

India's Spherical Tokamak

Prelims: Current events of national and international importance | Science & Technology

Why in News?

The Institute for Plasma Research (IPR) in Gujarat has commissioned the nation's first spherical tokamak and initiated plasma experimentation.

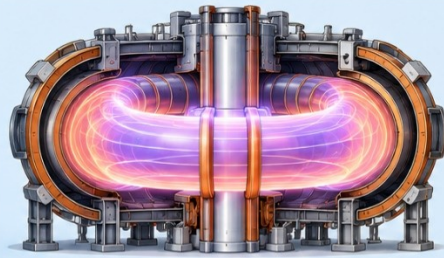
- **Tokamak** - It is a device that confines extremely hot plasma through the use of magnetic fields, enabling the conditions necessary for nuclear fusion.
- **Rationale for Magnetic Confinement**
 - At the temperatures required for fusion, matter exists in the **plasma** state and cannot be contained by conventional material walls.
 - Therefore, powerful magnetic fields are employed to confine and **control the plasma**.

Global Spherical Tokamak Research

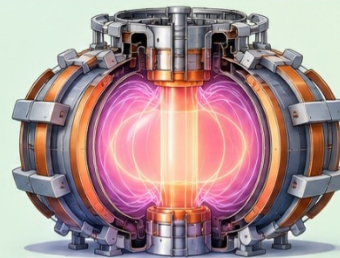
- India participates in a broader international research initiative.
- Notable international examples
- **United Kingdom**
 - MAST-U — Mega Ampere Spherical Tokamak Upgrade
 - ST40 — Tokamak Energy
 - STEP — Spherical Tokamak for Energy Production
- **United States**
 - NSTX-U — National Spherical Torus Experiment Upgrade
- **Japan**
 - QUEST — Q-shu University Experiment with Steady-State Spherical Tokamak
- Additional countries with active spherical tokamak programs are as follows:
 - China
 - South Korea
 - Russia
 - Italy
 - Spain

Conventional Tokamak vs Spherical Tokamak

Two
Designs
Same Goal
Fusion



Conventional Tokamak



Spherical Tokamak



Shape

Doughnut/torus

More spherical/compact



Objective

Magnetic plasma
confinement

High-pressure plasma
in compact configuration



Research
focus

Fusion confinement

Compact, high-performance
confinement

BASIC MECHANISM OF NUCLEAR FUSION

From Heat to Clean Energy

Cleaner
Safer
Brighter
Tomorrow

1

Fuel heated to
extremely high
temperature



Hydrogen fuel
(isotopes like deuterium
and tritium) is heated
to temperatures of
over **100 million °C**
— hotter than the Sun's
core.

2

Plasma
formation



At such high
temperatures, the fuel
becomes a **plasma**
— a hot, ionised gas
of charged particles
(nuclei and electrons).

3

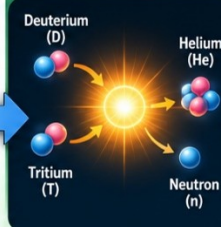
Magnetic fields
confine plasma



Powerful **magnetic
fields** **confine** the
plasma, keeping it
away from the reactor
walls and maintaining
the extreme
temperature and
pressure.

4

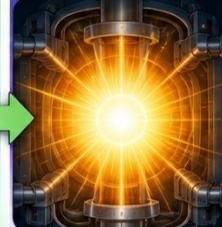
Fusion conditions
achieved



At sufficient
temperature, pressure
and confinement time,
nuclei **overcome their
repulsion and fuse** to
form a heavier nucleus
(e.g., helium).

5

Energy
released



The fusion reaction
releases a **large
amount of energy**
in the form of
high-energy neutrons
and heat, which can
be harnessed to
generate electricity.



Clean Energy



Abundant Fuel



Safer Future



A Greener Planet



• Benefits

- **Large-scale electricity generation** - It has the potential to produce substantial quantities of electricity on a continuous basis.
- **Low-carbon energy** - It could serve as a low-carbon power source, thereby reducing reliance on fossil fuels.
- **Absence of chain reaction** - In contrast to **nuclear fission**, fusion does not depend on a self-sustaining chain reaction.

- **Inherent safety** - It ceases automatically if the extreme conditions necessary for its maintenance are disrupted.
- **Potential energy security** - Commercially viable fusion could offer a long-term electricity supply and decrease dependence on imported fuels.
- **Technological advancement** - It fosters expertise in **plasma physics, superconducting magnets, advanced materials, and engineering.**

Reference

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