Rossi's Reactors – Reality or Fiction?

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A tabletop prototype of a new kind of nuclear device was demonstrated at the University of Bologna, several months ago. It generated thermal energy at the rate of 12 kW. A set of one hundred of such interconnected devices, able to generate energy at a much higher rate (up to 1000 kW) is said to be now commercially available. The inventor claims that the energy was produced via nuclear fusion of hydrogen and nickel. This note addresses conceptual difficulties associated with such interpretation. Experimental facts reported by the inventor seem to conflict with accepted knowledge. This, however, should not be a justification for the rejection of experimental data. Refutations and confirmations should be based on independently performed experiments.

1 Introduction

An interesting website, describing an ongoing research project, has been created by an Italian engineer Andrea Rossi [1]. He is the inventor of a tabletop device in which powdered nickel, mixed with common hydrogen, reported to generate thermal energy at the rate of 12 kW, for six months. A large percentage of nickel was said to be converted into copper, during that time. The device was recently demonstrated at the University of Bologna. The most obvious questions, raised by the reported features of the reactor are:

1. What lowers the coulomb barrier, between the atomic nuclei of hydrogen and nickel?

2. Is the reported accumulation of copper consistent with the well known half-lives of radioactive copper byproducts?

3. Is the measurable isotopic composition of nickel, in spent fuel, consistent with the amount of released energy?

4. The radiation level, outside the operating 12 kW reactor, was said to be comparable to that due to cosmic rays. Spent fuel, removed from the reactor, one hour after the shutdown, was found to be not radioactive [1]. How can these purported facts be explained?

Results from earlier experiments (2008 and 2009) are described in [2]. In one case the device was used to heat a "small factory" (probably two or three rooms) for one year.

2 Reported 2011 results

One demonstration of the device – January 14, 2011, at the University of Bologna – is described in [3–5]. Subsequent experiments – February 10, and March 29, 2011 – are described in [6–8]. In both cases the apparatus consisted of a cylinder containing nickel. Pure hydrogen was forced to flow through the hot nickel powder. The amount of powder was 100 grams [8, 9], or slightly more than one cubic inch, depending on the level of compression. Reactions between nickel and hydrogen turned out to be extremely exothermic,

generating thermal energy at the rate of about 12.4 kW. This was 31 times higher than the rate at which electric energy was supplied, to operate the equipment [4].

In the February experiment the amount of thermal energy was determined from the flow rate of cooling water, and the difference between its input and output temperature. In the January experiment the water flow rate was slower; the entering water was a liquid, the escaping water was a vapor. The amount of thermal energy released was determined from the amount of liquid water (initially at 15 ^{o}C) transformed into 101 ^{o}C vapor. Rossi claims that most heat is produced from nuclear reactions:

$$p + Ni \rightarrow Cu,$$
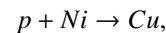
where p is nothing but ionized hydrogen. This is very surprising because the temperature of hydrogen was below the melting point of nickel. Addressing this issue in [10] Rossi reported that about 30% of nickel was turned into copper, after six months of uninterrupted operation. A schematc diagram of the reactor, and additional details are in [11, 12].
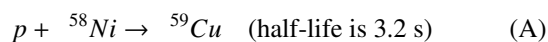
Comment 1

Many physicists have studied fusion of protons with nickel nuclei. But their protons had much higher energies, such as 14.3 MeV [13]. Rossi's protons, by contrast, had very low energies, close to 0.04 eV. The probability of nuclear fusion, expressed in terms of measurable cross sections, is known to decrease rapidly when the energy is lowered. How can 0.04 eV protons fuse with nickel, whose atomic number is 28? Rossi is convinced that this is due a catalyst added to the powdered nickel. The nature of the catalyst has not been disclosed. This prevents attempts to replicate the experiments, or to discuss the topic theoretically. Secrecy might make sense in some business situations, but it is not consistent with scientific methodology.
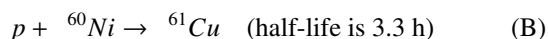
Comment 2

How can 30% of nickel in Rossi's reactor be transmuted into

copper? This seems to be impossible, even if the coulomb barrier is somehow reduced to zero by his catalyst. To justify this let us focus on the ^{58}Ni and ^{60}Ni isotopes–they constitute 94.1% of the nickel initially loaded into the device. The reactions, by which copper is produced, from these isotopes, would be:

$$p + \ ^{58}Ni \rightarrow \ ^{59}Cu \quad \text{(half-life is 3.2 s)} \qquad \text{(A)}$$

and

$$p + \ ^{60}Ni \rightarrow \ ^{61}Cu \quad \text{(half-life is 3.3 h)} \qquad \text{(B)}$$

The reported amount of accumulated copper – 30% of the initial nickel being turned into copper, after six months of operation–would indeed be possible, via reactions (A) and (B), if the produced copper isotopes were stable, or had half-lives much longer than six months. But this is not the case, as shown above. The produced copper isotopes, ^{59}Cu and ^{61}Cu, rapidly decay into ^{59}Ni and ^{61}Ni. Each reaction, in other words, would lead to accumulation of these isotopes of nickel, not to accumulation of copper, as reported by Rossi. The accumulation of copper would practically stop after several half-lives. Note that ^{63}Cu and ^{65}Cu, if produced from fusion of protons with ^{62}Ni and ^{64}Ni, would be stable. But natural abundance of these isotopes of nickel, 3.63% and 0.92%, respectively, is too low to be consistent with the claimed accumulation of 30% of copper.

Comment 3

How much of the original ^{58}Ni should be destroyed, after six months of continuous operation, in order to generate thermal energy at the rate of 12 kW? Let us again assume that Coulomb barriers are somehow reduced to zero by Rossi's secret catalyst. The ^{58}Ni is 68% of the total. On that basis one can assume that 68% of 12 kW is due to the radioactive decay of ^{59}Cu, and its radioactive daughter, ^{59}Ni. Thus $P'_1 = 0.68 \times 12 = 8.16$ kW. This is the thermal power. The nuclear power P_1 must be larger, because neutrinos and some gamma rays do escape from the vessel. As a rough estimate, assume that the nuclear power is

$$P_1 = 16 \text{ kW} = 16,000 \text{ J/s} = 10^{17} \text{ MeV/s}.$$

The excited ^{59}Cu, from the reaction (A), releases 3.8 MeV of energy, as one can verify using a table of known atomic masses. In the same way one can verify that the energy released from its radioactive daughter, ^{59}Ni, is 4.8 MeV. In other words, each transformation of ^{58}Ni into ^{60}Ni releases $3.8 + 4.8 = 8.6$ MeV of nuclear energy.

The number of reactions (A) should thus be equal to $10^{17}/8.6 = 1.16 \times 10^{16}$ per second. Multiplying this result by the number of seconds in six months (1.55×10^7) one finds that the total number of destroyed ^{58}Ni nuclei is 1.80×10^{23}, or 17.4 grams. A similar estimate can be made for other initially present nickel isotopes. The overall conclusion is that the isotopic composition of nickel, after six months of operation, at

the 12 kW level, would change drastically, if the reaction A were responsible for the heat produced in the reactor invented by Rossi.

The amount of ^{59}Ni, for example, would increase from 0% (natural abundance) to 17.4%. The amount of ^{58}Ni, on the other hand, would be reduced from 68% (natural abundance) to 50.6%. The isotopic composition of nickel in spent fuel was measured, according to [1], but results remain "privileged information".

Comment 4

The level of radioactivity, next to the reactor generating heat at the rate of 12 kW, was reported as not much higher than the natural background [5]. Is this consistent with reaction (A) being responsible for most of the heat? The answer is negative. How can this be justified? In the steady state the rate at which radioactive atoms, in this case ^{59}Cu, are decaying is the same as the rate at which they are produced. That rate, as shown in Comment 3, is 1.16×10^{16} atoms per second. In other words, the expected activity is

$$1.16 \times 10^{16}/3.7 \times 10^{10} = 313,000 \text{ Curies.}$$

The emitted radiation would include gamma rays of 1.3 MeV, able to escape. The level of radiation, next to the reactor, would depend on the wall thickness. It would certainly exceed the background by many orders of magnitude. Absence of excessive gamma radiation might be an indication that the reactions producing heat were different from the p+Ni fusion.

3 Addendum

Note that the reported fuel power density of 120 W/g would be at least ten times higher than in a fuel element of a nuclear reactor based on ^{235}U. What can be more desirable than higher safety and lower cost? Did Rossi really invent a new kind of nuclear reactor? Logical speculations, such as those above, are not sufficient to answer this question. Only independently performed experiments can do this.

Rossi's claims, if confirmed, would present a challenge to theoretical physicists. Physics, unlike mathematics, is based on confirmed experimental facts, not on axioms. Newly discovered facts often lead to improvements of accepted theories. Let's hope that Rossi's incredible results can be independently confirmed in the near future.

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