Lithium Walls as the Plasma Facing Surface for the tokamak reactors.

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OUTLINE

Plasma facing surfaces are positioned in the most crucial place in the quasi-stationary fusion (DT) reactor, i.e., between

- the plasma
- and the 14 Mev neutron energy absorbing layer.

The conceptual solution for the plasma facing surface affects control and robustness of both:

- plasma regime and
- the entire reactor.

OUTLINE

Magnetic propulsion (invented in Dec. 1998) put Intense Lithium Streams (20 m/sec) to the scope of the tokamak research and resulted in

a concept of LiWall tokamaks

LiWall concept introduced 2 new elements into the tokamak fusion

1. Absorbing and renewable plasma facing wall surface:
   (a) LiWalls and energy extraction from the plasma;
   (b) Effect on plasma energy confinement;
   (c) Effect on plasma stability;
2. Yacht Sail approach for the tokamak fusion reactor design:
   (a) . . . , . . .

Only one of key points, i.e., the power extraction from the plasma is addressed in this short presentation.

Intense Lithium Streams (20 m/sec) have extraordinary power extraction capabilities

$$\Delta T_{max} = q_{wall}\sqrt{\frac{4t_{flight}}{\pi\kappa\rho c_p}}, \quad \Delta T_{max} \le 200^o\ C, \quad t_{flight} \simeq 0.25\ sec, \quad d_{skin} \equiv \sqrt{\frac{\kappa t_{flight}}{\rho c_p}} \simeq 3\ mm$$

For an illustrative example they are

$$R = 6\ m, \quad a = 1.6\ m, \quad q_{wall} \simeq 3.5\ \frac{MW}{m^2}\ \left(14\ \frac{MW}{m^2}\right)_n, \quad P_{wall} = 4\pi^2 R a q_{wall} \simeq 1.3 GW$$

even with no reliance on vortices in the streams.

Intense lithium streams can keep guide-wall temperature low (250-300^o C) at the neutron wall loading $> 10\ MW/m^2$, thus, making wall surface compatible with the FLiBe blanket. (This important reactor issue is out of the scope of this presentation).

Li coated copper wall (1–3 cm) has extraordinary power extraction and RESEARCH capabilities.

$$\Delta T_{max} = q_{wall}\sqrt{\frac{4t_{exposure}}{\pi\kappa\rho c_p}}, \qquad d_{skin} \equiv \sqrt{\frac{\kappa t_{exposure}}{\rho c_p}}, \qquad (t_{flight} \simeq 0.25\ sec, \qquad d_{skin,Li} \simeq 3\ mm)$$

For copper

$$\kappa_{Cu} \simeq 10\kappa_{Li}, \qquad (\rho c_p)_{Cu} \simeq (\rho c_p)_{Li}, \qquad t_{exposure} \simeq 10 t_{flight} \simeq 4\ sec, \qquad \Delta T_{max} \leq 200^o\ C$$

$$d_{``skin'',Cu} \simeq 10 \cdot 3\ mm \simeq d_{Cu}$$

It is a misinterpretation that I ever suggested a tokamak experiment with the flowing lithium. Litium should be deposited on a surface with a massive copper behind it. Copper serves two purposes: (a) as a stabilizer of the plasma facing temperature and (b) as a temporary stabilizer of MHD modes.

Most of physics and technology research as well as training for the Li-Wall tokamak-reactor can be done exclusively on machines, which experimentators are familiar with (starting with CIRCULAR cross-section tokamaks).

TFTR had

$$\boxed{S_{wall} \simeq 90\ m^2, \quad P_{heat} \simeq 40\ MW, \quad q_{walls} \simeq 0.5\ MW/m^2}$$

PBX-M (modified for the Li/copper wall physics/technology studies, including continuation of what was terminated by the TFTR shutdown), will have practically the same wall loading as future LiWall based tokamak reactor

$$\boxed{S_{wall} \simeq 30 - 40\ m^2, \quad q_{walls} \simeq 1 - 1.3\ MW/m^2}$$

if moved to the TFTR cell (assuming same power of NBI will be reinstalled).

DD equivalent of Lawson criterion, upon the results on PBX/DIII-D class of machines, may be demonstrated on tokamaks similar to TFTR (might be slightly non-circular) with no divertors and with

the Li coated COPPER walls.

Then, if allowed, a very limited N of DT shots might be designed by the theory/exper. community (as Fu/Nazikian did successfully on TFTR) and fired in order to measure everything possible about the alpha-driven instabilities in the burning plasma.

LiWall concept is not sensitive to the energetic particles deposition. Nevertheless, because the alpha particle instabilities will be intrisically in the tokamak fusion reactor, it is important to learn about them as much as possible during the pre-reactor level of limited DT experiments.

For the reactor itself, (with Intense Li streams), nothing seems to be "dangerous" in an unexpected energetic particle deposition.

With the energy confinement time being not a challenging problem for the reactor if it works in one of the best tokamak regimes (TFTR lithium conditioned regimes, DIII-D QDB H-mode, low recycling LiWall regime), high energy alpha particle losses might be tolerable or even good for the additional He pumping.

"First hand" information on physics of energetic particles (and associated instabilities) from the burning plasma might be crucial for optimization the reactor operation.

Within the concept of LiWalls, the development toward the burning plasma relies solely on experiments with lithium coated solid walls (e.g., copper with an intermediate material, compatible with the thin Li layer) and

- with recoating Li surface between discharges (which would give several seconds for demonstrating burning) or by continued Li pellet injection or with a DOLLOP-like facility (for extended length of the discharge).
- with MHD stabilization of free-boundary modes at high betas by the copper shell with an assistance of feedback system.

Thus, most of the physics of the burning plasma and calibration of our knowledge will be done in a reliable fashion.

For the future tokamak demo- and, then, commercial- reactors this approach is consistent with merge of the plasma physics with the technology of the Intense Li Streams being developed at some stage in a parallel way (without tokamaks).