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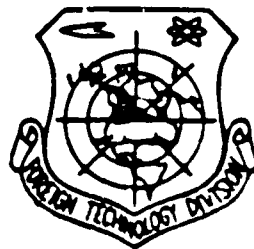
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CHINA'S HIGH ALTITUDE SIMULATION TEST STAND FOR AIRCRAFT ENGINE UNDER CONSTRUCTION

by

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CHINA'S HIGH ALTITUDE SIMULATION TEST STAND FOR AIRCRAFT ENGINE UNDER CONSTRUCTION

Liu Daxiang and Zhou Hanzhong

A high altitude simulation test stand for aircraft engine (briefly called high altitude stand) is a large experimental equipment for ground simulation of altitude and speed conditions during flight in order to evaluate aircraft engine operating performance; the test stand was developed after the 1940s to meet experimental requirements of supersonic aircraft engines. In the 1960s, with higher altitude and speed of aircraft flight along with continually improving aircraft mobility, not only were many engine performance and functional items needed to conduct testing on a high altitude stand, but also continuous tests on a high altitude stand (for a considerable portion of such tests) have had to be conducted for the main purpose of evaluating the structural strength of the engine. For example, as specified in the Flight License Standard for Aircraft Engines in FAR33 of the Federal Aviation Administration (FAA), United States, in 150 hour continuous operation testing of supersonic civil aircraft engine, 30 x 1 hours of testing should be conducted on a sea level stand, and 30 x 4 hours should be conducted on a high altitude stand in order to simulate conditions of the highest (intake) total temperature and total pressure possibly appearing in simulation flights. As pointed out in a 1973 report compiled by a joint investigation team from the Defense Department and NASA in the United States, over a period of five to six years for development of a modern

propulsion system, 50,000 hours of testing should be conducted on high altitude stands, with use of three or four testing compartments. Therefore, if a nation does not possess its own high altitude stands, it is impossible to independently develop its own high performance aircraft engine.

At present, a high altitude simulation test stand (Number 101 High Altitude Stand) is being built at a site in Southwest China; the test stand will utilize a continuous air source. This high altitude stand is being designed and built entirely by Chinese personnel; most of its equipment is made in China. To develop China's aviation undertaking, the units involved in the field made serious project verification along with sufficient preparations in advance and decided on the site for building the high altitude simulation test stand for aircraft engines in 1970; construction has begun. However, due to insufficient funds and ten years' disturbance due to the Cultural Revolution, the equipment and system performance tests of the first stage project began in 1980. The design requirements were basically achieved. Subsequently, the high altitude test stand began to assume the experimental task of aircraft engine exhaust directly discharged into the atmosphere to successfully accomplish certification tests of high altitude performance/function and anomaly flow field of a homogeneous flow field for an aircraft model. At present, construction of the second stage project is under way in all aspects. The test stand will be completed in the near future for testing and operation.

Principal Equipment

The Number 101 High Altitude Stand is composed of an air source station, an air processing system, a suction system and a testing compartment, among others.

The air source station consists of 14 air compressors, including air compressors for air supply and air compressors for air suction; these compressors are distributed in two building structures as shown in Figure 1. The equipment includes 10 air compressors (Model DA3500) driven by Model TDY-12000 synchronous motors; and 4 Model DA1000 air compressors driven by Model TKE-5000 asynchronous motors through a gear shift box for higher speed. For comprehensive utilization, besides 6 DA3500 compressors for air suction units, other compressors can be used either as air supply or air discharge.



Fig. 1. One of the Air Source Stations for the Number 101 Test Stand.

The following considerations are heeded for selecting multiple air compressor sets: First is to satisfy the flow requirements of the tested engine under certain operating performances for parallel operation of multiple compressor sets. Secondly, it is required to simultaneously simulate the environmental pressure of high altitude flights for conducting air suction in series at two or three stages under certain conditions. Therefore, there is a vast source of air for the high altitude stand; its valves, pipeline systems and maneuver and control systems are somewhat complex. To ensure safe and coordinated operation of various sets under different experimental operation situations, each set has a constant

pressure ratio adjustment/antishock system and hydraulic reverse stop valve. As indicated in testing and experimental situations, the equipment of the air compressor sets and the coordinated systems of the air source station can satisfy the experimental requirements; their operation is reliable.

Air processing system: its functions are to provide temperature reduction or increase treatment for air at the air source station; the temperature reduction equipment consists of an ammonia refrigerator, a water air separator, a silica gel drier, a cyclone dust remover, and an expansion turbine. First, the ammonia refrigerator lowers the temperature (from 40°C to 5°C) of air provided by the air source station. This low temperature air can mix with air (whose temperature has not been reduced) to directly enter an experimental compartment. Or, through an expansion turbine the temperature of the low temperature air can be further reduced to -70°C to be mixed with air at 5°C in order to obtain the required air flow and temperature (for simulation) at the tested engine intake.

The heating equipment includes three large heating furnaces using natural gas as fuel; the heating furnace can heat air (to 500°C) that enters the furnace pipe. Then the heated air is blended with other air in order to satisfy the required temperature of intake air for engine testing.

The air suction system is for providing experimental conditions at high altitude; the system has the function of cooling the low pressure, large volume combustion gas from its high temperature to be discharged into the atmosphere after a pressure increase, thus maintaining a static pressure in the test compartment at a simulated flight altitude. In addition to the above mentioned air suction compressor, the air suction system includes an exhaust pressure expander, an exhaust cooler, a circulating cooling water softening system, and an exhaust gas

pressure regulating valve. The exhaust gas pressure expander utilizes the kinetic energy of the engine exhaust to increase the low static pressure of the air in the test compartment, and to raise the air flow pressure at the intake of the suction air compressor in order to reduce the number of gas action oil pumps. Therefore, actually the exhaust pressure expander corresponds to a first stage large volume air suction pump.

The exhaust cooler has the function to cool the 1700°C high temperature combustion gas (discharged from the engine) to a range between 40 and 50°C in order to meet the temperature requirements of the gas suction pump. Meanwhile, the volume and flow of the combustion gas is reduced to about one sixth. Therefore, actually the exhaust gas cooler also has the function of reducing the load of the gas suction pump. The exhaust gas cooler is composed of three stages. The first two stages are of the indirect heat exchange type. The first stage reduces the combustion gas temperature from $1,700$ to $1,000^{\circ}\text{C}$; the second stage reduces the temperature of the combustion gas to 150°C from $1,000^{\circ}\text{C}$. The third stage is the flame extinguishing stage using the direct (water) injection heat exchange method to further reduce the temperature of the combustion gas to a range between 40 and 50°C . When designing the cooler, in addition to the consideration that certain antiknock capability should exist, six antiknock torches are installed in advance of the first stage cooler. These torches can ignite any fuel oil blended gas that may exist to prevent detonation. Therefore, engine testing is allowed to begin only after ignition of these torches. Providing appropriate injection water in the flame extinguishing stage can also prevent backward propagation of an ignition source that may remain, thus avoiding damage to the gas suction pipeline. At the end of the cooler, there is a gas exhaust gate 2 meters in diameter; the gas exhaust gate can be used during engine starting and during oil sealing. When an overpressure exists in the interior of the cooler, the exhaust gate can have a certain

protection function. With certain measures used in the experimental procedure, safe operation of the cooler can be ensured.

During testing, both the first and second stage coolers use cyclic softening water for cooling; in the front part the following components are installed: a pressurized water spraying ring at the front, and a heat exchange pipe and front pipe board for post-test rinsing. These components are used to remove dirt and condensate remained on the pipes and pipe board (caused by engine exhaust) in order to prevent corrosion of the cooling pipe and lowering of heat transfer efficiency. When a negative temperature [below 0°C] air current passes through these pipes, to protect the coolers and shunt pipeline and to prevent freezing, steam heating rings are placed in advance of the flame extinguishing section and in the shunt pipelines. When the temperature of the air current is lower than 5°C , the ring automatically injects steam to raise the temperature of the air current. When the equipment has not operated for a long time, the cooling water jacket and cooling water pipe are filled with an anti-corrosion solution in order to prevent corrosion.

The high altitude test compartment is the connection type, 23 meters in overall length, 140 tons in weight and with 3.7 meters internal diameter. The compartment is divided into two sectors: a front and a rear compartment. These two sectors are divided with a partition board; an air flow pipe is installed inside the partition board. For flow field homogeneity in providing air, a rectifying grid grating and a netting are installed in the front compartment.

A movable compartment cover is placed above the rear compartment; there is a thrust platform frame inside the compartment for installation of the engine to be tested (Figure 2). To prevent destruction of the test compartment by accidental

explosion, 10 explosion windows (0.6 meter in diameter) are installed in the compartment. During testing, approximately one twentieth of the engine air current enters the compartment to reduce the compartment temperature to less than 120°C in order to protect the measuring sensors and lead wires. To ensure engine testing, 17 or 18 sets of testing equipment systems are installed in the high altitude test stand building; a control room is built with a complete set of control equipment for effective maneuvering and control of the engine and related equipment to be tested according to requirements. Moreover, there is an advanced system for automatic data collection and processing. The system is divided into sector by sector display and over limit alarming for obtaining test results in data and curves within 2 to 3 minutes. The number of measurement points for each test may be 1,000 to 1,200.



Figure 2. #101 High Altitude Test Stand With an Engine

Testing Range, Items and Capability

When the sea level static air flow is 120 kilograms per second for the test object (turbojet or turbofan engine), the highest simulation altitude of the high altitude stand under construction is 25 kilometers; the maximum simulation M number is 2.5.

The operating principle of the No. 101 high altitude stand is shown in Figure 3. Compared with advanced high altitude stands abroad, the scale of the No. 101 high altitude stand is not large, and its testing capability has certain limitations. However, upon completion the stand can be used for the following tests.

1. Engine test of high altitude performance: altitude/speed and throttling characteristics;

2. Coordinated operating characteristics of the main components of the tested engine within the entire range of the flight envelope;

3. Windmill characteristics of the engine;

4. Air start boundary and reignition range;

5. Ignition extinguishing boundary of the engine's combustion chamber;

6. Ignition envelope of the supercharged combustion chamber, and the boundary of steady combustion;

7. Engine characteristics of the high altitude transition state (including acceleration, deceleration, encounter acceleration, as well as on-and-off supercharging of the fast and slow thrust oil nozzle);

8. Effect on engine's steady running of the intake air flow field anomaly;

9. Adjustment required testing on the main and supercharged combustion chamber; and

10. Determination tests on the strength and oscillation of the entire engine and some components with partial load continuous running.

After appropriate equipment remodeling, the No. 101 high altitude stand can be used to conduct environmental condition experiments (in addition to the 10 above mentioned items), such as freezing and prevention of freezing, cold and hot climate start, start at simulated altitude, smoking, dynamic state pressure, and temperature anomaly effects.

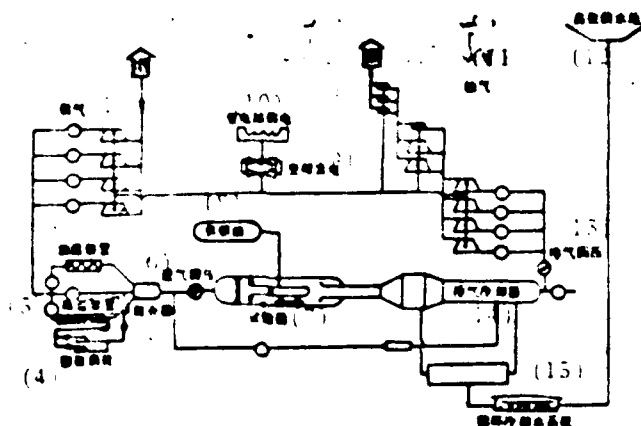


Figure 3. Diagram Showing Operation Principle of ATF.
Key: 1 - air supply; 2 - heating apparatus; 3 - temperature reducing apparatus; 4 - expansion turbine; 5 - mixer; 6 - pressure regulation for inlet air; 7 - test compartment; 8 - fuel oil supply; 9 - frequency variation power generation; 10 - power supply by transformer substation; 11 - gas suction; 12 - high level water supply pool; 13 - pressure regulation of exhaust gas; 14 - cooler for exhaust gas; 15 - circulating cooling water system.

After more than 10 years' effort, major progress has been made in the construction of the No. 101 high altitude stand. As indicated by test results of the first stage project, performances of the completed equipment and systems of the power supply, air source station and test compartments have attained or

exceeded the design indexes. Precision of automatic pressure adjustment and temperature adjustment of intake air is high. The three stage series gas suction experiment can conduct normal operation at intake pressure lower than 0.015 kilogram per square centimeter. As indicated by the construction and testing situation, the No. 101 high altitude stand is expected to attain the overall performance design indexes after completion of the second stage project. With testing since 1980, a number of experiences on experimental organizing and management suitable to China's conditions have been obtained with certain levels of experimental, simulation and testing techniques as well as training of a number of engineers and technical workers of the rank and file at a relatively high technical level. The scheduled experimental items have been successfully accomplished on high altitude simulation tests of a engine model with its exhaust directly discharged to the atmosphere. This considerably strengthens the authors' confidence. It is expected that Asia's first high altitude simulation test stand with a continuous air source will be completed and operation will begin in the near future.

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