Part 2: Japanese Presentation：“Research on diagnosis and reliability/availability analysis for complex energy system- A case study for Heliotron J device at IAE”

- At the Institute of Advanced Energy (IAE),Kyoto, there are many facilities where a lot of equipment are used to compose zero-emission energy infrastructure, such as various sensing instruments, electric motors, transformers, valves, piping, and electric wires and cables.
- The case study for Heliotron J facility is a joint research project that began last year, where two subjects have been conducted: (i) deterioration diagnosis by applying higher harmonic diagnostic system to several electrical devices, and (ii) reliability evaluation of a water-cooled system by applying GO FLOW.

III-3 Introduction of Heliotron J facility and the scope of the case study

by Hidekazu Yoshikawa (Kyoto University)

III-4 Degradation diagnosis of Heliotron components by higher harmonics diagnosis method

by Junya Nitta(Arcadia Co.)

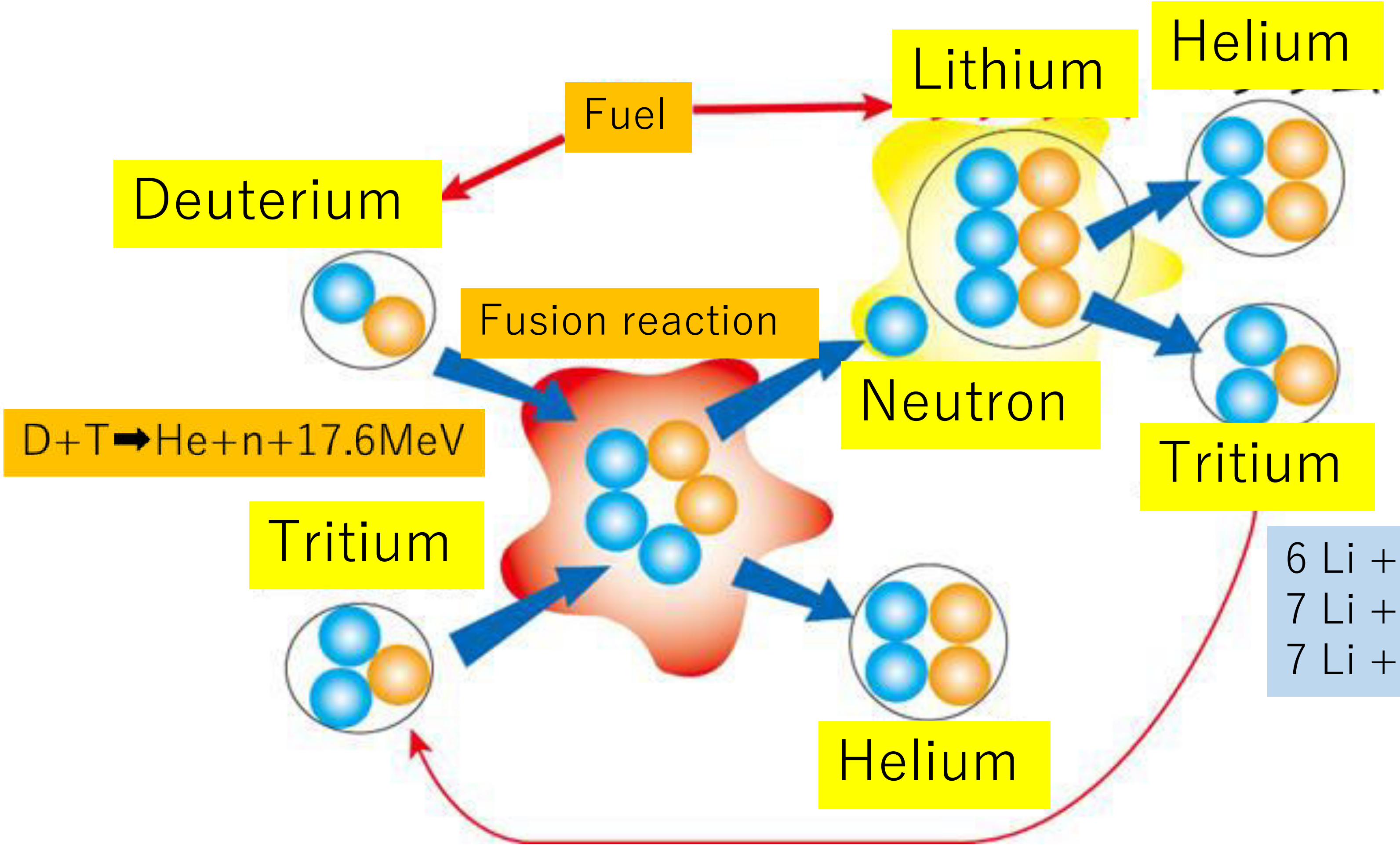
III-5 Reliability/Availability evaluation of Heliotron J by GO-FLOW

by Takeshi Matsuoka (Utsunomiya University)

III-3 Introduction of Heliotron J facility and the scope of the case study

Hidekazu Yoshikawa (Kyoto University)

Principle of nuclear fusion reaction



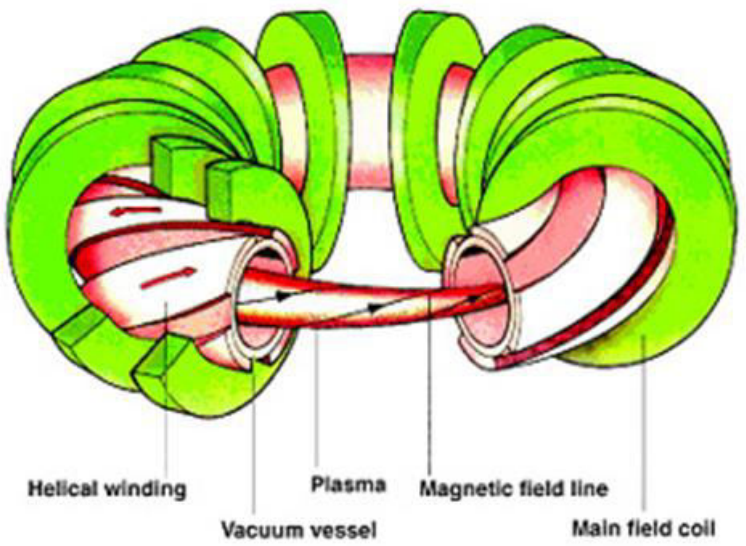
6 Li + n → 3 H + 4 He + 4.78 MeV
7 Li + n → 3 H + 4 He + n − 2.47 MeV
7 Li + n → 6 Li + 2 n + 4.78 MeV

Main points of fusion power generation by magnetic confinement

- In a vacuum vessel, deuterium and tritium, which are used as fuel, are placed in an ultra-high-temperature plasma state to cause a fusion reaction.
- Superconducting coils are used to effectively confine ultra-high-temperature plasma with a magnetic field, and various coil methods have been proposed.
- NBI, ECH and RCIP are used to maintain ultra-high temperature plasma.
- In the blanket surrounding the walls of the vacuum vessel, lithium is flowed and reacts with neutrons to produce tritium and helium, as well as to extract thermal energy and recover tritium.
- The divertor concentrates helium to protect the vacuum wall and recover heat.

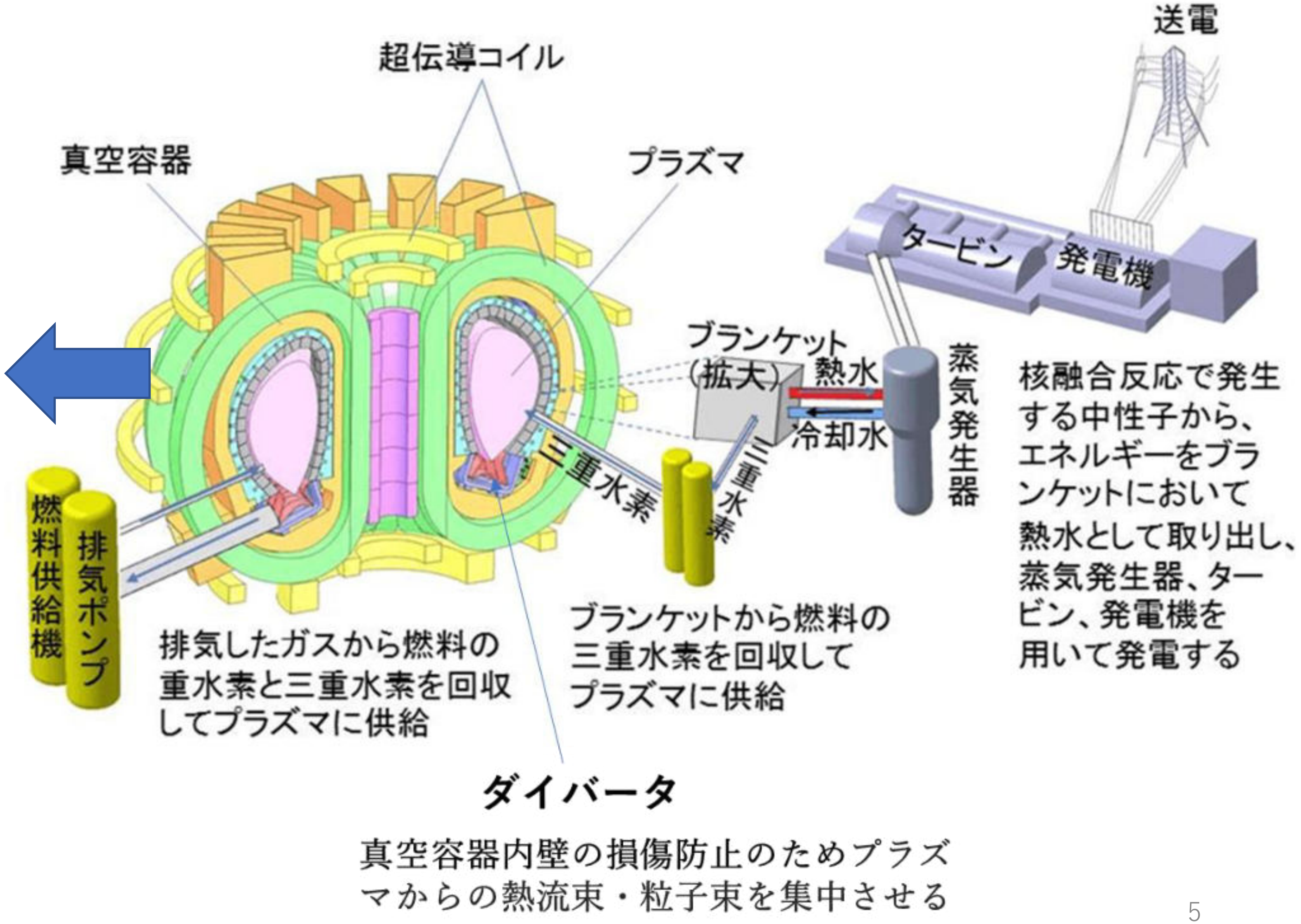
Image of a tokamak fusion power generation system and helical system

Helical magnetic coil



・The spiral coil surrounding the vacuum vessel is a feature of the helical system.
・No current is passed through the plasma.

Tokamak magnetically closed fusion power generation

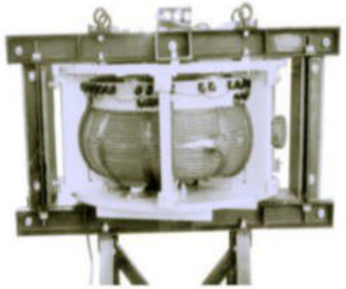


Long history of Kyoto University Heliotron

1958
Proposal of Heliotron field

ヘリオトロン
-ギリシャ神話の太陽神ヘリオスから-
考案
宇尾光治博士
(1925 – 1992)

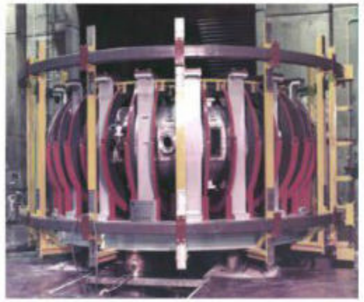
1959
Heliotron A



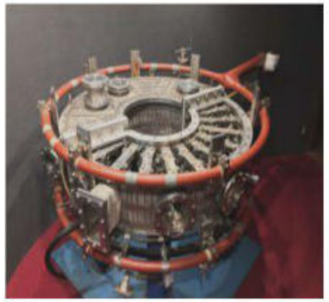
1960
Heliotron B

1965
Heliotron C

1970
Heliotron D



1975
Heliotron DM



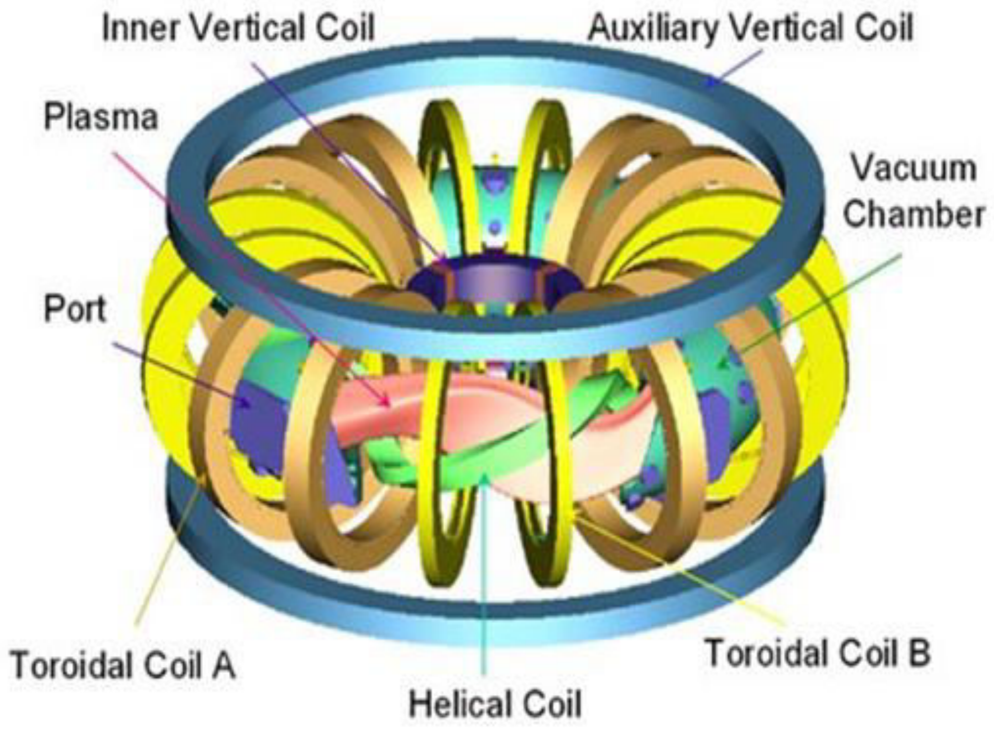
1980
Heliotron E

1981
Heliotron DR

2000
Heliotron J

Coil configuration of Heliotron J

- The spiral coil surrounding the vacuum vessel is a feature of the helical system.
- No current flowing through the plasma
- Kyoto University Heliotron does not use superconducting coils and does not experiment with DT reactions
- A large-scale LHD (Large Helical Design) based on Kyoto University's Heliotron E is being tested at the National Institute for Fusion Science under the direct control of the Ministry of Education.

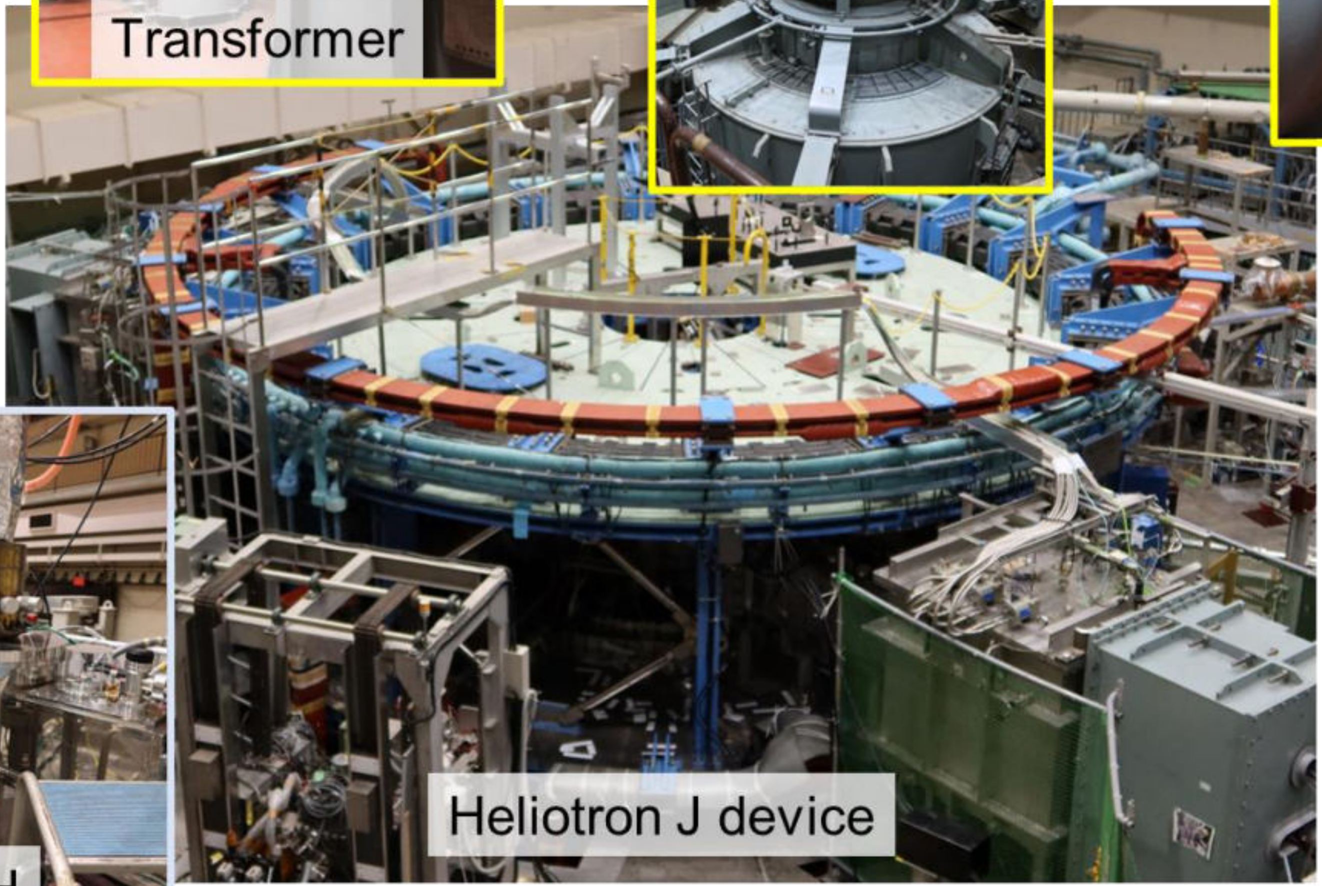


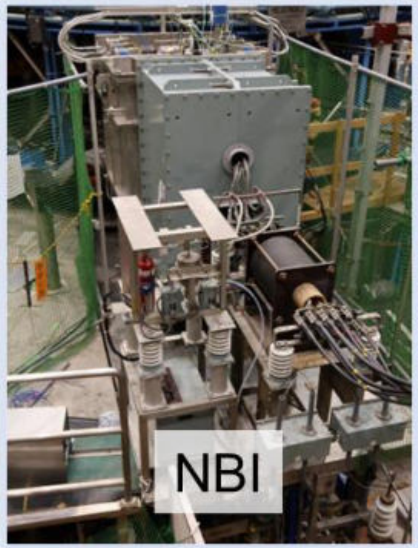
Major Components of composing Heliotron J system

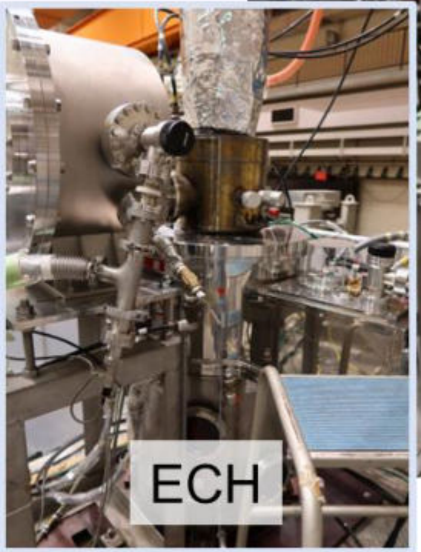
Neutral Beam Injection

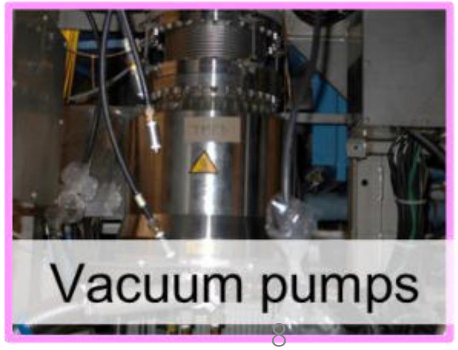
Electron Cyclotron Heating

Ion Cyclotron Range of Frequencies Heating





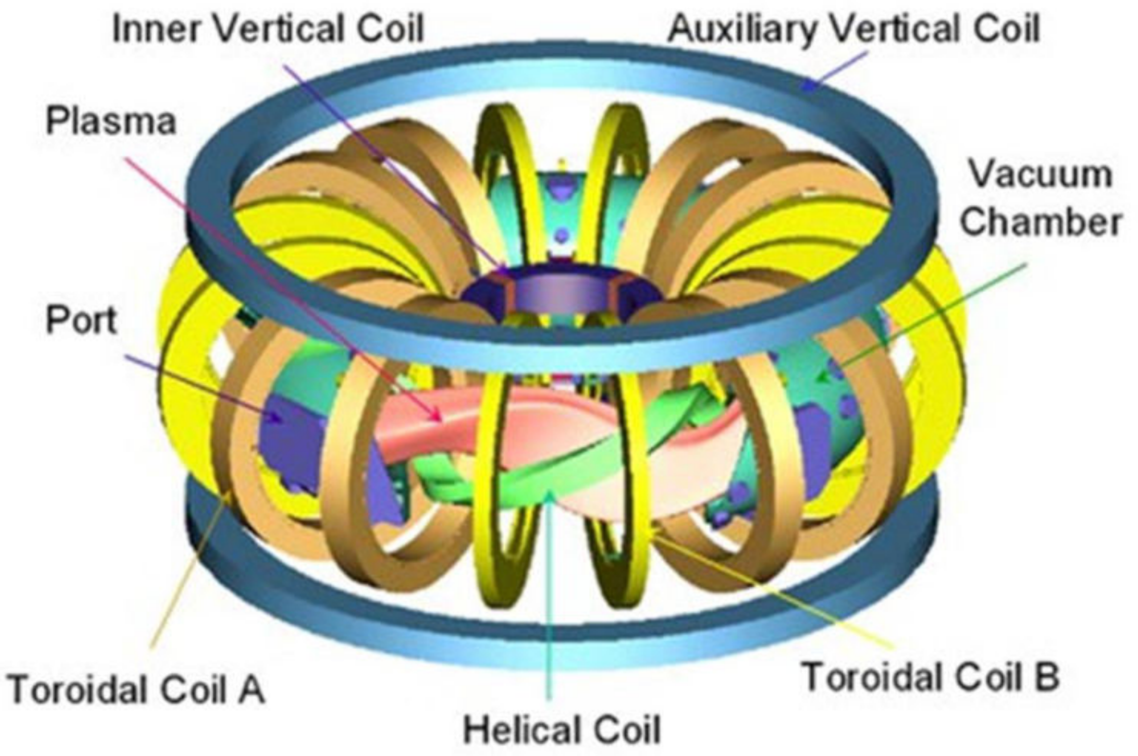


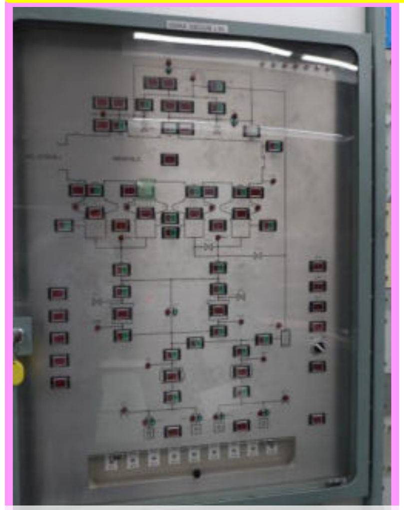


These devices have individual measurement equipment (temp, press, flow, volt, cur) and independently controlled → used as interlock signals to main control systems

External control parameters

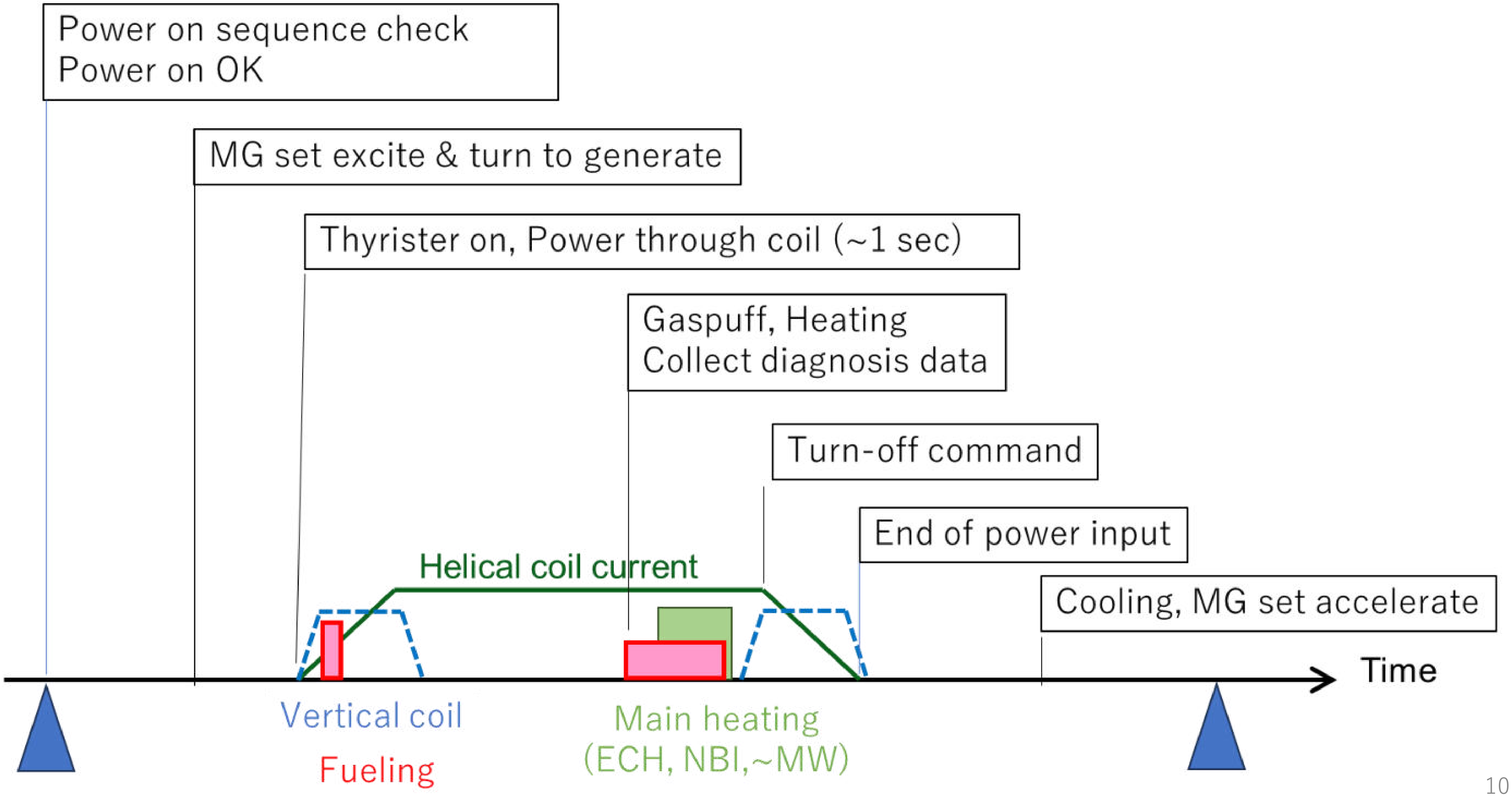
- Coil currents → Configuration (a, R, V, B, ε_h, ε_b, ε_t …)
- Heating (P_{ECH}, P_{NBI}, P_{ICRF}) x (Pulse width, timing…)
- Fueling (Gas species, fueling rate, timing, etc.)



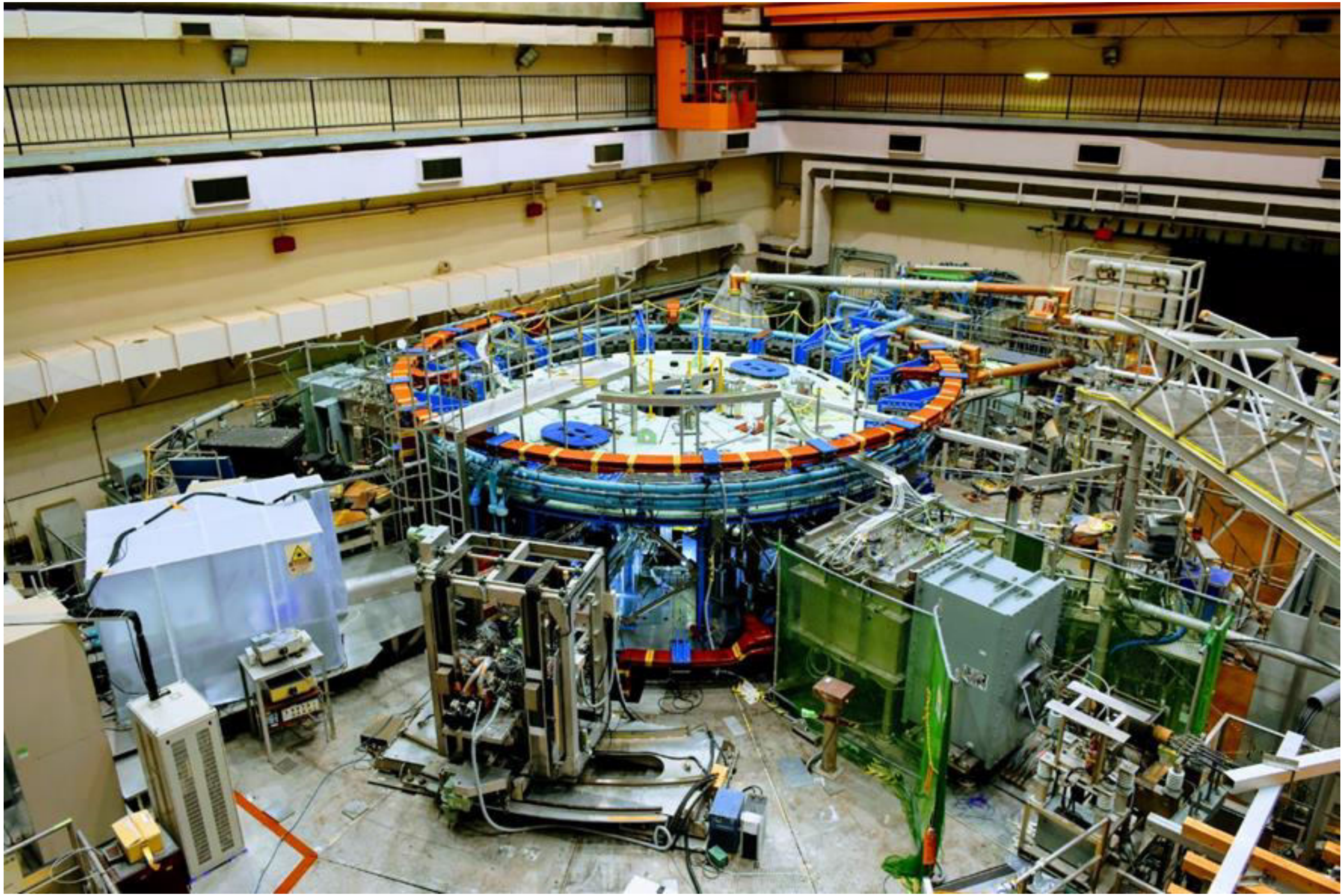


Distributed control boards for Heliotron J system

Timing chart of one plasma shot (ca. 3 second)



Bird's-eye view of the current Heliotron J apparatus

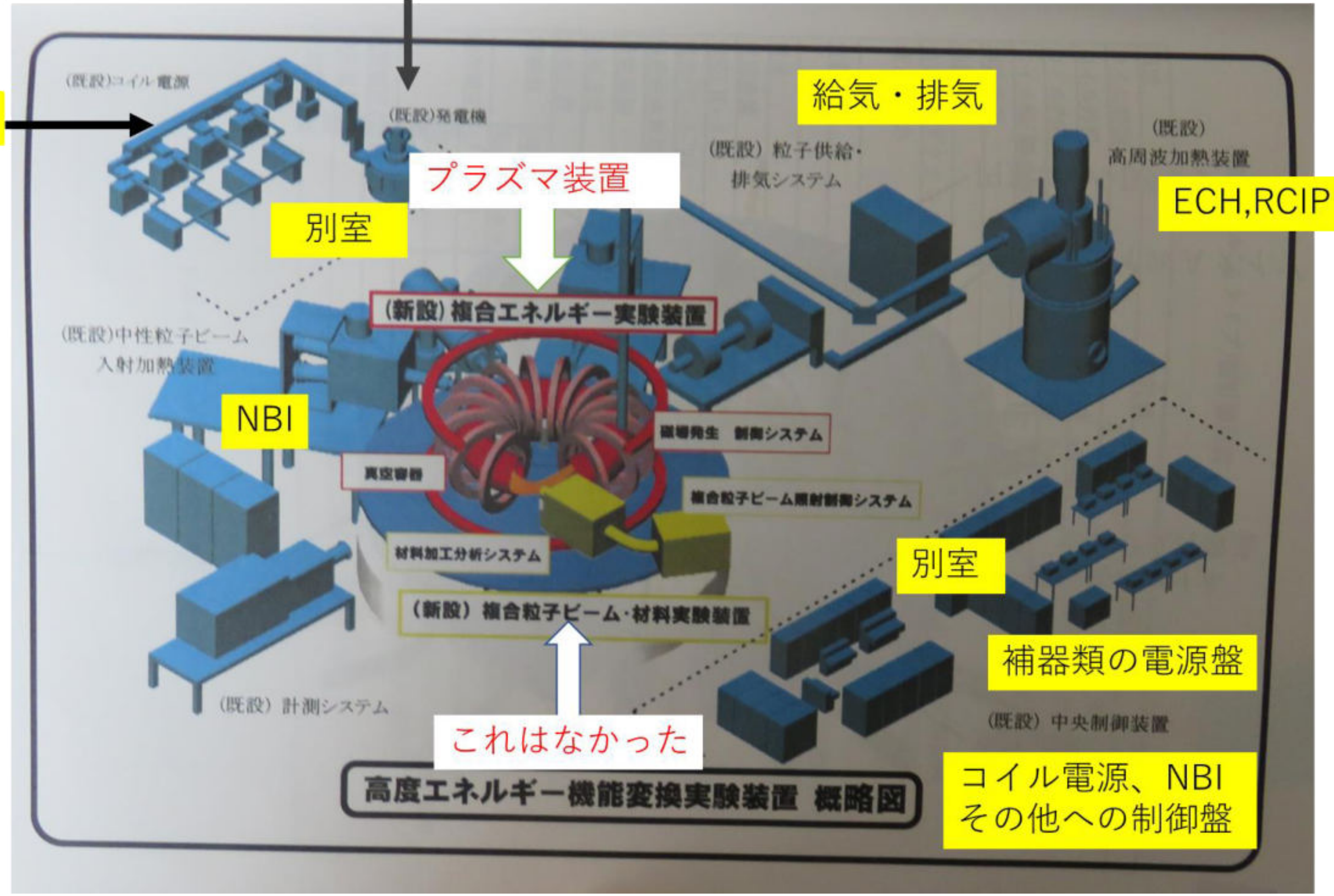


Walk-through of the Heliotron J apparatus

ヘリオトロンJ

フライホイール
付発電電動機

サイリスタ



The scenery of Heliotron J plasma Apparatus and vacuum vessel section

Overview of an electric generator with fly feel and a view of the power distribution board

Rows of power control panels for electric generators and NBI equipment

Scenery of the main control room

Summary of Heliotron J Facilities

Research Objectives	**The emphasis has shifted from the original goal of heliotron to the realization of fusion power generation to the role of basic research at universities, and in order to physically understand and model the behavior of various plasmas, we will effectively and stably generate plasma states with degrees of freedom, cause material interactions between plasma materials and walls and impurities, exhaust plasma, and generate methods for detailed observation. It is positioned as a research and development of technologies that can be investigated, and as a contribution to experimental research and human resource development on the elucidation and application of basic scientific theories related to abstract complex systems and complex systems, as well as the behavior of plasma, including nuclear fusion.**
Eligibility for facility use	In order to contribute to this purpose, universities nationwide are also claiming to provide it for joint use by researchers and for the education and research of undergraduate and graduate students
Basic Design Policy	Only the plasma device in the center will be replaced with a new one, and the peripheral equipment will be used using the existing one. As a helical plasma device, the biggest feature of Heliotron J is that the magnetic coil system has been renewed from the number of poles L = 2 to the number of poles L = 1 in the Heliotron E so far.
Maintenance Practice	Constructor of Heliotron J (Hitachi) is responsible for operational maintenance and repair of major Heliotron device while the rest auxiliary equipment by the staff of Heliotron center.

Summary of Heliotron J Equipment Design 1

Vacuum vessel	**The vacuum vessel is made of stainless steel. The system of vacuum pumps for vacuuming vessels has a complex configuration.** **The injection of gas into the vacuum vessel is referred to as the air supply system.** **Considering a new pellet injection method in addition to the conventional injection method (gas puff method)**
Electric power	The conventional method of stepping down the three-phase alternating current of the commercial power supply and the power generation motor with a transformer and then opening and closing with a rectifier thyristor remains the same. After rectification, there is a part that makes a distribution connection to each coil part, and the distribution rate is switched on the control console. The conductors of the helical coils are grooved and wound on the outer wall of the vacuum vessel, and the other vertical and horizontal coils are grouped together and have wiring through which current flows.
Magnetic coil	Basically, a magnetic field is generated by confinement in a vacuum vessel with a group of three independent coils, helical, vertical, and horizontal. A superconducting coil is not used. The cooling system of the entire coil remains the same as before, and the connection from the coil to it is new. To cool the entire coil, pure water is passed through the flow path inside the coil, the heat is removed by the secondary tap water in the heat exchanger outside the plasma equipment room, and the heat is dissipated in the cooling tower on the roof.
Plasma heating	The power supplies of the three plasma heating devices (ECH, NBI, ICRF) installed adjacent to the plasma vessel are arranged in a separate room, and the power supply operation is set on a separate operation console in the control room.

Summary of Heliotron J Equipment Design 2

Gas Emissions	**Helical diverter is considered for the discharge system of gases from vacuum vessels. Exhaust air from the vacuum vessel is emitted directly from the rooftop.**
Plasma Monitoring	Several windows called ports are provided in the vacuum wall, and the donut outer diameter, inner diameter, upper and lower 4 directions, circumferential 33 divisions, measurement, various plasma heating, pellet injection, vacuum exhaust, beam dump, Thomson, limiter, etc. are allocated for different applications. Various probes such as high-speed video cameras are installed. The task is to observe the interaction between plasma and matter in the periphery of the inner wall of the vacuum vessel, but it is unclear about devices such as pulling out plasma by limiters and diverters to interact with materials
Viewing Experiment Data	The plasma experiment is a pulse experiment performed every 10 minutes in which direct current is applied from each power source to the coil group and each plasma heating device, and a printer record of about 3 seconds of a remarkable transient change in the main parameters in the plasma for each shot is output. In addition, the plasma observation data is displayed on the monitor after the shot is completed, and is distributed to all experimenters via the Internet.