Dufour, J., J. Foos, and J.P. Millot. *Cold Fusion by Sparking in Hydrogen Isotopes. Energy Balances and Search for Fusion By-products. A Strategy to Prove the Reality of Cold Fusion*. in *Fourth International Conference on Cold Fusion*. 1993. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304.

COLD FUSION BY SPARKING IN HYDROGEN ISOTOPES ENERGY BALANCES AND SEARCH FOR FUSION BY PRODUCTS

J. Dufour, J. Foos, J.P. Millot
SRSA/CNAM
292 Rue St Martin
75003 Paris FRANCE

I. INTRODUCTION

The idea of transmuting hydrogen isotopes into heavier species (helium), at room temperature, with the aid of palladium acting as a kind of catalyst can be traced back as early as 1926 [1,2]. In 1989, a rebirth was given to the concept [3,4]. By electrolysing heavy water with a palladium cathode, Jones, Fleischmann and Pons claimed to obtain significant energy production, in excess of the electrical energy introduce into the apparatus to carry out the electrolysis. This excess energy was tentatively explained by nuclear fusion reactions of the deuterium present in the cathode, reactions justified by the observation of the emission of neutrons, with an energy corresponding to the known reaction channels of deuterium hot fusion. The amount of neutrons measured was nevertheless many orders of magnitude lower than what would be expected to explain the energy generation observed.

Since 1989, a great number of various approaches were explored, implying contacting hydrogen isotopes and palladium (or metallic hydride forming metals such as nickel): liquid state electrolysis, pressure variation of hydrogen isotopes in contact with palladium, low pressure electrical discharges in hydrogen isotopes with palladium cathode, sparks in hydrogen isotopes, solid state electrolysis, with protonic conductors....

For the time being, no firm correlation has been established between the excess energy measured and the possible nuclear ashes, which are often detected at levels close to the detection limits of the methods used (^{4}He, ^{3}H, neutrons, high energy radiations, isotopic changes in the host metal...). In the present state of the art, we thus define cold fusion as being the abnormal thermal effects that are observed when a hydrogen isotope is contacted with a metallic hydride forming metal, under various physical or chemical conditions. The object of the work which we are carrying out, is to try to firm up the above mentioned correlations. For that, we are aiming at obtaining excess energy in the order of tens of watts on periods of several weeks, to measure the amount of possible nuclear ashes well above the detection limits of the methods used. We shall give in this paper an overview of the results already obtained and indications on the improved calorimetric system which is now under construction.

II. CONCEPT USED AND MAIN RESULTS

Among the various methods available to contact hydrogen isotopes with metallic hydride forming metals, we have chosen to contact hydrogen isotopes in the gaseous phase (H_2 or D_2) at a pressure round the atmospheric pressure, with dissymetrical electrodes, at least one of them being made of a metallic hydride forming metal. A transient electrical discharge (sparks or ozoniser discharge) is struck between the two electrodes through the gaseous hydrogen isotope.

Precise and repeated energy balances show that excess energy is generated in the system, in a fully reproducible way. The amount measured on a steady state basis (several days), excludes chemical or physical explanations or at least classical ones. This excess energy is observed with both hydrogen and deuterium and with various metals (stainless steel was tested and gave a positive response).

On the basis of electrical energy input to the reactor, energy breakeven has been obtained (taking into account an efficiency of 50 % for electricity generation). Excess energy up to 2.5 W has been measured.

With the calorimetric set-up we have been using until now and which will be described below, we cannot exclude a systematic error that could explain the excess energy we measure. We are thus starting the operation of a new calorimetric system that will exclude such errors. We shall describe in this note, the results obtained with the first calorimetric set-up (system I), which measures powers by measuring heat fluxes and the main characteristics of the new one (system II).

III. EXPERIMENTAL

The calorimetric set-up used until now (system I), has been previously described in detail [5]. We thus give here only the main features of it.

The reaction is carried out in a Pyrex reactor as represented in Fig. 1. The sparks are generated by using a car ignition system, comprising an electronic ignitor, which is powered by a DC current, low voltage (14v) generator and generates high voltage pulses by discharging a capacitor through a coil. The 3 parts of the set-up (car ignition system, coil and reactor) are each placed in a calorimeter, as shown in Fig. 2.

The electrical supply of the system is represented in Fig. 3, which also shows the 4 elements of the energy balance of the system:

- electrical power input P(E), measured at the outlet of the DC generator
- thermal power generated by the ignitor T_I.
- thermal power generated by the coil T_C.
- thermal power generated by the reactor T_R.

The entire installation is housed in an insulated portable cabin, placed in the shade. The internal temperature of the cabin is kept at a mean value of 21°C, by the regulating action of a ventilation fan and an electrical radiator. The three power meters are installed in such a way that they receive no direct heat (or cold) from any source (sun, radiator, ventilation).

IV. STRATEGY USED FOR THE POWER BALANCE OF THE SYSTEM

Any excess power produced in the system will show up as a positive difference between the thermal power output and the electrical power input:

$P(F)= T_I+ T_C+T_R- P(E)$

In contrast, P(F) should be zero when no excess power is produced (with fluctuations around zero due to the noise in the measurements).

To identify such an excess of power P(F), the strategy was as follows:

1. Establish the calibration curves of the three power meters.
2. Measure precisely the electrical power input P(E).
3. Use the three calibration curves obtained and the electrical power input to establish the power balance of three types of experiments:
    - Reference experiments.
    - Active experiments.
    - Control experiments.

These types of experiments will be defined below.

The detailed protocol used to measure the elements of the power balance has been described [5] together with the precautions taken to avoid possible systematic errors. The possible influence on the results of electromagnetic interference, of contact resistances used in the electrical network, of the position of the thermometers in the power meters, of the background temperature variations, and of the way the system is heated have been evaluated.

V. EXPERIMENTS RUN AND RESULTS

The following types of experiments have been run. Their results are summarized in figure 4:

A. Reference experiments in which heat is generated in the reactor by replacing the sparks by a resistance, heat being also generated in the coil and the ignitor through calibrating resistances. In this series, P(F) should fluctuate round zero, yielding the base line of the system. 40 of these experiments were run (26 reference type 1 where use is made of an additional resistor to heat the ignitor and the coil and 14 reference type 2 where use is made of the internal resistance of the coil and the ignitor for heating). Reference type 1 experiments are indicated by Ref. 1 in figure 4, and Reference type 2 by Ref. 2.

B. Active experiments were then assessed against this baseline. In active experiments the reactor contains a hydrogen isotope, in contact with at least one metallic hydride forming metal, and a discharge is struck through it. Two types of active experiments were assessed:

- sparks through hydrogen isotopes between two metallic electrodes. 21 of these experiments were run, and indicated by Act. Spa. in figure 4.

- ozoniser discharge through hydrogen isotopes between one metallic electrode and one dielectric barrier (Pyrex). 22 of these experiments were run according to an experimental set-up which has been described [6]. These experiments are indicated by Act.Ozo. in figure 4.

C. Control experiments of two types were finally run:

- sparking through nitrogen or argon between two metallic electrodes (Con.N2Ar in figure 4). 3 of these experiments were run.
- ozoniser discharge through hydrogen isotopes, between two dielectric barriers (Pyrex). In this type of experiments the discharge is of the same type as in active experiments (the gas is a hydrogen isotope) but is never in contact with a metal (Con.Ozo. in figure 4). 6 of these experiments were run.

Fig. 4 is an overview of the results of the 92 experiments run. The excess power P(F) measured is plotted against the chronological sequence of the experiments (the measurements were made during a period of 18 months). The excess power measured fall clearly into 2 different categories:

- Reference and control experiments form a category with mean value 0.03 W and standard deviation 0.54 W.
- Active experiments form a second category, with mean value 1.6 W and standard deviation 0.44 W.

From these figures, the difference between the 2 categories is statistically highly significant. Provided no systematic error can explain this difference, it can be concluded that striking a discharge (spark or ozoniser) through a hydrogen isotope gives excess power production, when the hydrogen isotope is in contact with at least one metallic hydride forming metal. This excess power production have been observed to last up to 216 hours, is fully reproducible and starts within 2 days after starting an experiment (we cannot give any indications on the first two days of an experiment, due to the thermal inertia of the calorimetric system).

A number of possible systematic errors have been examined as mentioned above. None of them was found able to explain the results we obtain. Of special interest are the control experiments that seem to exclude a systematic error on the way the reactor is heated (resistance or electrical discharge).

Most of the experiments have been run with the combination deuterium/palladium. A few (8) have been run with the combination hydrogen/palladium or deuterium/stainless steel. The results obtained fall within the category of the active experiments. Due to their small number, it is impossible to give a precise evaluation of the excess power they have generated.

VI. CONCLUSION

Striking a discharge (spark or ozoniser type) through a hydrogen isotope in contact with at least one metallic hydride forming metal, yields, in the set-up we have used, excess power production that is fully reproducible and stable over long periods. No systematic error has been found that could explain the statistically significant excess power production we have measured.

One possible explanation of this phenomena is an hypothetical class of nuclear reactions, based on the virtual neutron concept [5,6].

To completely exclude the possibility that a systematic error can explain our results, we have designed and are starting a new calorimetric system (system II), where only one calorimeter is used (adiabatic and flow type calorimeter).

A search for nuclear ashes is also being carried out [6].

We hope this effort will shed more light on cold fusion.

REFERENCES

1. F. PANETH and K. PETERS, “Uber die Verwandlung von waterstoff in Helium,” Naturwissenschaften, 14, 958 (1926).
2. J. TANDBERG, “Method for producing Helium,” Swedish patent application (1927).
3. S. E. JONES et al.; “Observation of Cold Nuclear Fusion in condensed matter”, Nature, 338, 739 (1989).
4. M. FLEISCHMANN and S. PONS, “Electrochemically Induced Nuclear Fusion of Deuterium”, J. Electroanal. Chem., 261, 301 (1989)
5. J. DUFOUR, “Cold Fusion by Sparking in hydrogen isotopes”, Fusion Tech. 24, 205 (1993)
6. J. DUFOUR et al., “A strategy to prove the reality of Cold Fusion” Proceedings: Fourth International Conference on Cold Fusion Volume 1: Plenary Session Papers p. 9/1, 9/13

FIGURES

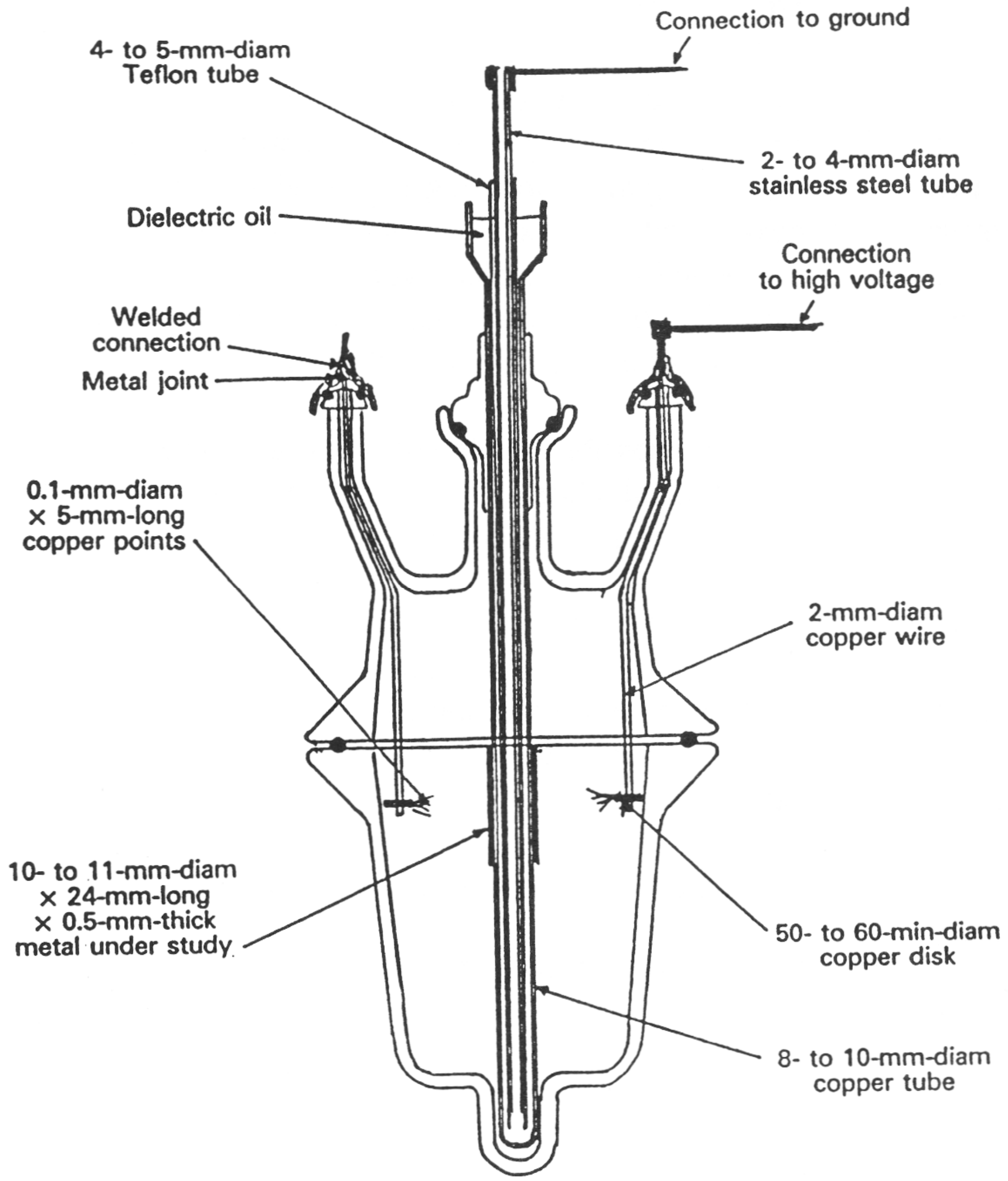

Fig. 1. Reactor.

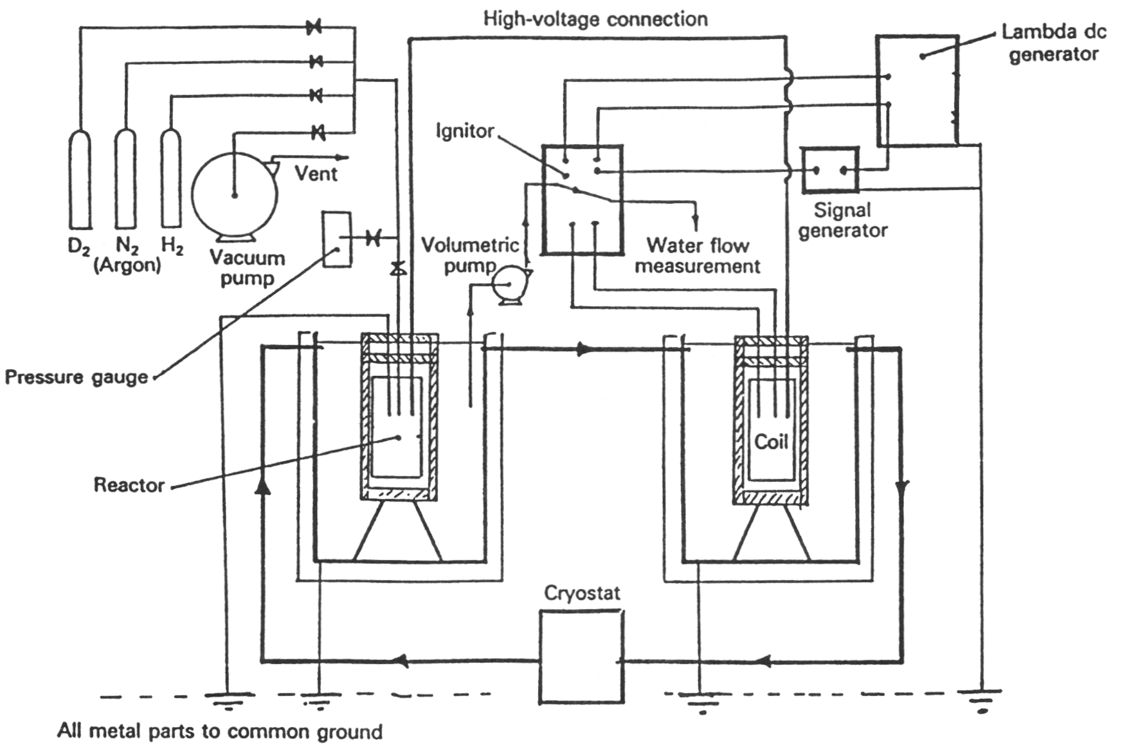

Fig. 2. Overall setup.

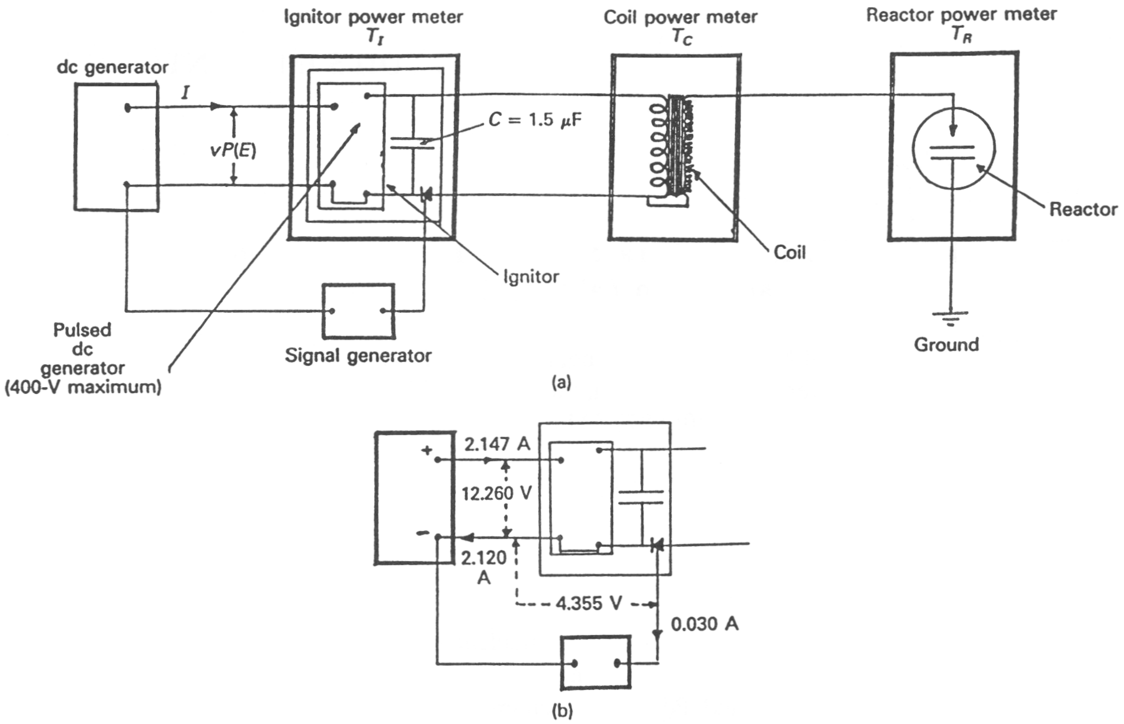

Fig. 3. Electrical supply and power balance.

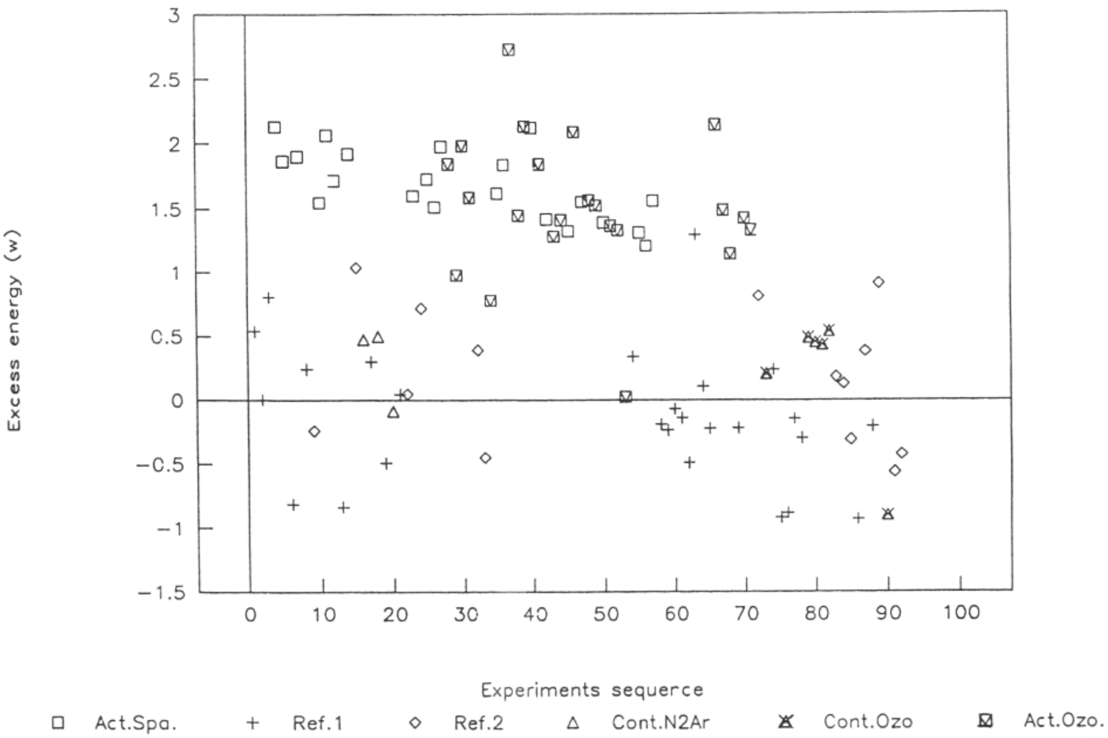

Fig. 4. Excess power in all experiments as a function of experiments sequence.