High Temperature Energy Catalyzer Test

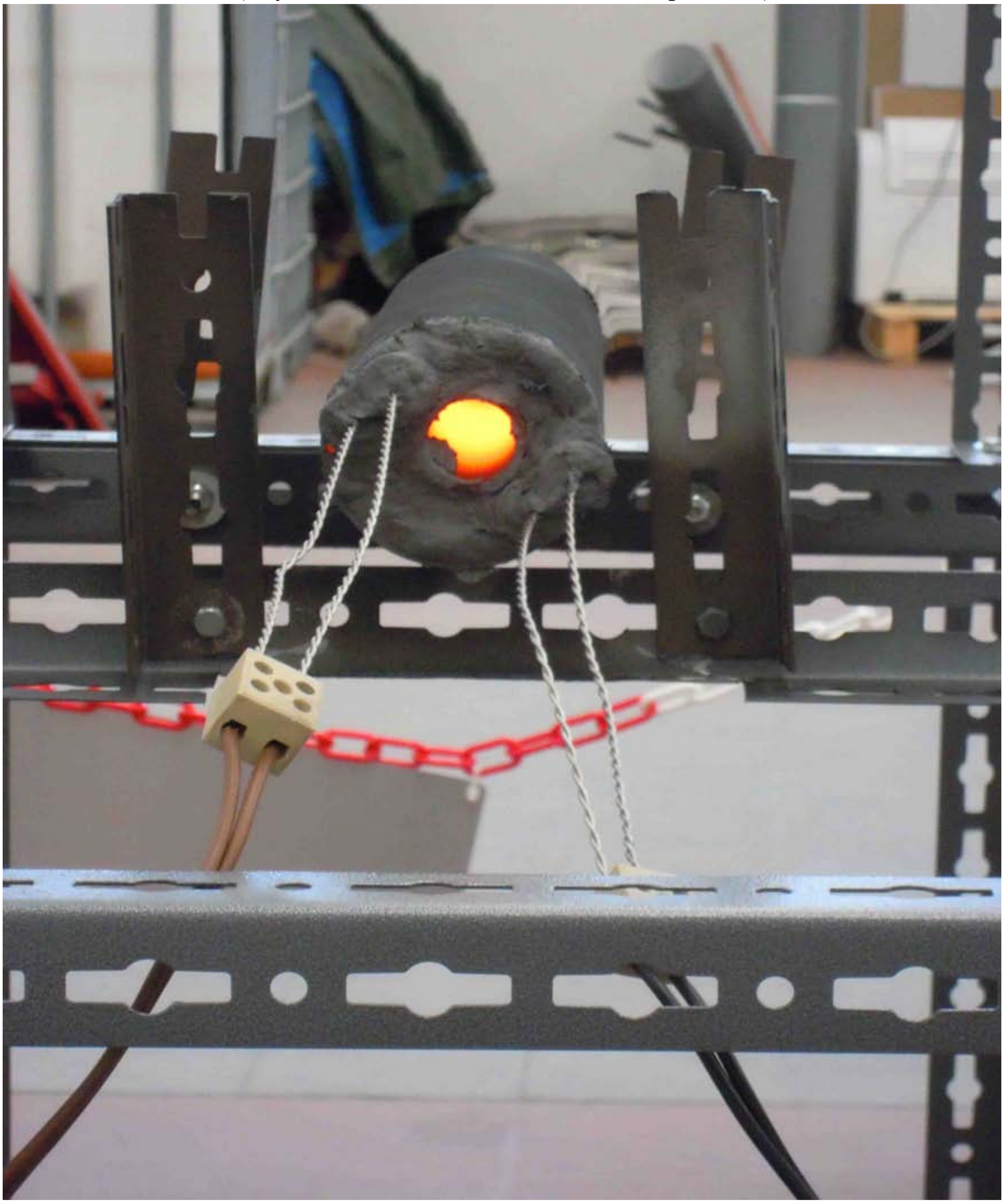
(Aug. 7th, 2012).

On Aug. 7th 2012, I conducted a test on the high temperature (800-1200° Celsius) Energy Catalyzer in the course of the current product certification process. On this occasion, the range of temperatures and COP obtained were found to be comparable to the ones recorded for similar power input values in the previous validation test (see full report attached) performed on July 16th, 2012.

(Signed)
Fabio Penon, M.Eng (Nuclear Engineering Specialist).

E-Cat Certification:
Fabio Penon , M.Eng. (Nuclear Engineer, Product Certification Specialist)

Radiation Protection Report:
David Bianchini, M.Sc (Physicist, Radiation Measurements Specialist).



Place and time

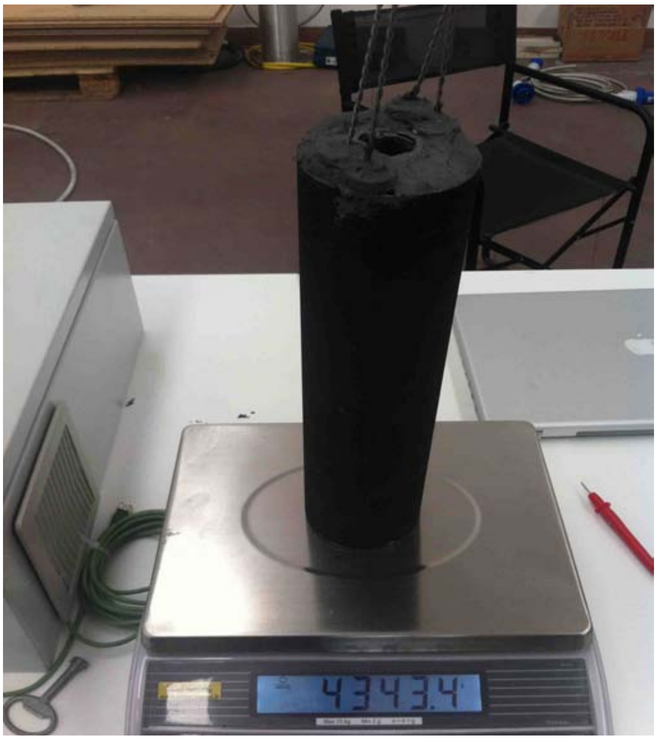
EFA Srl (EFA Ltd).
Bologna, Viale dell'Elettricista 6D
July 16th, 2012

Introduction

The object of this report are the measurements performed on the E-Cat module for the purpose of determining the power density in kW/kg, and the energy density in kWh/kg, of the source contained within the above-mentioned module subject to measurement. The values are the coordinates of said source in the Ragone diagram. Calculations attached to the present report are based on the data recorded by the infrared camera in use, as well as on observations performed during the test.
The mass of the active charge was obtained by subtracting, from the weight of the complete module as measured at the start of the test, the weight of its inert components as measured both before and after the test. Therefore, the mass of what is considered to be the active charge also includes elements that are not part of it, f.i. the weight of paint and sealant putty, for which only a partial measurement was possible, as may be gathered from the photographs. More information will be given below.

Description of the E-Cat Module and determination of its active mass

The complete E-Cat module weighs 4343.4 grams, as measured at the start of the test.



The module is consists of an assembly of four components, plus the active charge (Nickel and catalyzer) and a tablet which acts as a hydrogen reserve. Tablet and charge masses are not known. The module is sealed with Saratoga TE7 1200 1200° smelter-grade putty sealant.

The first component is made of AISI 316 paint-coated stainless steel: length 33 cm, Ø 8.559 cm, weight 1272.7 g, as measured before assembly. The cylinder was subsequently painted also internally with the same black coating, heat resistant up to 1200°.

The second component is the inner cylinder, made of the same stainless steel alloy: Ø 3.385 cm, weight 705 g, as measured before assembly. The cylinder was subsequently painted on both outer and inner surfaces with black coating, heat resistant up to 1200°.

The third component is a set of two 220 V resistors, total weight 2292.8 g; resistance values measured at the start of the test are 11.8 and 12.2 Ω. In parallel the recorded value was 6 Ω. Resistors were powered in parallel.
Lastly, there are four ceramic cable fittings for the resistors, each weighing 6.1 g, for a total of 24.4 g.

Upon completion of the test, after a long period of cooling, the E-Cat cylinder was dismantled to verify that the components were still the same, and to weigh the Saratoga sealant putty.

First, the whole E-Cat module was weighed. Its weight was determined to have decreased from an original weight of 4343.4 g to 4340.8 g. The loss of 2.6 g in weight is due to dusting lost in the dismantlement process and to the partial flaking of the surface layers of coating and sealant. The apparatus was subsequently dismantled.

The inner cylinder was weighed first; its weight was seen to have decreased from an original weight of 705.4 g to 702 g. The decrease in weight of 3.4 g is presumably due to the partial loss of coating and to the surface melting of the steel, which appeared rough to the touch.

The putty sealant was only partially chiseled away, and was collected on a sheet of paper. The tare weight of the sheet of paper, 4.6 g, was subtracted from the resulting weight of 32.3 g, thus giving a net weight of 27.7 g of putty.

Lastly, after removing the inner cylinder and two of the ceramic fittings, while leaving the active charge inside the apparatus, the E-Cat module was weighed. This measurement, yielding 3606.6 g, was performed in order to further determine the weight of the active mass; no use was made of it on account of the irregular residues of sealant putty and the unknown weight of the paint.

Weight difference calculation is summarized in the following table.

COMPONENT	WEIGHT IN GRAMS	REMARKS
E-Cat Module	4343.4	Weight at start of test
External cylinder	1272.7	New, painted on outer surface
Internal cylinder	705.4	New, unpainted
Resistors	2292.8	New
Ceramic fittings (tot. 4)	24.4	New
Sealant putty	27.7	Collected after the test
WEIGHT DIFFERENCE	**20.38**	**MASS TO BE CONSIDERED AS ACTIVE**

In summary, the mass to be considered as active is 20.38 grams.

<u>Measuring setup</u>

- Optris PI 160 infrared camera, 30° x 24° lens; 160 X 120 pixel (4 x 3 mm) UFPA sensors. Spectral range 7.5 to 13 µ. Precision: 2% of measured values. Initial measurement range: from 0 to 250° C. Final measurement range: from 150° C to 900° C. Data acquisition: 1frame/sec. Snapshot in text format every 60 secs. Distance from lens to E-Cat module: 70 cm. Average room temperature = 35° C.

- Resistor power supply control box provided with integrating wattmeter panel, manually controlled.

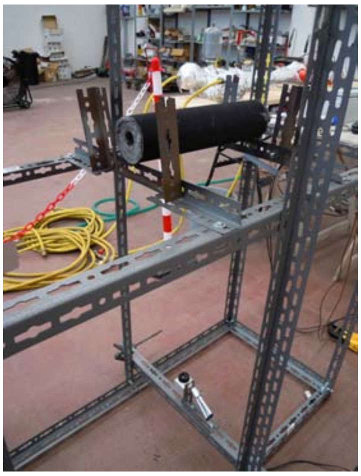
- Voltmeter connected to resistors downstream from the control box.

- Clamp ammeter connected downstream from the control box.

- Instruments for radiation control; see attached radiometry report.

- E-Cat support frame.

In the following photograph, the E-Cat module is visible above, and the Optris infrared camera may be seen below.



The distance between camera lens and the lower surface of the module is 70 cm.

Choosing the area of observation and calculation methods

The infrared camera records data at a rate of 1 frame per second.

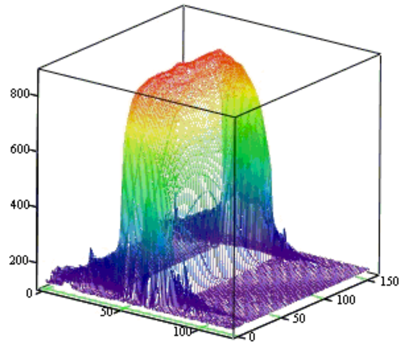
In order to process the data, 420 frames were extracted from the recording, one for every minute of recording time. Each frame was selected at zero seconds, and labeled as Frame HOUR-h-MINUTES, thereby implying that seconds are always = 00. For instance, Frame 17h49 refers to the frame taken at 5:49:00 PM. Extracted data are attached.

In the course of data analysis, it was found that the cylinder was not perfectly centered on the optical axis of the infrared camera, and that the axis was slightly rotated with respect to the horizontal pixel row, so that the side of the cylinder was engaging three rows of adjacent pixels. This positioning made it impossible to apply shape correction factors which had previously been elaborated for a geometric situation requiring centering the axis within +/- 1.5 mm, equal to one row of pixels at a distance of 70 cm from the camera lens.

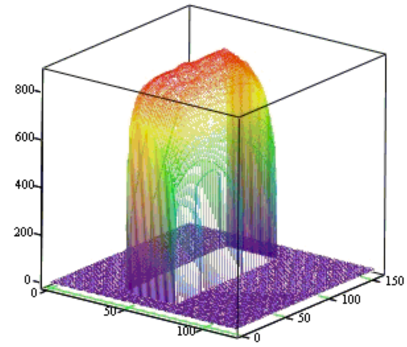
Moreover, from 4 PM onwards, the cylinder, which was simply resting on the support bars, moved slightly, and rolled repeatedly into different positions. This movement, which was recorded by the infrared camera, may be ascribed to the progressive failure of internal fastening devices due to the considerable temperatures reached by the device, thereby causing repeated displacements of the center of gravity which forced the cylinder to assume new positions of equilibrium.

For this reason, it was initially decided to extract the thermal image of the cylinder by circumscribing it with a calculation window capable of blotting out the support bars while continuing to trace the cylinder's movements.
The images were conventionally treated as matrices. Row and column addresses were measured starting from the upper left corner, to which an address of 0,0 was assigned.
The calculation window row addresses were 30 to 75, and column addresses 15 to 135.
This window was wide enough to accommodate the thermal image of the cylinder even after its movements, but contained background pixels as well, which had to be deleted to avoid calculation errors.
Thus, a second window was opened, with row addresses 76 to 119 and column addresses 0 to 159, centered exclusively on the background. The maximum temperature of this second window was used as acceptance limit for the temperatures of the first calculation window.

By cleaning up the first window (diagram on left), a clean, noise free image was generated, the data of which was now confined to the E-Cat alone (diagram on right).



M17h49



$Area\_calcolo(M17h49)_{1,0}$

Section analysis immediately brought out the fact that the temperatures on the side of the cylinder were not consistent with those of the central area.
For instance, in Frame 17h49, recorded at 5:49:00 PM, the peak temperature is seen to be 871° C, while the average temperature is 820.2°C.[1]

However, frame matrix data indicate that the temperature recorded off the side of the cylinder falls to slightly above 300° C, which is not compatible with average and peak temperatures.

It was initially felt that the angle of irradiation on the edge of the cylinder was close to 90°, and that the recorded temperature along the edges would have been perforce lower than the actual temperature. Cosine attenuation, on account of which temperature is attenuated according to the fourth root of the cosine, applies to irradiated power measured according to Stefan-Boltzmann's Law.
For 85.5°, the fourth root is 0.529, so that temperature should not have been lower than 820 x 0.529 = 434° C, which is still far in excess of the recorded minimum temperature of 306° C.

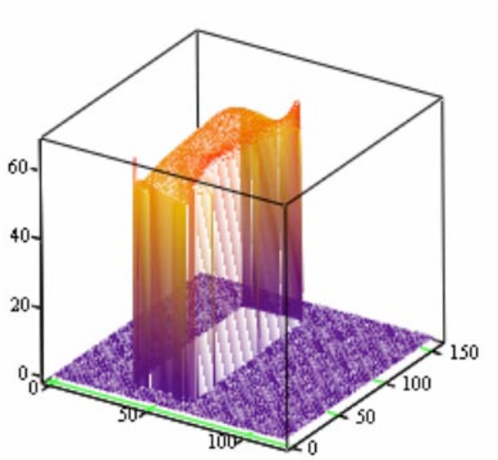
It was concluded therefore that the low temperature recorded on the edges was due to a layer of hot air stripping heat off the E-Cat cylinder by convection. This layer covered the real layer, so that the infrared camera was actually recording the temperature of the air. A previous

[1] In interpreting the images given below, please keep in mind that the Italian system uses the comma to indicate decimal places. Thus 871,8° C is equal to 871.8° C.

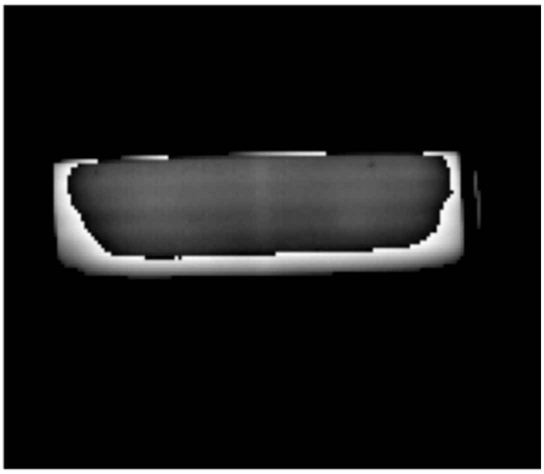
analysis conducted with dedicated software had already shown that at 1000° C heat loss by convection is in the order of 8% of the total heat generated by the E-Cat cylinder.

The next step was to find a way of suppressing the edge effect while at the same time keeping the cylinder's small displacements into account.
Histogram analysis, extended to several initial, intermediate and final frames, as well as to the whole body of data, lead to the conclusion that the edge effect is efficiently suppressed by choosing the first 3760 hottest pixels of the image. In the above instance, the image area is made up of 3906 pixels, a value which remains almost constant for the other frames as well, so that suppression is entirely limited to the 146 coolest pixels.
The robustness of adopting this principle was confirmed by progressively eliminating the calculation window, extending the "3760 hottest pixels" choice criterion to the whole image, and comparing the results with ones which had been previously obtained.
The E-Cat cylinder stands out clear against the background, even without a calculation window, starting from the image taken at 11:35:00 AM (Frame 11h35) onwards. Below, two images are displayed, the first taken at 11:35:00 AM (Frame 11h35), the second, to be compared with the previous one, taken at 5:49:00 PM (frame 17h49).

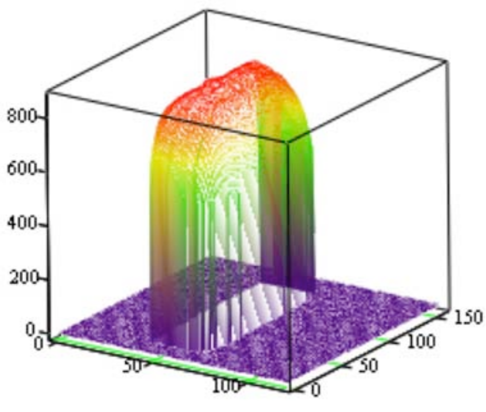
Immagine_scelta(M11h35,3760)$_{0,0}$



Immagine_scelta(M11h35,3760)$_{0,0}$

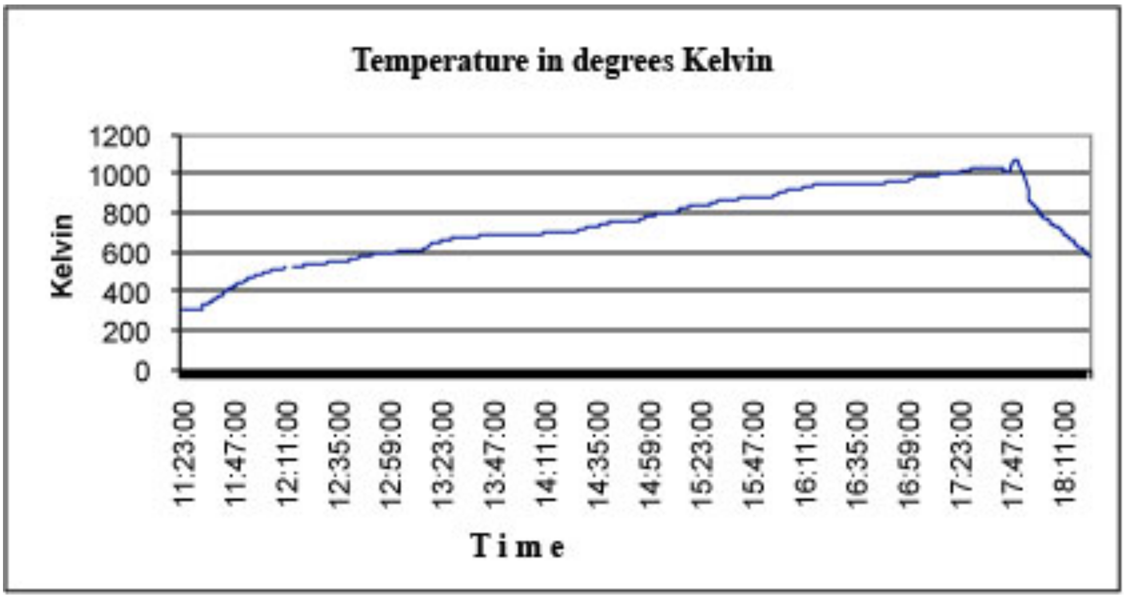


Immagine_scelta(M17h49,3760)$_{0,0}$



Immagine_scelta(M17h49,3760)$_{0,0}$

Data elaborated with the above-described criterion have been converted to MS Excel format, and are attached to this report. A summary, including data collected after shutting down the E-Cat, may be seen below.



Measurement phases

ACTION	TIME	REMARKS
E-Cat power supply switched on	11:21 AM	Voltage: 8 Volts, Current: 1 Amp.
Infrared camera switched on	11:21:52 AM	Range 0-250° C
Infrared camera range commuted	12:11:37 PM	150-900°
E-Cat power supply switched off	5:50 PM	Voltage: 147 Volts, Current: 24.25 Amp.
Infrared camera switched off	6:23:05 PM	

E-Cat power supply was effected through a control box panel provided with a kWh meter which did not allow separate evaluation of the voltage and current supplied to the module. For this reason, a voltmeter and a clamp ammeter were installed downstream from the control box, so as to monitor power data independently from the panel meter. Due to the fact that panel meter data were found to be quite discordant from those measured by the voltmeter and the ammeter, it was decided to ignore the former and use only the voltmeter and ammeter data recorded manually in the course of the test. Voltage was gradually increased step by step to higher values as E-Cat temperatures were shown to stabilize.

Power and energy density calculation

This was effected through Stefan-Boltzmann's formula,

$E=e*s*T^4*A$

where

E = Energy in J.
e = normal emissivity, supposed to be = 1 only for the purpose of the initial calculation. The result may be adapted to paint emissivity, which is estimated at 0.96.

s = coefficient $5.67*10^{-8}$ J/($m^2 K^4 s^2$).
T^4 = Average of fourth power of Kelvin temperature (°K).
A = Area of radiating surface (m^2).

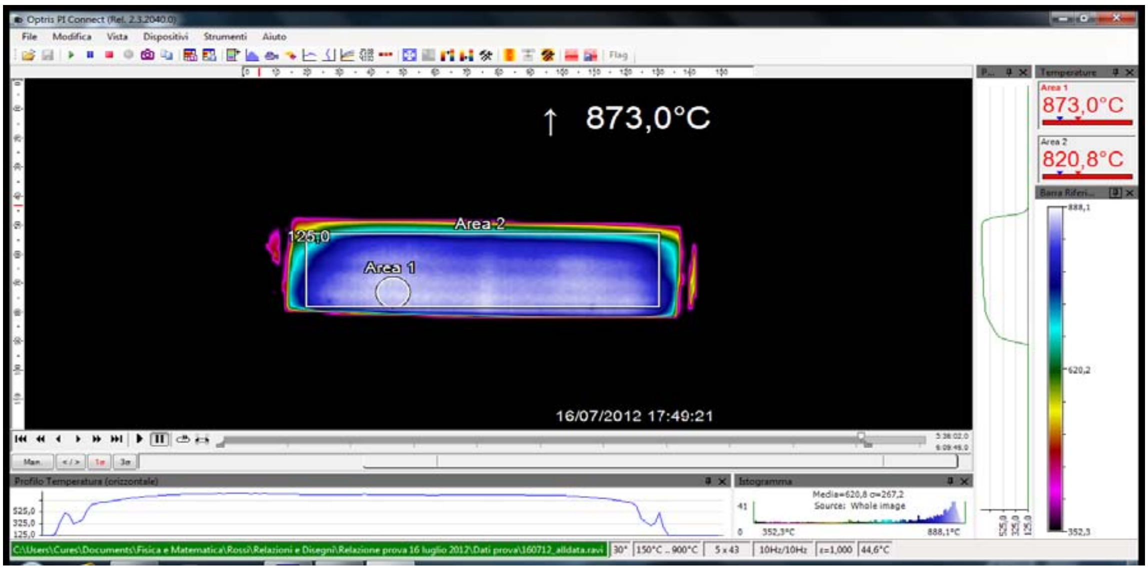
Technical data

COMPONENT	VALUES	REMARKS
Outer cylinder Ø	0.08559	By measurement
Length	0.33 m	By measurement
Area of outer cylinder	0.08873 m^2	By calculation
Inner cylinder Ø	0.02985	Thickness measured: 2 mm
Length	0.33 m	By measurement
Inner area of inner cylinder	0.03095 m^2	By calculation
Total radiating surface, outer + inner	0.11968 m^2	By calculation
Value of resistor 1	11.8 Ω	By measurement
Value of resistor 2	12.8 Ω	By measurement
Resistors in parallel	6 Ω	By calculation
Maximum rated power for resistors	8.069 kW	By calculation. $220^2/6$
Maximum power input during test	3.56 kW	By measurement. V = 147 Volts A = 2428 Amp.
Room temperature during test	35° C	Recorded by infrared camera
Test duration	6.48 hrs.	From 11:21 AM to 5:50 PM

The circular ends of the E-Cat cylinder were not taken into consideration, as lying outside the infrared camera's field of view and composed of smelter-grade sealant putty. This material, though rated for a temperature of 1200° C, became fissured in the latter part of the test.

Average room temperature, as recorded by the infrared camera, was 35° C.
This value was subtracted from the calculated data.

The highest average E-Cat module temperature was calculated from Frame 17h49 (5:49:00 PM) and was 800.98° C, taking room temperature into account. The local peak of 873° C was reached at 5:49:21 PM.



The test was terminated at 5:50 PM in order to keep the data within the infrared camera's range of measurement (150° to 900 C).

During the test, the internal temperature of the cylinder, which may be seen to be glowing white hot in the photograph on the front page of the present report, was measured as well. In some points, the internal temperature of the cylinder reached 1200° C. This measurement, which had not been previously scheduled, was performed with a thermometer with laser pointer; some difficulties were caused by the required distance of at least 1 m from the heat source, and the need to converge and stabilize the beam on the entry hole. Values ranged from 1100° C to 1200° C, and were seen to increase from the entrance of the hole to the center of the cylinder.
Analysis lead to the hypothesis that, on account of the quasi stationary state involved, inner irradiation power and outer irradiation power might be equivalent. In this case, the coefficient by which the external temperature must be multiplied in order to obtain the internal temperature would be the fourth root of the ratio between the external and the internal area, i.e. 1.301. The results are in fair agreement with the perfunctory measurements performed.

The test lasted in all 6.48 hrs. (in decimals).

Power and energy consumption are summarized in the following chart.

Time	Difference (in minutes)	Difference (decimal fractions of hr.)	Voltage (V)	Current (A)	Power (kW)	Energy (kWh)	Total (kWh)
11:21 AM	0:00	0.00	8	1	0.01	0.001	0.001
11:31 AM	0:10	0.17	22	4	0.09	0.007	0.009
11:36 AM	0:05	0.08	33	6	0.20	0.211	0.220
12:40 PM	1:04	1.07	41	7.68	0.31	0.178	0.398
13:14 PM	0:34	0.57	55	10	0.55	0.495	0.893
14:08 PM	0:54	0.90	59	10.6	0.63	0.198	1.091
14:27 PM	0:19	0.32	65.5	11.7	0.77	0.115	1.206
14:36 PM	0:09	0.15	72	12	0.86	0.302	1.509
14:57 PM	0:21	0.35	80	14.1	1.13	0.301	1.809
15:13 PM	0:16	0.27	92	15.9	1.46	0.366	2.175
15:28 PM	0:15	0.25	100	17.2	1.72	0.831	3.007
15:57 PM	0:29	0.48	113	19.36	2.19	0.510	3.517
16:11 PM	0:14	0.23	121	20.7	2.50	2.046	5.562
17:00 PM	0:49	0.82	135	22.8	3.08	1.283	6.845
17:25 PM	0:25	0.42	147	24.25	3.56	1.485	8.330
17:50 PM	0:25	0.42					
Energy consumption (kWh)	**8.330**						
Total hrs.	**6.48**						
Average power (kW)	**1.28**						

The calculations which follow will be performed according to two hypotheses:

• that the temperature of the inner cylinder is equal to that of the outer cylinder. This is the worst-case hypothesis;

• that the power irradiated by the inner cylinder is equal to that irradiated by the outer cylinder.

The average temperature of the E-Cat module between 11:21:00 AM and 5:50:00 PM, corrected to allow for room temperature, is 776.706° K.

In the first hypothesis, the average power irradiated by the E-Cat module is 2.468 Kw; in the second hypothesis it is 3.66 kW.

Power density

As previously described, the active mass is estimated at 20.38 g. In this instance, both average power density and peak power density should be calculated, inasmuch as the latter is more significant.
The highest average temperature of the external surface was found to be 1074.13° K, equivalent to 800.98° C. This result was gathered from the 5:49:00 PM frame (Frame 17h49). At this temperature, the E-Cat module irradiates 9.033 kW according to the first hypothesis, and 13.39 kW according to the second hypothesis. Power input to the resistors at 5:49:00 PM was 3.56 kW.

MAXIMUM POWER IRRADIATED BY THE E-CAT MODULE AT 5:49:00 PM.	
First hypothesis	Second hypothesis
9.033 kW	13.39 kW
AVERAGE POWER IRRADIATED BY THE E-CAT MODULE	
2.468 kW	3.66 kW

POWER DENSITY

MAXIMUM POWER DENSITY	
First hypothesis: inner temperature equals outer temperature.	(9.033-3.56)/0.02038 = 269 kW/kg
Second hypothesis: inner and outer irradiated power are equal.	(13.39-3.56)/0.02038 = 482 kW/kg

In the chart which follows, average values are used.

AVERAGE POWER DENSITY	
First hypothesis: inner temperature equals outer temperature.	(2.468-1.28)/0.02038 = 58 kW/kg
Second hypothesis: inner and outer irradiated power are equal.	(3.66-1.28)/0.02038 = 117 kW/kg

ENERGY DENSITY

This is obtained simply by multiplying the average power by the number of hours of the test.

ENERGY DENSITY	
First hypothesis: inner temperature equals outer temperature.	((2.468-1.28)/0.02038) x 6.48 hrs. = 378 kWh/kg
Second hypothesis: inner and outer irradiated power are equal.	((3.66-1.28)/0.02038 x 6.48 hrs.= 758 kWh/kg

Conclusions and critical remarks.

The E-Cat energy source is not conventional.
In the Ragone diagram, its energy density places it very far from any conventional source. The mass which is considered to be active at the denominator is surely higher than the actual one, because a residue of sealant putty remained stuck to the resistors, as may be seen in the photograph on p. 5 of the report, and its inert weight was not subtracted from the total.
On the other hand, power consumption measurements were less than optimal, because of the reported problem with the control panel; the smallness of the mass at the denominator is however sufficient to absorb measurement tolerances.

Attached documents.

The following documents, for independent perusal on the part of the third parties whom the present report is intended for, are attached:

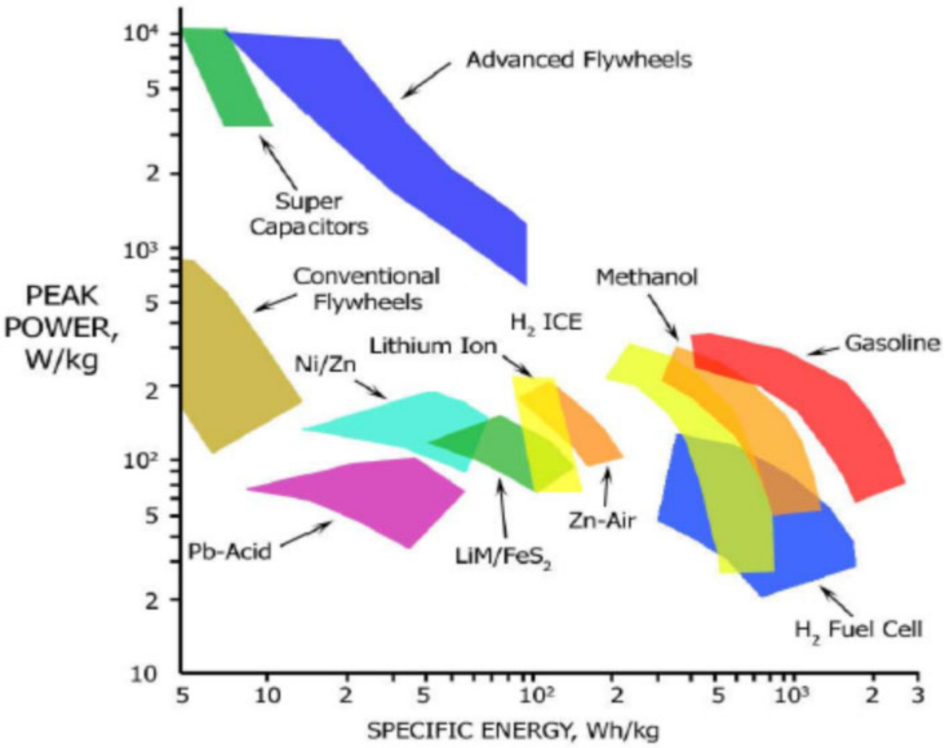
• 1 MS Excel file giving calculation results on two columns of data. The first column gives the time of the snapshot frame used for the calculation, the second one yields the result of the calculations performed, i.e. the average temperature of each snapshot frame, expressed in degrees Kelvin, to be inserted in the Stefan-Boltzmann formula.

• 2 data files of radiometric data recorded from the infrared camera at one frame per second.

• 420 data snapshots in text format — extracted from the data once every 60 seconds and used for the subsequent calculations — denominated Frame HOUR-h-MINUTES. These data have been extracted at zero seconds every minute, so that, f.i., Frame 17h49 contains the frame taken at 5:49:00 PM.

• The report on radiometric surveillance performed during the test, stating that no health hazards whatsoever were present.

Ragone plot of Energy Storage



David Bianchini, M.Sc.
Via Emilia Ponente 375
40132 - Bologna
VAT No. 0137800578

To the kind attention of :
EFA Srl [EFA Ltd.]
Via Marsili 4
40100 Bologna
Tax Code and VAT No. 02826781208

Bologna, July 18th 2012.

Experimental evaluation of the photon radiation field in the proximity of an industrial prototype

INTRODUCTION

On July 16th 2012, at the EFA Srl. plant located in Via dell'Elettricista 16, Bologna, I performed measurements of the photon radiation field for the purpose of radiation protection.
The present report is therefore concerned with field evaluation in proximity to an industrial prototype (see Fig. 1) during a demonstration of the same held for a third party.

The process, geometry and materials used in the prototype are unknowns which I am not cognizant of.

The evaluation of the radiation field may not be correlated to criteria of functionality of the system, nor may it be used for comparison in systems other from the present one, with respect to the process, the geometry or the materials used in manufacture.

The position of the measuring instrument with respect to the prototype was chosen as near as possible to the prototype itself, compatibly with the high temperature generated by it.

Fig. 1. Photograph of the prototype showing one point of measurement during startup phase.

Testing was carried out with no interruption in the measurements given below, which therefore represent to all intents and purpose a continuous monitoring. Measuring position was varied in order to geometrically take into account different angles of view.

"Background" measurements were performed in proximity to the prototype at about 10:00 AM, about one hour before starting the prototype.

This measurement is meant to detect, for the purpose of protection against radiation, the possible presence of X and γ photon radiation due to startup and use of the prototype. In no way does the measurement take into account attenuation of photons produced by the materials inside the apparatus, and in no way may it be traced back to the production of photons on the part the apparatus, or to the lack thereof.

METHODS

A measurement protocol was defined as follows:

• In agreement with ICRU (International Commission on Radiation Units and Measurements; ref. Report 57-1998) definitions, it was decided to evaluate the operational quantities of ambient dose equivalent H*(10) as an indicator of quantity of X and γ fields.

• Measurements of ambient dose equivalent were performed in dose rate mode.

• Measurement position is not fixed, but varies around the apparatus at a minimum distance from its external structure of d = 20 cm. This choice aims to monitor possible anisotropic radiation by mapping the solid angle of radiation around the cell.

• Detection at lower distances proved impossible due to the high temperature generated by the prototype.

MATERIALS

Measurements were performed with the following instrumentation:

• AUTOMESS 6150 AD-b (s/n 93883);

• last calibration certificate: SIT 065/R No. 9521/S/12/10, Dec. 20th 2010;

• 3" × 3" Zinc sulphide probe (ZnS organic scintillator);

• measurement range 23 keV — 7 MeV;

• claimed resolution: 1 nSv/h;

• measurement range 50 nSv/h — 99.99 µSv/h.

RESULTS

Measured values are shown in the following table:

<table>
<tr><th>Time</th><th>Measurement</th><th>Average value H*(10)[nSv/h]</th><th>Maximum value H*(10)[nSv/h]</th></tr>
<tr><td>10:00 AM</td><td>Background</td><td>85 ± 50</td><td>140 ± 50</td></tr>
<tr><td>11:05 AM</td><td>Startup</td><td rowspan="2">90 ± 50</td><td rowspan="2">135 ± 50</td></tr>
<tr><td>5:20 PM</td><td>End of measurement</td></tr>
</table>

The uncertainty on the measurement is estimated in accordance with the methodologies described in ICRU Report 76, *Measurement Quality Assurance for Ionizing Radiation Dosimetry* (2006).

The instrument has a threshold value, with audible alarm, equal to 200 nSv / h, which was never exceeded.

CONCLUSIONS

The measurements show that, within the instrumentation limits given above, there are no significative differences in H*(10) with respect to instrumental and ambient background.

The dosimetry measurement is not dissimilar from the ambient and instrumental background within the instrument's sensitivity, both in average and peak values.

(Signed)
David Bianchini, M.Sc.