§23. Use of Polarized Deuterium — Helium-3 Fuels for an Energy Production

Momota H., Takahashi T. (Graduate Univ. for Advanced Science), and Tomita Y.

After the discovery[1] of plentiful of minable helium-3 on the Lunar surface, fusion scientists have tried to find out the methods for utilizing this attractive fuel for fusion reactors. Among various approaches, a field-reversed configuration (FRC) for confinement of fusion plasma appears the most promising candidate for a D-^{3}He fueled fusion reactor. A conceptual design of D-^{3}He fueled fusion reactor "Artemis" [2] has been carried out showing that bases of engineering needed for constructing a commercial reactor are conventional and the cost of electricity from "Artemis" design is as cheap as 30 mills/kw · h. A low neutron yield allows us a large variation in selecting reactor materials and reduces the problem of disposal of radioactive waste. Representative plant parameters of "Artemis" and the cost of electricity and safety assurance from "Artemis" are tabulated in Fig.1 and Fig.2, respectively.

Table1: Representative Parameters of Artemis

Output Electricity (MW)	1000
Fusion Power (MW)	1757
Power to the Heat Converters (MW)	668
Power to Direct Energy Converters (MW)	1099
Annual Consumption of Helium-3 (kg/years)	63.7
Heat Load on the First Wall (MW/m2)	2
Neutron Load on the First Wall (MW/m2)	0.18
Radius of the First Wall (m)	2.28
Total Weight of the Reactor (tons)	4900

Table2: Cost of Electricity and Safety Assurance from Artemis

Total Capital Cost (Direct Cost)	1,800 M$ (1,030)
Cost of Electricity	0.03 $/kW · h
Level of Safety Assurance	1
Occupational Whole Body Exposure	1.4 mSv/13 days
Public Surface Exposure in Normal	4 mSv/50 years
Intruder Dose of Radioactive Wastes	0.002 mSv/years

A use of polarized D-^{3}He fuels into commercial reactors has been examined[3]. Evaluations have been carried out along two variants: One keep the neutron yields same as "Artemis" and another keep the plasma volume same as "Artemis". Figure 3 shows the plasma volume in the case of constant neutron yields and the fusion neutron power fraction in the total fusion power in the case of constant plasma volume, respectively as functions of the concentration of fuels .

Through out the calculations, we assumed the polarized D-D reaction being unchanged from the unpolarized one. Effects of nuclear elastic scattering are also ignored. Resultant errors due to these assumptions will be less than 10% and bring our results to a pessimistic one.

Table 3: Representative Reactor Parameters of Various Operation Modes

	Small V	Artemis	Low n
Fusion Power (MW)	1747	1757	1550
Ratio between 3He and D	0.91	1.35	2.95
3He Consumption (kg/years)	73.6	63.7	89.4
Plasma Volume (m3)	33.4	196	⇦
Plasma Length (m)/Radius (m)	14/0.87	22/1.7	22/1.7
Electron Density (E21/m3)	8	5.1	5
Plasma Temperature (keV)	84	83.5	84
Maximum Magnetic Field (T)	6.81	5.36	5.24
Required Energy Confinement (s)	1.54	6.87	7.14
Radius of the First Wall (m)	1.47	2.28	2.28
Neutron Yields (MW)	⇨	56	23
Neutron Wall Loading (MW/m2)	0.43	0.18	0.072

W learn, in the table, possibilities of constructing a small power plant with a reasonable neutron yields or a power plant with small neutron yields.

Favorable characteristics of polarized fuels is attributed simply to the enhancement of D-^{3}He reactivity by applying polarization, which reaction contributes largely to the total fusion power. The resultant neutron fraction in the total fusion power can decrease to 1.3% with the same volume of the fusion core as Artemis. The wall loading of neutrons can be very low compared with that from unpolarized "Artemis" design or a reactor design with D-T fuels. This mode gives us a large degree of freedom in a choice of reactor materials. Another operation mode with neutron yields same as "Artemis" design decreases the volume of the core plasma and allows us to construct an economic fusion reactor.

References

[1] L.J.Wittenberg, J.F.Santarius, and G.L.Kurcinski; Fusion Technol. **10** (1986) 167.
[2] H.Momota,*et al.*; Proc. Seventh Int. Conf. on Emerging Nuclear Energy Systems (World Interscience, 1993) 16.
[3] Y.Tomita, T.Takahashi, and H.Momota; to be published in Nuclear Inst. and Methods in Physics Research, A.