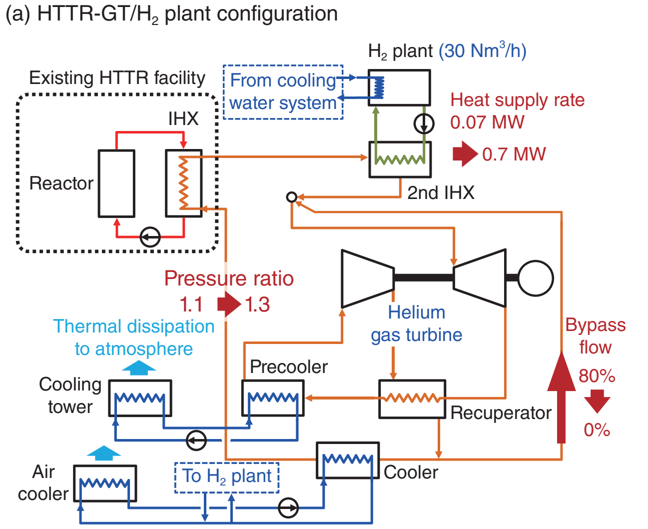
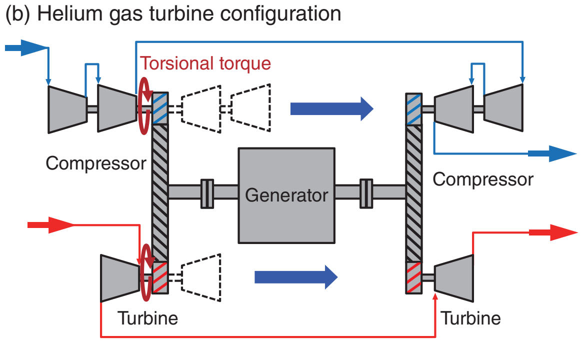
6–5 Demonstration of Hydrogen-Cogeneration Technology using the HTTR

— Designing the Helium Gas Turbine to Enable an Operability-Demonstration Test —





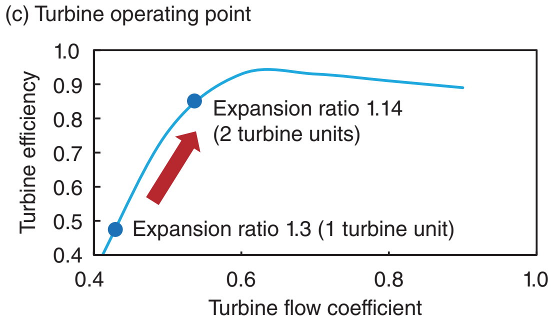


Fig.6-10 Configuration of the HTTR-GT/H_2 plant and the helium-gas turbine
Operability-demonstration tests are enabled by increasing the cycle pressure ratio with two turbine units connected end to end at the generator shaft and increasing the turbine efficiency with each turbine unit having a low optimal-expansion ratio.

We have been conducting research and development toward commercialization of highly efficient, CO_2-emission-free H_2 cogeneration by application of heat provided from a high-temperature gas-cooled reactor (HTGR) with inherently safe characteristics.

One of the key technologies for commercialization is a control method that considers the unique characteristics of HTGRs and closed-cycle helium gas turbines, namely (1) prevention of turbine overspeed by system-pressure control against loss of a generator load; (2) mitigation of turbine-inlet-temperature escalation by introducing low-temperature helium from the compressor outlet against upsets of the hydrogen-production plant (H_2 plant), and (3) start-up and shut-down operations by primary coolant-inventory control, which does not rely on a large external power supply. We are aiming to construct an HTTR gas turbine-cogeneration plant (HTTR-GT/H_2 plant) to perform demonstration tests for the control methods.

The requirements for the design of HTTR-GT/H_2 plant are to not only enable operability-demonstration tests but also minimize modification of the existing HTTR facility. In response, a heat-application system is devised as a secondary system and a second intermediate heat exchanger and a helium-gas turbine are installed in cascade to demonstrate the series operation of the H_2 plant and the helium-gas turbine in the commercial system (Fig.6-10(a)). In addition, design improvements for the helium-gas turbine are proposed to enable the observation of plant-dynamic behavior. First, two turbine units are connected to each end of a generator shaft to eliminate shaft vibration owing to torsional torque generation (Fig.6-10(b)). Second, two turbine units with a low optimal-expansion ratios are employed instead of one turbine unit with a high expansion ratio to operate at 90% efficiency while meeting the turbine-speed limit owing to structural integrity, and waste heat is utilized to maximize power-generation and H_2-production outputs (Figs.6-10(a) and (c)).

As a result of a heat-and-mass-balance evaluation and a manufacturability assessment by an equipment supplier for the HTTR-GT/H_2 plant design, it was confirmed that operability-demonstration tests such as loss of generator load, simulation of the upset of the H_2 plant, and start-up and shut-down operation tests can be performed in the HTTR-GT/H_2 plant with key achievements: H_2 cogeneration with a power output of 1 MW at a cycle pressure ratio above 1.3 and an H_2-production rate of 30 Nm^3/h, and elimination of bypass flow from the recuperator outlet to turbine inlet.

Further study will be made for component design and safety analysis of the HTTR-GT/H_2 plant. The external committee will review the results and make recommendations as to whether the project is ready to proceed to the construction phase.

Reference
Imai, Y., Sato, H. et al., Design Database of Helium Gas Turbine for High Temperature Gas-Cooled Reactor, JAEA-Data/Code 2016-007, 2016, 27p. (in Japanese).