DEMONSTRATION PROJECT FOR CONVERSION FROM HCFC-22 TECHNOLOGY TO AMMONIA/CO2 TECHNOLOGY IN THE MANUFACTURE OF TWO-STAGE REFRIGERATION SYSTEMS FOR COLD STORAGE AND FREEZING APPLICATIONS AT YANTAI MOON GROUP CO. LTD.

FINAL REPORT

March, 2014

Executive Summary

Demonstration project for conversion from HCFC-22 technology to Ammonia/CO2 technology in the manufacture of two-stage refrigeration systems for cold storage and freezing applications at Yantai moon group co. Ltd. was approved by the 60th Executive Committee meeting at a funding level of US $ 3,964,458.

This demonstration project was successful completed, and established the suitability of Ammonia/CO2 technology as a viable replacement for HCFC-22 technology in the manufacture of integrated two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd.

The project covers product redesign and development, production line conversion, process tooling modifications, testing and performance evaluation, product trials, prototype testing, production line conversion, technical assistance and training, to convert one production line of capacity 100 units annually.

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

1. Introduction

In 2007, the 19th Meeting of Parties of the Montreal Protocol agreed on accelerated phase-out of HCFCs. To achieve the compliance goal, China is implementing HCFCs phase-out sector plan in the Industrial & Commercial Refrigeration and Air-conditioning (ICR) sector from 2012. The Yantai project was established as a demonstration earlier in 2010 for preparation and support of the sector plan implementation.

The Executive Committee approved the Yantai demonstration project at the 60th meeting in 2010 with a funding level of US $ 3,964,458. The project's implementing international agency is UNDP, and implementing national agency is Foreign Economic Cooperation Office (FECO), Ministry Of Environmental Protection, China.

The objective of this demonstration project is to establish the suitability of Ammonia/CO_2 technology as a viable replacement for HCFC-22 technology in the manufacture of two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd.

As a result of the conversion project, about 250 tons of HCFC consumption will be phased out, reducing greenhouse gas emission by 1.66 million tons CO2 eq.

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 2008 HCFC consumption in the sector was about 42,000 metric tonnes.

The industrial and commercial freezing and refrigerating equipment sub-sector (including compressor condensing unit) covers applications widely used in food refrigeration, industrial refrigeration systems, fruit and vegetable preservation, food processing and infrastructure construction projects. With improving living standards, the demand for food processing and cold storages infrastructure is increasing at an annual rate of over 10%. Due to sustained economic development, oil and chemical industry, energy, construction and other infrastructure-related investments are rising rapidly, enhancing the demand in emerging market. The demand for industrial refrigeration equipment in pharmaceuticals, mine freezing, water dams and coal-bed gas liquefaction is also expanding. The current and potential demand for large-scale low-temperature freezing and cold storage equipment in all these fields is significantly high. In recent years, the average annual growth rate of large-scale industrial freezing and cold storage equipment has been over 15%. The total HCFC consumption in this sub-sector during 2008 was about 4,000 metric tonnes, making it one of the largest sub-sectors in the ICR sector.

Yantai Moon Group Co. Ltd. was established in 1956, specializing in manufacturing of air conditioning and refrigeration products and engineering design, installation, commissioning and technical advisory services in the areas of frozen foods, food processing, industrial refrigeration, central air conditioning and fruit and vegetable preservation technologies. In 1998, Yantai Moon Group Co. Ltd. was listed on Shenzhen Stock market. The enterprise has independent intellectual property rights for some models of its refrigeration compressor manufacturing technology. Yantai Moon Group Co. Ltd. is located in the Shandong province and employs 2,989 persons, of which 640 are technical staff. Yantai Moon Group Co. Ltd. focuses on self-reliance in technology development, but at the same time also has many partnerships with international companies, to bring the latest technologies into the Chinese market. Yantai Moon Group Co. Ltd. offers integrated systems for Freezing and cold storage equipment, Industrial refrigeration systems and Central air-conditioning equipment etc.

In 2009 Yantai Moon Group Co. Ltd. manufactured the following HCFC-22 based integrated refrigeration systems:

No	Product Line	Evaporating temperature (^{o}C)	Quantity (Nos.)	HCFC consumption (metric tonnes)
1	Water Chillers	+2	190	N/A
2	Brine Chillers	-15	320	N/A
3	Low-temperature secondary inlet	-25 to -40	120	N/A
4	Low-temperature two-stage	-35 to -55	100	250

Of the above, the last, namely, two-stage low-temperature refrigeration systems (highlighted above), each with an average HCFC-22 charge quantity of about 2,500 kg, is the target for conversion in the current project.

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-507	3,900	Low temperature applications	High GWP. Azeotropic non-flammable blends of HFC-125 and HFC-143a. Refrigerating capacity comparable to R-502. Good heat transfer characteristics at low temperatures. Synthetic lubricants needed.

Comprehensive considering technical factors, commercial factors, health and safety factors, and environmental factors, Yantai Moon Group Co. Ltd. selected a combination of Ammonia/ CO_2 in a cascade design as the technology of choice for its low-temperature two-stage integrated refrigeration systems, considering the favorable environmental and thermodynamic properties of these two alternatives.

1.3 Technical Solution

The NH3/CO2 cascade refrigeration system is constituted by two separate refrigeration circuits; the high temperature circuit and the low-temperature circuit. The low temperature circuit with CO2 as refrigerant is used for the actual cooling. The high temperature circuit with NH3 as the refrigerant is used to condense the CO2 of the low temperature circuit. The two circuits are thermally connected to each other through a cascade condenser, which acts as an evaporator for the high temperature circuit and a condenser for the low temperature circuit. After absorbing heat from the brine in the CO2 evaporator, the refrigerant CO2 in the low temperature circuit is compressed in the CO2 compressor, which increases the enthalpy of CO2. The discharged CO2 refrigerant from the compressor rejects the heat to NH3 of the high temperature circuit in the cascade condenser. Then the cooled CO2 refrigerant is throttled by the expansion valve, and enters the CO2 evaporator. The heated NH3 in the cascade condenser is compressed in the NH3 compressor, which increases the enthalpy of NH3. The discharged NH3 refrigerant from the high temperature NH3 compressor unit flows into the NH3 condenser, in which NH3 rejects the heat to the cooling water system or air cooled condenser. The relevant schematic is as below:

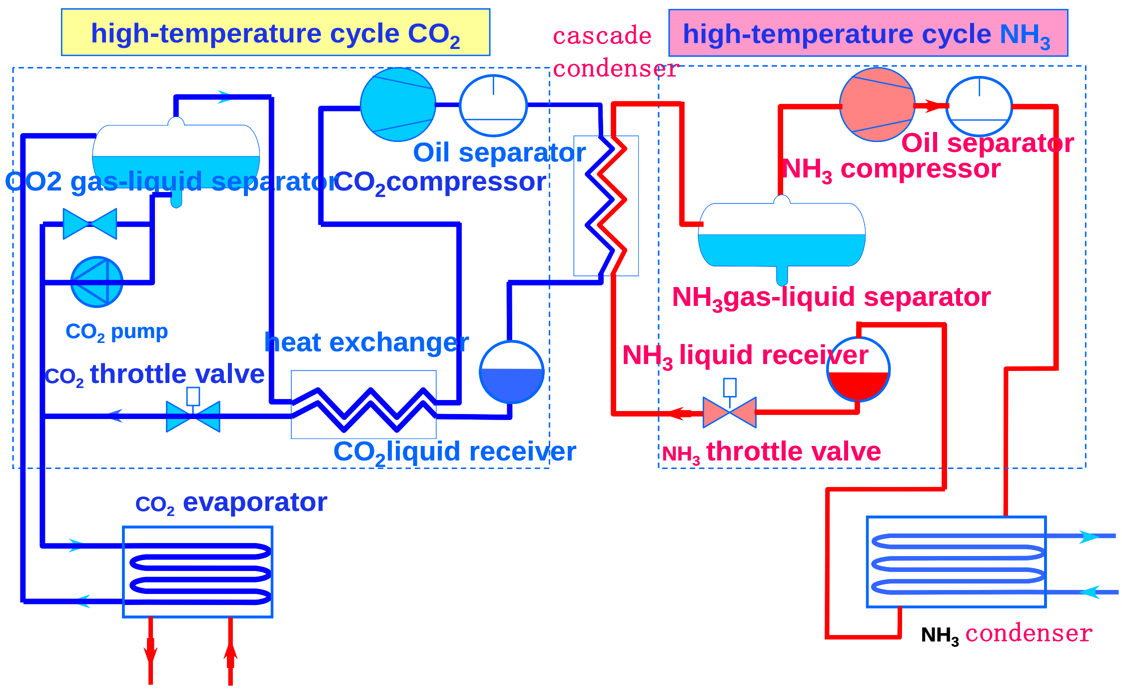

Fig 1. System schematic

As the characteristics of CO_2 are different from conventional low-temperature refrigerants, the key points of this technical solution are as follows:

- Develop intermediate-pressure compressor with CO_2 as the refrigerant;
- Design and manufacture mid-pressure vessel for higher pressure;
- Develop CO_2 heat exchangers which match large unit volume refrigeration capacity and high latent heat of $CO_{2;}$
- Design and develop heat exchangers of the low-temperature side which can withstand high pressures and low temperature;
- Develop fully automatic, safe, efficient and reliable control system for the refrigeration system.

2. Project Implementation

After the project was approved in 2010, FECO and UNDP signed the Project document in January 2011, and the Contract between Yantai Moon Group and FECO was signed in May 2011. After one year and a half period of implementation, the conversion project was completed by the end of 2012, and all the progress milestones required were reached and verified by the end of 2012. The project successfully passed national acceptance in July, 2013, and the production line is commercial running now.

According to the project implementation plan, the following activities were carried out: Product and process redesign, Modification of production lines, Modification of test devices for product performance, Manufacturing of prototypes, Personnel training, and technology dissemination, etc.

2.1 Product and process redesign

The project completed redesign of NH_3/CO_2 cascade refrigeration systems with twin-screw compressors by November 2011, including design of CO2 compressors (see the table below), design of system components in the CO2 refrigeration system, and modification of the existing product lines of compressor and pressure vessels, design of test devices for CO2 refrigeration system, design of user demonstrations for the early users of NH_3/CO_2 cascade refrigeration systems.

The three specifications of CO2 screw compressors for the project are as below:

Model	Theoretical displacement (m3/hr)	Status
LG12R	152	Design completed
LG16R	300	Design completed
LG20R	600	Design completed

The details of redesigns are as follows:

The refrigeration system design parts:

- Design of screw compressor rotor profiles and structural design of compressor
- Design of high pressure vessel matching with CO2 screw compressor units
- Design of pressure vessels for high pressure, high-pressure low-temperature and other components matching with NH_3/CO_2 cascade refrigeration system with twin screw compressors
- Design of electric control and application software control
- Design of performance tests
- Design of demonstration for the first user of NH_3/CO_2 cascade refrigeration system

The process design parts:

- Design of casting and forging manufacturing process for CO2 screw components;
- Design of CO2 screw compressor shell strength test device;
- Design of strength test device for CO2 pressure vessel of high-pressure low-temperature;
- Design of machining process includes design of CO2 compressor housing, rotors, oil pump parts and tube sheet of heat exchanger;
- Design of the welding technology of CO2 pressure vessel of high-pressure low-temperature, shell and tube heat exchanger;
- Design of CO2 finned tube air cooler for high pressure and low temperature process including design of outer shell sheet metal process and expanding tube process;
- Design of product assembly process, including assembly, pipe connections, air tightness testing

- Blank manufacturing of CO2 compressor components, including design of casting model, casting box, forging dies
- Design of CO2 finned tube of high-pressure low-temperature fin dies, dies baffle for punching, and half of the stamping dies for baffle;
- Design of special high-strength alloy machining tools for the high-strength components such as CO2 compressor housing, special measuring tools and special inspection equipment tools, including design of special cutter for compressor rotor machining, a variety of special boring tool and milling cutter for compressor shell processing, special boring tool for tube plate holes, fin-hole punch, as well as the design of special measuring tools and detection tools for machining process
- Special process equipments for CO2 compressor and high-pressure low-temperature CO2 pressure vessel, including fixtures for all kinds of mechanical processing, positioning fixtures of welding and expansion joint, working sleeves matching with the products and station apparatus for turnover and store of parts;
- Design for modifying product line of the existing conventional refrigeration system, including processing arrangements, products site planning and special equipment layout for the added CO2 compressors and high-pressure low-temperature CO2 pressure vessels

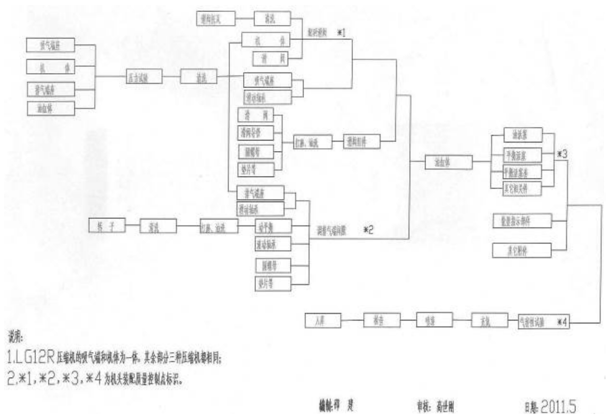

Fig 2. Technical process diagram

存档申请单

YB/Y(Z)10.006－0

申请部门：　　2011 年 5 月 17 日　　编号：

产品名称		产品代号		
总张数	A_0	A_1	A_2	A_3	A_4
存档时间	(　　)年	等级(　　)	一般(✓)	机密(　　)	绝密(　　)
备注	设计规范				入库确认
申请人		接收人		批准人	

Fig 3. Drawings documents recording

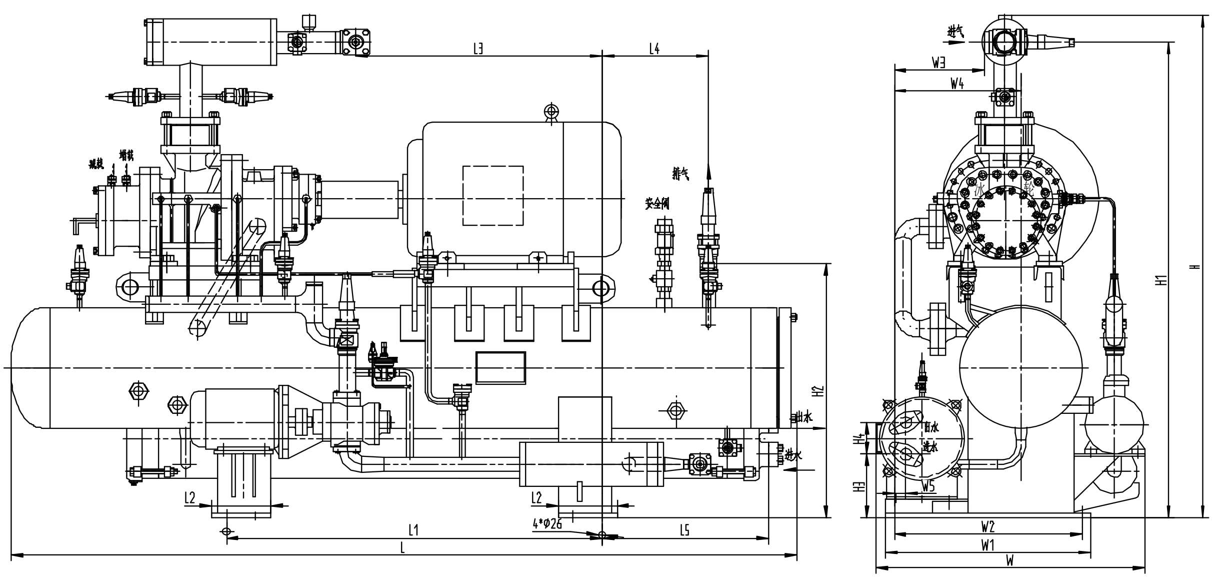

Fig 4. System structure

The technical programs were partly supported by university research institutions, and all the technical programs were passed internal assessment.

2.2 Modification of production lines

The production lines modification is composed of two key parts, compressors producing lines modification and pressure vessel producing line modification.

2.2.1 Compressors producing lines modification

The former compressor producing lines are at designed working pressure is 20 bar and the CO_2 compressor designed pressure is 50 bar. So the producing line were modified according to the high pressure requirements, and some dedicated devices were manufactured or procured and installed in the producing line, including high-strength processing tools, cutters, compressor cast models and cast boxes, etc.

Fig 5. Compressor housing cast model and rotor cast box

Fig 6. Compressor tooling and cutters

Totally 44 cast models (16 for shell, 6 for rotors and 22 for other) and 44 cast boxes (16 for shell, 6 for rotors and 22 for other) are manufactured based on the new technical renovation. The processing tools and the cutters have been purchased and positioned in the compressor product line, including 49 sets of tools and 13 kinds of cutters that, more than 16000 sets of cutters, cover all processes of compressor manufacturing.

2.2.2 Pressure vessel producing line modification

As the former manufacturing lines of the pressure vessels was below the pressure of 20 bar, the relevant parts of vessel producing lines were modified, including production process link of the added high-pressure low-temperature CO2 pressure vessel, such as CO2 oil separator, CO2 liquid receiver, oil filters, suction filters, tube processing and welding for shell and tube heat exchanger, oil cooler, cascade heat exchanger, CO_2 regenerator, heat exchanger for defrost, tube expander, welding and assembly for CO_2 shell and tube evaporator.

As materials of tube sheet and cylinder for the CO_2 pressure vessels of high-pressure low-temperature are different from the conventional components materials, the corresponding process equipment and control were added during production and test process, such as welding, expanding joint and inspection.
The strength test and air tightness test were built for the high-pressure low-temperature pressure vessel. And the test environment of cold shock in the low temperature was also built up. Welding equipment of stainless steel container and high-pressure low-temperature vessel were added, as well as welding test plate and assessment method of high-pressure low-temperature vessel.

Fig 7. Welding machine


Fig 8. Tooling


Fig 9. High pressure test equipment for CO_2 vessel

2.3 Modification of test devices for product performance

As a new refrigeration system, the high temperature refrigeration system can be tested in the existing performance test laboratory after product commercialization, while the product test device of the CO_2 refrigeration system requires new facility construction.

The modification of test equipment was completed in 2012. The test devices of CO_2 compressor housing strength and air load were added.

Fig 10. Testing equipment

2.4 Manufacturing of prototypes

Prototype assembling of two types of compressors and manufacturing of sample products were finished in 2012. Two types of prototype compressors have been assembled and sample products were also manufactured.

Fig 11. L20R compressor and system

Fig 12. L20R800 compressor and system

Fig 13. Prototype

The performance parameters of prototypes are as follows:

LG12R (152.4 m3/h)

Te \ Tc	Refrigerating capacity(kW)					Power(kW)				
	-5	-10	-15	-20	-25	-5	-10	-15	-20	-25
-55	90.6	110.7	123.8	139.1	182.3	77.1	59.4	45.4	39.4	34.3
-50	118.8	140.0	160.3	181.6	227.8	80.3	62.3	48.2	41.4	34.9
-45	156.1	182.4	207.6	226.3	273.0	69.1	56.1	46.8	40.4	32.7
-40	199.6	234.7	262.7	288.9		69.7	57.2	48.4	38.9	
-35	255.8	291.7	318.6	346.3		66.0	54.1	41.9	33.4	
-30	312.6	351.6	379.5	412.4		57.7	47.1	35.3	25.3	
-25	372.1	425.9	454.3	488.2		55.6	39.3	26.9	14.3	

LG16R（603.8 m3/h）

Te \ Tc	Refrigerating capacity(kW)					Power(kW)				
	-5	-10	-15	-20	-25	-5	-10	-15	-20	-25
-55	358.8	438.4	490.4	551.3	722.5	305.6	235.4	180.0	156.2	135.8
-50	470.8	554.5	635.0	719.4	902.8	318.1	247.0	191.1	164.0	138.4
-45	618.6	722.6	822.5	896.6	1081.6	273.7	222.1	185.3	160.1	129.7
-40	790.9	929.8	1041.0	1144.5		276.3	226.6	191.8	154.0	
-35	1013.7	1155.9	1262.4	1372.2		261.7	214.4	165.8	132.2	
-30	1238.5	1393.1	1503.5	1634.2		228.8	186.7	139.7	100.4	
-25	1474.4	1687.6	1799.9	1934.5		220.4	155.8	106.6	56.8	

LG20R(803.1 m3/h）

Te \ Tc	Refrigerating capacity(kW)					Power(kW)				
	-5	-10	-15	-20	-25	-5	-10	-15	-20	-25
-55	477.2	583.1	652.2	742.3	972.5	406.5	313.0	239.4	210.4	182.7
-50	626.1	737.5	844.6	956.8	1200.7	423.0	328.5	254.2	218.2	184.1
-45	822.7	961.1	1093.9	1192.4	1438.5	364.0	295.4	246.5	213.0	172.5
-40	1051.9	1236.7	1384.5	1522.2		367.5	301.4	255.1	204.8	
-35	1348.2	1537.4	1679.0	1825.0		348.1	285.1	220.6	175.9	
-30	1647.2	1852.7	1999.7	2173.4		304.2	248.3	185.8	133.5	
-25	1961.0	2244.4	2393.9	2572.9		293.2	207.2	141.8	75.6	

2.5 Personnel Training

The personnel trainings were carried out during project implementing, and the trainings are including design, production, marketing and debugging. The following personnel were included in the training:

- Related designers, technicians.
- Production management persons, manufacturing workers.
- Product application engineer.
- Technician for installation and debugging, equipments maintenance personnel.
- Related user operators, equipment administrative personnel.

Yantai Moon carried out a total of R&D personnel training 4 times, manufacturing personnel training 4 times, the marketing personnel training1 times, product application engineer training 3 times, the user training for equipment administrative personnel and equipment maintenance personnel 2 times. 734 persons were trained.

Designers and technicians training

Manufacturing workers training

Application engineer training

Equipment maintenance personnel training

Fig 14. Training

2.6 Technology Dissemination

Yantai Moon carried out several activities in technology dissemination to promote market. The details activities are as follows:

- Technical communication with engineering design companies, introduction of product, and promotion and recommendation plan.
- Technical communication with construction companies, product promotion and recommendation, and application technology.
- Application promotion in relevant industry associations.
- Organize product release conference, and display product and application technology.
- Communicate with government environmental protection departments to enhance publicity campaign.
- Advertisement and promotional brochures.

- Participate in exhibitions, such as International Refrigeration Exhibition in China, Chinese Fisheries Exposition, and Chinese Food Processing Exposition; display the product and application technology.
- Provide free technology, debug and maintenance to users of the demonstration project.

Totally, 13 times of technology exchange and products exhibition were organized and participated, such as Fujian Food Processing Exposition and Chengdu cold storage construction conference etc.

Fig 14. Technology Dissemination

2.7 Marketing

The producing line is commercial running. The NH3/CO2 cascade refrigeration systems have come into the markets, and about 60 units of refrigeration systems sales contracts were signed.

Fig 15. Running NH3/CO2 system in customer

3. Outcomes

The project has been completed; it has successfully passed national acceptance in July 2013. The production line is commercial running, and the IOC will be disbursed to enterprise in the next 2 years according to new products sales quality. The suitability of Ammonia/CO2 technology as a viable replacement for HCFC-22 technology in the manufacture of two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd.is established.

- The product and testing lab designs were completed in 2011. The tools and process equipment for the pressure vessel production line were installed.
- The design of key components and the production line were completed in 2012. The conversion of the production line was also completed in this year.
- The high pressure test equipment for CO2 vessel was completed in 2012. The prototype building and testing equipment were completed. Training and technology dissemination are finished.
- Training, technology communication, and product promotion including advertisements were completed in 2012.
- The project was audited by the National Audit Office in the first quarter of 2013.
- The financial and performance verifications, including the milestone verifications and the final verification, were completed.
- The producing line is under commercial production. The NH3/CO2 cascade refrigeration systems have come into the markets, and about 60 units of refrigeration systems sales contracts were signed.

4. Technical performance

- The normal range for large-scale low-temperature industrial refrigeration applications is between -35℃ to -55℃, and this is exactly the best operating evaporation temperature bracket for NH3/CO2 cascade refrigeration system, in which the NH3/CO2 system will has great efficiency.
- NH3/CO2 cascade refrigeration system technology can effectively address the toxicity exposure issue of ammonia. Comparing with the pure NH3 refrigeration system, the new systems use NH3 and CO2 cascade system and the toxicity is reduced greatly. The new system only use one tenth of quantity of the old system's NH3. Besides, HN3 is only cycle operating inside the refrigerating unit at the machine room which is separated from persons in the operator access area. And CO2 (non-toxic) is cycle operating inside the tubes from machine room and operator access area.
- Compared with normal refrigerating systems (R22, NH3), the system with CO2 as refrigerants can exert great efficiency in low temperature conditions. But in normal temperature condition, CO2 has some problems such as low efficiency, high pressure, large volume of system, and high cost.
- NH3/CO2 cascade refrigeration system technology can overcome the disadvantages of pure CO2 system and toxicity of NH3. Furthermore, the energy efficiency is promoted more than 20% compared with the old system.
- The system can be used at any normal climate conditions and produce low-temperature from 0℃ to -55℃.
- Most of the large-scale low-temperature refrigeration systems use open-type compressors and open system design, with a significant amount of leakage and low recovery rate of refrigerant during maintenance, thus annual consumption of HCFCs in servicing for such systems is very high. Thus, replacing HCFCs in such applications gains high priority from an environmental standpoint.

5. Project management and monitoring

The project was under the overall management and coordination of the Foreign Economic Cooperation Office, Ministry of Environment Protection of China. UNDP was the implementing agency for the project, which provided international coordination and technical assistance.

The project employs the Performance-based Payment (PBP) mechanism in its implementation. Under the PBP mechanism, the enterprise tasked to carry out the conversion would play the role as a key executer, which is responsible for all the activities related to the conversion. The procurement was organized fully in line with the marketing principle ensuring cost-effective and timely installation of equipment for NH3/CO2 systems based manufacturing operations.

FECO and UNDP were 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.

Before each payment, FECO invited independent experts to verify whether the performance for each milestone that the payment depends on have been satisfying. The verification reports were submitted and accepted by UNDP as the main supporting documents for requesting the installment of payment.

During the projects implementation, FECO and UNDP organized 4 verification missions combined with monitoring and evaluation at Yantai Moon factory (i.e., 25 November 2011, 19 February 2012, 18 June 2012 and 6 December 2012). The experts group included technology experts and finance experts, FECO staff and UNDP staff as well. The experts team traced the project implementation situations, evaluated the project technical issues and progress, and verified whether the performance for each milestone that the payment depends on have been satisfying. Each verification activity was carried out in a process of planning, preparation, data confirmation, technical material checking, on-the-spot investigation, result conformation and conclusion.

The project also passed national audit in March, 2013.

5.1 Project progress

The project was implementing smoothly according to the program schedule, and was completed by the end of 2012. It successfully passed national acceptance in July 2013 and national audit on site in March, 2013.

The capacity of the production line has been converted to use substitute refrigerants and is capable of manufacture the converted products. The converted products came into markets and have been put into use by users in Yantai, Weihai, and Dalian, etc. The market has expressed interest.

Each of milestones was achieved and verified, the details are as follows:

Milestones		Status
1st	Signing of the contract	FECO signed contract with the enterprise in May 2011
2nd	Designs of products and performance test lab; Installation of process equipment and tools of pressure vessel product line;	Finished and verified in November 2011.
3rd	Cast models and cast boxes; Completion of high pressure test equipment for CO2 vessel; Manufacturing of components of CO2 high-pressure low-temperature vessel for performance test equipment;	Finished and verified in February 2012.
4th	Positioning of special tools and special cutters for compressor product line; Installation and debugging of performance test equipment; Prototype assembling of two types of compressors; Manufacturing of sample products;	Finished and verified in June 2012.
5th	Reconstruction of rest device, and purchasing and manufacturing of test tolls of compressor product line; Reconstruction of pressure vessel product line; Training, technology communication, advertisement and project verification.	Finished and verified in July 2013.

5.2 Conversion cost

Total Project Costs

The total contract amount with the enterprise is US$ 3,698,236, including ICC US$ 2,490,936, and IOC US$ 1,207,300.

Incremental Capital Costs

The actual incremental capital costs for conversion was US$ 4,188,630, among which US$ 2,490,936 was funded by the MLF, and the US$ 1,697,694 was co-financed by the enterprise.

The details of ICC are as follows:

No.	Cost Head		Actual cost (US$)
1	**Product and process redesign**		
	System	System redesign	32,130.95
	Process	Process redesign	
	Miscellaneous	Documentation and research	
	Compressor	Compressor redesign	166,666.67
	Software	Heat exchange analysis software	93,133.14
	Certification	Testing and certification	49,019.61
		Sub-total	**340,950.37**
2	**Modification of production lines**		
	Compressor	Compressor parts casting model	148,962.42
		Compressor parts casting box	39,491.17
		Tooling for CO2 compressor	192,900.29
		Measuring and inspection tools	19,117.65
		CO2 compressor machining tool	500,578.38
		CO2 compressor casing test device	78,675.59
		Co2 compressor air load test device	180,392.16
	Pressure vessels	Equipment for stainless steel parts	110,351.31
		Tooling for stainless steel containers	16,425.16
		High-pressure testing of CO2 vessels	57,026.14
		Testing for CO2 U-tub	134,836.60
		Tooling for CO2 U-tube	
		Development cost for CO2 U-tube	
		CO2 high pressure air drying system	13,316.99
		Magnetic flaw detector for CO2 vessels	6,045.75
		Universal shock testing for CO2 vessels	5,555.56
		Impact testing for CO2 vessels	3,594.77
		Low-temperature test room	79,084.97
		Welding test plate for CO2 vessels	39,183.01
		Sub-total	**1,625,537.91**
3	**Modification of test devices for product performance**		
	Test devices	Materials and installation of test devices	910,926.47
	Pressure vessel parts	Components of pressure vessels ten types	
	Instruments	74 different test device instruments	
	Software	Test software and debugging	
	Consumables	Refrigerant and lubricants	
	Commissioning	Test device commissioning	
		Sub-total	**910,926.47**
4	**Manufacturing of prototypes**		

	CO2 compressor	Four sets/specification x 2 specifications	344,207.24
	Pressure vessels	Matching pressure vessels and parts	365,867.65
	Pressure vessels	System pressure vessels	377,366.38
	Ammonia system	High temperature ammonia system	-
	Controls	Electrical and other controls	32,065.48
		Sub-total	**1,119,506.75**
5	**Personnel training**		
	Training	Training for about 300 persons	62,847.88
		Sub-total	**62,847.88**
6	**Technology dissemination**		
	Workshop	Technology dissemination workshop	128,860.46
	Communication	Technology communication	
	Events	Participation in exhibitions	
		Sub-total	**128,860.46**
7	**Contingencies**	For enterprise	0
		Sub-total	0
ICC for enterprise		**TOTAL**	**4,188,630**
		Total fund by MLF	**2,490,936**
		Co-financing by enterprise	**1,697,694**

Incremental Operating Costs

The agreed total incremental operating costs calculated for one-year duration amount to US$ 1,207,300.
The production line is commercial running, and the IOC will be disbursed to enterprise in the next 2 years according to new products sales quantity. The data of IOC is preliminary value.

The cost for the baseline HCFC-22 based two-stage systems are summarized as below:

No.	Item	Cost (US$)
1	Low pressure screw compressor units	21,250
2	High pressure screw compressor units	14,779
3	Condenser	8,853
4	Siphon tank	1,338
5	High-pressure liquid receiver	2,470
6	Intercooler	1,853
7	Low-pressure cycle barrel	3,706
8	Canned motor pump	1,176
9	Piping and auxiliary materials	9,750
10	Valve	4,368
11	System control cabinet	3,176
Total		**72,720**

The cost for the NH3/CO2 cascade systems to replace the above would be as below:

No.	Item	Cost (US$)
1	NH_3 screw compressor units	15,000
2	Condenser	8,852
3	NH_3 liquid receiver	1,030
4	NH_3 oil receiver	250
5	CO_2 screw compressor units	15,808

6	CO_2 condenser evaporator	5,206
7	CO_2 gas-liquid separator	3,294
8	CO_2 Low-temperature cryogenic pumps	2,030
9	CO_2 liquid receiver	2,470
10	CO_2 heat exchanger	3,118
11	CO_2 auxiliary heat exchanger	2,059
12	Heat exchanger for defrosting	1,765
13	Heat source pump for defrosting	1,471
14	Auxiliary cooling units	4,426
15	Piping and auxiliary materials	6,338
16	Valve	7,794
17	System control cabinet	3,882
Total		**84,793**

6. Impact

The project was completed and 250 metric tonnes of HCFC-22 usage was phased out. Over a 15-year life-span of the refrigeration systems manufactured by the enterprise and covered by this project, direct and indirect emission reductions amounting to about 1.66 million CO2-eq tonnes will be achieved, thus contributing to protection of both the ozone layer and the climate system.

The technology route is innovative, the resulting product has significant advantages in terms of environment friendliness and energy efficiency, and the safety performance is greatly improved. Thus, the market prospect and competency of the products are sound. The project has been a good demonstration and promotion of advanced HCFC alternative technologies in the industrial and commercial refrigeration sector.