CONCEPTUAL DESIGN OF THE HELICAL VOLUMETRIC NEUTRON SOURCE FFHR-b2

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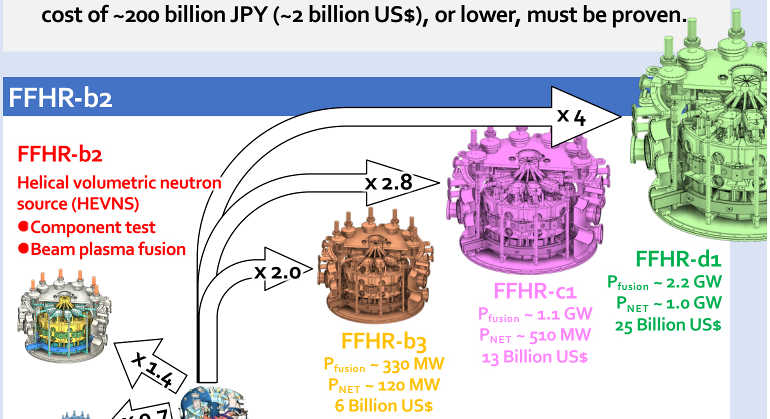
SUMMARY

- **The FFHR-b2, of which the device size is 1.4 times larger and the magnetic field is ~ 2 times larger than those of the LHD, is an optional device for component test in the development strategy toward the helical fusion reactor.**
- **The main mission is to demonstrate three new technologies of ① HTS magnets, ② ceramic pebble divertor, and ③ cartridge-type liquid metal blanket, in the real reactor condition.**
- **The NBI heating of 5 MW produces 5 MW of the fusion output and 0.022 MW/m² = 8 x 10¹⁵ n/m²/s of the 14 MeV neutron flux.**
- **Although the neutron flux is 10^2 – 10^3 times smaller than that required for the material test, it is enough for the component tests to clarify the TBR of the blanket, the performance of the divertor, the life of the superconducting magnets, and so on.**
- **To promote the commercial use of the FFHR-b2, the construction cost of ~200 billion JPY (~2 billion US$), or lower, must be proven.**

FFHR-b2



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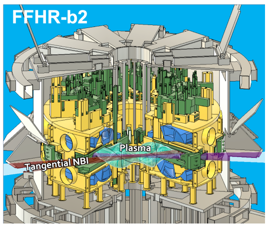


FIG. 1. Schematic view of the FFHR-b2.

TABLE 1. Device parameters.

	FFHR-a1	FFHR-b1	FFHR-b2	FFHR-b3	FFHR-c1	FFHR-d1
R_c (m)	2.73	3.90	**5.46**	7.80	10.92	15.60
B_c (T)	4.0	5.7	**5.33**	6.6	7.3	4.7
P_{fusion} (MW)	0	~5	**~5**	~300	~1,100	~2,200
C_{direct} (10^8 JPY)	~500	~1,200	**~2,000**	~5,200	~13,300	~24,400
t_{life} (years)	-	~0.36	**~2.7**	~5.3	~36.7	~60.0

THREE NEW TECHNOLOGIES: ① HTS magnets

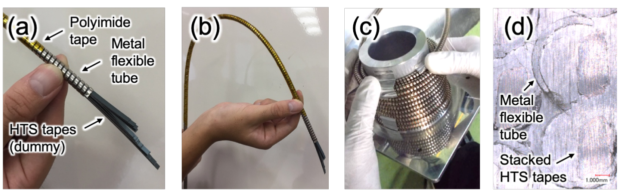
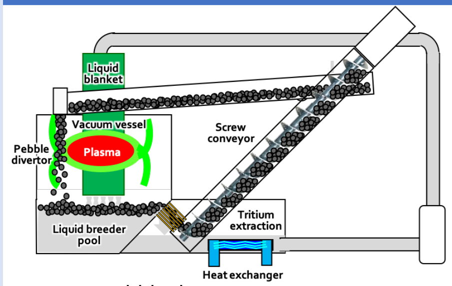
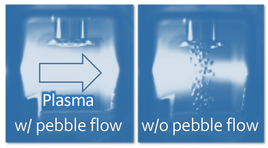


FIG. 2. (a) The WISE conductor, (b) flexibility, (c) a solenoid coil without insulation, and (d) the cross section of the solenoid coil sliced after impregnation with low melting point metal.

WISE (Wound and Impregnated Stacked Elastic tapes) conductor: Simply stacked HTS tapes are bundled inside a metal flexible tube. After the coil winding, the coil is heated and impregnated by a low melting temperature alloy. It is easy to wind a helical coil with this conductor.

THREE NEW TECHNOLOGIES: ② Ceramic pebble divertor





Exp. in the TPDsheet-U in Tokai Univ.

FIG. 3. A conceptual diagram of the ceramic pebble divertor REVOLVER-D3.

Ceramic pebble divertor, **REVOLVER-D3**: A new limiter/divertor system using falling massive ceramic pebbles as the plasma facing material. The ceramic pebbles are dropped to the inboard-side ergodic layer and play a role of limiter. The pebbles then flow into the liquid metal pool, where liquid metal exhausted from the blanket cartridges is filled.

THREE NEW TECHNOLOGIES: ③ Liquid metal blanket

Cartridge-type liquid metal blanket, **CARDISTRY-B2**: An improved version of the cartridge-type helical blanket system. Total number of cartridges are roughly halved. Tangential ports for the effective NBI heating are equipped. The liquid metal flows inside the cartridges and then exhausted to the pool, i.e., the free surface of the liquid metal is exposed to the plasma.

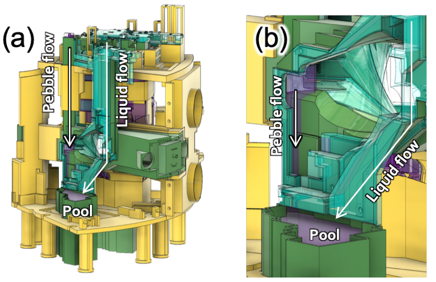


FIG. 4. Schematic views of the CARDISTRY-B2.

The liquid metal should satisfy several requirements of low vapor pressure, low density, low melting point, low corrosiveness, high TBR, and high neutron shielding. Ternary or quaternary alloys, including Li, Sn, Pb (or Bi), and Er, are selected as the candidates of the FLM (Functional Liquid Metal).

TABLE 2. Candidates of the Functional Liquid Metal (FLM) for the CARDISTRY-B2.

name	composition (at%)	density (g/cm³)	liquid phase temperature (℃)	melting point (℃)	vapor pressure (Pa at 500℃)	TBR	neutron loss ratio
ELP-17	$Pb_{82.8}Li_{17}Er_{0.2}$	9.5	185	210	1.6×10^{-3}	1.41	0.545
ELP-25	$Pb_{74.8}Li_{25}Er_{0.2}$	8.7	186	328	1.4×10^{-3}	1.47	0.625
ELP-25 + Be	$Pb_{74.8}Li_{25}Er_{0.2}$	↑	↑	↑	↑	1.90	0.840
ELB-25 + Be	$Bi_{74.8}Li_{25}Er_{0.2}$	8.3	252	422	1.4×10^{-3}	1.89	0.822
ELS-25 + Be	$Sn_{74.8}Li_{25}Er_{0.2}$	5.6	215	468	1.8×10^{-5}	1.70	0.859
ELPS-25 + Be	$Sn_{68.8}Pb_{6}Li_{25}Er_{0.2}$	5.9	177	477	8.4×10^{-5}	1.72	0.864
ELBS-25 + Be	$Sn_{43.3}Bi_{31.5}Li_{25}Er_{0.2}$	6.9	135	599	4.2×10^{-4}	1.78	0.856

EXPECTED PERFORMANCES

To estimate a typical fusion output in the FFHR-b2, **the DPE method** has been applied on the radial profile data obtained in the LHD experiment.

An improvement factor, H, and a degradation factor, f_{deg}, due to the Shafranov shift were considered.

If 5 MW of tangential D beam is injected to the 100 %T plasma of H = 1.0 – 1.3, 5 MW of fusion output will be achieved at the density of ~1 x 10^{19} m^{-3} and the central beta of ~1 %.

Q > 1 can be achieved in FFHR-b2.

The maximum neutron flux on the blanket 1st wall will be ~0.022 MW/m² ~ 8 x 10^{15} n/m²/s. This is large enough to test the functions of the blanket.

It is also possible to examine the lifetime of the HTS magnet irradiated by up to 10^{23} n/m²/s of neutron fluence.

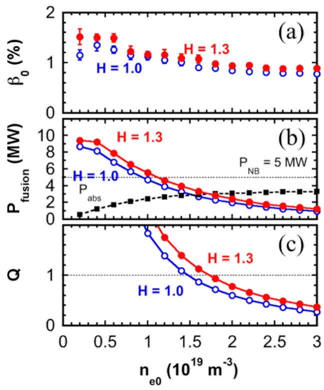


FIG. 6. Calculation results (a) β_0, (b) P_{fusion} and P_{abs}, and (c) Q, plotted with respect to n_{e0}. Open and Closed circles denote H = 1.0 and 1.3, respectively.