A Nitrogen Recharge System for China's Manned Space Science and Utilization System Application

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***Abstract*—A novel Nitrogen recharge system to apply China's Manned Space Science and utilization system is showed in this paper. It contains a gas cylinder unit, a control unit, a terminal valve unit, a transducer unit and pipelines. The system is mainly responsible for supplying Nitrogen resource to space payloads. The system of ground test platform was established. The feasibility of the nitrogen recharge system is verified. Nitrogen flow relative flow resistance curve is obtained based on the performance test analysis. Experiment results indicate that the setup is conducted to verify design index requirements. The experimental results were satisfactory and justified the proposed Nitrogen recharge system.**

Keywords—Nitrogen recharge system, Flow, Pressure, Valve

I. INTRODUCTION

Nitrogen, chemical formula is named N2, is a colorless and odorless gas. In our earth, nitrogen accounted for 78.08% of the total air, which is of course one of the primary component of the atmosphere[1].

The gas of nitrogen having typical chemical inertia, it is often used as a protective gas to prevent certain objects from being oxidized when exposed to the air. As the basis of life, Nitrogen is not only the nutrient for chlorophyll[2,3], but also the ingredients for protein[4]. Although most conditions cannot use pure nitrogen directly, they are essential for life. Plants also rely on nitrogen as a nutrient, and even some plants themselves have the ability to absorb nitrogen. Nitrogen is also mainly used as a replacement gas, a washing gas, or a safety gas. The liquid nitrogen cooling die can improve die temperature, extrusion speed and temperature of profile to advance production efficiency and Surface quality of Aluminum profile[5]. As a kind of detection mediums of flushed and leakage, nitrogen is widely used in the field of manned space flight, space liquid filling system[6][7].

With the development of space science and technology, it has come true for human beings and other living creatures on earth to enter space, which brings a lot of new hopes and challenges. Space laboratory and space station have always been the topical field of research, it has great scientific, application and engineering value. China's space station (CSS) will be aimed to leading edge of scientific exploration, human survival and space activities, and will develop extensive experiments of space science technic, and space applications.

Nitrogen recharge system is a very important part of space application system because it provides the necessary basic condition for research of China's Manned Space Science and utilization system. Pressurized Nitrogen are used on the CSS for a variety of purposes. Additionally, the CSS program is mandated to maintain a supply of Nitrogen sufficient to repressurize a module in the event of a depressurization. Nitrogen is also used in experiments, The utilization system provides a scientific experimental payloads with nitrogen having specific temperature, stable pressure and flow according to the requirements.

II. BASIC PRINCIPLE

There are many scientific payloads on the Space Station. The nitrogen recharge system provide nitrogen to scientific payloads, the nitrogen must have a specific temperature, a steady pressure and the certain flow.

The nitrogen recharge system is mainly composed of gas cylinder unit, control unit, terminal valve unit, transducer unit and pipeline, The structure diagram of this nitrogen recharge system is shown in Figure 1.

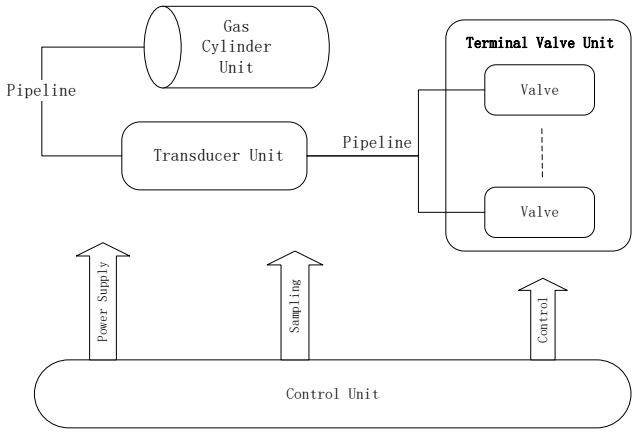

FIGURE 1 STRUCTURE DIAGRAM OF THIS NITROGEN RECHARGE SYSTEM

The gas cylinder unit as the key core of the nitrogen recharge system is the source of gas flow, the gas cylinder unit mainly contains the nitrogen bottle, the pressure transducer, depress valve, Manual cut - off valve, and so on. Figure 2 shows the gas cylinder unit.

FIGURE 2 THE GAS CYLINDER UNIT

Gas bottle storing 30MPa high pressure nitrogen gas is the source of supplying gas in nitrogen recharge system. The nitrogen bottle store 30Mpa high-pressure nitrogen gas. The manual cut-off valve is a manual valve, which need operate by person. When unscrewing the manual cut-off valve, the nitrogen in gas cylinder unit will output. If there is no the requirement of nitrogen, the valve is screwed by manual operation. For security reasons ,Manual cut - off valve is a manual operating interface to the astronaut, which mainly used to prevent gas leaking. The pressure transducer monitors the pressure of output nitrogen, it senses gas pressure physical parameter and outputs analog voltage with range from 0 to 5 voltage. The depress valve with filter has two stages decompression structure which adopt reverse non-unloading decompression method. At first the gas is filtered to remove impurities, and then, through the component of depress valve, it converts a high-pressure gas into a low-pressure gas to meet the working need of pressure. The first stage decompresses the pressure to no more than 2.0 MPA, and the second stage further relax the pressure to the required working pressure.

The control module of nitrogen recharge system is composed of pressure transducers, gas flow transduces, temperature sensors, cut-off valves, electronics controller and so on. The function of control module is sampling the transducers parameters and switching valves. The low pressure gas is divided into two main channels. Each channel assigns a cut-off valves called cut-off valves are operated by electronics controller when the electronics controller received the operation instructions. All of the transducers can get the recharge system parameters of pressure, temperature and flow. Of course, as the brain of the nitrogen recharge system, electronics controller provide the power supply, cut-off valves controlling, transducers parameter sampling, data processing and information communication.

The structure diagram of the control module shows in the solid box of Figure 2. The power supply produced voltage of 3.3V, 5V, 12V, 28V. The power supply of the measuring board and main-control board is 3.3V and 5V. The power supply of temperature sensors and pressure transducers is 12V. The voltage of 28V is for valves. The measuring board selects and takes sample analog voltage of temperature sensors and pressure transducers at a polling interval, the quantitative data of measuring board output main-control board. Of course, there is an intelligent processor on the main-control board, it can communicate with other system and switch all of electric controlling cut-off valves.

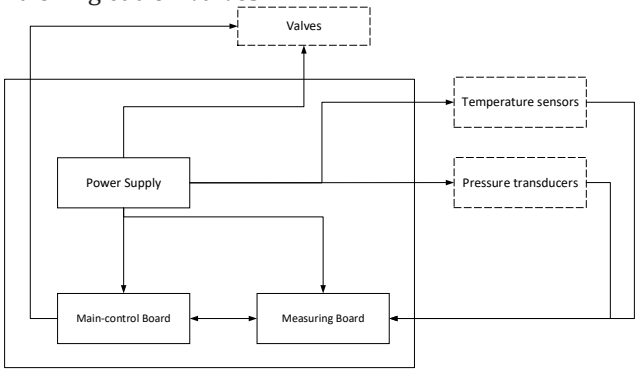

FIGURE 3 STRUCTURE DIAGRAM OF THE CONTROL MODULE

The terminal unit contains several cut-off valves with electronic controlling of which are same to valve of the control module. These cut-off valves of terminal unit are called terminal valves. All of connections of nitrogen gas are through pipelines.

III. SYSTEM DESIGN

In this section, in order to validate the effectiveness of the proposed method, the system platform of the Ground test was build. The schematic diagram of nitrogen recharge system is shown in figure 4.

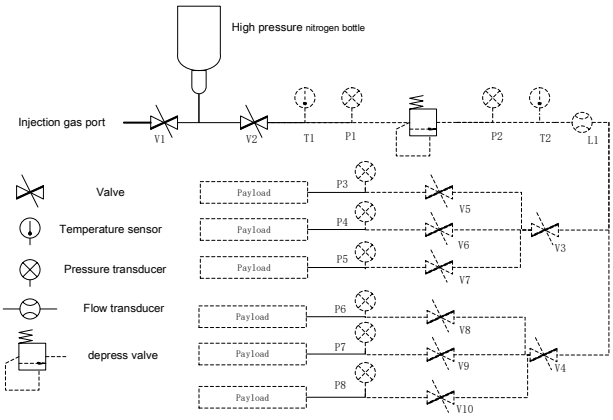

FIGURE 4 THE SCHEMATIC DIAGRAM OF NITROGEN RECHARGE SYSTEM

When there is no gas in the high pressure bottle, switch on valve V1 left side of the bottle and fill nitrogen gas through Injection gas port, otherwise switch off the valve of the injection gas port. Once the high pressure bottle can supply gas, open the valve V2. operating valve of injection gas port is manual, other valves operate with electronic controlling. One channel is separated two parallel main channels, each of

main channel has three branch. V5~V10 are valves of branch channels, V3 and V4 are valves of main channels. All of V3~V10 keep off at normal state, only a main channel valve and a branch channel valve are open at the same time. A photograph of the Ground test platform is shown in Figure 5.

FIGURE 5 THE PLATFORM IS EQUIVALENT TO ACTUAL SYSTEM

IV. MEASUREMENT RESULT

By switching combination control of these valves select supplying nitrogen for payload, the flow resistance and the output pressure characteristic of the system are measured when output flow is from 1L to 7.36L. The control module got all the measurement data and communicated with computer by RS422 bus. Table 1 shows that the first channel measurement result of Pressure, Flow resistance and Flow.

Table 1 Pressure & Flow resistance & Flow

Input Flow of payload (kg/hr)	Output pressure of nitrogen bottle (KPa)	Input pressure of payload (KPa)	Flow resistance (KPa)
1	835	828.8	6.2
2	818	795.9	22.1
3	799.1	750.4	48.7
4	779.9	691.4	88.5
5	749.9	600.8	149.1
6	721.7	486.2	235.5
7	691.1	297.9	393.2
7.36	679.6	179.7	499.9

The input flow resistance of payload is equal to Output pressure of nitrogen bottle minus Input pressure of payload. The input pressure of payload at different input Flow of payload is shown in Figure 6. The flow resistance at different input flow of payload is shown in Figure 7. It concluded that with the increase of the input Flow of payload, the flow resistance of the system increases and the input pressure of payload decreases.

V. CONCLUSION

According to the principle and design specification of the nitrogen recharging system, the ground modeling experiments platform is established. After the effective test, the results indicate that the setup is conducted to verify design requirements. The conclusion provides guidelines for the space nitrogen recharging system.

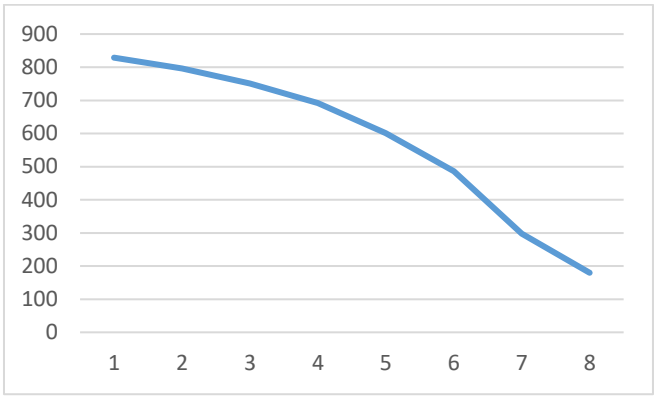

FIGURE 6 THE INPUT PRESSURE OF PAYLOAD AT DIFFERENT INPUT FLOW OF PAYLOAD

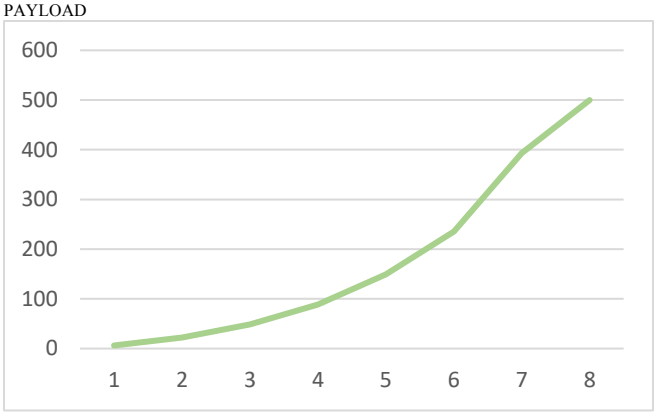

FIGURE 7 THE FLOW RESISTANCE AT DIFFERENT INPUT FLOW OF PAYLOAD

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