Study and Development on Fully Automated Sounding System

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Abstract: Intelligent and unattended upper air sounding system enables full coverage of upper air meteorological observation. Fully automated sounding equipment not only reduces operation cost but also allows more flexibility of site selection and observation schedule. This article introduces the requirement, characteristic, function and others, as well as provides specific scheme for upper air atmospheric observation in gale situation.

Keywords: fully automated; sounding system; study and development

1. Introduction

Regarding NWP, upper-air observation data should be provided as initial field[1]. WMO assumes various factors which may influence observation data quality exist, including observation environment, observation instruments and operation regulations etc, in particular emphasis of direct effect of stability and precision of observation instruments on observation data quality[2].

Since 1920s, radiosonde systems have gotten rapid development[3]. In China, radar sounding system is main sounding mechanism. Since 2002 CMA has begun to upgrade upper-air sounding system from 59-701 mechanical radiosonde system to L band electronic radiosonde system, which has achieved more dense and more accurate observation data in terms of spatial and temporal aspect. However GPS sounding systems play dominant role in the world, which can be operated easily under almost all-weather conditions[4]. Considering results of WMO international radiosonde intercomparisons, GPS sounding systems can take big advantage, which would be future developing orientation for meteorological sounding[5][6][7]. Currently radiosondes from Finland VAISALA Company have occupied big quotation of international market, especially occurrence of RS92 with GPS mechanism since 2001, which has indicated fully development for sounding technology of Finland VAISALA Company[8].

Nowadays automatic sounding systems have been developed in Finland VAISALA Company and France MODEM Company and so on, which have been put into operation in some countries. In China, the fully automatic sounding system is an intelligent and unattended upper-air sounding system developed by Nanjing Daqiao Machine Co., Ltd and CMA Meteorological Observation Center, the only upper-air unattended weather station in China, capable of automatically observation temperature, humidity, air pressure, wind speed and wind direction from the ground surface up to the height of 36km within the scope of 200km. The system can send out control

instruction to the remote location weather station for implementing upper air meteorological observation at preset time or by remote control at monitoring center.

The meteorological observation of upper-air sounding station needs high manpower cost, especially in the remote area, mountain area, desert, island and other climate sensitive area, where the distribution of upper air meteorological observation network still has blank space. Therefore, the requirements of upper-air meteorological observation automation are specially significant and necessary. The fully automated sounding system not only reduces operation cost but also allows a flexible choice for site selection and launching schedule.

The development of fully automated sounding system fills in the gap of upper air weather observation in remote area, mounting area, desert, island and other no inhabited areas, reduces manpower and provides denser meteorological data. This system, which has enormous economic and social benefits, can be widely applied in meteorology, agriculture, water conservancy, civil aviation, environmental protection, national defense and other fields.

The success of the automated system can enrich the technique and comprehensive ability of Chinese meteorology monitoring equipment, so as to adapt to the transition from manual meteorological observation to automated remote-control observation, as well as achieve quantificational observation with high precision, high spatial and temporal resolution, continuity, automation and integration.

The major features of fully automated sounding system are: automatically activate, test radiosonde (automatically switch to the next radiosonde test and turn off the previous sonde battery if the radiosonde is invalid), automatically inflate the balloon (hydrogen gas or helium gas), automatically release the radiosonde, produce meteorological products and send the meteorological message to the exterior network at preset time after automatically receiving sonde signal. All the process will be fully automatic if no external interference. Meanwhile, the monitoring center can provide long-distance diagnosis, video monitoring and online support. Also the fully automated sounding system has the following functions: automatically switch to another hydrogen cylinder and send off gas change alarm for operators to supplement radiosonde, change the radiosonde frequency from the central station, release the radiosonde without obstruction with wind speed less than 20m/s.

The fully automated sounding system combines mechanical engineering, auto-control technology, computer technology, digital image monitoring technology, communication and network technology.

At present, the balloon releasing technology under gale condition is still under research and no report about related products can be found internationally. If the fully automated sounding

system can not work in gale weather, it would cause large limitation in operation utilization. In order to solve this issue, the research team has paid much attention to balloon releasing equipment under gale condition. Finally this equipment passed wind channel test in the national key laboratory and implemented field gale (20m/s) balloon launch, both achieve desirable results.

2. Operational Requirements

The radiosonde network is the key part of national comprehensive observation system, the refined weather information from which is the foundation of current model forecast, numerical forecast, pre-warning forecast and other weather service. Currently, CMA owns 120 regular upper-air sounding stations, the densest network in Asia.

According to the requirement of upper air weather observation, the reasonable distribution space of regular upper air weather observation station is about 200km, but the current average space in China is approximate 300-500km. To be more specific, in east China, the distribution space is about 200km, but in west China, especially in Qinghai-Tibet plateau, due to some certain limitation(natural condition, economic level and technological level), sparse and uneven distribution space has caused limited utilization of observation information, whose real distribution space in some harsh area may be over 500km. Considering the observation requirement of mesoscale synoptic system, weather observation in northwest of Eurasian landmass and Qinghai-Tibet plateau weather system is very important for weather forecast of China, so the lack of meteorological information in northwest will severely affect the quality and practical results of regular upper air weather observation information.

3. Major Functions

3.1 Operation Mode

The fully automated sounding system has three kinds of operation mode: automatic operation (time operation), manual operation and waiting for releasing balloon under gale condition.

3.2 System Management and Remote Control Function

The fully automated sounding system has system setup, system operation management, operation log recording and remote location control functions. The central station can remotely control the devices. When wind speed is less than 20m/s, the system can automatically activate radiosonde battery, check the radiosonde, automatically load radiosonde and balloons, automatically fill the balloon with hydrogen, rotate cover lid to windward direction and open it through the action of cover lid flowing device, automatically launch radiosonde, automatically track radiosonde and receive sounding data and perform data processing. 24 radiosondes can be loaded in this system, i.e., it can perform 24 consecutive upper-air meteorological observations.

If the wind speed exceeds 20m/s, the system automatically switches to waiting state after

the balloon is inflated. As soon as the instantaneous surface wind becomes less(below 20m/s), the cover lid will rotate to windward direction and release the sounding balloon.

3.3 Upper-air observation Function

The fully automated sounding system uses BD/GPS radiosonde to perform upper-air meteorological observation, which is carried by a ascending balloon to measure atmospheric temperature, humidity, air pressure, wind speed and wind direction. The data will be sent to the ground receiving device in the form of radio signal, and then data processing system will process the data and send out meteorological message so as to provide weather and climatic information for meteorological service.

3.4 Balloon Releasing Function under Gale Condition

When ground surface wind speed exceeds 7m/s, the launch of sounding balloon will become very difficult. Because of development of balloon releasing device under gale condition, it enables the balloon to be released smoothly as long as the ground wind speed does not exceed 20m/s.

Before releasing the balloon, wind speed and wind direction data measured by ground meteorological instrument will be input into the computer. Then the computer controls the cover lid to rotate to windward direction and open it, so the wind interference is reduced to minimum when sounding balloon flies off from the vessel.

3.5 System Setup Function

The system can perform serial port setup, network setup and system parameter setup.

3.6 System Operation Management Function

The system can manage the use of radiosonde: it records the loading data, loading position and frequency. When the amount of used radiosonde reaches to 20, the system will automatically send off an alarm to monitoring center for supplementing radiosonde. Once the radiosondes are supplemented, the system still put priority to previously loaded radiosonde.

Also the system can manage the use of hydrogen: the gas feeding system consists of two hydrogen cylinder racks and gas bus bar. When one group of hydrogen cylinders on one rack is used up, the system will automatically switch to another group of hydrogen cylinders through the control of gas bus bar and inform the monitoring center for supplementing hydrogen.

3.7 Radiosonde Frequency Adjustment Function

Once the radiosondes are loaded at one time, their frequency is set at a fixed value. When there is something abnormal about the temperature and humidity measured by radiosonde, but the transmitting signal is still very strong and need to re-release the sonde, or the pre-set frequency is interfered by outside frequency, the monitoring center can adjust the frequency of receiver and radiosonde ready for releasing at remote location station.

3.8 Hydrogen Safety Ensurence

- Enforce national hydrogen safety standard;
- The hydrogen cylinder room and gas bus bar room are well ventilated;
- The hydrogen cylinder room and gas bus bar room are well grounded;
- The line incoming box has lightning arrester;
- The hydrogen cylinder room and gas bus bar is equipped with explosion protection lamp and switch;
- The hydrogen cylinder room and gas bus bar room have antistatic floor;
- The hydrogen cylinder room and gas bus bar have hydrogen concentration meters inside. Once the hydrogen has leakage and its concentration is over 0.4% indoors, the monitoring center gives off audio and photic alarm and automatically shut off hydrogen valve switch and turn off the power supply;
- After accomplishing the replacement of hydrogen cylinder, it is necessary to measure the concentration of filling joint with portable concentration meter and ensure the hydrogen hose is well connected with the hydrogen cylinder joint.

3.9 Fault-Tolerance Design

3.9.1 Prompt Function of Manual Misoperation

When operating manually, if there is misoperation, the device will not stop work together with dialog to prompt correct operation in case of device damage.

3.9.2 Cover Lid Rotation Limit Function

When operating manually or debugging, both the input value and accumulation value of cover lid rotation angle can not exceed ±180° in order to avoid device damage.

3.9.3 Radiosonde Self-Check Function

The system can automatically check whether the temperature, humidity, air pressure and received satellite number are acceptable and within pre-set threshold. If they exceed the scope, the system will automatically turn off radiosonde power supply and check the next consecutive radiosonde until it is eligible, finally launch it.

3.9.4 Automatic Recovery Function

When the system halts in emergency because of abnormal situation, press the reset key and the system can automatically recover to its initial state.

3.10 Redundant Design

The hydrogen concentration meters are installed at three positions in the system, each of them has two hydrogen concentration meters, so if one of them fails, the safety of whole system will not be affected.

There are three anemometers in the system. If one of them fails, the wind observation system still can work normally through software identification to ensure the normal launch of sounding balloon in gale situation.

The system has two groups of hydrogen cylinder collecting devices to ensure its continuity of operation.

3.11 Long-Distance Video Monitoring Function

Its fundamental function is to transmit the video signal form the monitoring spots of remote location station and hydrogen cylinder room to the central station, then manger performs comprehensive monitor to operation of all devices through real time video. It transfers the alarm signal from remote location station to the central station through various sensors and can trigger alarm output device or startup video record to prevent hidden safety trouble and investigate the accidents so as to fulfill the management of unattended remote location weather station.

4. Configuration

Remote location station

Central station

Gas banks

Wireless bridge

The fully automated sounding system consists of three parts including remote location unattended station, central station and communication transmission system, the remote location station consists of a fully automated observation station and a hydrogen station. (refer to the picture).

The fully automated observation station consists of a shelter and a launcher vessel (refer to the following picture). More specifically, the shelter is divided into 2 rooms, the operation room and device room. The operation room houses the computer and other control devices; the device room houses the automated daisywheel, gas control and digital control module and other control devices. The launcher vessel has automated gas filling device and balloon launch device inside, cover lid open-close and rotating device and wind direction following device. The fully automated observation station also is equipped with the following systems: BD/GPS sounding signal receiving system, gas conveying system, power distribution system, and ground automated weather station and other affiliated equipments.

The hydrogen station is a shelter structure (refer to the following picture), the interior of which is divided into three compartments: hydrogen cylinder room, gas bus bar room and air conditioner power distribution room. The hydrogen cylinder room has two hydrogen cylinder racks and two hydrogen concentration meters inside. The gas bus bar room locates in the middle of shelter, which has gas bus bar and two hydrogen concentration meters inside.

The central station consists of network server system, system management software, image monitoring system and others; the communication transmission system consists point to point (or point to multi-point) wireless bridge (or GPRS or CDMA or satellite communication)； major components of fully automated sounding system are as follows:

4.1 Power Distribution System

a. Line incoming box

b. UPS host (C3KRS) + storage battery box

C. Remote location power supply control box

4.2 Device Control Subsystem

a. Digital device control box

b. Pneumatic control box

c. Radiosonde daisywheel

d. Balloon tube and cover lid open-shut device

e. Cover lid gyre supporting device

f. Opening device of electric window

g. Control computer and software

4.3 BD/GPS Sounding Signal Receiving Subsystem

a. UHF sounding receiver and antenna

b. Ground automated weather station

c. Radiosonde ground check box

d. Humidity meter of balloon releasing room

e. BD/GPS transponder

f. Data processing computer and software

4.4 Transmission Control Subsystem

a. Wireless bridge and antenna

b. Network exchange

c. Monitoring video camera and software

d. Monitoring unit

e. HD video tape recorder and image monitoring software

4.5 Gas Conveying Subsystem

a. Hydrogen cylinder collecting device

b. Gas bus bar and hydrogen concentration meter

c. Hydrogen conveying duct

4.6 Central Station

a. Video decoder

b. Server 1 and sounding data processing software

c. Server 2 and remote control software

d. IP SPC exchange and telephone

e. Network exchange

f. Wireless bridge and antenna

g. Video displaying system on TV wall

h. Power supply distribution system of central station

4.7 Corollary Equipment and System

a. Shelter of fully automated observation station

b. Shelter of hydrogen station

c. Air conditioner

d. Air compressor/desiccator

e. Lightning-proof system

5 System Performances

5.1 Fully Automated Observation Station

5.1.1 Remote Control Subsystem of Long-Distance Power Supply

The fully automated observation central station carries out long distance (local) control to remote location station through network to implement the distribution of AC power supply.

5.1.2 Device Control Subsystem

The fully automated observation central station controls the devices of remote location station through the network, so they can perform the following functions in preset sequence: computer startup, gas pressure monitoring and opening control, battery activation, running of rotating plate, radiosonde loading through feeding support arm, automatically balloon inflating, running startup of wind-proof cover lid, automatically releasing of balloon and radiosonde, shut of cover lid, reset of rotating plate, withdrawal of charging releasing mechanism and returning to the waiting state for the next balloon.

5.1.3 Sounding Signal Receiving Subsystem

It adopts BD/GPS radiosonde to perform upper air observation. The UHF sounding signal receiving system of remote location station automatically tracks and receives the sounding data, records the data from ground meteorological instrument and processes the meteorological data. After observation, it automatically produces meteorological message.

5.1.4 Transmission Monitoring Subsystem

The communication transmission device adopts high-speed wireless bridge connecting system. It combines the state of the art technology and results of network communication and wireless transmission to realize the mix transmission of large flux data and real time operation. In the process of system operation, the central station performs real time video monitoring to relative positions of remote location station through the network. The display image is clear and stable and the image delay time is less than 500ms.

5.1.5 Balloon Launch System under Gale Condition

Currently 2-3 operators are needed to cooperate to perform the observation task for regular upper air weather observation, in particular low success rate of releasing sounding balloon in gale situation. Usually, when the ground surface wind speed exceeds 7m/s, it is impossible to launch the sounding balloon smoothly. The balloon releasing system under gale condition inflates the balloon in the balloon launch vessel in order to make interference from the exterior small, and before releasing balloon, the ground anemometer measures wind speed and wind direction, then the cover lid of balloon releasing vessel rotates to the windward direction and opens to reduce interference minimum and implement balloon launch without obstruction in the condition of gale (less than 20m/s).

5.2 Hydrogen Gas Station

The hydrogen gas station is used to inflate the sounding balloon and has the following functions: switch between hydrogen cylinder racks, hydrogen gas supplement prompt, hydrogen leakage alarm, automatic shutoff of hydrogen feeding and power supply of device room.

There are 2 groups of hydrogen cylinder collecting devices in the hydrogen cylinder station, each of which consists of 15 hydrogen cylinders. After one group of hydrogen uses up, the system will automatically switch to the other group of hydrogen cylinders and give off an alarm to the monitoring center. One group of hydrogen cylinders can inflate 45 balloons with the weight of 300g or 23 balloons with the weight of 750g.

The gas bus bar is used to control the hydrogen inflating valve and the switch of hydrogen cylinder collecting devices and adjust the pressure of hydrogen.

5.3 Central Station

The central station consists of the wireless bridge, 2 servers, video decoder and image display TV wall as well as others, among which the transmission terminal and servers form special IP network, the TV wall is used for real-time image monitoring of remote location station. The video decoder takes charge of image monitoring. Server 1 takes charge of BD/GPS sounding data receiving and processing while server 2 takes charge of controlling the automatic devices of remote location station.

5.4 Other Affiliated Devices

There are air compressor, air conditioner/desiccator and lightning protection equipment, which can provide normal working condition for this system.

6. Major Technical Specification

6.1 System Working Condition

① Ambient temperature	Outdoor:	-40℃～+60℃;
	Indoor:	0℃～+40℃
② Relative humidity	Outdoor:	0～100%RH;
	Indoor:	30%RH～80%RH
③ Altitude	≤3000m	
④ Wind speed	≤21m/s (instantaneous wind speed 60 m/s)	
⑤ Power supply	AC: 220V/50Hz;	
	Power consumption: 8KVA	
⑥ Inflating gas	Hydrogen gas or helium gas	

6.2 Automated Radiosonde Launcher

① Sounding balloon	300g～750g
② Number of loaded radiosonde	24
③ Remote control distance	30km (communication mode specific)
④ Working time	continuous for 24 hours

6.3 BD/GPS Sounding System

① working band: 403MHz±3MHz；

② Observation scope: Max. observation height: ≥35km;

Max. observation slant range: ≥200km.

③ Observation elements and tolerant error (standard deviation):

Temperature Measuring scope: +50～-90℃; Error: ±0.2℃.

Air pressure Measuring scope: 1060～5hPa; Error: ±0.5hPa.

Humidity Measuring scope: 0～100%RH; Error: ±3%RH.

Wind speed Measuring scope: 0～100m/s; Error: ±0.3m/s.

Wind direction Measuring scope: 0～360°; Error: ±5°.

6.4 Structure and Dimension

① Working shelter of remote location station

Dimension: 5500mm×2400mm×2400mm; Weight: ≤5000kg.

② Balloon launcher vessel

Dimension: φ2200mm×3430mm; weight: ≤1000kg (with roof).

③ Gas feed shelter

Dimension: 4012mm×2438mm×2976mm; weight: ≤3000kg.

7 Conclusions

In view of the outlook of weather observation, “remote sensing, remote measuring, continuity and automatization” will be major development trend. The MET offices have attached more importance to new-style fully automated sounding system, which is mostly located in remote area where are difficult to access. This system is an unattended sounding system, and can release balloon is harsh condition (especially in gale situation) and has remote control capability, so it provides a new option for the construction of upper air observation site in remote area (such as Qinghai- Tibet plateau).

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Fig. 1　Remote Location Unattended Station of Automated Sounding System

Fig. 2　Remote Location Unattended Station of Automated Sounding System

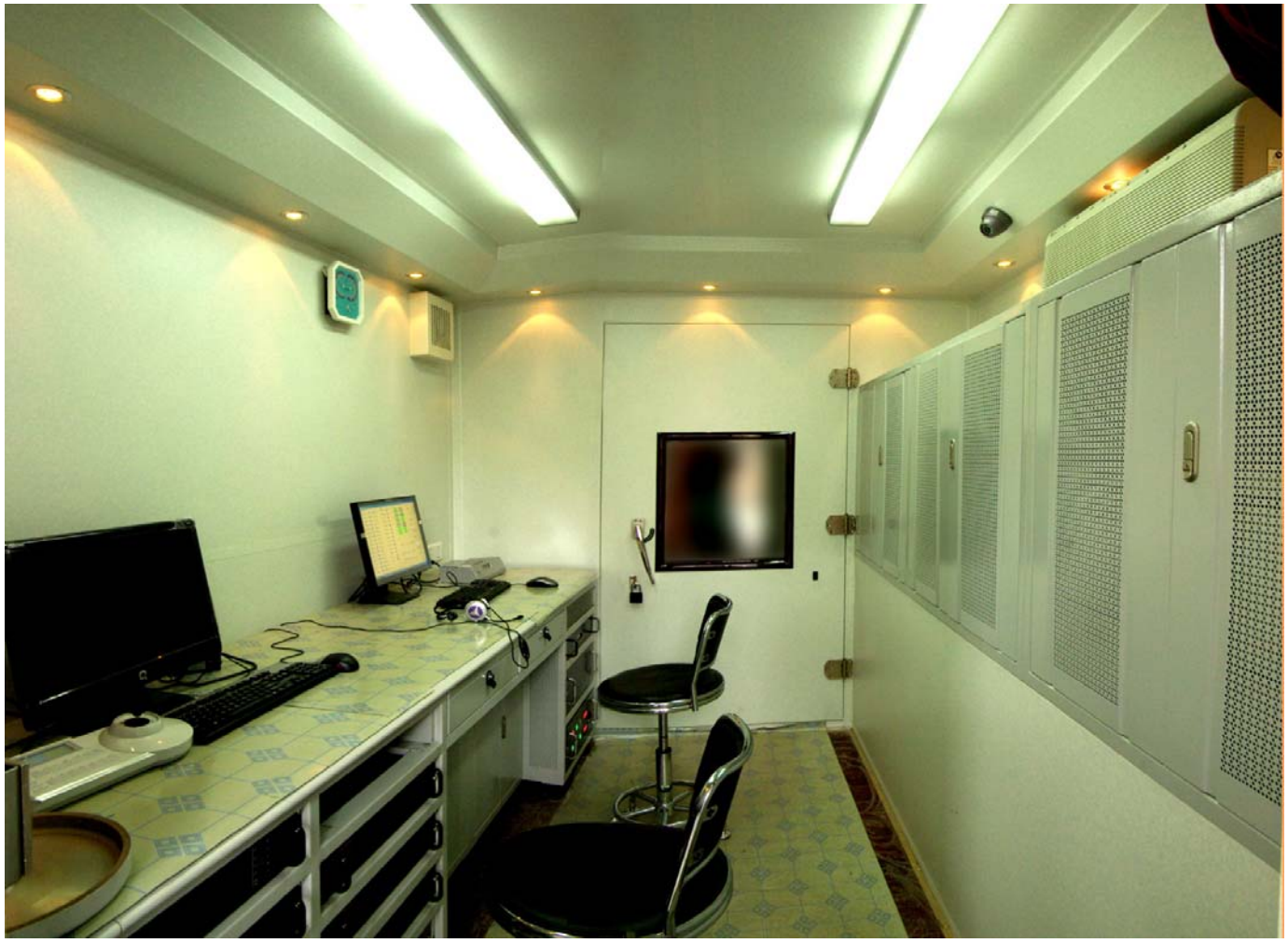

Fig. 3 Monitoring Center of Automated Sounding System

Fig. 4 Monitoring Center of Automated Sounding System

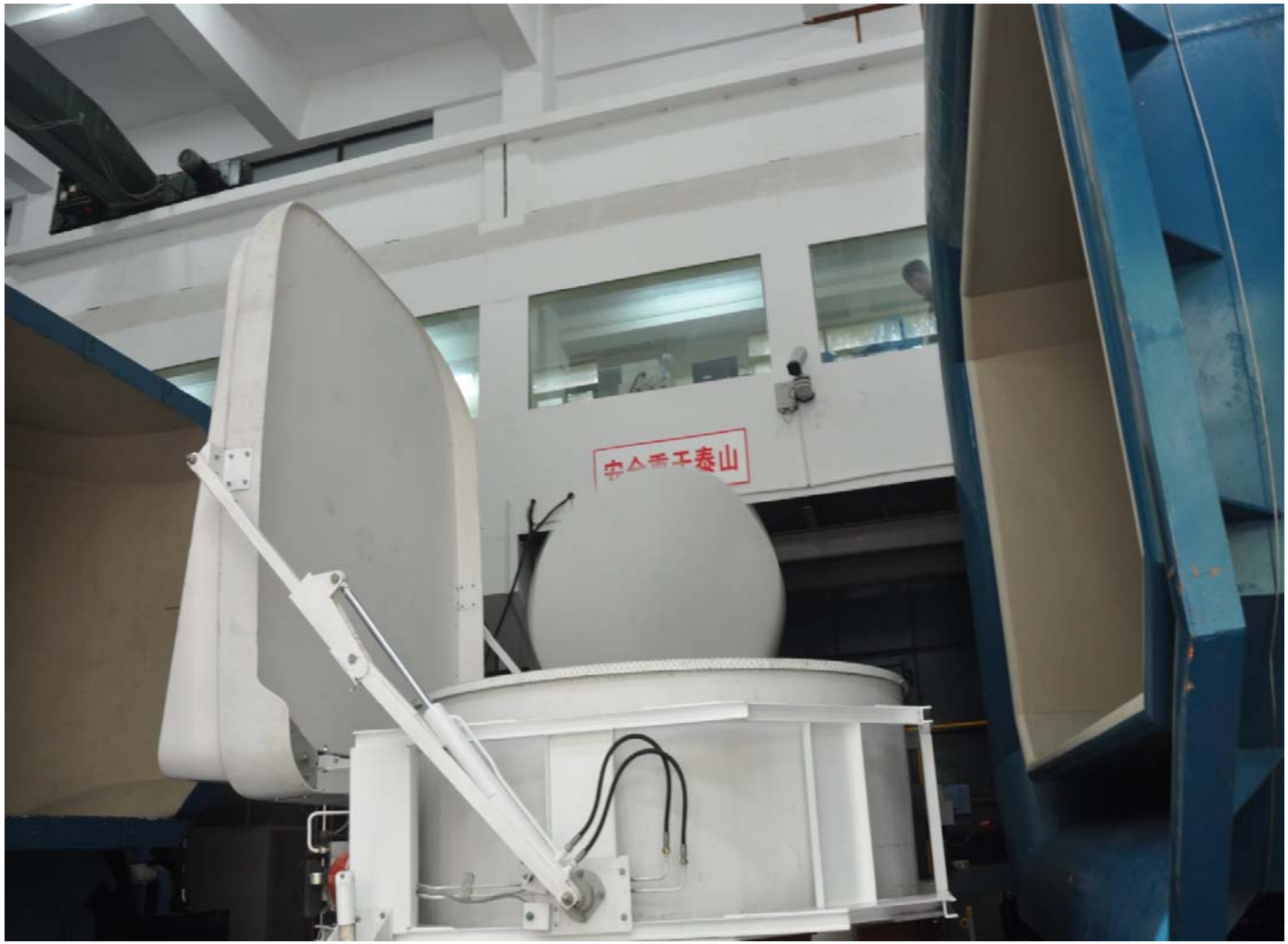

Fig.5 Wind Tunnel Test

Fig. 6　High and Low Temperature Test of Remote Location Unattended upper-air sounding system