High Temperature Air Combustion (HiTAC) semi-industrial test stand

Semi-industrial test furnace was built to verify the benefits of HiTAC combustion, such as energy saving, low NOx emission and enhancement of heat transfer (production increase or furnace downsizing). The test furnace can be equipped with different high-cycle regenerative systems (HRS) as well as Oxy-fuel system and conventional system (figure 2.1). These HRS systems are equipped with “honeycomb” regenerators to provide the necessary hot combustion air and recover the heat.

![HiTAC test furnace at KTH (right side and back wall view). Pair of dual-type HRS burning system is located in the right side wall. Gas fuel and combustion air supply system is in the back wall side.](image)

The nominal capacity of the furnace is 500kW, the inner dimensions of the furnace body were 3.500 x 2.200 x 2.200 m. The furnace body is insulated with a 0.3 m thick layer of ceramic fiber material. The inner volume of the combustion chamber is 6.7 m³. There are also number of openings in the furnace body for observations and measurements inside the combustion chamber. The following different burning systems can be installed to the furnace for combustion process investigation:

- One-flame High-cycle Regenerative System (HRS) system, which provides a single HiTAC-flame in the combustion chamber with the firing-capacity of 200 kW,
- Dual type HRS manufactured by Nippon Furnace Kogyo Kaisha Ltd (NFK), Yokohama, Japan, (2 pairs, NFK-HRS-DF). The capacity of one pair is 100 kW (total capacity 200 kW). The system operates at different switching time (15 - 60 seconds) and at different configuration: Stagger, Counter and Parallel,
- Radiant tube HRS-RT system that consists of a pair of burner and having 160 kW firing capacity. This system can be used together with the W-shape radiant tube that is currently installed inside the furnace,
- Oxy-fuel burner system with capacity up to 200kW, (air replaced with re-circulated and oxygen enriched flue gases)
- Conventional combustion system with or without outside recovery system (recuperator)

To provide a wide range of flow and pressure required by a variety of HRS systems, frequency converters control the fans of the draft system (figure 2.2), the forced and the induced fans. Figure 2.2 shows schematically main equipment and accessories of the test furnace.

**Figure 2.2. Schematic diagram of HiTAC furnace at KTH, EFT**

The heat is taken away from the furnace by four horizontal cooling tubes made of a special temperature resistant kanthal alloy. The pipes were cooled with air and provide a large range of load to be removed from the furnace.

Furthermore, the test furnace is equipped with two different flue gas channels. One of these is for hot flue gases equipped with water-cooling jacket (figure 2.1), others are for cold flue gases coming from the regenerators (HRS directly). The flue gas channel for hot gases allows the furnace to be run in conventional mode. In addition, it can also be used when the flue gas suction rate, in case of HiTAC, is below 100%, in which some of the flue gases have to be extracted through the hot flue gas channel.

Burning systems can be fired with different gas fuels having different fuel calorific value and composition. Up to date, LPG is used. The possibilities for natural gas firing would be there in the near future.
Diagnostic Equipment

The HiTAC furnace body has an extensive set-up of different measurement systems including several measurement points for temperature, pressure and flow rates. The aim of these measuring equipments is to visualize the temperature in any place inside the furnace, energy and mass balance of test furnace and regenerators and mapping the furnace from inside for the heat flux and flue gases composition. The following diagnostic equipments are available:

- Temperature measurements: more than 120 thermocouples are used to measure furnace wall temperature at different locations, radiant tube temperature profile, flue gases and air temperatures for furnace and regenerators energy balance calculations. They are mainly K-type, S-type and R-type thermocouples.
- Water-cooled Suction Pyrometer (SP): for safe and more accurate measurement of gas temperatures at any point inside the furnace.
- Water-cooled Radiation Heat Flux Probe (RHF): The radiation pyrometer is used to measure the total heat flow due to the radiation falling the tip of the probe inserted in the furnace.
- Water-cooled Total Heat Flux Probe (THF): The Total heat flux meter is a conductivity plug-type heat flow meter. The instrument measures the total heat flow, both convection and radiation that is absorbed by it’s receiving surface.
- Flue Gas Sampling and Conditioning: the sample is extracted from the furnace by means of a water-cooled sampling probe using the computer controlled traversing system. The sampling and conditioning system is not only designed to ensure the gas sample has the same composition at the analyser inlet as that at the beginning of sampling but also to consider the dynamic influence caused by the operation nature of HRS.
- Micro GC: consists of 4 different modules and each module consists of analytical column, TCD and other GC components. The micro GC can detect and quantify CO, CO2 O2, N2 and CxHy up to C8 at any point inside the furnace with a very short time, down to 35seconds.
- Nox Chemiluminescence analysers: Measures NOx emissions out of combustion.
- Ionization probe: It is used to study the structure of HiTAC flame and to measure the ion current in the flame as a judgment of existing position of HiTAC flame, which is transparent flame.
- Data acquisition: manufactured by NI, USA and Keithely, USA. These Systems are capability to log up to 200 input voltage or amperage signals. Some modules are capable to provide output signals for controls.

In addition, a separate 100 kW furnace is also available for use as a compliment to large-scale testing.