COMITETUL DE STAT PENTRU ENERGIA NUCLEARA
INSTITUTUL DE FIZICA ATOMICA

FR-134-1975
June

USE OF CODE DTF-4 FOR DETERMINING THE COEFFICIENT OF BACK - REFLECTION OF THE NEUTRON WITHIN THE THERMONUCLEAR PLASMA OF A THERMONUCLEAR REACTOR CONTROLLED BY THE RATE OF THE FISSION REACTIONS

Part I

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Abstract The neutron problems are discussed of the thermonuclear reactor controlled by the rate of the fission reactions. The results obtained by rolling the DTF-4 program in a spherical geometry in the case of an "external source" problem enable to draw conclusions concerning the problems of the neutronics system of this thermonuclear reactor type. A relation is deduced for estimating the coefficient of back-reflection of the neutron within the thermonuclear plasma and the focusing [illegible] is discussed of the neutronics of this reactor type.

1. Introduction

In paper /1/ the principles are discussed of a new type of thermonuclear reactor. In this new type of reactor, the study of which is carried on in papers /2, 3/ the thermonuclear plasma in a stationary regime exists freely in the fusionable fuel medium. The fusion reaction does not evolve explosively since outside a control sphere of very small volume the energy balance is in the vessel is small at the energies of the neutrons yielded by fusion (14 MeV). The material of the thermonuclear reactor vessel, whatever its composition constitutes a high-pass filter for the fusion neutrons owing to their high energy *).

The whole of the inside wall of the thermonuclear reactor vessel is lined so as to stop the penetration of thermal neutrons into the reactor vessel. The penetration of the thermal neutrons into the thermonuclear reactor vessel is to be avoided because they interact with the uranium impurities in the fusionable material present in the thermonuclear reactor vessel where they produce fission reactions and by so doing consume the fissionable material.

The scattered neutrons in the wall of the reactor vessel are back-reflected in the thermonuclear plasma . The back - reflection of the neutrons in the thermonuclear plasma should be achieved in the energy range of 5 - 20 KeV when the thermonuclear reactor is working at T_o = 10 KeV and in the 10-200 KeV range when the reactor is working at T_o =100 KeV. For technological reasons the reflection occurs for all the neutrons the energy of which exceeds the thermal energy. This kind of reflection favours the production of the fission reactions within the thermonuclear plasma because the fissionable ions in this plasma are not monoenergetic but this energies possess an approximately Maxwellian distribution.

The neutronic system of back-reflecting the neutrons is necessary for achieving a pin-point focussing of the neutrons re-

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*) The gigantic reasonances appearing in some materials at this energy have too small an amplitude for influencing the behaviour as a high-pass filter for the neutrons the energy of which is in the MeV field.

reflected in the thermonuclear reactor centre. By using a pin-point focussing in the centre of the thermonuclear reactor a neutron distribution is achieved that, from the energy standpoint, repeats the distribution in the wall of the thermonuclear reactor vessel while from the density standpoint amplifies this distribution / 1 /. The neutronic system of back-reflection should practically cover the whole inside surface of the thermonuclear reactor vessel so as to fulfil these conditions. The inside surface of the thermonuclear reactor vessel will then look as a honeycomb formed by the cavities of back-reflection of the neutrons.

In the spaces between these cavities the inside surface of the reactor should be lined with a material liable to stop the penetration of the neutrons under 100 KeV (or under 20 KeV) into the reactor vessel except when they are along the focussing direction*).

The intensity of the neutron source constituted by the thermonuclear plasma is 10^{21} - 10^{24} n/s according to the thermonuclear reactor power. The control of this reactor is obtained by a uniform space distribution of the temperature within a central zone of the thermonuclear plasma due to its energy balance to which participates also the power due to the fission reactions. In this central zone of the thermonuclear plasma, the power yielded by fission represents a fraction of o.o5 - o.5 of the power supplied by fusion. The control , by

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*) These conditions are not absolutely restrictive. It is enough that the ratio between the neutrons fulfilling a conditions and the neutrons not fulfilling this condition be kept by the neutronic system at the value of lo.E.g. the ratio between the neutrons penetrating into the reactor vessel through the non-lined space between the cavities and the neutrons penetrating through this space after lining it.

means of the neutron system, of the power yielded by fission in the central zone of the thermonuclear plasma determines the temperature of this zone and consequently controls the power of the thermonuclear reactor / 1 /. Outside the central zone of the the thermonuclear plasma when no power is produced by fission reactions the energy balance can no more maintain a uniform distribution of the temperature. Outside the central zone where the power is produced by fusion reactions, the energy balance is obtained by the radial decrease of the temperature. The temperature diminution leads to the decrease of the power supplied by fusion down to a limit where practically there remains none. The radius at which the fusion power is practically reduced to zero constitutes the limit of the thermonuclear plasma / 5, 6 /. In the adjacent zone of the thermonuclear plasma, the latter is cooling rapidly even for a small increase of the radius owing to the bremsstrahlung and to the thermal conductivity of the electrons. The plasma cooling in the zone adjacent to the thermonuclear plasma due to the bremsstrahlung (chiefly, but also to the other type of radiations which when the temperature goes down begin to play animimportant role) leads to a substantial decrease of the plasma pressure *). The pressure in the cool plasma is smaller by several orders than that in thermonuclear plasma. This pressure decrease is due to the conversion of the kinetic energy of the ions into radiation and only in a small proportion is it the result of the redistribution by thermal conductivity of the kinetic energy of the thermonuclear ions and of the ions from the cool plasma or from the gaseous medium surrounding the plasma. In this manner,

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*) By the decrease of the kinetic energy of the ions.

a confinement is produced of the thermonuclear plasma within the coole plasma. The confinement frontier of the thermonuclear plasma is somehow unstable. At the size of the thermonuclear plasma which is fixed in the center of the vessel zone where the fission power is produced the oscillations of the confinement frontier represent fluctuations that do not influence the mean power of the thermonuclear reactor. This is due moreover to the fact that the fusion power generated around the confinement frontier is only a very small part of the total power of the thermonuclear reactor. Besides,owing to the spherical symmetry of the thermonuclear plasma the effects of the regions with a growing tendency of the confinement frontier are compensated by the effects of the regions with a decreasing tendency of this frontier.

So as to achieve the control of the thermonuclear reactor, a central zone of the thermonuclear plasma should receive from the fission reactions a fission power representing a percentage of the fusion power. The most suitable percentage allowing the working of this type of thermonuclear reactor would be 10% / 4 /.

Particularizing for the thermonuclear reactor with deuterium-tritium*), each fusion reaction yields a neutron and 3.5 MeV energy within the thermonuclear plasma. In order that within the thermonuclear plasma the fission power should represent one tenth of the fusion power and taking into account that a fission reaction within this plasma yields approximately 170 MeV in the form of the fission fragments energy a fission reaction should correspond to 5oo fusion reactions.

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*) A similar computation can be applied to the thermonuclear reactor with deuterium.

From the standpoint of the thermonuclear reactor neutronics, this condition means that to every 5oo neutrons yielded by the neutron source, at least one shoul produce a fission reaction within the thermonuclear plasma. If the neutronics of the thermonuclear reactor fulfils this condition a mean space fission power will be produced within the whole of the thermonuclear plasma equal to one tenth of the fusion power.

Altnough not quite impossible, this condition is most difficult for the nucleonics of thermonuclear reactor. The difficulty is due to the fact that the neutrons produced by the thermonuclear plasma source should be back-reflected into it, this process taking place with a strong diminution of the neutron flux. The back-reflected neutron in the thermonuclear plasma has only a small probability - given the density of the fissionable material within it - to produce a fission reaction.The highest probability of producing fission reactions within the thermonuclear plasma is possessed by the neutrons belonging to the energy group corresponding to the energy of the fission - able ion in the thermonuclear plasma for which the neutrons appear as thermal ones. But, among the back-scattered neutrons in the thermonuclear plasma, very few belong to this energy group which is the preferred group in the fission reactions.

As a matter of fact however, the conditions to be fulfilled by the nucleonics of the thermonuclear reactor are much easier.

It is to be desired that in the thermonuclear reactor the fission power should represent the lowest possible percentage of the total fusion power. On the other hand, the fission power should represent at least in a given region of the thermonuclear plasma a high enough percentage necessary to ensure the control of the thermonuclear reactor. These two contradictory conditions compound to an optimum when the ratio between the volume V_{fu} of the thermonuclear plasma and the volume of the central zone V_{fi} of this plasma where the energy balance can be controlled by the fission reactions is comprised between limits / 4 /*)

(1)**) $$\frac{V_{fu}}{V_{fi}} = 10^4 - 10^7$$

Relation (1) imposes to the thermonuclear reactor nucleonics the condition that on the central zone of the thermonuclear reactor within volume V_{fi} a fission reaction should occur for every $5.10^6 - 5.10^9$ neutrons yielded within the thermonuclear plasma. This is mainly the principal task of the thermonuclear reactor nucleonics***).

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*) It is easy to see that in this case the fission power is practically null with regard to the fusion power so that this type of thermonuclear reactor although only controlled by fission reactions works as a pure thermonuclear reactor.

**) This at first sight "strange" behaviour is due to the fact that the fission products yielded within the small volume V_{fi} leave this volume with alomost the whole of this energy. The volume up to which limit the fission products acquire by cooling the temperature of the thermonuclear plasma is approximately the volume controlled by the fission reactions. Since the cooling path of the fission products is long enough, the volume controlled by the fission reactions is much greater than the volume within which these reactions take effectively place.

***) There are still other problems not less important belonging also to the nucleonics of this thermonuclear reactor, e.g. the disposal of the huge energy brought by the neutrons within the vessel of the thermonuclear reactor. In this paper, the only problems under discussion are those of the nucleonics related to the working principle of this thermonuclear reactor type.

REFERENCES

/ 1 / G.Cristea, "Thermonuclear reactor the plasma of which is controlled by nuclear fission", IFA, FR-114-1973, Bucharest, Romania.

/ 2 / G.Cristea, "Questions about the feasibility of a thermonuclear reactor the plasma of which is controlled by nuclear fission", IFA, FR-118-1974, Bucharest, Romania.

/ 3 / G.Cristea, "Control of a thermonuclear reactor, the plasma of which is controlled by nuclear fission", IFA, FR-122-1974, Bucharest, Romania.

/ 4 / G.Cristea, unpublished work.

/ 5 / G.Cristea, "Theoretical considerations concerning the size of thermonuclear plasma core of the thermonuclear reactor controlled by the rate of the nu - clear fission reactions", Part I, IFA, FR-131-1975, Bucharest, Romania.

/ 6 / G.Cristea, "Theoretical considerations concerning the size of thermonuclear plasma core of the thermonuclear reactor controlled by the rate of the nu - clear fission reactions", Part II, IFA, FR-132-1975 Bucharest, Romania.