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# Erratum to "Proposal of a Deuterium-Deuterium Fusion/PWR Fission Hybrid Reactor" [World Journal of Nuclear Science and Technology, 2024, 14, 190-233]

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## Abstract

The original online version of this article (Lindecker, P. (2024) "Proposal of a Deuterium-Deuterium Fusion/PWR Fission Hybrid Reactor" World Journal of Nuclear Science and Technology, 2024, 14, 190-233. (https://www.scirp.org/journal/paperinformation?paperid=137109), contains inaccuracies in the text, which, however, do not impact the calculations and the results. Extracts of the modified text are given below. The modified article could be downloaded from this direct link: http://f6cte.free.fr/Proposal_of_a_Deuterium-Deuterium_fusion_PWR_fission_hybrid_reactor.pdf.

## Keywords

Erratum, Fusion Reactor, Fission Reactor, Hybrid Reactor, Nuclear Energy, Deuterium-Deuterium Reactor, Colliding Beams, Deuterium, Racetrack, Stellarator, Power Plant, PWR

### 1.1. Goal, Presentation and Notations Used

The goal of this article is to describe a hybrid power plant formed by:

- A Deuterium-Deuterium (D-D) fusion reactor is proposed by the author in a previous article [1] which is based on the article [2]. This fusion reactor uses a magnetic confinement and a plasma heating system.

The standard way to heat the plasma, so as to stabilize the plasma temperature, is to use devices such as neutral atoms/molecules injection, but also radio frequencies (ECRH or ICRH) and possibly magnetic compression at the heating beginning, etc. Moreover, the injection of pellets of Deuterium ice permits to feed the reactor. The set of plasma heating systems is symbolized here by two opposite beams of D+ ions and electrons injected by ions and electrons beam guns, even if in reality these beams could not reach the plasma core as the magnetic confinement would prevent it. However, for the calculations, it will be considered that it is possible, which would not change the results, but simplify the analysis. Moreover, two opposite beams permit to avoid a net plasma current.

Note 1: the injection of neutral atoms/molecules at high energy would be more or less equivalent because these particles are mainly ionized at the center of the plasma and give their kinetic energy in excess to the plasma. The advantage is that these neutral particles are not confined by the magnetic field, so they can enter into the plasma core. However, in that case, the kinetic energy is mainly carried by the sole D+ nuclei, not by the electrons.

Note 2: the plasma neutrality is supposed to be controlled, through a Divertor electronic or ionic sheath, implicitly taking into account the particle losses and the particles injected. This complex problem is not addressed in this paper.

The two opposite beams (symbolized here by D+/electrons particles, but neutrals particles in reality), initially directed axially, circulate inside a figure of "0" configuration, also called a Stellarator "racetrack". The global injected current is nil. This reactor would produce nuclear fusions with a mechanical gain (Q), *i.e.*, fusion power/mechanical injection power, depending on the pipe radius (Rp) superior to 1 in [1] but inferior to 1 for this hybrid reactor. For example, at Rp = 2 m, Q = 0.184, versus Q > 10 for a D-T Stellarator of the same radius, as for example the Helias 5-B project.

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## 2.1. Generalities

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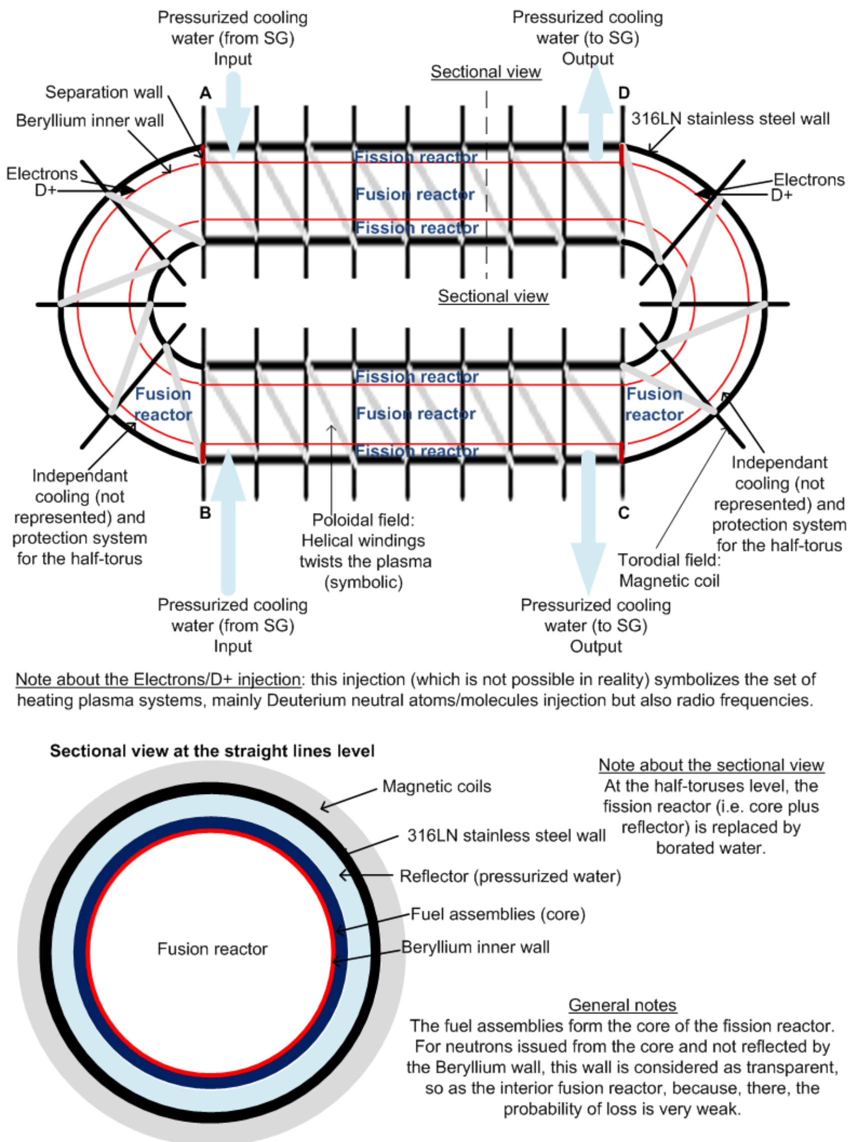


**Figure 2.** D-D/PWR fusion reactor principle diagram.

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The fusion reactor is described in [1]. D+ ions and electrons are supposed to be directly injected, at the same energy, with elevated currents, up to the moment when the currents circulating in the figure of "0" reach their nominal values (the global current being nil). In permanent working, the electrons and the D+ ions are supposed to be injected (at E_inj) at a rate that allows to cover losses and fusions so as to keep the beam neutral. The working of such a D-D fusion reactor is continuous, 24 hours a day.

Note: In this document, the direct injection of D+ ions and electrons, which is not physically possible, is a simple way to take into account the necessary plasma heating. See §1.1.

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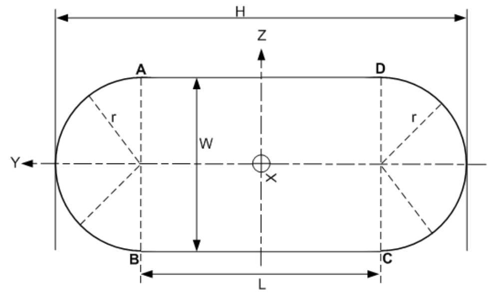


Figure 3. Geometry of the D-D fusion reactor on the YZ plane, along the axis of the reactor.

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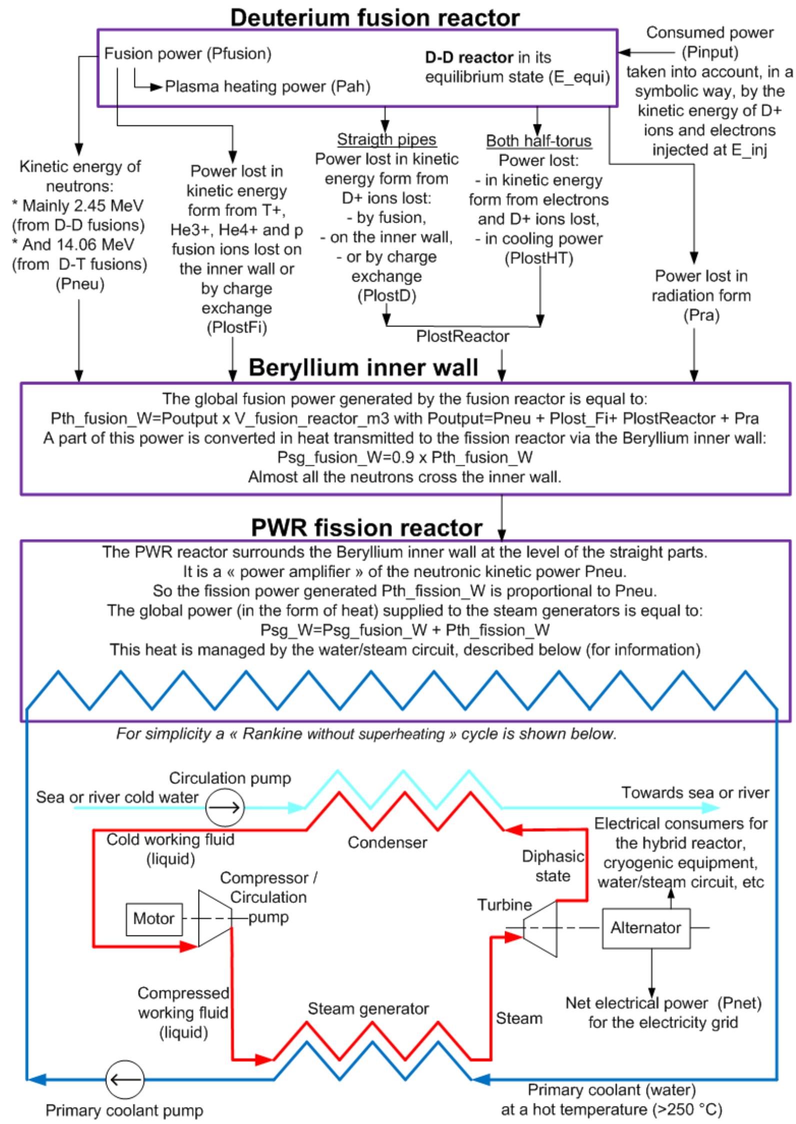


Figure 4. D-D/PWR hybrid reactor energy balance.

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## 2.2. Presentation and Working of the Fusion Reactor—Why This Type of Fusion Reactor

Presentation and working of the fusion reactor (see [1] for details))

From an initial rectilinear movement, the behavior of the injected particles (D+ ions/electrons) (**Figure 2**) quickly becomes isotropic before thermalization. Note that in the real case of injected neutral Deuterium particles, these ones are quickly ionized in D+ ions and electrons.

The Coulomb collisions between D+ ions and electrons permit a permanent exchange of energy between these particles. Plasma is heated, for a part, by fusion products: T+, p, He3+ and He4+ ions and maintained at an equilibrium energy E_equi. Replacement particles (D+ ions/electrons) are injected at E_inj to replace the lost particles and to heat the plasma.

Note that in the real case of injected neutral particles, the kinetic energy of these particles is mainly carried by atomic nuclei (D+) and not by electrons, due to the difference of masses, the speed being the same. So this lack of energy might be compensated either by a higher injected energy of the neutral particles, i.e., about twice the kinetic energy E_inj or by a radio-frequencies heating.

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## 3.4. About Charge Exchanges between Ions and Gas Neutrals

In [1] (§2.2.4), it was supposed that permanent losses were caused by charge exchanges on neutrals, coming from the residual gas inside the reactor and from the gas stored on the wall surface. This behavior exists at the beginning of the heating operation but disappears progressively, so charge exchanges will not be considered. Consequently, the variables $\gamma cep = \gamma ceT = \gamma ceHe3 = \gamma ceHe4 = \gamma ceD$ will be forced to 0.

Note that there is a normal neutralization of charged particles of all kinds, lost by radial diffusion, on a Divertor plate or on the wall, followed by the molecular vacuum pumping of a part of these neutral particles at the Divertor level, and, for the other part, by ionization of these neutral particles. This complex problem is not addressed in this paper.

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## 5.6. Points to Deepen

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- The plasma heating using injection of charged particles (D+ and electrons), as taken into account in this document for the calculations, must be replaced by a set of real plasma heating systems as described in §1.1.
- The complex problems of plasma neutrality control, molecular vacuum pumping of neutral particles and management of the neutralized particles must be considered.