DEMONSTRATION PROJECT FOR AMMONIA SEMI-HERMETIC FREQUENCY CONVERTIBLE SCREW REFRIGERATION COMPRESSION UNIT IN THE INDUSTRIAL AND COMMERCIAL REFRIGERATION INDUSTRY AT FUJIAN SNOWMAN CO., LTD.

FINAL REPORT

24 SEPTEMBER 2018

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And

United Nations Development Programme (UNDP)

Executive Summary

Demonstration project for ammonia semi-hermetic frequency convertible screw refrigeration compression unit in the industrial and commercial refrigeration industry at Fujian Snowman Co., Ltd. was approved at 76th Executive Committee (ExCom) meeting at a funding level of US$1,917,296, of which US$ 1,026,815 was funded by the Multilateral Fund, US$ 890,454 was contributed by the company as counterpart funding.

This demonstration project was successful completed in March 2018, with two demonstration sub-projects that took place in two locations in China. The ammonia semi-hermetic frequency convertible screw refrigeration compression unit is to replace the HCFC-22 refrigeration unit.

The demonstration project covers product design, process redesign, construction of test devices for product performance, manufacturing of prototypes, personnel training and technology dissemination etc.

The successful completion of the demonstration project contributes to promotion of replacing HCFC-22 refrigeration systems in cold storage and freezing applications with the NH_3/CO_2 refrigeration system (NH_3 as the refrigerant, CO_2 as the secondary refrigerant).

1. Introduction

In 2007, the 19th Meeting of Parties (MOP) of the Montreal Protocol agreed to accelerate phase-out of HCFCs. To achieve the compliance targets, China is implementing HCFCs Phase-out Management Plan (HPMP) in the Industrial and Commercial Refrigeration and Air-conditioning (ICR) sector from 2010. In order to find solution for phasing out HCFCs in small- and medium sized cool storage system in the industrial and commercial refrigeration industry in the Stage II of HPMP, China proposed a demonstration project for ammonia semi-hermetic frequency-convertible screw refrigeration compression units, to be supported by the Multilateral Fund (MLF).

The Executive Committee approved the demonstration project at Fujian Snowman Co. Ltd. demonstration project at its 76th meeting in 2016 at a funding level of US $ 1,026,815. The project International Implementing Agency is the United Nations Development Programme (UNDP). The National Implementing Partner is the Foreign Economic Cooperation Office (FECO), Ministry of Ecology and Environment (MEE), China (formerly the Ministry of Environmental Protection, MEP).

The successful implementation of this demonstration project provides the demonstration of ammonia semi-hermetic frequency convertible screw refrigeration compression unit for enabling replication of this technology in similar applications in this sector in China and facilitate HCFC reductions for compliance with the HCFC control targets.

According to the system demonstrated, the manufacturing line of the R22 compressor was converted to that of NH_3 compressor. the production capacity of the converted manufacturing line of compressor is 3,000 units annually and thus resulted in reductions of 359 metric tons (MT) of HCFC-22 usage at

Fujian Snowman Co. Ltd., Furthermore, over a 15-year life-span of the refrigeration systems manufactured by the enterprise, the consumption of HCFCs for servicing of those systems is expected to be 226.16 MT in the life cycle. The total GHG emission reductions amount to about 1,041,602.60 CO2-eq tones, thus contributing to protection of both the ozone layer and the climate.

1.1 Background

The Industrial and Commercial Refrigeration and Air Conditioning (ICR) Sector in China has experienced remarkable growth in the past two decades, averaging at about 12% annually, due to the steep growth in the demand for consumer, commercial and industrial products, resulting from rapid overall economic development. This sector is categorized into several sub-sectors, namely: compressors, condensing units, small-sized air-source chillers/heat pumps, commercial and industrial chillers/heat pumps, heat pump water heaters, unitary commercial air conditioners, multi-connected commercial air conditioners, commercial and industrial refrigeration and freezing equipment, mobile refrigeration and air conditioning equipment and refrigeration and air conditioning components and parts. The 2014 estimated HCFC consumption in the sector based on ongoing surveys was about 40,805 metric tons, 98% of that HCFC is HCFC-22.

Refrigeration equipment is regarded as one important end-user product as stated in the Sector Plan for Phase-out of HCFCs in the Industrial and Commercial Refrigeration and Air-Conditioning Sector in China and it includes food display cases, transport refrigeration, icemakers, quick freezers, cold stores, refrigerated warehouses, beverage cooling equipment, etc. The main end-users are supermarkets, shops, air-conditioned refrigeration warehouses, restaurants, food distributors, kitchens of hotel, food process plants, etc. These systems are all medium and small industrial and commercial system which uses HCFC-22 as one important refrigerant. The amount of HCFC consumption is above 25% of ODS consumption in the industrial and commercial refrigeration sector. The refrigerant substitute is important for these field products. So, the new core technology developed for medium and small industrial and commercial refrigeration is significant for ODS substitute.

Fujian Snowman Co., Ltd. was established in March 2000, with a registered capital of RMB 600 million. The headquarter is located in MinJiang Industrial Zone, Fuzhou, Fujian Province, and the company covers an area of 300 acres in Binhai and Liren new industrial park of Changle City. The company has developed into the largest professional manufacturer of ice-making system, and it became a professional high-tech enterprise integrated with R&D, designing, manufacturing, sales and engineering unit installation of compressors, ice-making equipment, cooling water equipment, ice storage system and cooling system. The products are widely used in cold-chain logistics, food processing, ice storage cooling, mine cooling, nuclear power plant construction, water conservancy and hydropower and other fields.

Ice making machine：Fujian Snowman owns more than 100 exclusive patents with intellectual property rights. It has developed more than 40 types of products, especially its ice making machine sales ranking at the top in China.

Screw refrigeration compressor units: The Company has developed dozens of new types of high efficiency and energy saving screw refrigeration compressor, its technology has reached the international advanced level.

Compressor manufacture: Packaged systems with open (NH3), semi-hermetic (HCFC-22) and hermetic screw compressors (HCFC-22) and also reciprocating compressors (HCFC-22). The enterprise has two famous brands of compressors, which are SRM and RefComp.

Industrial refrigeration systems: Fujian Snowman Co., Ltd. is one of the largest manufacturers of integrated industrial refrigeration systems, such as large capacity brine chillers, ice makers, etc. based on screw compressors, with a 40-60% market share.

Fujian Snowman Co., Ltd. is committed to technology innovation, focusing on environment protection, energy efficiency and safety. Over 30-40% of its refrigeration products use natural substances.

In 2015 Fujian Snowman Co. Ltd. manufactured the following HCFC-22 integrated refrigeration systems:

No	Product Line	Evaporating temperature (°C)	Quantity (Nos.)	HCFC consumption (metric tons, MT)
1	Water Chillers	-5 to +3	50	N/A
2	Ice maker	-30 to -15	400	23
3	Brine Chillers	-40 to 3	11	N/A
4	Ice storage system	-18 to -5	20	1

1.2 Technical choice

Some of the zero-ODP alternatives to HCFC-22 currently available for this application are listed below:

Substance	GWP	Application	Remark
Ammonia	0	Industrial refrigeration and process chillers	Flammability and toxicity issues. Material compatibility issues. Regulatory issues.
CO_2	1	Refrigeration in a secondary loop and in stationary and mobile air conditioning systems	Major redesign of system components needed. Investment costs are prohibitive
R-404A	3,260	Low temperature applications	High GWP, less efficient at medium temperatures, synthetic lubricants needed

R-404A has high GWP and requires synthetic lubricants, although its thermodynamic properties are suitable for low-temperature applications. Its long-term sustainability from an environmental perspective is considered doubtful.

Ammonia is a traditional natural refrigerant with good environment properties as well as favorable thermodynamic properties. The operating pressures are low, it has low flow resistance and it has

excellent heat transfer characteristics. Being a single substance, it is chemically stable. It has high refrigeration capacity. It is widely available at affordable prices. However, ammonia is quite reactive; it is toxic and moderately flammable. It is also not compatible with non-ferrous materials.

CO_2 was a commonly used refrigerant in the late 19th and early 20th centuries, however, its use gradually faded out. CO_2 has many favorable characteristics. It has Zero ODP and GWP of 1; it is inert, non-toxic and chemically stable, is compatible with almost all materials and available widely at affordable prices. For a given refrigeration capacity, the system components with CO_2 are much smaller compared to other refrigerants. However, the main disadvantage with CO_2 is its high operating pressures, which requires special designs for the system and components. Furthermore, CO_2 is also not very efficient at high ambient temperatures.

Fujian Snowman Co. Ltd. has selected ammonia semi-hermetic frequency convertible screw refrigeration compression unit with CO_2 in its design as the technological choice for its low-temperature coolant integrated refrigeration systems, considering the favorable environmental and thermodynamic properties of these two refrigerant alternatives.

2. Project Implementation

2.1 Product design

To meet the project goal, the following design had been carried out based on manufacturing process. The design elements comprised of the following

- **The design of ammonia semi-hermetic frequency convertible screw compressor**

The project adopted the latest screw rotor "T" profile design for screw refrigeration compressor, making the screw compressor running smoothly and reducing noise greatly. It was completed at the end of March 2017, and the strength analysis of the compressor shell and silicon steel plate of compressor motor rotor is shown in Fig.1 below.

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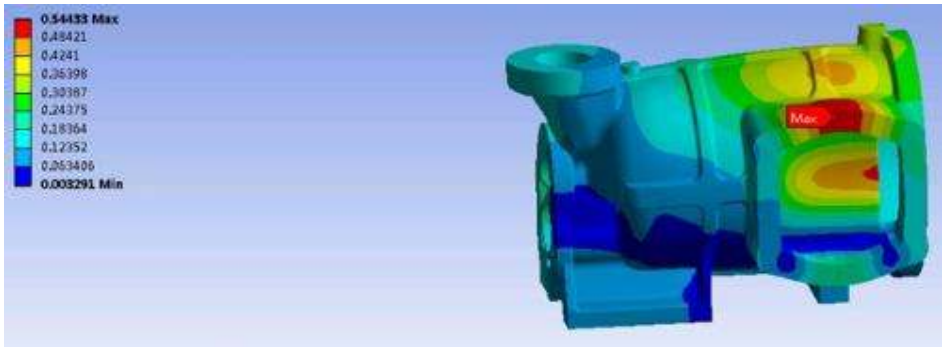

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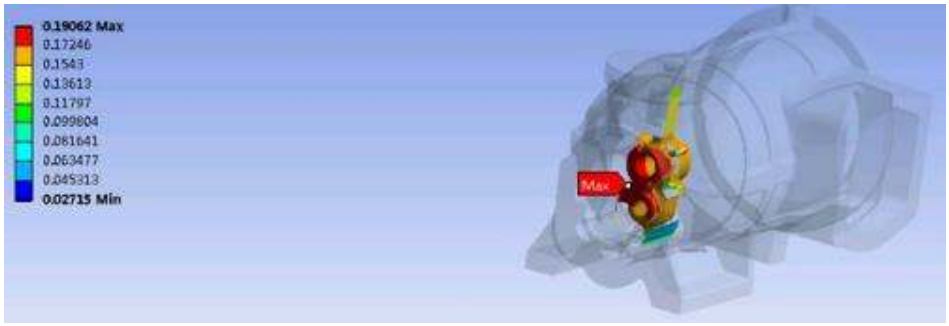

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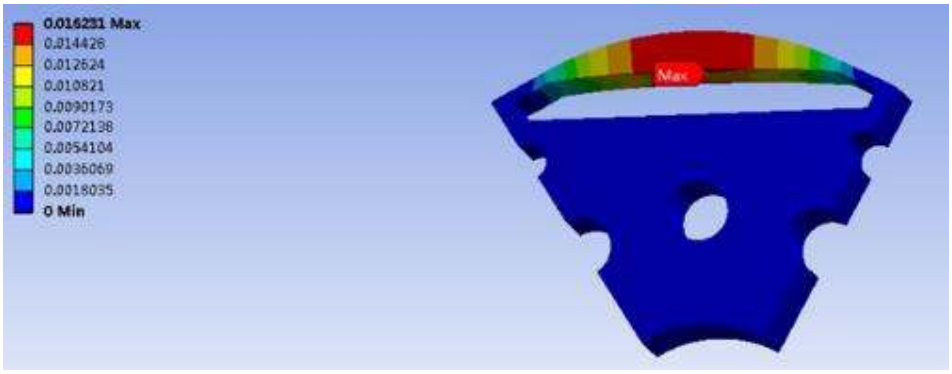

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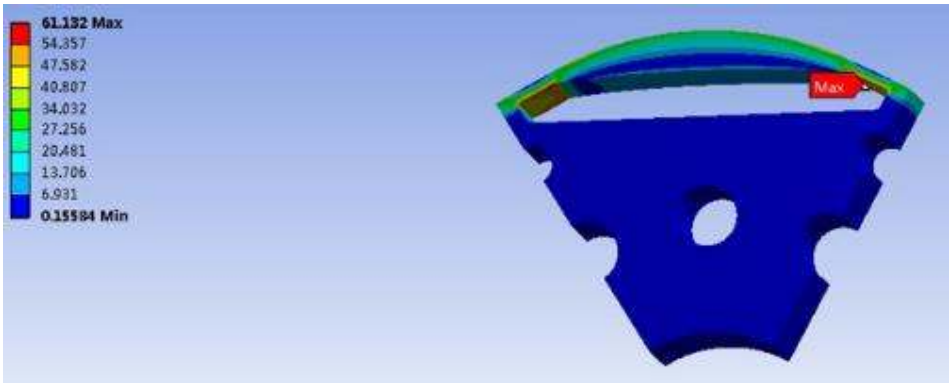


(e)

Fig.1 Screw design and strengthen design of the compressor parts

The system using the subcooling economizer can increase the COP and the cooling capacity, and the operation of the subcooling economizer is a key part for the SRS series semi-hermetic single machine double stage screw compressor. The subcooling economizer is shown in Fig.2.

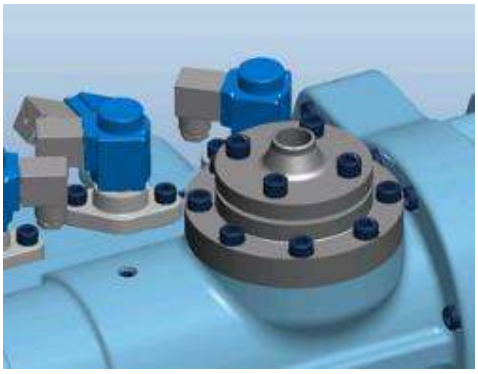


Fig.2 Subcooling economizer

- **The design of special motor for the ammonia semi-hermetic frequency convertible screw compressors;**

The Compressor Department completely designed and developed the semi closed motor for ammonia before March 2017 which is shown in Fig.3. Because of the strong corrosiveness of ammonia to the copper wire in the motor, the project focused on the corrosion resistance of the electromagnetic line and develop a long term electromagnetic line for ammonia refrigerant.

Fig.3 Type of motors

The cooling sleeve is made of aluminum alloy with good thermal conductivity, the motor is cooled fully, and the operation is stable. The cooling mode of the motor cooling adopts the dual cooling mode of oil cooling (or water cooling) and the refrigerant spray to ensure the motor running for a long time. The gas expansion and useless overheating caused by the suction cooling are avoided, and the efficiency of the compressor is significantly improved; at the same time, the motor overheating caused by inadequate motor cooling is avoided at the same time. The structure of the cooling sleeve is shown in Fig.4.

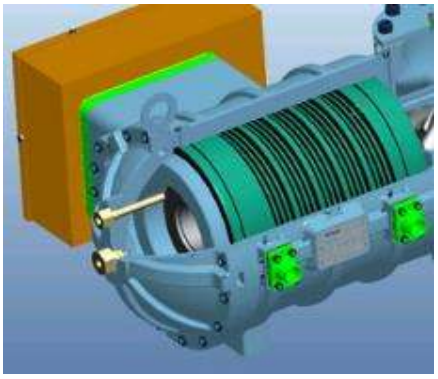


Fig.4 Structure of cooling sleeve

- **The design of NH_3 system of screw frequency convertible compressors unit**

The project completed the theoretical analysis of the system and the design of the whole machine at the end of March 2017. Fig.5 shows the variation of COP of NH_3 / CO_2 as the second refrigerant in refrigeration system with the isentropic efficiency of compressor. As the decrease of isentropic efficiency of compressor, the COP decrease linearly. When the evaporation temperature is -25 ºC, the COP is 1.09 at the given isentropic efficiency of 0.4. And the COP is 2.18 at the given isentropic efficiency of 0.8, correspondingly.

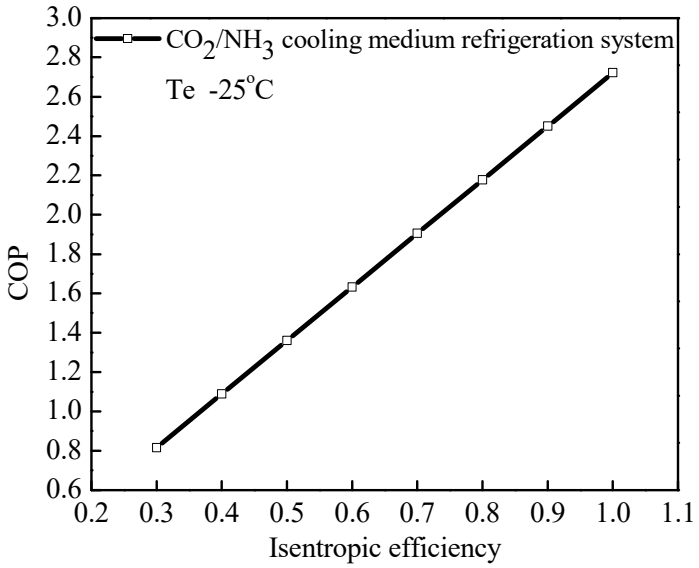


Fig.5 COP of NH_3/ CO_2 as second refrigerant refrigeration system varies with the isentropic efficiency of compressor

Table 1 The COP NH_3/CO_2 as second refrigerant refrigeration system varies with isentropic efficiency

NH_3 / CO_2 as second refrigerant refrigeration system								
Isentropic efficiency	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
COP	0.82	1.09	1.36	1.63	1.91	2.18	2.45	2.72

The design of the whole machine is shown in Fig.6.

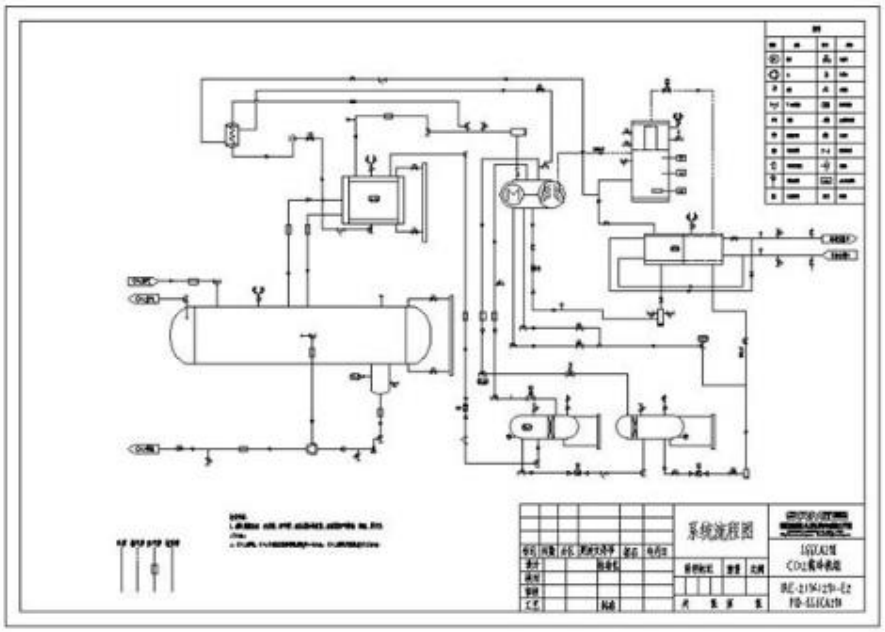
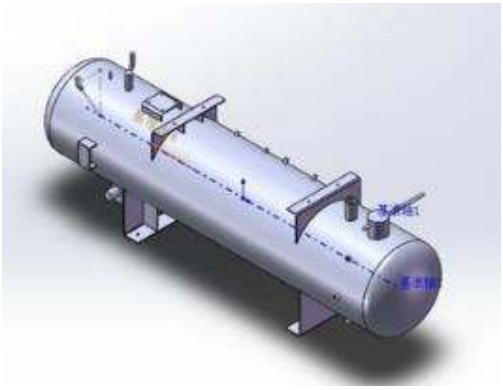


Fig. 6 System flow map of the NH_3/CO_2 compression unit

- **The design of NH_3 related pressure vessel screw frequency convertible compressors**

The pressure vessel design includes the design of high efficiency oil separator, CO_2 liquid storage device and economizer. The work of pressure vessel process analysis, processing control route, tooling design, pressure vessel forming, and welding process design are all completed by the Department of Pressure Vessel. The designed pressure vessel is shown in Fig.7.



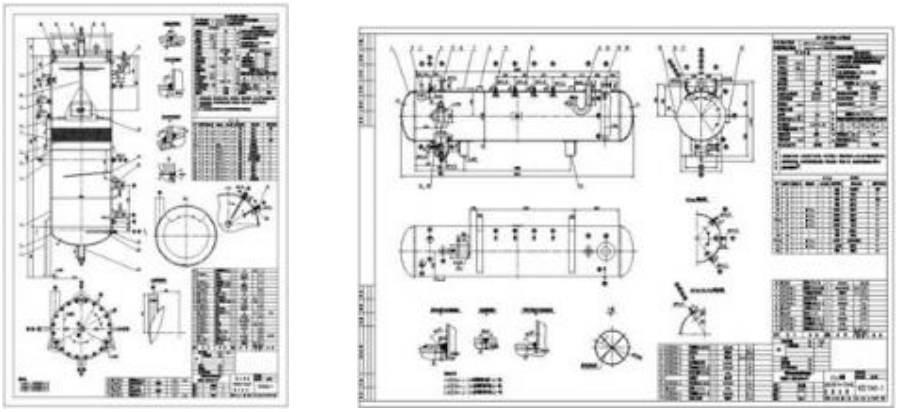
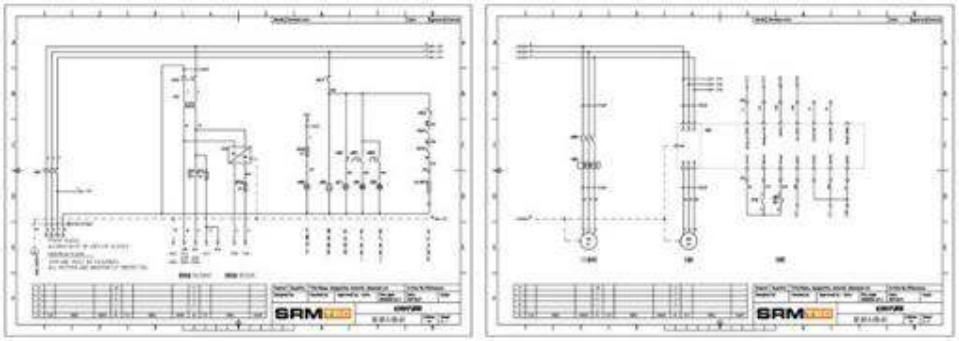


Fig.7 Pressure vessel design drawing

- **The electric control system design of compression unit;**

The electrical automation technology department has finished the design of the electric system of compression unit. The design work included the electrical drawing design of the unit, control cabinet and starting cabinet.



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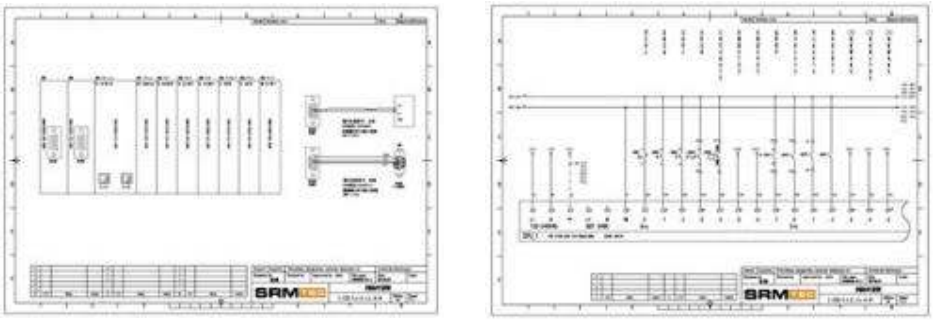


(c) (d)

(e)

(f)

Fig.8 Drawing and picture of electric cabinet

- **The applied controlling software design.**

The system controlling concluded some hardware and software. The control system hardware is almost used foreign country brand which are shown in Table 2 and Fig.9. The software is shown in Fig.10.

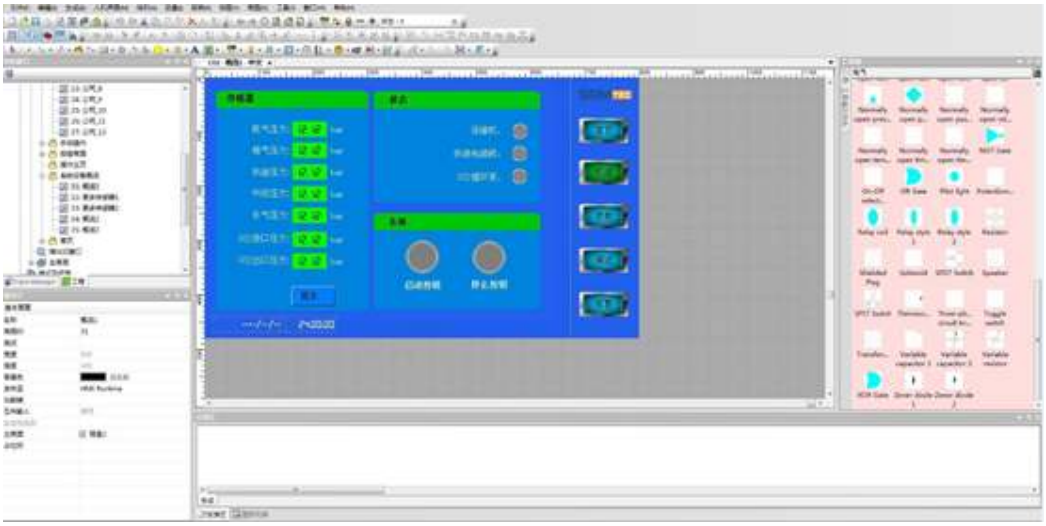
Table 2 The control system hardware

Name	Function	Brand
Electric expansion valve	Control of R717 refrigerant supplier	Parker
ICS Servo main valve+ CVP Guide valve	Control the internal pressure of the container	Danfoss
EVRA Solenoid valve	Control the flow of pipeline	Danfoss
Differential pressure switch	Detection of pressure difference between front and back of pump	Danfoss
Oil flow switch	Detection of lubricant oil flow	Hanike

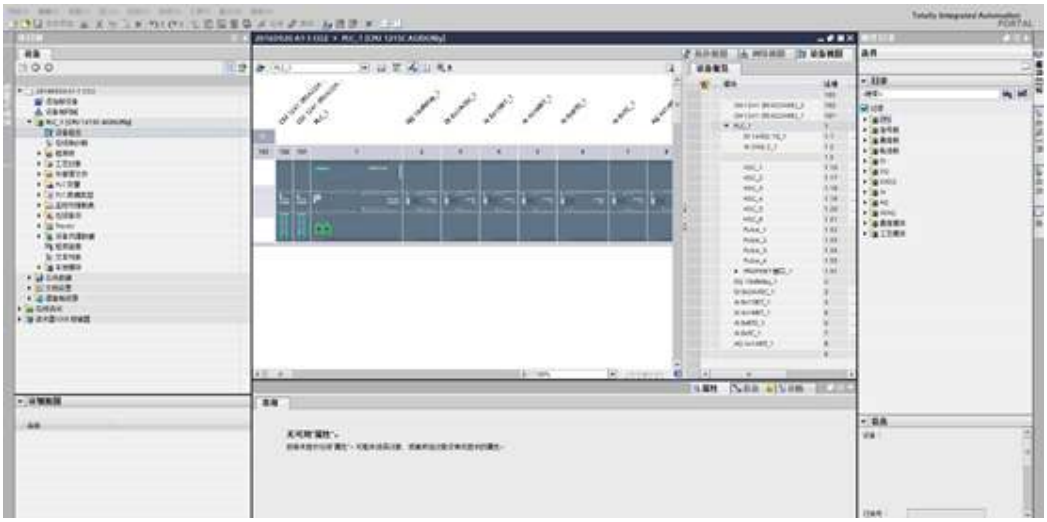
PLC

Touch screen

Fig.9 The PLC and Touch screen



Software 1



Software 2

Fig.10 The controlling software design

- **The design of three type of compression units**

The compression unit technology department completed the design of three types of compression units before June 2017, including system diagram, assembly drawing, structural drawing and production drawing. The 3D drawing of the system is shown in Fig.11.

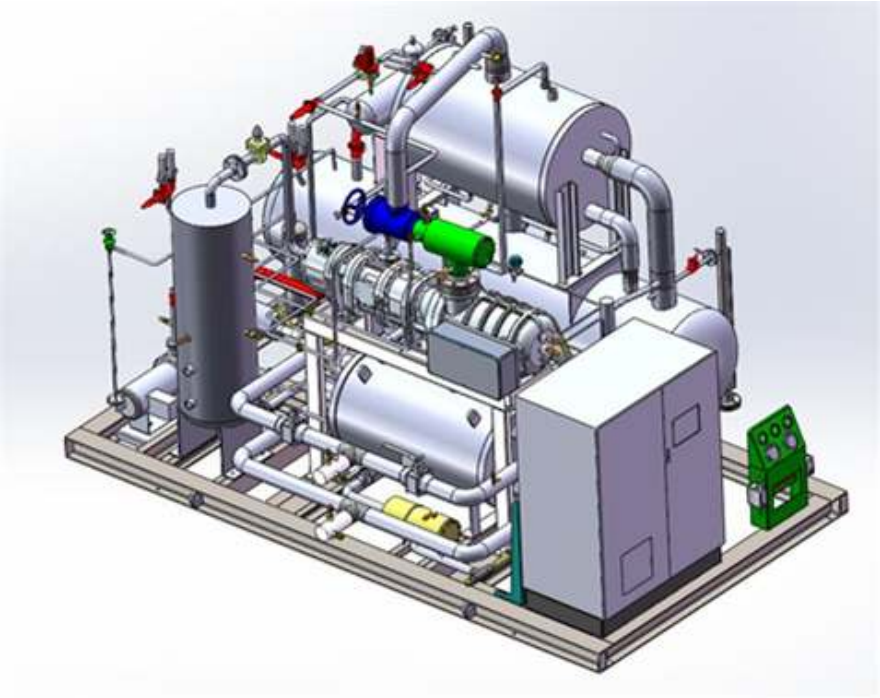
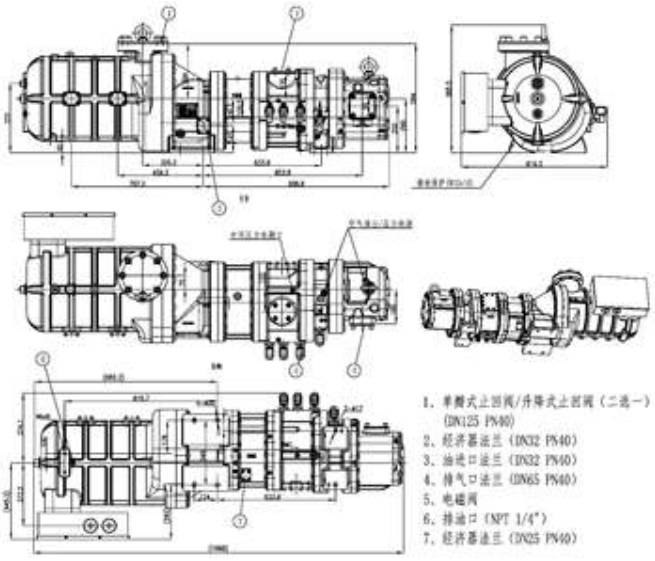
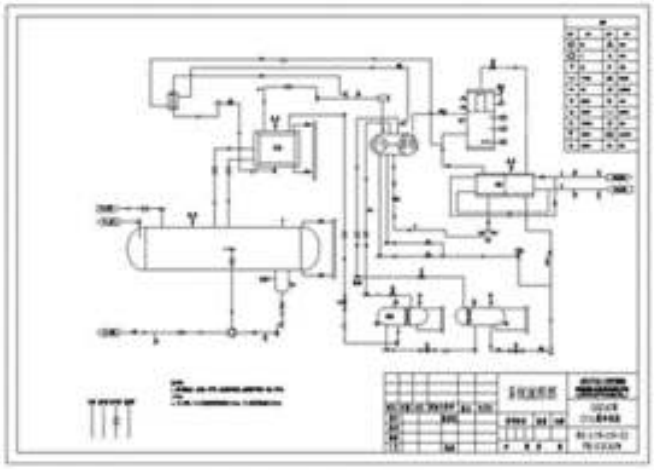


Fig.11 3D drawing of the compression unit

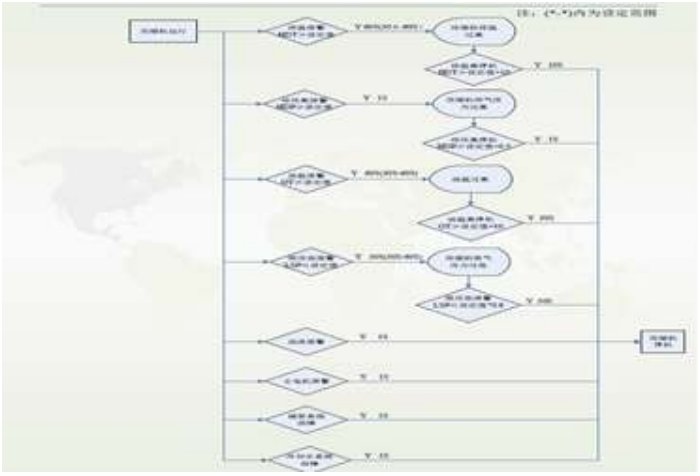
2.2 Process design

The process design is based on the compressor design and other parts design. Some process is changed because the special design of the system. The system flow chart and the control flow chart are all changed in this project, which are shown in Fig.12.





（system flow chart）



（Control flow chart）

Fig.12 Some flow charts of the project

2.3 Construction of test devices for product performance

As a new refrigeration system, the NH_3 system cannot be tested in the existing performance test laboratory mainly because of NH_3 corrosiveness and changes of system and pressure. The product test device of the medium and small NH_3 refrigeration system requires new facility construction. The test devices of NH_3 semi-hermetic compressor housing strength and air load are to be added. In addition, the following additions had to be done:

- **Pressure vessel strength testing device**

The pressure vessel technology department set up a pressure vessel test device and completed the related pressure vessel test which is shown in Fig.13.

Fig.13 Pressure vessel testing device

- **NH_3/CO_2 compression unit performance test equipment**

According to the design of the compressor and the unit performance testing device, the test center and the pressure vessel technology department set up and debug the performance test bed. The devices are shown in Fig.14.

(a)

(b)

(c)

Fig.14 Compressor and units testing device

2.4 Manufacturing of prototypes

According to the industrialization requirement of the NH_3 refrigeration system, three specifications of refrigeration systems had to be developed in October 2017. Before commercialization, the prototype of refrigeration system had to be manufactured and tested before mass production. As processing parts are numerous and processing precision is strict, the waste rate from casting to completion is very high.

Hence, three sets of rough parts had be produced for each compressor size. One set of rough parts had been manufactured for other auxiliary equipment.

- **Total nine sets of NH_3 semi-hermetic screw compressor prototypes manufactured**

The compressor production department and purchasing department completed the manufacture of three types of prototypes. Three sets for each SSSCA50, SSSCA210 and SSSCA60 prototypes were produced. Three types of compression units are shown in Fig.15.

（SSSCA60）

（SSSCA210）

（SSSCA50）

Fig.15 Picture of three types of compression units

- **The experimental test data of the prototypes and analysis**

This unit is CO_2 cooler unit, with SRS-12L compressor, it uses NH3 as its refrigerant, CO_2 as its secondary refrigerant. Design conditions are at evaporating temperature -8 °C and condensing temperature 35°C.The system uses vertical oil separator, NH_3 water-cooled condenser (VAHTERUS), CO_2 condensing evaporator (VAHTERUS) and oil cooler (VAHTERUS), It is equipped with CO_2 reservoir and flash economizer, and it uses an electronically controlled valve (Parker) as its fluid regulator.

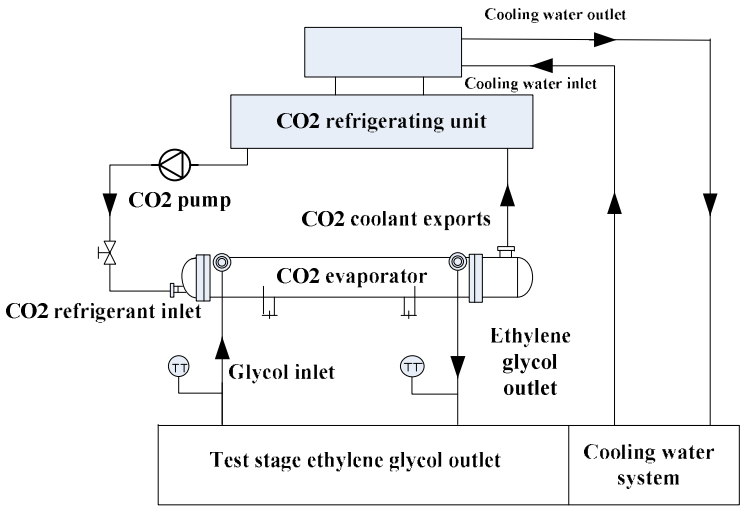


Fig.16 Test rig of the NH_3/CO_2 system

Table 3 Test result of SSSCA50

Test date	Jan. 25th 2018			Note
NH_3/CO_2 secondary refrigeration package SSSCA50	Suction pressure	bar	2.75	Saturation temperature: -11.4 ºC
	Discharge pressure	bar	13.43	Saturation temperature:34.8 ºC
	Middle offset pressure	bar	5.26	Saturation temperature:6.2 ºC
	Suction temperature	ºC	-11.1	
	Discharge temperature	ºC	72.3	
	Oil supply temperature	ºC	44.3	
	Compressor working power	kW	68.1	
	Rotation speed	RPM	3550	
Cooling water system	Water inlet temperature	ºC	26.85	
	Water outlet temperature	ºC	32.74	
	Water flow	m^3/h	42.95	
	Water pressure drop	kPa	50.12	
CO_2 system	Pressure before pump	bar	30.3	
	Pressure after pump	bar	34.59	
	CO_2 liquid supply temperature	ºC	-5.2	
	Pump power	kW	5.5	
Ethylene glycol system	Inlet temperature	ºC	3.08	
	Outlet temperature	ºC	-1.8	
	Water flow	m^3/h	41.7	
	Water pressure drop	kPa	12.85	
Unit refrigeration capacity		kW	216.3	
Compressor input power		kW	68.1	
Compressor COP		/	3.17	
Unit total power (compressor + CO_2 pump + inverter)		kW	73.6	
COP		/	2.94	
NH_3 charge amount		kg	16.8	Actual charge

Table 4 Test result of SSSCA60

Test date	Feb. 2nd 2018			Note
NH_3/CO_2 secondary refrigeration package SSSCA60	Suction pressure	bar	0.85	Saturation temperature: -36.8 ºC
	Discharge pressure	bar	13.62	Saturation temperature: 35.3 ºC
	Middle offset pressure	bar	3.14	Saturation temperature: -8.94℃
	Suction temperature	ºC	-36.2	
	Discharge temperature	ºC	72.8	
	Oil supply temperature	ºC	42.5	
	Compressor working power	kW	31.9	
	Rotation speed	RPM	3550	

Cooling water system	Water inlet temperature	ºC	26.56	
	Water outlet temperature	ºC	32.65	
	Water flow	m^3/h	13.68	
	Water pressure drop	kPa	57.70	
CO_2 system	Pressure before pump	bar	13.41	
	Pressure after pump	bar	17.55	
	CO_2 liquid supply temperature	ºC	-32.1	
	Pump power	kW	3.0	
Ethylene glycol system	Inlet temperature	ºC	-25.1	
	Outlet temperature	ºC	-28.2	
	Water flow	m^3/h	21.7	
	Water pressure drop	kPa	12.08	
Unit refrigeration capacity		kW	56.7	
Compressor input power		kW	31.9	
Compressor COP		/	1.77	
Unit total power (compressor + CO_2 pump + inverter)		kW	36.2	
COP		/	1.57	
NH_3 charge amount		kg	21.4	Actual charge

Table 5 Test result of SSSCA210

Test date	Feb. 6th 2018			Note
NH_3/CO_2 secondary refrigeration package SSSCA210	Suction pressure	bar	0.83	Saturation temperature: -37.2 ºC
	Discharge pressure	bar	13.62	Saturation temperature:35.3 ºC
	Middle offset pressure	bar	3.47	Saturation temperature: -6.29 ºC
	Suction temperature	ºC	-36.7	
	Discharge temperature	ºC	75.3	
	Oil supply temperature	ºC	46.8	
	Compressor working power	kW	96.3	
	Rotation speed	RPM	3550	
Cooling water system	Water inlet temperature	ºC	26.40	
	Water outlet temperature	ºC	32.27	
	Water flow	m^3/h	39.92	
	Water pressure drop	kPa	57.70	
CO_2 system	Pressure before pump	bar	13.39	
	Pressure after pump	bar	17.62	
	CO_2 liquid supply temperature	ºC	-32.1	
	Pump power	kW	5.5	
Ethylene glycol system	Inlet temperature	ºC	-24.8	
	Outlet temperature	ºC	-28.3	
	Water flow	m3/h	52.3	
	Water pressure drop	kPa	15.03	

Unit refrigeration capacity	kW	167.1	
Compressor input power	kW	96.3	
Compressor COP	/	1.73	
Unit total power (compressor + CO_2 pump + inverter)	kW	102.3	
COP	/	1.63	
NH_3 charge amount	kg	37.0	Actual charge

Table 6 the testing result of three type compression units

Model	Theoretical displacement (m^3/hr)	Theoretical NH_3 charge (kg)	Actual NH_3 charge (kg)
SSSCA50 (SRS-12L)	262	17	16.8
SSSCA210 (SRS-1612LM)	652	48	37.0
SSSCA60 (SRS-1008L)	221	22	21.4

2.5 Personnel Training

The company technical center conducted training for designers, technicians, production managers, manufacturing workers, installation personnel, product application engineers, equipment managers, and sales personnel designed for the project.

Fujian Snowman Co. Ltd. has organized 37 times of technical commission and personnel training under this project. Totally 679 class hours training were conducted, and 1,871 persons were trained. The training list is shown in table 7.

Table 7 the training list of this project

No.	Trainees	Training content	persons /Times	Class hour
1	Designers, technicians	Process design training for screw compressor, compressor rotor, compressor housing, mechanical assembly and so on.	471/9	17
2	Production management and manufacturing workers	Basic knowledge of welding, classification of welding methods and basic concepts, training of welder's work permit.	195/4	8
3	Installation and commissioning personnel	Machining exception handling process, nonconforming product handling procedure, cause analysis of machining collision tool, etc.	223/5	14
4	Salesman	Compressor features and application scope, compressor unit characteristics, unit electrical and control knowledge introduction, etc.	504/10	28
5	Product application engineer	The cooling principle, the electric control principle and the training of CO_2 as second refrigerant unit, etc.	478/9	16

Fig.17 Training workshop based on the project

2.6 Technology Dissemination

Small and medium cold storage includes refrigeration storage in large and small supermarkets, low-temperature cold storage, and food freezing storage. Ammonia or fluorine is often used as refrigerant in traditional small cold storages, which poses a potential safety hazard to the environment and the surrounding environment. The system demonstrated in this project is less charged with NH_3. It can be used in a small system with dense population.

NH_3 refrigeration system with ammonia semi-hermetic frequency convertible screw refrigeration compressor is new to domestic refrigeration industry. With the test of performance of prototype units at the end of 2017, the demonstration project has also been built and tested. The system unit also been shown in some exhibition such as the International Refrigeration Exhibition in China for the technical dissemination in 2018.

The following projects are used to disseminate the technology.

- Chengdu Taigu cold chain project uses NH_3/CO_2 as second refrigerant system.

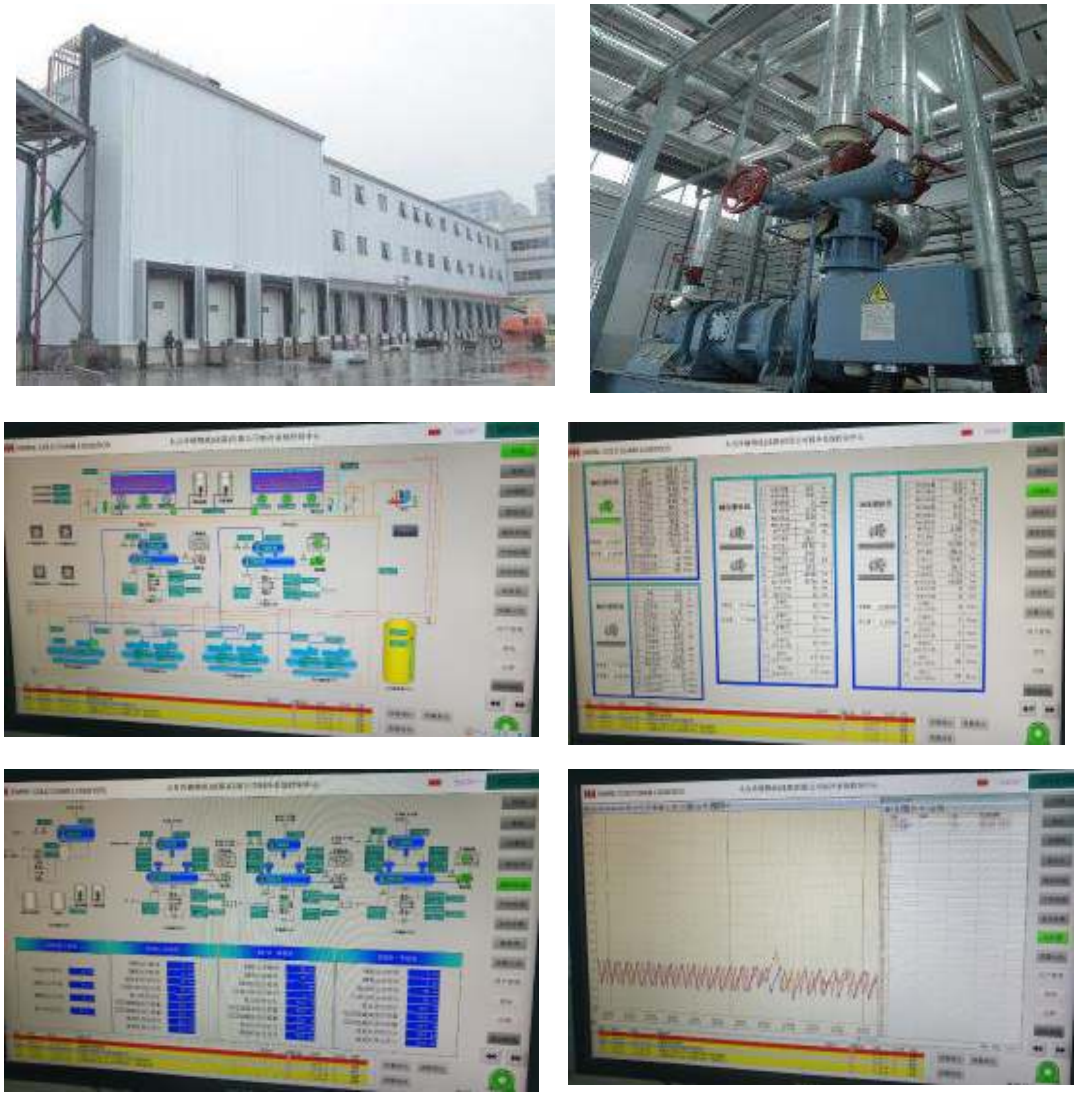


Fig.18 Application of the project system in Chengdu

- Participate in exhibitions, such as the International Refrigeration Exhibition in China, April 2018, Chinese Fisheries Exposition, and Chinese Food Processing Exposition; display the product and application technology.

Fig.19 The dissemination in International Refrigeration Exhibition in China April 2018

2.7 Management

The project is under the overall management and coordination of the Foreign Economic Cooperation Office, Ministry of Ecology and Environment of China. UNDP is the international implementing agency for the project, which provide international coordination and technical assistance as needed.

The project employs the Performance-based Payment (PBP) mechanism in its implementation. Under the PBP mechanism, the enterprise is tasked to carry out the conversion playing the role of a key executer, which is responsible for all the activities related to the conversion (with supervision of the technical expertise team hired by FECO and/or UNDP), including but not limited to: product redesign, procurement of raw material, components, equipment and consulting services as per the budget

allocation table, construction product testing devices, etc., and project technical commissioning. The procurement is organized fully in line with the marketing principle, so that the goods and services procured are high quality, most reasonable price and suitable for product line conversion to make sure the new alternative technology applied feasibly and successfully. The detailed arrangement on procurement is defined in the contract between FECO/MEP and the Executor (enterprises).

Besides that, FECO and UNDP are monitoring the implementation of the project with aim to ensure the project activities are in compliance with the UNDP financial rules and procurement rules. UNDP and FECO are not involved in the procurement activities of the enterprise by any means other than make payment to the enterprise in tranches for the costs of procurement and conversion, at agreed payment dates given in the payment schedule, and when milestones prerequisite for the tranche have all been achieved on time.

3. Outcomes

After the demonstration project was approved at the 76th ExCom meeting, UNDP, FECO and the enterprise took prompt action, the implementation of the demonstration project was relatively smooth. By the end of October 2017, the work, including the testing equipment, was basically completed. Since then, a great deal of work has been done in training, technical advocacy, especially on the testing. By the end of 2017, all the required elements of the demonstration project were completed. However, in accordance with the relevant regulations of China, the process of national acceptance was initiated, and the entire process was completed in March 2018.

In addition to requirement of the project, great importance was attached to the practical application of the new system by the enterprise. In October 2017, Fujian Snowman discussed the plan with relevant supermarkets on setting up the refrigeration system based on the new technology. In the last quarter of 2017, after a preliminary test of the system, two systems began to be installed in the supermarkets and the installations of the new systems were completed in early 2018. The investments of the two demonstration systems in the supermarkets were financed by the relevant owners of the supermarkets. To-date, after operating for more than half a year, operation of the two new systems in the two supermarkets are stable. It is expected that after one year's operation of the supermarket systems, a comprehensive evaluation will be conducted to access the performance of the two systems.

In conclusion, the demonstration project has achieved the following good results:

1) The project focus on the corrosion resistance of the electromagnetic line and develop a long term electromagnetic line for ammonia medium.
2) The motor cooling adopts double cooling methods of oil cooling (or water cooling) and refrigerant spray, so as to ensure the motor works stably for a long time.
3) The system adopts single compressor with two-stage to improve system efficiency.
4) The project had finished the target and the system test result is shown in Table 4 above.

5) The system in the demonstration project has been built in two locations in China at the beginning of 2018. The systems are operating successfully at Xiamen Taigu cold storage and runs safely for half a year, and at the Chengdu Taigu cold storage which also began to run safely for half of year.

4. Assessment

4.1 Project process

The project was implemented smoothly according to the program schedule and was completed at the beginning of 2018. It successfully passed national acceptance in March 2018.

Each of milestones was achieved and verified, the main parts of project are as follows:

Milestones		Status
1st	Signing of the contact	FECO and the enterprise signed contract in November 2016.
2nd	Completion of system design and compressor design	Finished and verified in May 2017.
3rd	Prototypes manufactured, and performance tested	Finished and verified in January 2018.
4th	Demonstration project has been built and operation	Finished and verified in January 2018
5th	Technical commissioning completed successfully and relevant personnel trained	Finished and verified in March 2018
6th	Project national acceptance	Finished and verified in March 2018

The project detailed milestones from the date of receipt of funds is given in the table below.

MILESTONE/MONTHS	2016		2017												2018		
	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Start-up of project activities																	
Project document signature																	
Project organizer committee																	
System design and compressor design																	
Motor design																	
Compressor design																	
Theoretical analysis and system design																	
Pressure vessel design																	
Electric system design																	
Three type of compression units design																	
Prototype manufacturing																	
Prototype manufacturing of compression units																	
Testing device																	
Pressure vessel testing device																	
Compressor/units performance testing device																	
Performance test of prototype																	
Training																	
Training																	
Technology Dissemination																	
Technology Dissemination and verification																	
Project acceptance																	
Project acceptance																	

4.2 Technical performance

1. NH_3 is a traditional natural refrigerant with good environment properties.

2. NH_3 has good thermodynamic properties with GWP<1.

3. The NH_3 refrigeration unit operating pressures are lower than R22 refrigeration unit.

4. For the same cooling capacity, the charge quantity for NH_3 is about 25% of that of R22 depending on the application.

5. The COP of NH_3 refrigeration unit is the same as the R22 refrigeration unit at the same working condition.

4.3 Actual conversion cost

Total Final Actual Project Costs

The total final actual project costs amount to **US$ 2,011,945.01**, US$ **1,026,815** was funded by the Multilateral Fund, and US$ **985,130.01** was contributed by the company as counterpart funding.

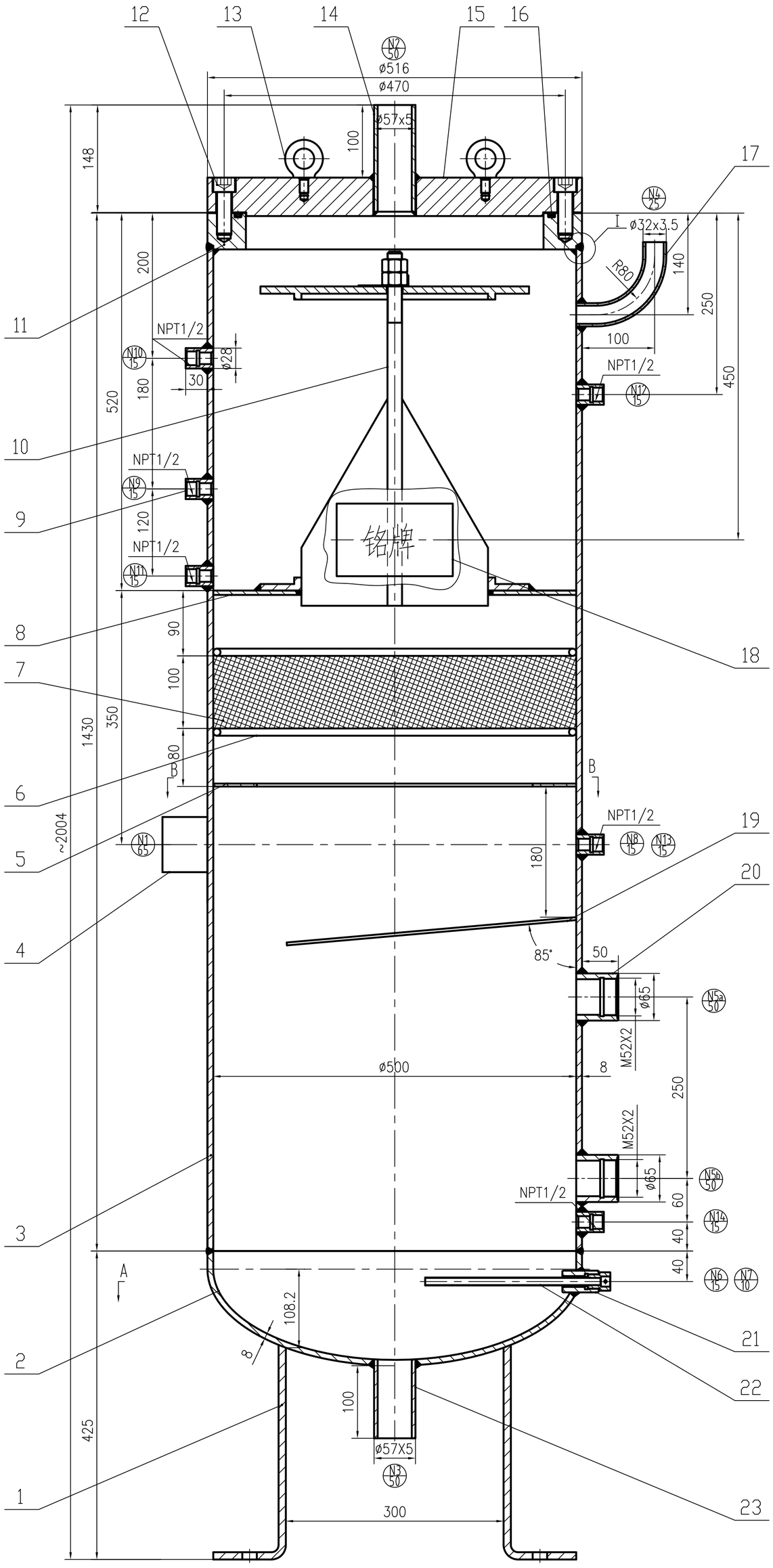
The detailed costs are indicated as follows：

No.	Content		Actual project cost(US$)		
			Actual cost (US$)	MLF fund (US$)	Counterpart funding (US$)
1	Product and process design	System design	118,393.63		118,393.63
		Process design	38,664.77		38,664.77
		Compressor design	163,325.45		163,325.45
		Heat exchange analysis software	83,787.10	83,787.10	0
2	Compression unit performance test device construction	Electric leakage detector	2,689.43		2,689.43
		Detector	4,628.24		4,628.24
		Helium detector	68,837.63		68,837.63
		Compression unit performance test equipment	458,965.66	458,965.66	0
		Pressure vessel strength test device	128,337.70		128,337.70
3	Material for the prototype production	NH_3 compressor	303,715.03	295,775.00	7,940.03
		NH_3 oil separator	30,869.21	30,869.21	0
		CO_2 liquid-storage tank	58,320.46	58,320.46	0
		Heat exchanger	78,696.08		78,696.08
		Starting cabinet（inverter）	62,519.06		62,519.06
		Electric control cabinet	8,387.40		8,387.40
		Valve parts, pipe, flanges	37,464.01		37,464.01
		Metal hose（testing）	9,799.88		9,799.88
		CO_2 Pump	30,157.53	30,157.53	0
		CO_2 (0.9999)	56,368.51		56,368.51
		NH_3	7,705.67		7,705.67
		Frozen Oil	2,054.85		2,054.85
		Helium	4,079.47		4,079.47
		Nitrogen	483.49		483.49
4	Training	Training on process and product design	134,474.84	68,940.04	65,534.80
		Welder training	9,419.43		9,419.43
		Material fee	8,705.07		8,705.07
5	Market Promotion	Market Promotion	101,095.41		101,095.41
Total			**2,011,945.01**	**1,026,815.00**	**985,130.01**

4.4 Impact

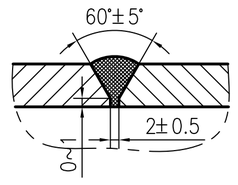
Following the system demonstration, the product line of the R22 compressor is successfully considered to be converted to NH_3, which results in production of new refrigeration system at production capacity of 3,000 units annually and thus achieved reduction of 359 metric tons of HCFC-22 usage at Fujian Snowman Co. Ltd. Furthermore, over a 15-year life-span of the refrigeration systems manufactured by the enterprise, the consumption of HCFCs for servicing those systems is expected to be 226.16 metric tons in the life cycle. The total GHG emission reductions amount to about 1,041,602.60 CO_2-eq tones, thus contributing to the protection of both the ozone layer and the climate.

The successful completion of the demonstration project contributes towards promotion of this technology for replacing HCFC-22 based refrigeration systems in cold storage and freezing applications and enable cost-effective conversions at other similar manufacturers in this sub-sector.



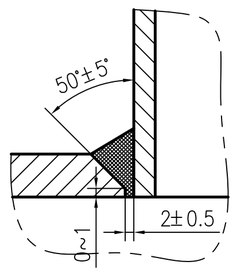
对接接头焊接形式

1:1



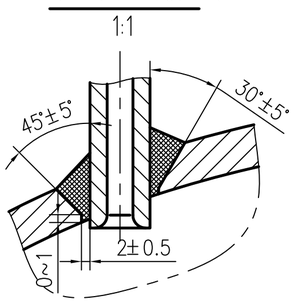
径向开孔焊接形式

1:1



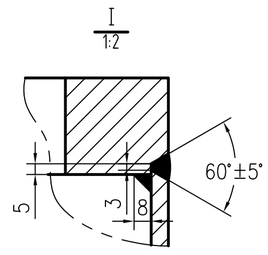
非径向开孔焊接形式

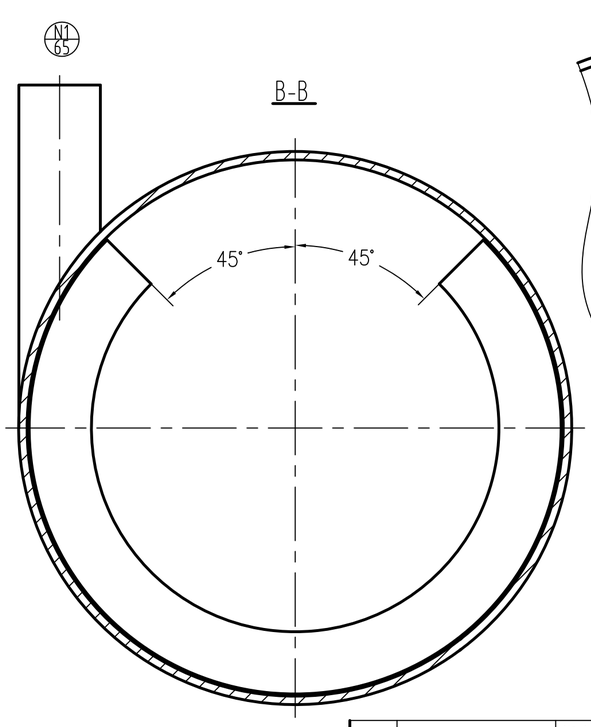
1:1

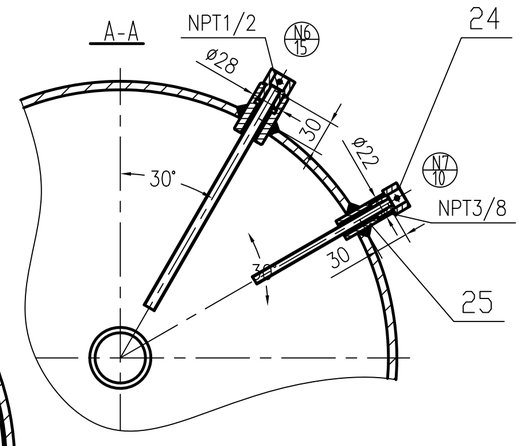


I

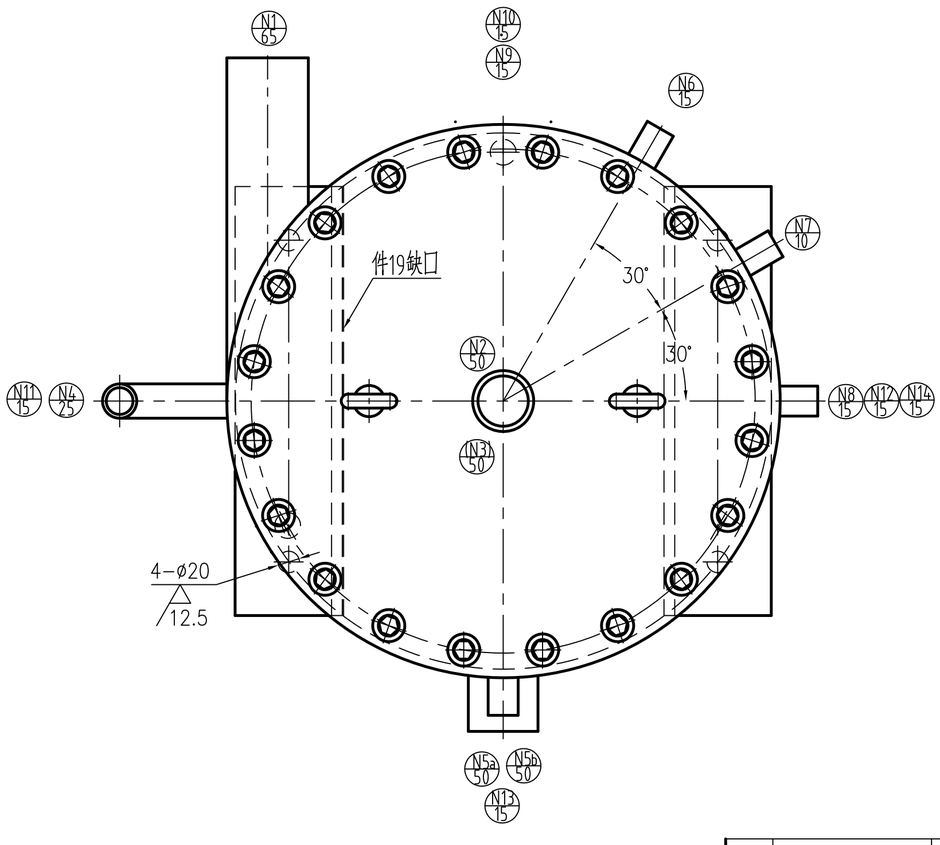
1:2

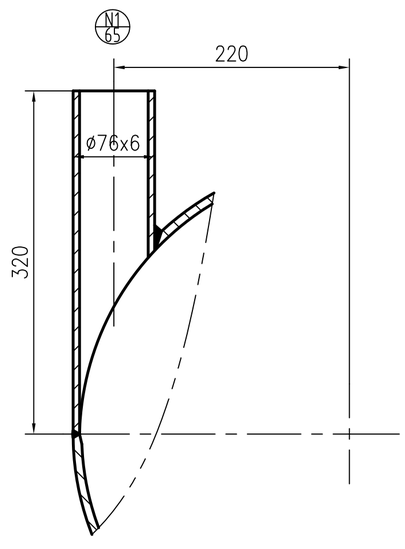






N1接管焊接形式





图纸目录：

1.YF500K-1，油分离器装配总图，A1一张

2.YF500K-2，油分离器零部件图，A1一张

3.YF500K-3，油分离器零部件图，A1一张

设计.制造与检验主要数据表						
设计.制造与检验所遵循的规范标准	TSG R0004-2009《固定式压力容器安全技术监察规程》					
	NB/T47012《制冷装置用压力容器》					
设计参数			制造与检验要求			
容器类别		II类	通用要求	1.除注明外,焊接接头采用全焊透结构并符合HG/T20583-2011中有关规定,角焊缝焊脚尺寸按较薄钢板的厚度,法兰的焊接按相应法兰标准. 2.油漆,包装和运输按JB/T4711-2003《压力容器涂敷与运输包装》规定.		
设计压力	（MPa）	2.0				
工作压力	（MPa）	1.7				
设计温度	（°C）	120				
工作温度	（°C）	110				
介质名称		R717 润滑油	焊接规程: NB/T47015-2011			
介质特性		低毒	焊材	母材	焊条牌号	
主要受压元件材料		Q245R,Q345R		碳钢与碳钢之间	J427	
主要材料标准		GB713		不锈钢与不锈钢之间	A102	
腐蚀裕度	（mm）	1		碳钢与低合金钢之间	J507	
焊接接头系数		1	无损检测	检测标准: NB/T47013.2		
全容积	（m^3）	0.3		焊接接头类别	检测方法	检测比例	技术等级	合格级别
安全阀启跳压力	（MPa）	1.8		A,B	RT	100%	AB	II
安全阀型号		A62H20-25		C,D	/	/	/	/
设计预期使用年限	（年）	20	试验	气压试验压力 （MPa）	2.3			
管口及支座方位		按本图		气密性试验压力（MPa）				
铭牌方位		按本图	热处理要求		不需要			

其它要求

1.设备检验合格后，对外所有开口均封闭，以防异物进入，筒体内部保留0.05MPa的干燥高纯度氮气保压。

2.设备制造完成后，外表面应进行抛丸处理，再喷涂底漆、面漆各二道，颜色按合同要求规定。

3.钢材切割周边50%。

注：三电加热器接口的安装尺寸以电加热棒护套尾部不相碰为准。

管口表

符号	公称尺寸	公称压力	连接标准	法兰型式	连接面型式	用途或名称	接管外伸长度
N1	65				焊接	进气口	见图
N2	50				焊接	出气口	100
N3	50				焊接	出油口	100
N4	25				焊接	安全阀口	见图
N5a~b	50		M52×2		螺纹	视液镜口	50
N6	15		NPT1/2		螺纹	加热器接口	30
N7	10		NPT3/8		螺纹	温控器接口	30
N8	15		NPT1/2		螺纹	排气温度检测口	30
N9	15		NPT1/2		螺纹	排气压力检测口	20
N10	15		NPT 1/2		螺纹	导气口	30
N11	15		NPT 1/2		螺纹	回油口	30
N12	15		NPT 1/2		螺纹	检修口	30
N13	15		NPT 1/2		螺纹	加油口	30
N14	15		NPT 1/2		螺纹	油位传感器	30

序号	代号	名称	数量	材料	单件重量	总计重量	备注
20		视液镜接头M52X2	2	20	0.5	1	
19	YF500K-2	挡板II	1	Q235B		8.9	
18		铭牌座	1	组合件		/	
17	YF500K-2	安全阀接管ø32x3.5	1	20		0.6	
16	GB/T3452.1	O型密封圈（ø425X7）	1	硅橡胶		/	
15	YF500K-3	上端盖	1	Q345R		73.6	
14	GB/T8163	接管ø57X5	1	20		1.1	
13	GB/T825	吊环螺钉M12	2	A2-70	0.8	1.6	
12	GB/T70.1	内六角螺钉M20X55	20	8.8级	0.15	3	
11	YF500K-3	凸缘	1	Q345R		28.5	
10	YF500K-3	滤芯安装架	1	组合件		21	
9	GB/T14383	螺纹接头NPT1/2	6	20	0.2	1.2	L=40
8	YF500K-2	隔板	1	Q235B		3.3	
7	YF500K-2	滤芯	1	06Cr19Ni10		/	
6	YF500K-2	固定架	2	Q235A	1.75	3.5	
5	YF500K-2	挡板I	1	Q235B		2.5	
4	YF500K-2	进气管ø76X6	1	20		3.3	
3	GB713	筒体ø516X8	1	Q245R		140	L=1390
2	GB/T25198	椭圆封头EHA500X8	1	Q245R		19.6	
1	YF500K-2	支座	2	焊接件	12.6	25.2	
25	GB/T14383	螺纹接头NPT3/8	1	20		0.3	L=50
24	YF500K-2	温度控制器护套	1	焊接件		0.8	
23	GB/T8163	接管ø57X5	1	20		0.8	
22	YF500K-2	电加热棒护套	1	焊接件		1.1	
21	GB/T14383	螺纹接头NPT1/2	1	20		0.3	L=50

设备净质量	(kg)	330	
其中	不锈钢质量	(kg)	
空质量	(kg)		
操作质量	(kg)		
最大可拆件质量	(kg)		

Snowkey®

福建雪人股份有限公司

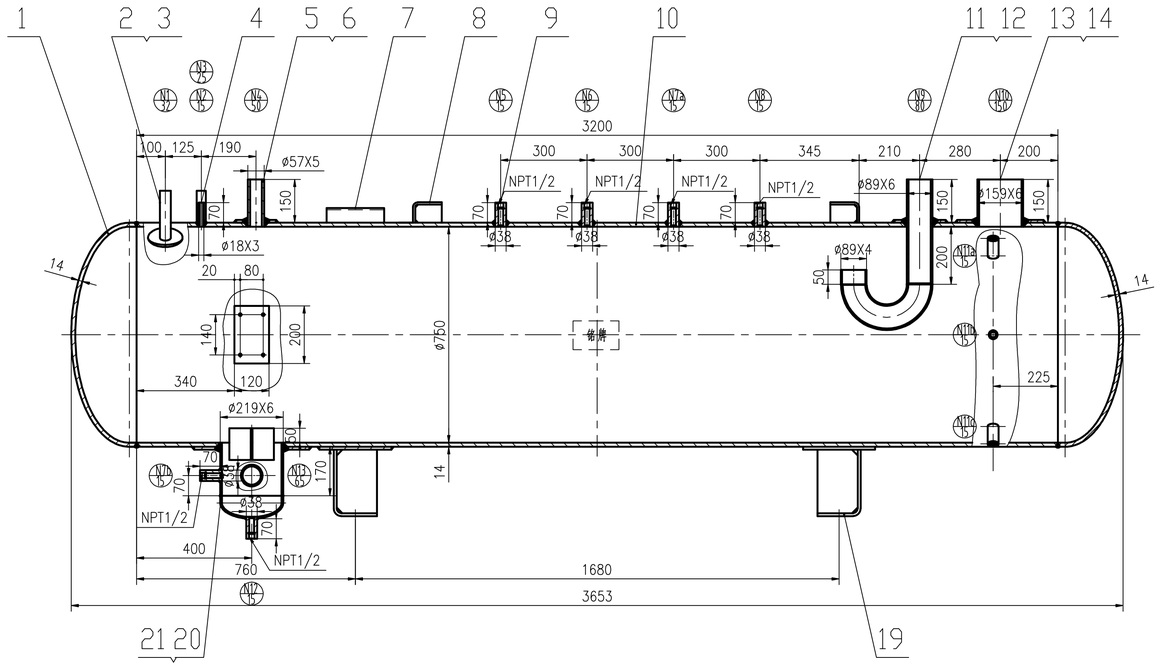
设计			标准化		
绘图			工艺		
校核					
审核			批准		

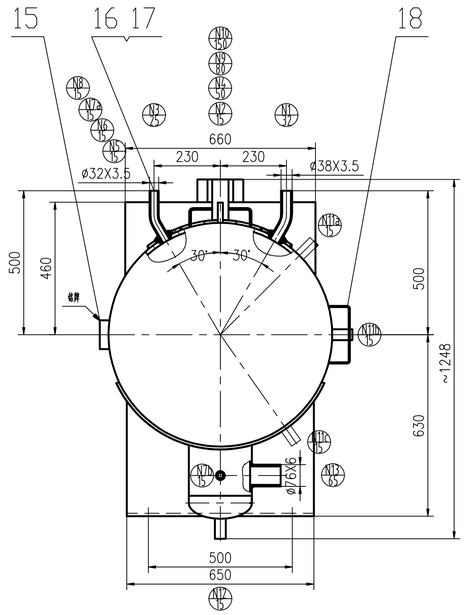
油分离器

DN500 V=0.3m^3

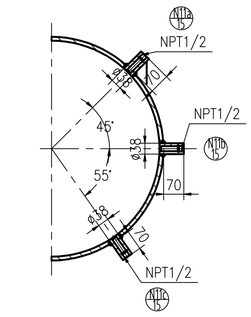
装配总图

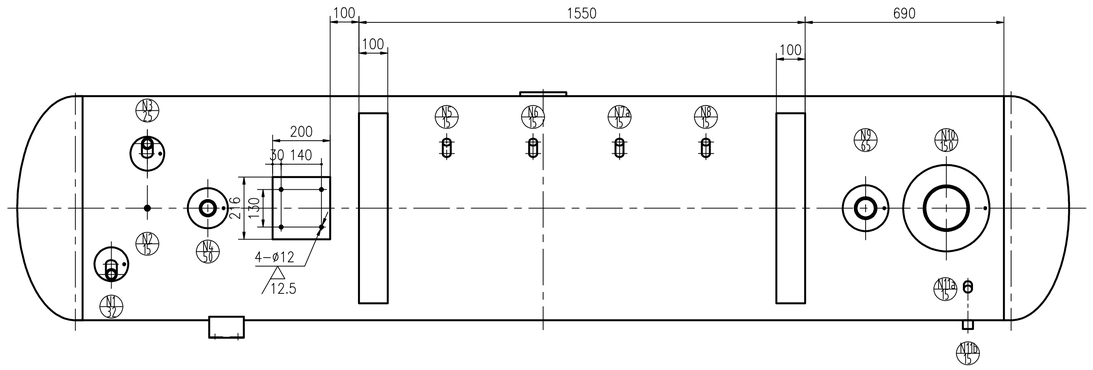
设计项目	
设计阶段	加工图
YF500K-1	
比例 1:4	第 1 张 共 3 张 2016年 0版



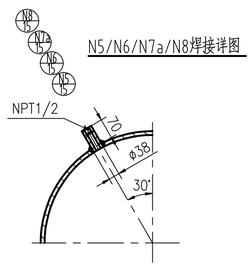


N11abc焊接详图

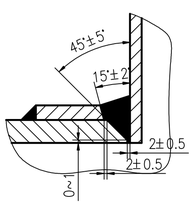




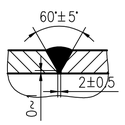
N5/N6/N7a/N8焊接详图



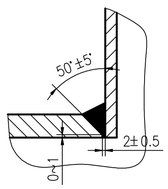
带补强圈开孔焊缝形式 1:2



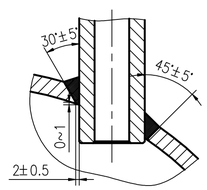
对接焊缝形式 1:2



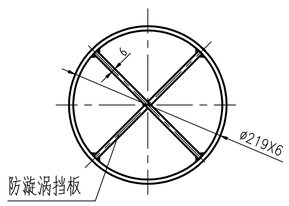
不带补强圈开孔焊缝形式 1:2



非径向开孔焊接形式 1:2



K向 1:4



图纸目录

1.WZE1540-1，CO2储罐装配总图 A1一张;

2.WZE1540-2，CO2储罐零部件图A1一张;

3.WZE1540-3，CO2储罐零部件图A2一张.

设计.制造与检验主要数据表

设计.制造与检验所遵循的标准规范	GB150.1~150.4-2011《压力容器》
	TSG R0004-2009《固定式压力容器安全技术监察规程》

设计参数		制造与检验要求		
容器类别	II类	通用要求	1.除注明外,焊接接头采用全焊透结构并符合HG/T20583-2011中有关规定,角焊缝焊脚高度按较薄钢板的厚度,法兰的焊接按相应法兰标准.	
设计压力 (MPa)	4.5			
工作压力 (MPa)	4.0		2.油漆,包装和运输按JB/T4711-2003《压力容器涂敷与运输包装》规定.	
设计温度 (°C)	-39			
工作温度 (°C)	-38			
物料名称	二氧化碳	焊材	焊接规程: NB/T47015-2011	
物料特性	无毒		母材	焊条牌号
主要受压元件材料	16MnDR		碳钢与低合金钢之间的焊接	J507RH
主要材料标准	GB3531		低合金钢之间的焊接	J507RH
腐蚀裕度 (mm)	1		低合金钢与不锈钢之间	A302
焊接接头系数	1			
全容积 (m^3)	1.54	无损检测	检测标准: NB/T47013.2	
安全阀开启压力(MPa)	4.2		焊接接头类别	检测方法 / 检测比例 / 技术等级 / 合格级别
安全阀型号	A62H32-63		A,B	RT / 100% / AB / II
设计预期使用年限(年)	10		C,D	
保温层材料	橡塑	试验	气压试验压力(MPa)	4.95
保温层厚度 (mm)	65		气密性试验压力(MPa)	/
管口及支座方位	按本图		热处理要求	不需要

其它要求

1.设备检验合格后,对外所有开口均封闭,以防异物进入.筒体内部保留0.05MPa的干燥高纯度氮气保压;

2.设备制造完成后,外表面应进行抛丸处理,再喷涂底漆、面漆各二道,颜色按压缩机组技术部要求;

3.钢材切割周边 25/.

管口表 安全阀口

符号	公称尺寸	公称压力	连接标准	法兰型式	连接面型式	用途或名称	接管外伸长度
N1	32	/	/	/	焊接	安全阀口	见图
N2	15	/	/	/	焊接	回液口	70
N3	25	/	/	/	焊接	放气口	见图
N4	50	/	/	/	焊接	进气口	150
N5	15	/	NPT1/2	/	内螺纹	检修口	70
N6	15	/	NPT1/2	/	内螺纹	测压口	70
N7ab	15	/	NPT1/2	/	内螺纹	测温口	70
N8	15	/	NPT1/2	/	内螺纹	冲注口	70
N9	80	/	/	/	焊接	进液口	150
N10	150	/	/	/	焊接	出气口	150
N11abc	15	/	NPT1/2	/	内螺纹	液位控制器口	70
N12	15	/	NPT1/2	/	内螺纹	排污口	70
N13	65	/	/	/	焊接	出液口	100

序号	代号	名称	数量	材料	单件重量	总计重量	备注
10	GB3531	筒体ø778X14	1	16MnDR		844.03	
9	WZE1540-2	接头NPT1/2(6000级)	9	06Cr19Ni10	0.39	3.51	
8	WZE1540-2	冷凝蒸发器支架	1	焊接件		7.6	
7	WZE1540-3	经济器支架	1	Q235B		3.26	
6	WZE1540-2	补强圈DN50X10-C	1	16MnDR		0.8	
5	GB6479	无缝管ø57X5	1	16Mn		1.05	
4	GB6479	接管ø18X3	1	16Mn		0.09	
3	WZE1540-2	补强圈DN32X10-C	1	16MnDR		0.69	
2	WZE1540-2	安全阀接管ø38X3.5	1	16Mn		0.6	
1	GB/T25198	椭圆封头EHA750X14	2	16MnDR	74.4	148.8	

21	WZE1540-2	补强圈DN200X10-C	1	16MnDR		6.8	
20	WZE1540-2	出液包	1	焊接件		15.08	
19	WZE1540-3	支座	2	焊接件	36.46	72.92	
18	WZE1540-3	油回热器支架	1	Q235B		1.2	
17	WZE1540-2	补强圈DN25X10-C	1	16MnDR		0.6	
16	WZE1540-2	排气口接管ø32X3.5	1	16Mn		0.5	
15		铭牌座	1	组合件		/	
14	WZE1540-2	补强圈DN150X10-C	1	16MnDR		3.3	
13	GB6479	接管ø159X6	1	16Mn		3.74	
12	WZE1540-2	补强圈DN80X10-C	1	16MnDR		0.86	
11	WZE1540-2	进液口接管	1	焊接件		5.42	

设备净质量 (kg)	1125
其中 不锈钢质量 (kg)	3.5
空质量 (kg)	
操作质量 (kg)	
最大可拆件质量 (kg)	

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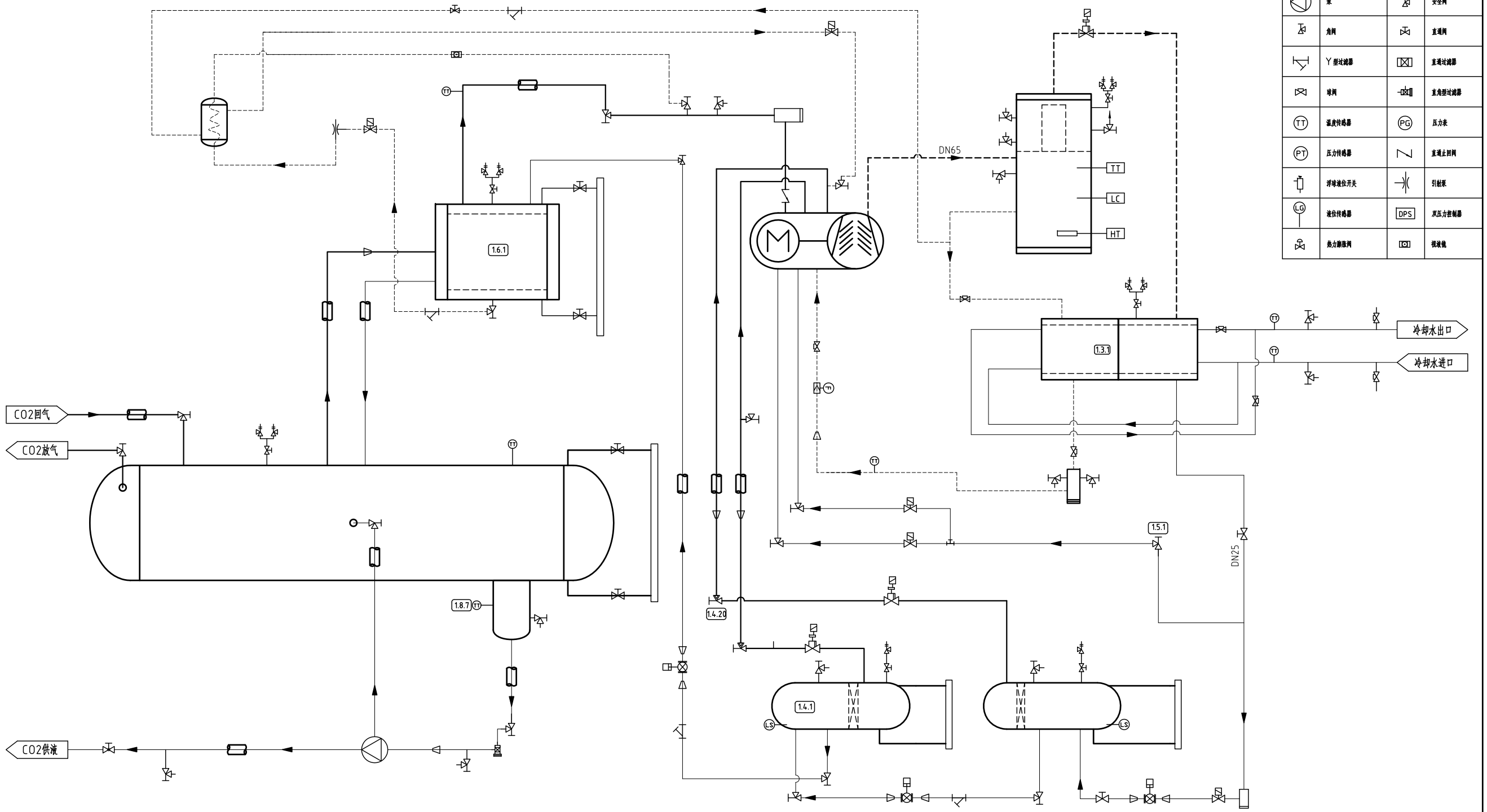
设计		标准化		
绘图		工艺		
校对				
审核		批准		

CO_2储罐 DN750 V=1540L 装配总图

设计项目	
设计阶段	加工图
WZE1540-1	
比例 1:10	第 1 张 共 3 张 2016年 0版

日期 | 姓名 | 专业 | 日期 | 姓名 | 专业

审核 | 校核 | 修改 | 修改内容 | 日期 | 序号



图例

图例	名称	图例	名称
M	电机		电磁阀
	泵		安全阀
	角阀		直通阀
	Y型过滤器		直通过滤器
	球阀		直角型过滤器
TT	温度传感器	PG	压力表
PT	压力传感器		直通止回阀
	浮球液位开关		引射原
LG	液位传感器	DPS	双压力控制器
	热力膨胀阀		视液镜

油管 排气管 吸气管 液体管

技术要求：

1、制冷剂低温段（经济器、回气管、经济器后供液管、经济器回气管路）保温，厚度为25mm；

2、CO2储罐、CO2冷凝蒸发器保温厚度为64mm，CO2管路保温厚度为25mm。

标记	处数	分区	更改文件号	签名	年月日
设计			标准化		
校对					
审核					
工艺			批准		

系统流程图

阶段标记	重量	比例

共 张 第 张

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