed on a frame so as to permit irradiation of all the surrounding space

The contacts points between the device and the frame were reduced to the minimum necessary for mechanical stability
It is possible to find a more detailed description of the device under test in the report: *Preliminary tests and heat energy production measurements of the E-Cat HT device*

3. Test set up

Measurement instrumentation

n. 1 IR Thermographic camera Optris PI 160

n. 1 Power Harmonics Analyzer PCE 830

4. History of the test

Throughout the test the operation of the device is now set: 1 minutes of operation fed constant power, then 2 minutes running in mode self sustained
The total duration of the test has been equal to 11 hours and 25 minutes

5. Calculation of COP

$$COP = \frac{\text{power produced } (P_P)}{\text{power absorbed } (P_A)}$$

5.1 Calculation of the power produced (P_P)

The power produced by Hot Cat is given by the sum of the power emitted by radiation and power emitted by convection.

$P_p = P_R + P_{cv}$

P_R (power emitted by radiation) = $\varepsilon \times \sigma \times T^4 \times A - \varepsilon \times \sigma \times T_r^4 \times A$

$\varepsilon = \frac{\text{power emitted from the real surface}}{\text{power emitted by a black body, having the same temperature}}$

σ = Stefan Boltzmann's constant = 5.67×10^{-8} w/($m^2 \times K^4$)

T = temperature of the emitting surface (°K)

T_r = room temperature

A = area of Hot Cat = $2 \times \pi \times R \times L$

R = radius of the Hot Cat = 0.05 m

L = length of the Hot Cat = 0.33 m

P_{cv} (power lost by convection) = $h \times A \times (T - T_f)$

h = convection coefficient

A = area of Hot Cat

T = surface temperature

T_f = fluid temperature

5.2 Calculation of the power emitted by radiation P_R

We divided the outer cylindrical surface of the hot cat in ten annular areas, each of which, the camera has detected the temperature during the entire duration of the test

The analysis of the data showed that during the entire test, the temperatures are developed in an approximately step shape with periodicity equal to about 3 minutes
The minimum and maximum values of the temperature in each of the areas were virtually always constant
In order to be conservative we assume the temperature of each area during the entire test was equal t

$T_{area-i} = T_{min-i} + (T_{max-i} – T_{min-i})/3$

where T_{area-i}, T_{min-i}, T_{max-i} are respectively the average temperature, the minimum temperature and the maximum temperature of the i-th area

For each area, we then calculated the power emitted by radiation according to the formula

$P_{R\ area-i} = \varepsilon \times \sigma \times T^4_{area-i} \times A_i$

where
ε = emissivity of a coated surface with black paint = 0.87
σ = Stefan Boltzmann's constant = 5.67×10^{-8} w/($m^2 \times K^4$)
A_i = surface of the i-th area

Summing up the ten calculated values we obtain
$\Sigma_i P_{R\ area-i}$ = 387.23W

To this power we subtract the thermal power due to room temperature.
Using the 25 ℃ average over the 11 hours and 25 mi nutes we obtain 40,38 W

Finally we get
P_R (power emitted by radiation) = 346,85 w

5.3 Calculation of the power lost by convection

P_{cv} (power lost by convection) = h x A x ($T – T_r$)

Convection coefficient (h) calculation:

The physical constants of the air at a temperature (T_{av}) intermediate between that of the surface of the cylinder (T) and that of the air (T_r):
$T = \Sigma_i T_{area\ i}/10$
$T_{av} = (T + T_r)/2 = (522 + 298)/2 = 410$ ℃
μ (viscosity) = 2.2×10^{-5} kg/(m x s)
ρ (density) = 0.86 kg/m^3
c_p (specific heat capacity at constant pressure) = 1.013 10^3 J/(Kg ℃)
k (coefficient of thermal conductivity) = 0.0346 w/(m ℃)
β (coefficient of thermal expansion) = 0.0024 ℃$^{-1}$
$\Delta T = T – T_r = 522 – 298 = 224$ ℃
D (diameter of the Hot Cat) = 0.10 m
g (gravitational acceleration) = 9,8 m/s^2

Gr (Grashof number) =

$$\frac{D^3 \times \rho^2 \times g \times \beta \times \Delta T}{\mu^2} = \frac{0.1^3 \times 0.86^2 \times 9.8 \times 0.0024 \times 224}{(2.2 \times 10^{-5})^2} = \frac{3.90}{4.84} \times 10^7 = 0.81 \times 10^7$$

Pr (Prandtl number) $= \frac{c_p \times \mu}{k} = \frac{1.013 \times 10^3 \times 2.2 \times 10^{-5}}{0.0346} = 0.64$

$Gr \times Pr = 0.81 \times 10^7 \times 0.64 = 5.18 \times 10^6$

Being the product (Gr x Pr) > 10^4, we can refer to the following semi-empirical correlation

Nu (Nusselt number) $= 0.525 \times (Gr \times Pr)^{1/4} = 0.525 \times (5.18 \times 10^6)^{1/4} = 25.04$

By the other hand recalling that

$Nu = \frac{h \times D}{k}$

we obtain

$h = \frac{Nu \times k}{D} = \frac{25.04 \times 0.0346}{0.1} = 8.66$ w/(m^2 °K)

We can then calculate the power lost by convection

$P_{cv} = h \times A \times (T - T_f) = 8.66 \times 0.1036 \times 224 = 200.97$ W

5.4 Calculation of the power absorbed (P_A)

The measures carried out have shown that the power absorbed by the resistors coils has been more or less constant during the test

P_A = power absorbed = 730 w

Given that the power was absorbed by the resistors coils only during 1/3 of the test time, we obtain

P_A = 730/3 = 243.33 wh/h

5.5 Calculation of the COP

$COP = \frac{\text{power produced } (P_P)}{\text{power absorbed } (P_A)} = (P_r + P_{cv})/P_A = (200.97 + 346.85)/243 = 2.25$

6. Conclusions

The measurements and calculation models used are decidedly conservative.
A more refined physical-mathematical modeling of the test would give most likely COP values higher
In the course of the tests were performed more than 200 sequences in operation mode fed for 1 minute, and self-sustained for 2 minutes.
The Hot Cat has always worked with continuity, keeping the interior of the same range of temperatures and then power

Abano Terme, 03/06/2013

Fabio Penon M. Eng.