東京大学 THE UNIVERSITY OF TOKYO

大学院新領域創成科学研究科
基盤科学研究系

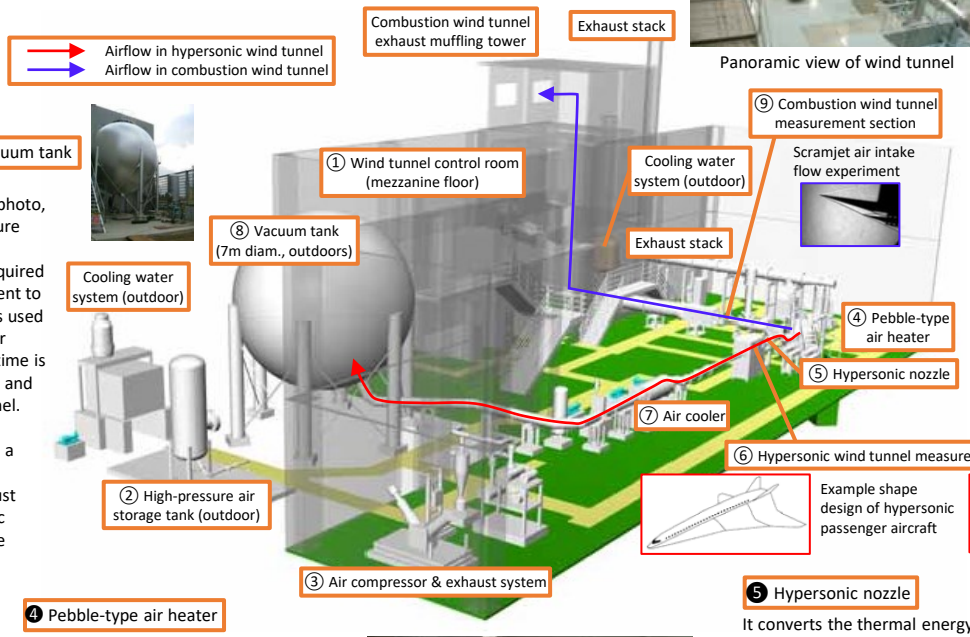
UT Kashiwa Hypersonic and High-Temperature Wind Tunnel: Bird's eye view

Using a single high-temperature, high-pressure air generator, two operation modes can be achieved: a hypersonic wind tunnel (ultra-high speed flow) and a combustion wind tunnel (ultra-high temperature flow).

❶ Wind tunnel control room

The wind tunnel and all ancillary equipment can be operated remotely from the control room. Various parameters such as stagnation pressure, temperature, and model attitude angle are set by the user from here during operation. The operating status of the wind tunnel is displayed continuously on the central monitoring panel and provided to the user as data.

Panoramic view of wind tunnel



❾ Combustion wind tunnel measurement section

Hot air from the heater is injected into the atmosphere as a jet. The airflow is exhausted outdoors through a muffling tower. The layout of the nozzle and open measurement section can be set by the user according to the needs of the experiment.

❼ Air cooler

A water-cooled heat exchanger for cooling the air used in the hypersonic wind tunnel before it is exhausted.

❷ High-pressure storage tank and ❽ vacuum tank

Both are installed outdoors.
The high-pressure air storage tank (right photo, cylindrical tank) stores 4m^3 of high-pressure (5 MPa) dry air produced by the ❸ air compressor. This air is adjusted to the required pressure by a regulating valve and then sent to the ❹ pebble-type air heater, where it is used as high-temperature, high-pressure air for experiments. The maximum experiment time is 30 seconds in the hypersonic wind tunnel and 100 seconds in the combustion wind tunnel. The vacuum chamber (left photo, large spherical tank) has a diameter of 7 m and a volume of approximately 180m^3. It is depressurised in advance by an ❸ exhaust system, and the air used in the supersonic wind tunnel is once dumped into it before being released into the atmosphere.

❻ Hypersonic wind tunnel measurement section

This is where the model is placed, and the hypersonic flow around it observed and measured. The vessel is sealed off from outside due to the low pressure during the experiment. The measurement section has an observation window (200mm diam., near centre of picture), which can be used for Schlieren photographs. The model is introduced into the measurement section by an injection device after the airflow has been stabilised. The angle to the airflow (pitch angle) can be freely changed in the range -10° to +10° during wind tunnel operation, via remote control from the ❶ wind tunnel control room. The wind tunnel can accommodate models with a cross-sectional diameter of up to 5cm.

Model mounting stand (cover removed for photo)

Hypersonic wind tunnel measurement section: airflow from right to left, the centre circle is the observation window and the nozzle section is visible on the right).

❸ Air compressor & exhaust system

They are used to pressurise the high-pressure storage tank and to depressurise the vacuum tank. To reduce noise and vibration effects, they are installed in dedicated small rooms inside the facility.

Air compressor

Air exhaust system (vacuum pump)

❹ Pebble-type air heater

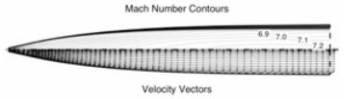
It uses a pebble heating system, in which hot air is obtained by passing air between pre-fired pebbles. The vessel is half embedded under the floor, its inner walls are covered with heat-resistant bricks, and it is filled with alumina pebbles. Once the pebbles have been pre-heated by a gas burner installed on the top surface, heat exchange is performed by passing air, issued from ❷ the high-pressure storage tank, from the bottom to the top of the heater, and high temperature air of up to 1500 ℃ can be obtained. This hot air is not only needed in the combustion wind tunnel, but also as an energy source for accelerating air in the hypersonic wind tunnel.

Interior view of the heater before being filled with pebbles (heat-resistant bricks can be seen on the sides and wire mesh to support the pebbles at the bottom).

Alumina pebbles used to fill heater.

❺ Hypersonic nozzle

It converts the thermal energy of the air obtained from the heater into kinetic energy. Because the inlet is narrow and the outlet is wide, the air passing through is accelerated. The degree of acceleration is determined by the inlet to outlet area ratio. The nozzle used in a hypersonic wind tunnel has a very narrow inlet, or throat. The outlet diameter is 200mm. The inside of the nozzle is smooth and bell-shaped, in order to provide uniform air flow in the measurement section. Several interchangeable nozzles are available, and can be used to generate flows with Mach numbers 7, 8 or 9.



Example of computer simulation results for flow through a hypersonic nozzle (inlet left, outlet right): the coarsening of Mach number contours (top half of figure) shows that a uniform flow is obtained at the nozzle outlet. The lower half of the diagram is a velocity vector diagram. The airflow is straight at the exit. It can also be seen that near the nozzle wall, a region of gradually accelerating air (called the boundary layer) develops towards the nozzle outlet.

Kashiwa Wind Tunnel Working Group, June 2006.
(Translated in November 2022.)