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TRANSIENT NEUTRAL GAS INTERACTIONS WITH PLASMAS AND WALLS *

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The use of neutral gas layers for confinement and/or heat removal in controlled fusion reactors has been the subject of many investigations in recent years. Alfven and Smars [1] appear to be the first to propose the use of a "gas blanket" when they suggested that heat losses from a hot plasma can be reduced by a strong magnetic field in such a way as to allow a layer of high pressure neutral gas near the wall to surround the plasma and balance its pressure. Although it was later shown by Lehnert [2] that the plasma pressure cannot be balanced by the neutral gas pressure in steady state, the question of such balance in the case of fully ionized plasma cores bounded by a partially ionized layer, as well as the question of the penetration process of neutral gas into a plasma, were addressed at an early date also by Lehnert [3]. A mathematical model for the application of a neutral gas layer to the heat removal problem in a Theta-Pinch reactor has been presented by Oliphant [4] in which estimates of the rate of heat flux from the plasma using a short-mean-free-path limit for thermal conduction, and a quasi-steady state assumption for the plasma and neutral gas profiles, were obtained.

This paper represents an extension of the work cited in ref. 4. A time-dependent one-dimensional computer code is utilized to study the transient development of a neutral gas blanket by examining the effects of diatomic neutral gas streaming into a magnetized plasma. The interactions of the incoming diatomic gas and the resulting monatomic gas with the plasma ions, electrons and alphas are examined in an effort to assess the impact of these interactions on the first wall. In the transient stage a collisionless diatomic neutral gas enters the plasma region and interacts via various atomic processes with the plasma tail adjacent to the wall. Simultaneously, the plasma reacts by undergoing continual readjustment through its own hydrodynamics and radiative processes. The plasma–neutral interactions produce diatomic and monatomic ions and monatomic meutrals, some of which will flow towards the wall and cause wall damage. However, as the neutral gas density and width near the wall grows the monatomic neutrals flowing toward the wall will be moderated by neutral–neutral collisions. It is assumed that when the neutral gas has a width approximately equal to three mean free paths the monatomic outward flowing gas will lose its energy in the neutral–neutral collisions. As a result the main energy loss mechanism gradually changes from monatomic bombardment of the first wall to simple heat flow. At this point the neutral gas is assumed to become collisional and a quasi-steady treatment of the neutral gas penetration problem must be adopted.

The most interesting results of this study are illustrated in figs. 1 and 2. Fig. 1 shows the monatomic neutral particle flux at the first wall as a function of energy at time of 35 ms for a diatomic neutral density of $10^{15}/\text{cm}^3$ in the neutral gas reservoir. We note three distinct fluxes. For energies less than 5×10^{-4} keV the flux is mainly due to diatomic neutral charge exchange with the low temperature plasma adjacent to the wall. In the intermediate energy range the flux is mainly due to monatomic neutrals from the disso-

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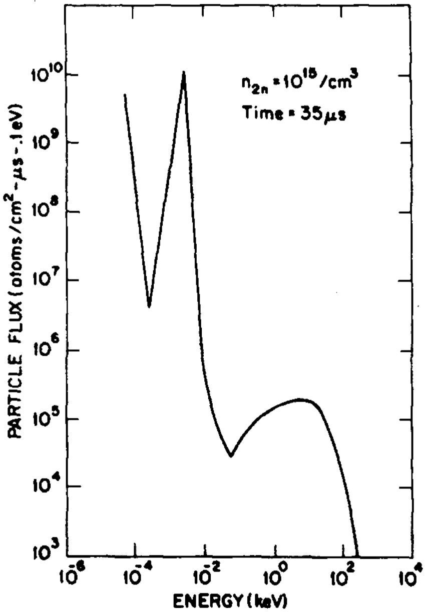

Fig. 1. Particle flux at first wall vs. energy.

ciation of the diatomic ions, while at higher energies the flux is primarily due to diatomic neutral charge exchange with the hot plasma in the core. Wall damage as represented by the sputtering yield is shown in fig. 2 where we note that the charge exchange energy dose (and hence the resulting sputtering) increases dramatically for densities less than $10^{16}/cm^3$. This is due to the increased neutral penetration into the hot plasma that occurs at low densities.

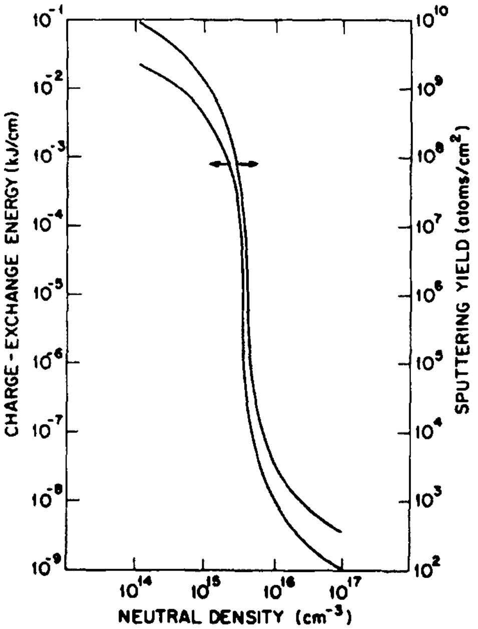

Fig. 2. Charge exchange energy and sputtering yield vs. neutral density.

References

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