D-3He Fusion: Physics, Engineering, and Applications

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Overview:
This poster explains why D-3He fusion fuel is not more popular than D-T fuel (physics), and why it should be (engineering and safety).

D-3He Fuel Leads to Lower Fusion Power Density, but This Can Be Overcome by Higher Magnetic Fields and “Beta”

- D-T fueled innovative concepts become limited by neutron wall loads or surface heat loads well before they reach β or B-field limits.
  - β = plasma pressure/ magnetic-field pressure
  - β measures how effectively the B-field is used.
  - D-T fueled FRC’s (β ~85%) optimize at B ≤ 3 T.

- D-3He needs a factor of ~80 above D-T fusion power densities.
  - Superconducting magnets can reach at least 20 T.
  - Fusion power density scales as β^2 B^2.
  - Potential power-density improvement by increasing β and B-field appears at right.

D-3He Fuel Eases Engineering Difficulties
The Low Radiation Damage in D-3He Reactors Allows Permanent First Walls and Shields to Be Designed

- Reduced neutron flux allows
  - Smaller radiation shields.
  - Smaller magnets.
  - Permanent first wall and shield.
  - Easier maintenance.
  - Increased charged-particle flux allows direct energy conversion of fusion energy to electricity.
  - Smaller neutron flux reduces activation of materials and radiation damage to them.

D-3He May Find Many Uses. Some of Them, Discussed Here, Are:
- Radioisotope production
- Electricity production
- Potentially proliferation-proof
- Space propulsion

3He Resources Are an Issue: Earth Contains 3He Sufficient Only for an Engineering Test Program, but Well-Developed Terrestrial Technology Gives Access to ~10^19 kg of Lunar 3He

- 400 kg 3He accounts for about 3.2 GW of fusion energy for BAD.
- 3He on lunar surface ~1000 kg available for terrestrial power.

3He Fuel Elevates Technology Challenges

- Beta-wall in D-3He reactors.
- High exhaust velocity.
- High heat loads.
- High specific power at low exhaust velocity.
- High magnetic fields.

High Heat Fluxes in D-3He Reactors Stem from High Power Density, but Are Manageable

- Charged-particle power transport from internal plasma to an FRC is capillary to edge region and then out of walls.
- Expanded flux tube in real chamber reduces heat and particle fluxes, so charged-particle transport power early slightly impacts the first wall.
- Neutrons from helium nuclei contribute to first-wall neutron load, giving a relatively small peaking factor along the wall.

D-3He Fuel Burns Less Easily than D-T Fuel, So It Faces Larger Physics Obstacles, Making It a Second Generation Fuel in Many People’s Minds

First generation:
- D + T → n (14.07 MeV) + 4He (3.52 MeV)
- D + D → n (2.45 MeV) + 4He (0.82 MeV) (50%)
- p → (3.02 MeV) + T (1.01 MeV) (50%)

Second generation:
- D + 3He → p (14.68 MeV) + He (3.67 MeV)

Third generation:
- 3He + He → 2 p + 4He (12.86 MeV)
- p + 3B → 3He (8.68 MeV)