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EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
IMPLEMENTATION OF THE MONTREAL PROTOCOL
Seventy-second Meeting
Montreal, 12-16 May 2014

Addendum

STATUS REPORTS AND COMPLIANCE

This document is issued to **add** a section on projects with specific reporting requirements.

1. This section addresses the projects and activities for which specific reports were requested in previous meetings and those requiring the Executive Committee attention. These reports are arranged in the following parts:

Part V: HCFC demonstration projects

Part VI: Financial audit report for the halon, CFC production and foam sector plans in China

Part VII: National CFC phase-out management plan in the Philippines (financial report)

Part VIII: HCFC phase-out management plan for Nigeria (stage I, third tranche) (implementation plan for the conversion of foam manufacturing enterprises in the refrigeration sector)

Part IX: Implementation of the national CFC phase-out plan: policy and regulatory component, Islamic Republic of Iran

2. Each part contains a brief description on progress, and the Secretariat's comments and recommendations.

PART V: HCFC DEMONSTRATION PROJECTS

China: Demonstration sub-project for conversion from HCFC-22 to propane at Midea Room Air Conditioner Manufacturer Company (UNIDO)

Background

3. At its 61st meeting, the Executive Committee approved for China the demonstration sub-project for conversion of room air-conditioning (AC) compressor manufacturing from HCFC-22 to propane at Midea Room Air Conditioner Manufacturer Company[1]. Through decision 71/13, the Executive Committee noted the interim report of the sub-project[2] and requested UNIDO to submit a final report to the 73rd meeting, on the understanding that it would only contain preliminary data on incremental operating costs (IOC). In advance of the 73rd meeting, UNIDO has submitted to the 72nd meeting information on the IOC. A report combining all information will be provided to the 73rd meeting.

Progress report

4. The interim report submitted to the 71st meeting, related to the conversion of one production line to the manufacturing of room air-conditioners using HC-290 (propane) as refrigerant at Midea Room Air Conditioner Manufacturer Company, completed in July 2013. The activities had included production-line conversion, safety certification, development of new products and of the production process, certification by a safety auditor, and the activities to obtain certification for the product and the production line by the Chinese authorities. The report had provided insight only into the incremental capital cost (ICC) of the conversion.

5. The information on the IOC was provided in a table showing the main cost differences for various steps in the manufacturing and installation process. As a result, the IOC per unit could be determined. The submission also included a table with the time needed for specific steps in the production process; additional production time is directly linked to an increase in production cost. The IOC per air

[1] Document UNEP/OzL.Pro/ExCom/61/32
[2] Document UNEP/OzL.Pro/ExCom/71/6/Add.1

conditioner is US $41.95; at a charge level of 1.2 kg/unit (as per project proposal), this amounts to US $34.96/kg of HCFC-22 phase-out.

6. The conversion has led to some savings in IOC, in particular in the cost for the heat exchanger and the refrigerant. Forty-five per cent of the IOC is related the increased time needed for installation of one HC-290 unit (approximately 37 minutes more at a rate of US $34.10 per hour of technician time, the overall cost increase is above US $20). The second highest cost increase (about US $15 per unit) is related to the necessity to seal the electronic parts to avoid the possibility that flammable gas could be present where sparks could occur. The compressor is about US $7.50 more expensive than a similar model using HCFC-22, based on data from the manufacturer Guandong Meizhi Co. This compressor is purchased from a production facility converted in a separate demonstration project; however, no report about IOC is available from that project yet.

Secretariat's comments

7. The Secretariat queried whether the additional cost for the sealed electronic parts was based on a small-scale production or a mass production. In the view of the Secretariat, for a mass production of millions of units the component costs for parts tend to be dominated by the material costs only. UNIDO advised that the units are equipped with a gas-tight electronic box which is sealed with glue. UNIDO confirmed that the current costs are associated with the product initiation and are expected to decrease in the future. In addition, UNIDO advised that the methodology for applying the safety measures is also being refined.

8. The Secretariat also queried whether the compressor presents any upgrade in energy-efficiency as compared to the HCFC-22 compressor. UNIDO replied that the energy efficiency of the compressor is 2 to 3 per cent higher than the previously used HCFC-22 compressor. With this moderate improvement, the defining characteristic of the compressor remains largely unchanged, as stipulated in decision 61/44.

Impact

9. This demonstration project has been instrumental in the demonstration of HC-290 technology as an alternative for small-sized AC systems, in particular mono-split systems for the residential AC market. HC-290 almost entirely eliminates the global warming potential (GWP) of the refrigerant as compared to HCFC-22 or HFC-410A as the main alternative to HCFC-22 in AC applications. The demonstration project has directly led to the use of HC-290 as a major alternative to HCFC-22 in the room AC (RAC) sector of stage I of the HCFC phase-out management plan (HPMP) for China. In the related sector plan, currently nine conversion activities are under implementation with an aggregated consumption of 3,741 metric tonnes (mt) for the production of approximately 3.1 million units/year towards the use of HC-290. In addition, three compressor manufacturers are currently being supported to convert to HC-290 technology under the same sector plan. Another nine equipment manufacturers are supposed to be converted to HC-290 technology in the future. HC-290 is considered in several conversion projects in the AC sector as one possible option, but its use depends often on the availability of production kits to be purchased from other manufacturers, particularly when local manufacturers only assemble the kits to air conditioners, charge and quality-test them. These kits will only become available on the market once more manufacturers have converted their production and gained the necessary know-how in product design and production technology.

10. Information by UNIDO indicates that the energy-efficiency of the HC-290 system is similar to that of HCFC-22 technology. As compared to the continued use of HCFC-22, the phase-out of the 240 mt of HCFC-22 under this demonstration project together with the conversion activities to HC-290 under the HPMP (influenced by this demonstration project) will reduce the emission of greenhouse gases (GHG) by 7.01 million tonnes of CO_2 every year.

Secretariat's recommendation

11. The Executive Committee may wish:

(a) To note the additional information on the demonstration sub-project for conversion from HCFC-22 to propane at Midea Room Air Conditioner Manufacturer Company in China by UNIDO contained in document UNEP/OzL.Pro/ExCom/72/11/Add.1; and

(b) To request UNIDO to submit a final report to the 73rd meeting in line with decision 71/13.

China: Demonstration project for HFC-32 technology in the manufacture of small-sized commercial air-source chillers/heat pumps at Tsinghua Tong Fang Artificial Environment Co., Ltd. (UNDP)

Background

12. At its 60th meeting, the Executive Committee approved for China the demonstration project for HFC-32 technology in the manufacture of small-sized commercial air-source chillers/heat pumps at Tsinghua Tong Fang Artificial Environment Co., Ltd., implemented by UNDP[3]. Through decision 71/15, the Executive Committee noted the interim report on the demonstration project[4] and requested UNDP to submit a final report to the 72nd meeting, on the understanding that it would only contain preliminary data on the IOC. A final report on the demonstration project has been submitted by UNDP to the 72nd meeting, and is annexed to this document.

Progress report

13. The conversion from HCFC-22 to HFC-32 technology at Tsinghua Tong Fang Artificial Environment Co., Ltd. was successfully completed. The project included product re-design and development, laboratory testing and performance evaluation, prototype testing, modifications of manufacturing equipment as well as new equipment, safety and other measures to handle the flammability of HFC-32. The demonstration project was to assess the technical feasibility and economic viability of HFC-32 technology for unitary and multi-connected commercial AC and heat pump applications.

14. The Tsinghua Tong Fang Artificial Environment Co., Ltd. manufactures 5,000 units annually of air-source heat pumps and chillers with capacities between 13 and 60 kW, based on three different models of 13, 30 and 60 kW, and with HCFC-22 charges between 5.1 and 24 kg. Including and beyond the products converted in this project, the enterprise has the capacity to manufacture around 8,000 refrigeration units of different types annually with refrigeration capacities between 13 kW and 3 megawatt and charges up to 90 kg of HCFC-22.

15. The implementation of this project started with the signing of the contract between the Government of China and Tsinghua Tong Fang Artificial Environment Co., Ltd. in January 2011. All three models were re-designed in 2011, which not only addressed the flammability of the substance, but also its characteristic to reach a high temperature at the end of the compression, resulting in design changes. The production line was converted during 2012, including: changes to the processing of the heat exchanger, reduction of the tube diameter from 9.5 to 7mm, which led to a number of changes in the production line; isolation of the charging area, including adequate ventilation and fire alarm systems for safety uses of flammable gases. The use of helium-leak detectors was introduced into the production

[3] Document UNEP/OzL.Pro/ExCom/60/24

[4] Document UNEP/OzL.Pro/ExCom/71/6/Add.1

process. The quality inspection, in particular the safety inspection of electrical systems, was upgraded and adapted to the presence of flammable gases. The enterprise trained 230 personnel. Tsinghua Tong Fang Artificial Environment Co., Ltd. passed national acceptance in December 2013; this leads to an overall implementation time of 36 months.

16. The original budget for ICC approved by the Executive Committee was US $733,530. The cost was determined prior to decision 66/52 on heat exchangers, and was based on only partial funding of heat exchanger conversion (subsequent projects received full funding for the heat exchanger conversion). The total eligible cost for the investment component was US $745,802. In addition, the report contained information on cost considered ineligible. All budget items have lower actual costs than previously estimated; however, the heat exchanger conversion costs were fully covered by the budget, in line with current practice of Executive Committee decisions.

17. The report also included information on the IOC as follows: the 13 kW model experienced IOC of US $163/unit (or US $32/kg), the 30 kW model had IOC of US $177/unit (or US $14.8/kg) and the IOC for the 60 kW model was US $286/unit (or US $11.9 /kg). Based on averaged costs for the three models 65 per cent of IOC are related to compressor cost, and 35 per cent to the sealing of electrical components. Incremental savings were achieved with the heat exchangers and the refrigerant.

Secretariat's comments

18. The Secretariat enquired whether the costs for the compressor are likely to fall with increasing production volumes. UNDP advised that indeed the price may way fall with more widespread use; however, the compressors are likely to remain more expensive than HCFC-22 compressors. This would partially be caused by the higher working pressure of HFC-32, which leads to a need for some structural enhancement of the compressor. In addition, changes related to the flammability (avoiding ignition sources) and measures to address the high discharge temperature of HFC-32 also increase cost. Regarding the sealing of electrical components, UNDP specified further that this item contains a number of different costs related to electrical parts of the system. In addition to a gas-tight electrical box, the fans are to be enlarged to increase air flow and must be explosion-proof.

19. The report also mentioned that the successful implementation provides an environmentally safe and cost-effective alternative. UNDP subsequently clarified that this statement compared the HFC-32 to other low-GWP technologies, e.g. HFO-1234yf. UNDP also advised that the energy-efficiency of the HFC-32 prototype was 3 to 5 per cent higher than that of the previous HCFC-22 system in cooling mode and about 3 per cent higher in heating mode. The enterprise assumes that further improvements in compressor design and better adaptation of the compressor to the HFC-32 properties, as well as further optimisation of the overall system will provide further energy-efficiency gains.

20. The Secretariat had questioned the role of safety standards in the marketing of the systems. UNDP advised that currently the new HFC-32 systems are produced in small quantities, not produced regularly, and are not being sold in the market. While potential customers are interested in these new products, the enterprise cannot sell them because of the restrictions within current standards. It is planned that the new products are installed and maintained exclusively by factory-trained servicing staff, at least during the introduction of such products into the market.

21. UNDP advised further that the National Standard GB 9237 "Mechanical refrigerating system used for cooling and heating – safety requirements", one of basic safety standards for refrigeration in China, restricts sales and operation of equipment using flammable refrigerants; this GB 9237 is a national version of the International Standardization Organization's (ISO) 5149-1993. UNDP informed further that ISO 5149 is currently in the process of revision and is expected to take effect after April 2014. The Foreign Economic Cooperation Office of the Ministry of Environmental Protection in China is currently reviewing the GB 9237 standard and is expected to be completed during the year.

Impact

22. This project has been instrumental in the demonstration of HFC-32 technology as an alternative for medium-sized AC systems. HFC-32 is flammable, but due to a lower overall flammability than e.g. hydrocarbons it is easier to design, market and operate as compared to hydrocarbon-based system. At the same time, HFC-32 has only 38 per cent of the GWP of HCFC-22 and only 35 per cent of the GWP of HFC-410A, the main alternative to HCFC-22 in AC applications.

23. The demonstration project has directly led to the use of HFC-32 as a major alternative to HCFC-22 in the industrial and commercial refrigeration (ICR) sector plan of stage I of the HPMP for China, where currently six conversion activities with an aggregated consumption of approximately 3,000 mt of HCFC-22 are under implementation towards the use of HFC-32. In addition, one compressor manufacturer is currently being supported to use HFC-32 technology. A second compressor manufacturer and another six equipment manufacturers will convert to HFC-32 technology in the future. HFC-32 has also been identified as an alternative technology in stage I of the HPMP in Indonesia, where three refrigeration and five AC equipment manufacturers are currently converting from HCFC-22 to HFC-32, with an associated consumption of more than 550 mt of HCFC-22. Further conversion activities to HFC-32 technology have been approved for stage I of the HPMP in Algeria (8.3 mt of HCFC-22) and Thailand (1,036 mt of HCFC-22) (the Secretariat has not yet received implementation reports showing that the conversion activities have already commenced).

24. Information by UNDP indicates that the energy-efficiency is similar to the HCFC-22 technology. As compared to the continued use of HCFC-22, this demonstration project with a phase-out of 61.9 mt of HCFC-22 together with projects where it has influenced the technology choice and which are currently under implementation will reduce the emission of GHG by 3.94 million tonnes of CO_2 every year.

Secretariat's recommendation

25. The Executive Committee may wish to:

(a) Note the final report on the demonstration project for HFC-32 technology in the manufacture of small-sized commercial air-source chillers/heat pumps at Tsinghua Tong Fang Artificial Environment Co., Ltd. in China by UNDP contained in document UNEP/OzL.Pro/ExCom/72/11/Add1; and

(b) Request bilateral and implementing agencies to consider the report on conversion from HCFC-22 technology to HFC-32 technology in the manufacture of small-sized commercial air source chillers/heat pumps, together with information on other alternatives, when assisting Article 5 countries in preparing projects for the phase-out of HCFC-22 in small and medium capacity air-conditioning applications, including small-sized commercial air-source chillers/heat pumps.

China: Demonstration project for conversion from HCFC-22 technology to ammonia/CO_2 technology in the manufacture of two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd. (UNDP)

Background

26. At its 60th meeting, the Executive Committee approved for China the demonstration project for conversion from HCFC-22 technology to ammonia/CO_2 technology in the manufacture of two-stage

refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd.[5], implemented by UNDP. Through decision 71/16, the Executive Committee decided to note the interim report on the demonstration project[6] and to request UNDP to submit a final report to the 72nd meeting, on the understanding that it would only contain preliminary data on IOC. A final report on the demonstration project has been submitted by UNDP to the 72nd meeting, and is annexed to this document.

Progress report

27. The conversion at Yantai Moon Group Co. Ltd. was successfully completed. It has been demonstrated that two-stage systems with ammonia on the higher temperature side and CO_2 on the lower side are a viable replacement for HCFC-22 technology for large-scale cold storage and freezing applications.

28. The converted production line has a capacity of 100 units per year. An average quantity of HCFC-22 charged in these systems is 2.5 tonnes. The large-scale refrigeration systems centre around a screw compressor. The conversion included design of three compressors for the refrigerant CO_2 for the low-stage of the refrigeration system; and three compressors for the high stage for ammonia. The refrigeration system had to be adapted both to higher pressures at stand-still as well as to lower volumes of refrigerant circulating.

29. Three prototypes for each of the three sizes were built, tested and delivered a refrigeration capacity of up to 1 megawatt at -55^{o} Celsius. In addition to the conversion activities, training of technicians activities were carried out, as well as technology dissemination such as participation in exhibitions. The production line is commercially running, and the IOC will be disbursed to Yantai Moon Group Co. Ltd. during the next two years depending on the number of converted systems sold.

30. The implementation of this project started with the signing of the contract between the Government of China and Yantai Moon Group Co. Ltd. in May 2011, and was concluded by passing the national acceptance in July 2013, putting the implementation time at 26 months. The project used the performance-based payment mechanism in its implementation, where the enterprise is the key executor of the conversion project, responsible for all activities related to the conversion. The report pointed out that the Government of China and UNDP were not involved in the procurement activities of the enterprise by any means other than payments to the enterprise in tranches to cover the cost of procurement and conversion, at agreed payment dates and when milestones have been achieved. The performance was verified before each payment.

31. The originally agreed budget for the demonstration project was US $3.078 million of ICC, with partial funding by the enterprise. The final list of expenditures of ICC amounted to US $4.1 million or 36 per cent more than the original budget (this increase was covered by the enterprise in addition to the originally agreed share of the cost of the enterprise, i.e. US $321,000). The main cost items were the modification of production lines for the compressor (28 per cent), the manufacturing of prototypes (27 per cent), the modification of test devices for product performance (22 per cent), and the modification of production lines for pressure vessels (11 per cent). The product and process re-design amounted to 8 per cent of the overall cost, and the training and technology dissemination to 5 per cent. The main increase in conversion cost as compared to the original estimate was due to the manufacturing of prototypes, which was about US $590,000 (more than double than the original cost). The modification of the compressor production line led to a cost increase of another US $230,000 (21 per cent higher than originally estimated). The other main cost increases were due to the modification of test devices for product performance (13 per cent increase) and modifications to the pressure vessels production line (6.7 per

[5] Document UNEP/OzL.Pro/ExCom/60/24

[6] Document UNEP/OzL.Pro/ExCom/71/6/Add.1

cent). The approved budget was only 8 per cent smaller than the budget requested by UNDP in their original submission, indicating that the cost increases were not foreseen.

32. The project has been audited, and the converted manufacturing facilities have been certified for compliance with the safety regulations. Contracts for the delivery for about 60 refrigeration systems employing the ammonia/CO_2 technology have been signed. The report informs that the energy efficiency of the systems increased more than 20 per cent compared with the existing HCFC-22 system. At the same time, the amount of HCFC-22 leakage, which had been substantial due to the use of open compressor, has been eliminated.

Secretariat's comments

33. The Secretariat requested some additional information on typical leak rates of HCFC-22 systems as previously manufactured. From the information provided the Secretariat estimates an overall leakage rate of 13 per cent or 320 kg of HCFC-22 per system per year.

Impact

34. The number of manufacturers of systems of this size is very limited globally, and the Secretariat expects only very few if any additional projects of this type coming forward. However, the conversion will fully eliminate the use of 250 mt of HCFC-22 per year in the charging of these systems. Since the replacement technology has virtually no GWP, it avoids the emission of GHG by 441,000 tonnes of CO_2 every year. In addition, the energy consumption of the systems appear to have been reduced by 20 per cent, leading to energy savings in operation, with a reduced emissions in energy generation in the order of 50,000 tonnes of CO_2 per annual production (100 units) per year, assuming these systems are operated in China.

35. In addition, the project allowed the technology of two-stage refrigeration systems with CO_2 in the lower stage to be demonstrated. This technology is also suitable for a number of other applications, among them smaller-scale storage and freezing systems, and supermarkets. The project demonstrated that this technology can principally be developed under and adapted to Article 5 country conditions.

Secretariat's recommendation

36. The Executive Committee may wish to:

(a) Note the final report on the demonstration project for conversion from HCFC-22 technology to ammonia/CO_2 technology in the manufacture of two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd. in China by UNDP contained in document UNEP/OzL.Pro/ExCom/72/11/Add.1; and

(b) Request bilateral and implementing agencies to consider the report on conversion from HCFC-22 technology to ammonia/CO_2 technology in the manufacture of two-stage refrigeration systems, together with information on other alternatives, when assisting Article 5 countries in preparing projects for the phase-out of HCFC-22 in cold storage and freezing applications with two-stage refrigeration systems.

PART VI: FINANCIAL AUDIT REPORT FOR THE HALON, CFC PRODUCTION AND FOAM SECTOR PLANS IN CHINA

37. On behalf of the Government of China, the World Bank provided a budget for the balance of funds for CFC production sector, CFC polyurethane foam sector, and the halon sector to the 72nd meeting pursuant to decision 71/12(b)[7].

CFC production sector

38. Table 1 presents the balance of funds by category and the planned completion dates for activities in the CFC production sector.

Table 1. Progress of work plan for activities beyond 2009 and funding allocation for the CFC production sector in China (US$)

No.	Category	Funding	Planned completion date
1	Recruitment of national and international expertise for technical support, and organization of the technology workshop on ODS alternatives, etc.	365,505	2014
2	Operation cost for China Compliance Centre (CCC)	2,996,831	completed
3	ODS import & export management activities	455,900	2014
4	Research and development on ODS alternatives	4,453,200	2016
5	Monitoring and management	224,604	2016
Total		8,496,040	

39. Under Category (1), a variety of activities, such as consultancy, auditing and training workshops have been carried out, including of the assessment of achievements and environmental effectiveness of China's compliance with the Montreal Protocol, an investigation of HCFC feedstock uses, and consulting services for the preparation of the project completion report.

40. Under category (2), total funds have been disbursed for operation cost for the China Compliance Centre.

41. Under category (3), a dedicated optical data transmission system has been established between the ODS import/export management office and the customs office to further strengthen the capacity of ODS import and export management. Approximately 90 per cent of these funds have been disbursed.

42. Under category (4), the programme to support research and development on low-global-warming-potential (GWP) ODS alternative technologies has been carried out. Nine proposals were selected to support these research and development activities.

[7] The Executive Committee decided to invite the Government of China to provide: (i) Through the World Bank, a report to the 72nd meeting explaining why the 2012 audit report indicated balances higher than the budgets approved at the 56th and 57th meetings for the halon and polyurethane foam sectors, and information on the resolution of the legal issue identified in the verification report to the 65th meeting with respect to the transportation of recovered halons to halon banks for recovery and recycling requested by decision 65/10(i)(ii); (ii) Through the relevant implementing agency, in future financial audit reports per decision 56/13, data on all funds from the Multilateral Fund that were being held by the Government of China for disbursement to final beneficiaries, and the interest accrued from those balances held by the Government of China, including data on the process agent II sector plan, the solvent sector plan and the refrigeration servicing plan; (iii) Comprehensive information on progress related to the work plans for the sector plans and its proposal on how to use potential balances for the consideration of the Executive Committee at the 72nd meeting.

43. Under category (5), funds are allocated for monitoring and management activities including consultancy, trainings, evaluation and verification.

CFC polyurethane foam sector in China

44. Table 2 presents the balance of funds by category and the planned completion dates for the CFC polyurethane foam sector.

Table 2. Progress of work plan for activities beyond 2009 and funding allocation for the CFC polyurethane foam sector in China (thousand US$)

No.	Category	Funding	Planned completion date
1	Screening and evaluation of CFC-free substitutes and development of new substitutes	2,660,000	2016
2	Additional provincial foam activities (capacity building for local authorities)	3,100,000	2016
3	Technical service for the foam enterprise for better application of new alternatives	1,400,000	2015
4	Continue monitoring of CFC phase-out in the foam sector	1,050,000	2016
5	Other technical assistance activities	713,000	2016
Total		8,923,000	

45. An amount of US $6.8 million had been reported as the balance in the 2009 annual plan. The World Bank explained that this was an estimated figure and the increase to US $8.923 million was a result of some of the companies closed down before their conversions, and some of the technical assistance activities that were delayed are now being implemented.

46. The activities in category (1) include ten projects addressing two types of research: 1) to develop a low-cost foam blowing agent with zero ODP and low global-warming-potential (GWP) that meets foam insulation property standards; and 2) research on pre-blended polyol formulas containing alternative blowing agent to optimize the stability and performance of the polyol and improve thermal conductivity of foam.

47. For category (2), success and lessons learned from implementation of CFC phase-out in the polyurethane foam sector will be compiled and disseminated to stakeholders for capacity building for local authorities, including workshops, training, public awareness activities, data collection, and supervision.

48. Category (3) will fund contracts for some systems houses to provide technical services for the best practices for the application of new alternatives used by foam enterprises.

49. Under category (4), the Foreign Economic Cooperation Office supports four key provinces, namely Hebei, Henan, Shandong and Tianjin, where most of foam companies and systems houses are located, to visit chemical dealers, systems houses, and foam enterprises to collect samples of blowing agents, pre-blended polyol, and final foam products, and to undertake inspection of raw materials used by the enterprises in their respective provinces.

50. Category (5) provides funding for the monitoring of project implementation, training meeting, publicity activities, verification activities, project evaluation, and project commission.

Halon sector plan

51. Table 3 presents the balance of funds by category and the planned completion dates for the halon sector plan in China.

Table 3. Progress of work plan for activities beyond 2007 and funding allocation for the halon sector plan in China (US$)

No.	Activity		Budget
1	Activities for halon banking	Halon 1211 stock maintenance and leakage prevention	1,500,000
		Halon banking management centre establishment and operation	1,000,000
		Establishment and capacity building for halon-1301 recycling centre	1,000,000
		Upgrade and improvement of halon-1211 recycling demo canter	300,000
		Development of management information system for halon banking	300,000
		Inventory investigation and registration of halon users nationwide	2,000,000
		Operation cost for collection, transportation, recycling and reclamation	2,000,000
		Disposal cost of contaminate halon and residues	1,456,397
		Sub-total	9,256,397
2	Technical assistance on halon banking and sustainable phase-out		1,403,888
3	Capacity building for China compliance	Establishment of overall ODS MIS	500,000
		Supervision and management for capacity building activities including trainings and workshops, etc.	700,000
Total			**11,860,285**

52. The Government of China did not provide any further explanation on the budget categories for the halon sector plan nor the completion dates of the individual activities as it only indicated that due to "the complexity of the task, it may need to be continued beyond 2015".

Secretariat's comments

Data on the process agent II, solvent and CFC refrigeration servicing sector

53. During the Inter-agency coordination meeting held in Montreal, in February 2014, the Secretariat discussed decision 71/12 and provided a format for the agencies to use for the response. The Secretariat also sent requests and reminders for information to all implementing agencies with respect to the process agent II (World Bank), solvent sector (UNDP), and CFC servicing sector (UNIDO, UNEP, and Japan). Agencies indicated that China would respond to the 73rd meeting.

Financial audit report on CFC production, CFC polyurethane foam and halon sectors provided to the 70th and 71st meetings

54. The Secretariat requested information on four major topics in the financial audit report submitted to the 70th meeting. Responses were not provided at that time nor in the submission to the 71st meeting.

55. The Secretariat provided 27 questions of clarifications on 18 March 2014 on the submission of the Government of China through the World Bank on the CFC production, the polyurethane foam and the halon sectors. As of 14 April 2014, no response has been achieved.

Interest

56. The Secretariat noted that no interest had been provided in the documentation.

CFC production

57. The information on the CFC production sector indicated that some of the funds had been disbursed but it did not indicate what had been disbursed for all budget items. Information was requested on the US $4.4 million in research and development activities by contract. This amount of funding should be justified further in terms of the contracts issued and how they relate to alternatives to the CFC production sector or for the consumption sector. Moreover, the Secretariat enquired how this research and development related to HCFCs that are covered under separate agreements.

58. Information on the separate allocations for the monitoring and management component was requested as well as the respective completion dates for the items so that they could be monitored.

Foam sector

59. It was also not clear how much of the budget indicated in Table 2 had been disbursed of the funding allocation; therefore, the Secretariat asked China to provide the balances as of the end of 2013.

60. China had reported that there had been a balance of US $6.8 million reported in 2009 but that the balance was actually US $8.923 million reported because some “beneficial” companies had closed before their facilities had been converted. The Secretariat enquired why these funds amounting to US $2.123 million should not be returned to the Fund. The Secretariat also enquired about contract values and purpose of the individual contracts amounting to US $2.66 million.

61. With respect to the development of alternative blowing agents, the Secretariat enquired how these projects were different from those already approved by the Executive Committee that addressed, *inter alia*, the stability and performance of alternative formulations to HCFC-141b blowing agent (including hydrocarbon-pre-blended polyols). The Secretariat asked how the results of the research and development paid for by the Multilateral Fund would be disseminated to other Parties. The Secretariat also requested information on the relationship between these planned activities and the polyurethane and/or extruded polystyrene (XPS) HCFC phase-out sector plans.

62. A justification for the need for capacity building for local authorities was requested given that the funding was requested four years after the phase-out. Moreover, it was not clear how the inspection of the use of non-CFC blowing was an incremental cost following the phase-out.

63. Concerning the intended use of funds to support systems houses, the Secretariat enquired how this would impact on HCFC consumption.

64. The Secretariat also enquired about the costs for monitoring in the past in order to assess the allocation of US $1.05 million per year. Similarly, a question on the previous costs for monitoring was requested to justify the US $0.713 allocated for training, publicity, verification, project evaluation and project commissioning.

Halon sector

65. With respect to the halon sector, the Committee has requested information concerning the ability to transport contaminated and un-reclaimed halon under current regulations for three consecutive meetings. Without the ability to transport used halon there could not be any halon reclamation. The document indicated that the framework for halon banking was developed in 2007 but it is not clear what activities had taken place since 2007. The Secretariat also asked what activities had been undertaken since the 71st meeting.

66. With respect to planned activities, the Secretariat requested that completion dates should be provided for each activity as had been done for the different categories of the CFC production sector and CFC polyurethane foam sector submissions.

67. Further clarifications of the costs were asked for the following cost items: stock maintenance and leakage prevention (US $1.5 million), collection and transportation of halon (US $2 million), the establishment of the halon banking centre (US $1 million), capacity building (US $0.7 million), and the upgrading of the demo centre (US $300,000). Concerning the costs for an inventory of halon users (US $2 million), the Secretariat indicated that surveys had been conducted through the project preparation for the sector plan and this would constitute double counting unless otherwise explained.

68. Further information on the cost for disposal of halon (US $1.5 million) was asked. A clarification was also sought as to why there had been two costs for a management information system (MIS) (US $300,000 and US $700,000) and why this level of funding was needed in the light of the other MISs China has for other ODS.

Conclusion

69. The Government of China, through the World Bank, had not provided the information requested by the Secretariat in order for it to assess how the remaining funds for the CFC, halon and CTC phase-out in China are to be utilized. The Executive Committee may wish to consider whether these accounts should be closed at the end of 2014 and a project completion report submitted to the first meeting of 2015 in the absence of receipt of any requested clarifications. The Executive Committee may also wish to request the financial audits for 2010, 2011, 2012, and 2013 for the process agent II, solvent, and CFC refrigeration sectors with a view to the return of unused balances at the end of 2014 and the submission of a project completion report to the first meeting in 2015.

Secretariat's recommendation

70. The Executive Committee may wish:

(a) To note the financial audit reports for the halon, CFC production and foam sector plans submitted by the Government of China through the World Bank pursuant to decision 71/12 as contained in document UNEP/OzL.Pro/ExCom/72/11/Add.1;

(b) To decide:

(i) To close the sector plans for CFC production, CFC polyurethane foam and halon, and to request the return of any remaining balances for these sector plans as at the end of 2014 and submit project completion reports to the first meeting of 2015; and

(ii) To request the financial audits for 2010, 2011, 2012 and 2013 for the process agent II, solvent and CFC refrigeration sectors to be submitted to the 73rd meeting, and the return of any remaining balances for these sector plans as at the end of 2014 and submit project completion reports for these plans to the first meeting of 2015.

PART VII: NATIONAL CFC PHASE-OUT MANAGEMENT PLAN IN THE PHILIPPINES (FINANCIAL REPORT)

Background

71. The Executive Committee considered the report of the implementation of the remaining activities under the NCPP at the 71st meeting, taking into account earlier decisions made regarding this project and also decided to request UNEP to submit to the 72nd meeting a financial report on the NCPP as of 31 December 2013 and to return the remaining funds to the Multilateral Fund (decision 71/18(b)). The present report is in response to this decision. The financial report was submitted by UNEP on behalf of the Government of the Philippines.

Secretariat's comments

72. The financial report indicated a balance of US $275,987.53 as of December 2013; funds amounting to US $260,575.90 have been obligated and disbursement is expected to be completed by May 2014; and an estimated balance of US $15,411.63 will be returned to the Fund.

73. In reviewing the expenditure report as well as the indicated commitments, the Secretariat sought clarifications on the following:

(a) Whether the financial report constitutes an official and final financial report for the NCPP endorsed by the Government of the Philippines, or whether this reflects UNEP's financial reporting requirement;

(b) A justification for the need for staff costs to be extended to May 2014;

(c) An explanation on the identified reallocation of balances between budget lines;

(d) An explanation on the large amounts of obligated funds which will be paid only in 2014; and

(e) A confirmation whether activities for the NCPP had been completed as of December 2013, and that the remaining obligations are for outstanding payments for these completed activities.

74. In its response, UNEP explained that the financial report was prepared by the Project Management Unit (PMU) using UNEP's financial reporting requirement, and is indicative based on estimates for the expenditures. The official audit of the NCPP finances is currently ongoing and is expected to be completed by May 2014. At such time, the actual balance of the project would be known and processes leading to its return to the Multilateral Fund could be initiated.

75. UNEP also explained that the Government had requested for the extension of the PMU staff particularly those related to financial matters in order to facilitate closing of the books and accounts.

76. With regard to the reallocation of funds to other budget lines, UNEP clarified that the Government of the Philippines, cognizant of the Executive Committee's decision to complete the project by end of December 2013, decided to allocate funds for the purchase of servicing equipment to be distributed to service shops in the region affected by the typhoon Haiyan. These sets of equipment were ordered before the end of December for beneficiaries that were identified with the assistance of the Department of Environment and Natural Resources regional office.

77. In explaining the large amounts for obligated/committed funds, UNEP indicated that these financial obligations were made before December 2013. The delays in payments were mostly due to late

invoices for services and goods rendered in 2013 (e.g. workshop/training costs). UNEP confirmed that they had reviewed supporting documents for these obligations and found them to be in order with financial regulations. In addition, UNEP explained that these were consistent with accounting rules and regulations of the Government.

78. The Secretariat encouraged UNEP to ensure the timely completion of the financial audit of the project, and to provide the Secretariat a copy of this once the exercise is completed.

Secretariat's recommendation

79. The Executive Committee may wish:

(a) To note the financial report for expenditures until December 2013 submitted by UNEP for the National CFC phase-out plan work plan for the Philippines as contained in UNEP/OzL.Pro/ExCom/72/11/Add.1;

(b) To approve the request for the extension of the Project Management Unit staff and its associated operational cost from January 2014 to May 2014 and not to accrue expenditures exceeding US$31,000 for this purpose;

(c) To request:

(i) The Government of the Philippines through UNEP to submit the official audited financial report duly signed by an independent or Government accredited auditors no later than June 2014;

(ii) UNEP to ensure the return of any balance that remain unspent based on the auditor's report to the Multilateral Fund no later than the 73rd meeting; and

(iii) The Government of the Philippines and UNEP to submit the project completion report to the first meeting of the Executive Committee in 2015.

PART VIII: HCFC PHASE-OUT MANAGEMENT PLAN FOR NIGERIA (STAGE I, THIRD TRANCHE) (IMPLEMENTATION PLAN FOR THE CONVERSION OF FOAM MANUFACTURING ENTERPRISES IN THE REFRIGERATION SECTOR)

Background

80. At the 62nd meeting, the Executive Committee approved the stage I HPMP for Nigeria. Based on the Agreement between the Executive Committee and the Government of Nigeria as well as the overall implementation plan of the HPMP, the conversion of 109 refrigeration foam enterprises implemented by UNIDO was intended to phase out 310.2 mt (34.12 ODP) tonnes of HCFC-141b by converting their foaming operations to methyl formate pre-formulated systems at an incremental cost of US $1,759,080. Through implementation of the first and second tranches of the HPMP in 2012-2013, UNIDO provided assistance through providing low pressure polyurethane foam injection machines for 30 beneficiaries with a total phase-out of 86.35 mt (9.50 ODP tonnes) of HCFC-141b consumption. However, in the progress report of the second tranche and the implementation plan for the third tranche, UNIDO informed that the funding approved for the sector was not sufficient to address the whole consumption of 310.2 mt of HCFC-141b as originally planned, and suggested to assist only some enterprises.

81. The Secretariat advised UNIDO to adjust the strategy and select more cost effective ways and suitable technologies to assist all eligible enterprises. After consulting with the Government of Nigeria, UNIDO proposed that it will provide low pressure foam machines to 46 enterprises with consumption above 2.2 mt and technical assistance including training on the use of methyl formate-based formulations, personal protection equipment and incremental operating costs, to smaller-sized enterprises. In this way, the project component will cover all the beneficiary enterprises and achieve the phase-out as originally planned. On this basis, the Executive Committee approved, at the 71st meeting, the third tranche of the HPMP for Nigeria and requested UNIDO to submit an implementation plan, no later than 15 February 2014, for the conversions of foam manufacturing in enterprises in the refrigeration sector, related to a consumption of 310.2 mt of HCFC-141b, including information of enterprises covered, allocation of the funding, activities to be undertaken and their schedule (decision 71/30).

Status report

82. UNIDO submitted the implementation plan confirming that 45 enterprises have been identified to receive assistance in the third tranche, with a total consumption of 130.15 mt (14.32 ODP tonnes) of HCFC-141b at a cost of US $645,172, resulting in a cost effectiveness of US $4.96 per kg. The implementation of the revised plan has commenced in January 2014. The procurement of equipment has started and the bids are being evaluated. It is expected that the equipment will be delivered in July 2014 and the installation, trial run, training and commission will be conducted in August 2014.

83. The plan also indicated that the technical assistance for the small enterprises to address the remaining 93.7 mt HCFC-141b is planned to be conducted in the fourth tranche using the funding of US $193,908. Training and personal protection equipment will be provided.

Secretariat's recommendation

84. The Fund Secretariat recommends the Executive Committee takes note of the implementation plan for the conversion of foam manufacturing enterprises in the refrigeration sector in Nigeria submitted by UNIDO as contained in UNEP/OzL.Pro/ExCom/72/11/Add.1.

PART IX: IMPLEMENTATION OF THE NATIONAL CFC PHASE-OUT PLAN: POLICY AND REGULATORY COMPONENT, ISLAMIC REPUBLIC OF IRAN

85. In September 2004, UNEP signed a Memorandum of Understanding with the Government of the Islamic Republic of Iran for US $100,000 for the implementation of the project on the "Implementation of the national CFC phase-out plan: Policy and regulatory component" (IRA/PHA/41/TAS/161). UNEP transferred US $90,000 to the Islamic Republic of Iran and so far only US $30,000 has been accounted for by the recipient Government. Since September 2008, UNEP has been consistently and regularly following up with the Government requesting an accounting of the US $60,000 through official letters and through discussions with Government officials during missions to the country and in the margins of regional/global meetings.

Secretariat's comments

86. Upon a request for an updated report on the issue and what measures would UNEP need to establish to avoid a similar situation in the future, UNEP reported that during a meeting on the HPMP for the Islamic Republic of Iran, held in Teheran on 2 March 2014, UNEP and the National Ozone Unit (NOU) informed UNDP, UNIDO and the Government of Germany (bilateral cooperation) about this issue. The NOU is in consultation with other governmental departments to identify a way forward. To avoid a similar situation from re-occurring under the HPMP, UNEP has requested the establishment of a dedicated Government bank account to transfer funds for the implementation of future activities. Beyond

the case of the Islamic Republic of Iran, UNEP has also taken the following overall measures to reduce the risk of such a situation re-occurring:

(a) Since 2008, UNEP has introduced additional financial reporting against each payment tranche;

(b) As of 2014, new legal agreements have been developed for implementation of activities with governments and other partners that would release payments as cash advances to cover six months of activities. Subsequent payments will only be made on receipt of an acceptable financial statement and progress reports demonstrating the required rate of implementation; and

(c) No new agreements will be signed with a government until the conditions under the current agreements have been fully met and the activities satisfactorily completed.

Secretariat's recommendation

87. The Executive Committee may wish to request UNEP to provide a status report on its discussions with the Government of the Islamic Republic of Iran on the unaccounted payment of US $60,000 for the implementation of the national CFC phase-out plan: Policy and regulatory component to the 73rd meeting.

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DEMONSTRATION PROJECT FOR HFC-32 TECHNOLOGY IN THE MANUFACTURE OF SMALL-SIZED COMMERCIAL AIR-SOURCE CHILLERS/HEAT PUMPS AT TSINGHUA TONG FANG ARTIFICIAL ENVIRONMENT CO., LTD.

FINAL REPORT

March, 2014

Executive Summary

Demonstration project for HFC-32 technology in the manufacture of small-sized commercial air-source chillers/heat pumps at Tsinghua Tong Fang Artificial Environment Co., Ltd. was approved by the 60th Executive Committee meeting at a funding level of US$1,229,336.

This demonstration project was successfully implemented, and established the suitability of HFC-32 technology as a viable replacement for HCFC-22 as a refrigerant in the manufacture of commercial air-source chillers/heat pumps at Tsinghua Tong Fang Artificial Environment Co. Ltd.

The project activities includes product redesign and development, manufacturing equipment modifications and additional equipment, safety and other measures to handle the flammability and high discharge temperatures of HFC-32, laboratory testing and performance evaluation, product trials, prototype testing, production line conversion, technical assistance and training.

The successful completion of the demonstration project contributes towards promotion of this technology for unitary and multi-connected commercial air conditioning and heat pump equipment and enables 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 plans in Industrial & Commercial Refrigeration and Air-conditioning (ICR) sector from 2012. The Tong fang project was established as a demonstration earlier in 2010 for preparation and support of the sector plan implementation.

The Executive Committee approved the Tong fang demonstration project in the 60th meeting in 2010 at a funding level of US $ 1,229,336. The project's implementing agency is UNDP. The national agency implementing this project is Foreign Economic Cooperation Office (FECO), Ministry Of Environmental Protection, China.

The objective of this demonstration project is to establish the suitability of HFC-32 technology as a viable replacement for HCFC-22 as a refrigerant in the manufacture of small-sized commercial air-source water chillers/heat pumps at Tsinghua Tong Fang Artificial Environment Co. Ltd.

As a result of the conversion project, about 61.9 tons of HCFC consumption will be phased out, reducing greenhouse gas emission by 170,000 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 includes 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 estimated HCFC consumption in the sector based on field surveys was about 42,000 metric tonnes.

Small-sized commercial air-source chillers/heat pumps are typically used in commercial establishments such as hotels, restaurants, shops and offices, both for cooling and heating, with low energy consumption and no water use. The self-contained design requires no separate plant or machine room. With the current emphasis on energy

conservation and environment protection, the market for these products experiences rapid growth. Based on data from field surveys, the production of such small-sized air-source chillers/heat pumps in 2008 in China was about 110,000 units, with a total HCFC-22 consumption of about 1,200 metric tonnes in about 12-15 enterprises.

Tsinghua Tong Fang Artificial Environment Co. Ltd. was established in 1989 and is located in Zhongguancun Science and Technology Zone, Beijing. The enterprise is a state-owned company, specializing in research and development, manufacturing and sale of the environmental products and systems. In the air conditioning field, the company actively carries out research and development of environmental control products, green construction, energy efficiency in buildings and renewable energy technologies. The enterprise employs 554 persons, which includes 84 managerial staff and 81 technical and research staff. The enterprise has five national product inspection centers, laying the foundation for sound research and development in this field.

Tsinghua Tong Fang Artificial Environment Co. Ltd. is the national leader in heat pump technology. The enterprise comprises a unique amalgam of industry, academia and research, and is abreast of the latest scientific progress on technology and environment.

Tsinghua Tong Fang Artificial Environment Co. Ltd. currently manufactures a range of heating and cooling products, with production capacity valued at about US$ 3 billion and manufactured on six production lines for various products as tabulated below:

Production Line	Products	Refrigeration Capacity	Installed Capacity	Actual production	Average refrigerant charge (kg)	HCFC-22 consumption (2009-tonnes)	Application
Water/ground source heat pumps/chillers	Water-source heat pumps	150 - 3000 kW	700 units	227	90	26.9	Heating/cooling in large buildings such as offices, malls, hotels
	Ground-source heat pumps	120 - 3000 kW		29	75		
	Chillers	400 - 2000 kW		54	80		
Large air-source heat pump/chillers	Screw	260 - 500 kW	700 units	34	75	2.55	
Medium air-source heat pump/chillers	Scroll	60 - 200 kW	1500 units	399	40	15.96	Heating/cooling in medium-sized buildings
Small air-source heat pump/chillers	Scroll	10 - 60 kW	5000 units	4073	15.2	61.9	Heating/cooling in small commercial spaces up to 1000 sqm
Air handling units	Central station air handling units	2000 to 20000 cum/hr	5000 units	NA	NA	NA	Large and medium sized buildings
Fan coil units	Various sizes	340 - 2380 cum/hr	5000 units	NA	NA	NA	Small buildings and individual spaces
Total						**107.31**	

Of these, one production line with a capacity of 5,000 units annually (as highlighted above) is for manufacturing small-sized commercial air-source chillers/heat pumps in the range of 10 to 60 kW. This production line was installed in 1999. The total production in 2009 was 4,073 units, with HCFC-22 consumption of 61.9 metric tonnes at an average HCFC-22 charge of 15.2 kg per unit. These units are manufactured in three models/configurations as below:

	60kW	30kW	13 kW
Unit Configuration			
HCFC-22 charge (kg)	24	12	5.1

This product range (small-sized air-source heat pump/chillers) has been selected for this project considering the relative small amount of refrigerant charge volumes, allowing flexibility for selection of alternative technologies.

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	Supermarket refrigeration in a secondary loop and in stationary and mobile air conditioning systems	Major redesign of system components needed. Investment costs are prohibitive
Hydrocarbons	<15	Small-capacity domestic and commercial refrigeration equipment	Flammability issues. Not widely used in large capacity systems
R-32	675	Small and medium-capacity commercial refrigeration and air conditioning applications	Single component refrigerant. Mildly flammable. Higher working pressures than HCFC-22. Higher refrigeration capacity per unit charge. Main component of R-410A
R-134a	1,300	Domestic, commercial refrigeration medium-temperature applications	Not efficient in low-temperature systems and industrial refrigeration applications. Needs synthetic lubricants
R-407C	1,520	Most air conditioning applications	Properties closely match R22. Temperature glide, synthetic lubricants needed, slightly less efficient than R22. Non-azeotropic mixture creates issues.
R-410A	1,710	Most air conditioning applications	Near azeotropic blend of R-32 and R-125. Higher pressures, better cooling capacity, low temperature glide, high GWP, synthetic lubricants needed
R-404A	3,260	Low temperature applications	High GWP, less efficient at medium temperatures, synthetic lubricants needed
R-507	3,900	Low temperature applications	Azeotropic non-flammable blend of HFC-125 and HFC-143a. Refrigerating capacity comparable to R-502. Good heat transfer characteristics at low temperatures

Tsinghua Tong Fang Artificial Environment Co. Ltd. carefully considered and applied the multiple factors and concluded that R-32 technology is most suited for application to its heat pump products, due to its expected technical performance and significant potential benefit with respect to global warming impact as compared to HCFC-22 (i.e., direct impact through adoption of low-GWP substance compared to HCFC-22 and indirect impact due to potential energy efficiency gains through system improvements). In addition, the enterprise had also carefully studied the international regulatory and market scenario, and noted that R-32 may potentially have wide acceptability in this particular market segment.

2. Project Implementation

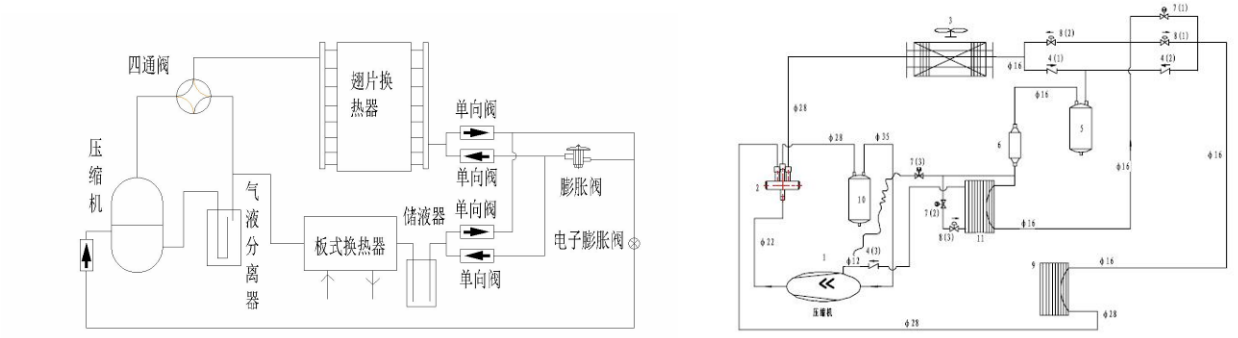
The project was approved by 60th Executive Committee meeting in 2010 at a funding of US $ 1,229,336. The project implementation started at 2011, the conversion project was completed by the end of 2012, and all the progress milestones required were reached and verified by the end of 2012. The project successfully passed national acceptance in December, 2013.

According to the project implementation plan, the following activities were carried out: Product and process redesign, Conversion of production lines, Prototype production trails and testing, and Processing and safety training, etc.

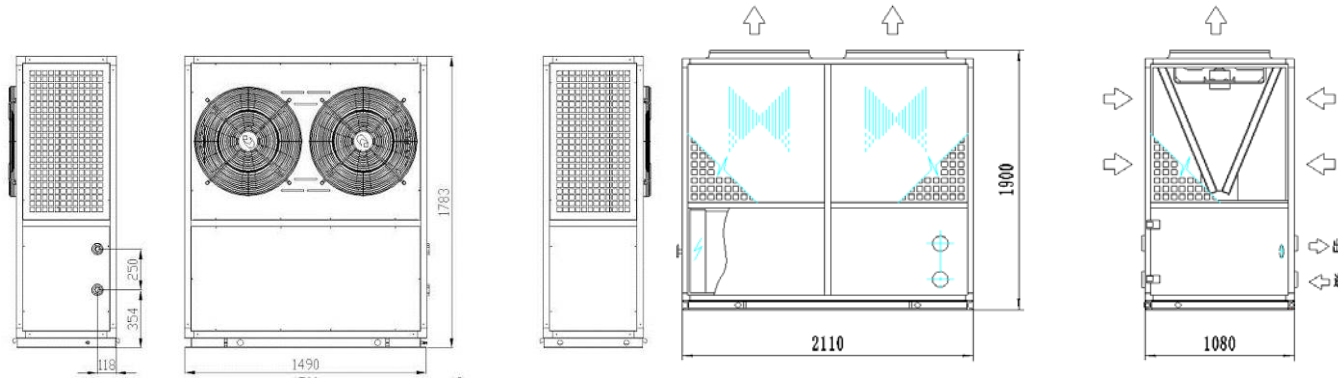
2.1 System, Components and Process Redesign

Three models (60kW, 30kW and 13 kW) of R32 systems redesign was completed in 2011, The redesign work included design and calculations, simulation and control software, remodeling of the compressors, expansion valves, finned tube heat exchanger, water-side heat exchanger, unit structure, electrical systems, prototype

manufacturing, test runs, compilation of production process, blueprint and complete bill of materials. Two kinds of design proposal was designed, one is liquid injecting cooling, and the other is air-supplying enthalpy-adding The redesign program passed evaluation of sector experts' team in October 21.



Liquid injecting cooling program and air-supplying enthalpy-adding program



Structure design

2.2 Conversion of the Production Line

The production line conversion is composed of Heat Exchanger Processing, Sheet Metal Processing, Product Assembly, and Quality inspection, testing and finishing, etc. the whole conversion was completed by the end of 2012.

2.2.1 Heat Exchanger Processing

Due to the lower charge and higher pressure with HFC-32, the finned tube diameter was reduced from 9.52 mm to 7 mm. Accordingly the finned tube punch dies and tube expander changed either. The tube straightening/bending machine (fin threading) was modified. A new brazing line for the heat exchanger suited for HFC-32 was introduced. Since HFC-32 is flammable, the grease left on the heat exchanger was removed for fire safety. For this, degreasing and dehydrating equipment was introduced.

Φ7 vertical tube expanding machine

Φ7 tube bending machine

2.2.2 Sheet Metal Processing

The sheet metal processing dies changed, including dies for end-plate hole punching and dies for end-plate rim bending and dies for rim bending.

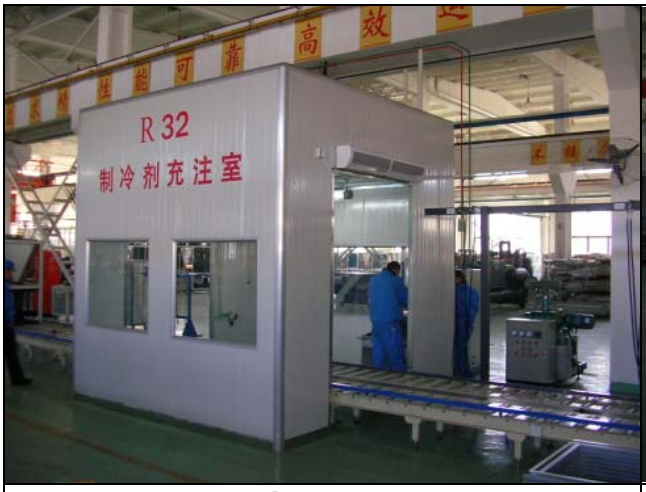
Die for end-plate hole-punching

Die for end-plate rim-bending

Die for rim-bending

2.2.3 Product Assembly

Due to the flammability of HFC-32, the charging area was isolated, with adequate ventilation, fire safety and alarm systems and explosion-proof fittings. The existing Halogen leak detectors cannot be used with HFC-32, because it contains no Halogen. Therefore Helium leak detectors were introduced.



R32 charging room

R32 units assembly line

	
Helium leak detector	**Helium refrigerant recovery machine**

	
Roots vacuum pump	**R32 charging machines**

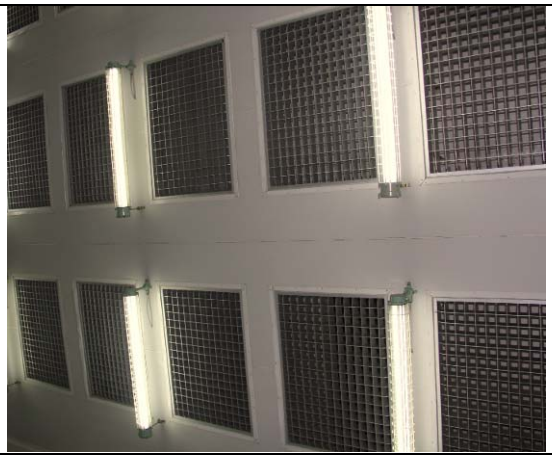
2.2.4 Quality inspection, testing and finishing

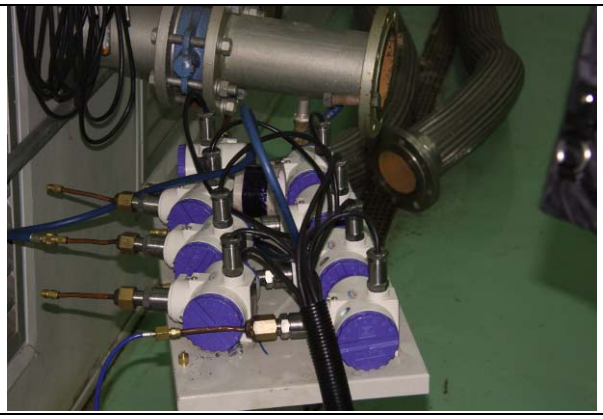
The safety inspection of electrical systems was enhanced by introducing appropriately sensitive devices with protective features. The inspection area was isolated with adequate ventilation, fire-safety and alarm systems and explosion-proof fittings. The existing test rig for HCFC-22 based products can be used with R32, and it modified such as test room ventilation and fire-safety, high-pressure sensor and sensor for monitoring HFC-32 concentration levels.

Assembly line inspection modification:

	
R32 products operating testing room	**Testing equipment for electronic safety performance**

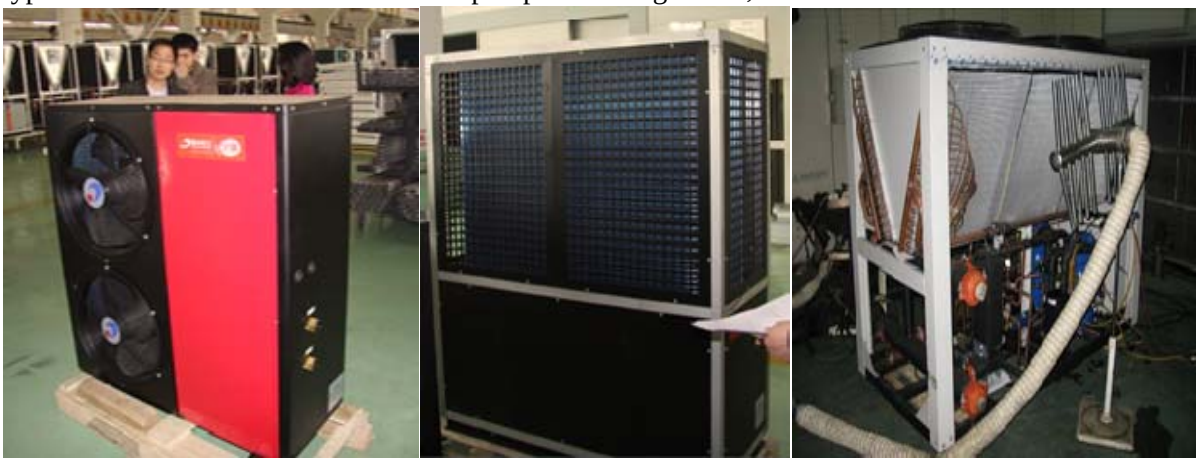
Testing room modification:

	
Electric explosion-proof cabinet	**Explosion-proof lamps**
	
Explosion-proof exhaust fans	**Explosion-proof motor**

	
Explosion-proof pressure sensors	**Explosion-proof RH testers**

2.3 Prototype production trials and testing

A pilot-level quantity of the selected models was subjected to prototype production, trials and testing to establish the process and fine-tune as needed and establish product performance through testing.
Three types of HFC-32 air-source chiller/heat pumps including 13kW, 30kW and 60kW were built in 2011.



13kW **30kW** **60kW**

The prototypes were tested by Tong Fang in 2011 and tested by third party test institution (Hefei General Machinery & Electrical Products Inspection Institute) in Feb 2012. The results of the test were qualified.

2.4 Process and safety training

Process and safety training were provided to the manufacturing, installation and maintenance personnel. It was verified that the internal technical acceptance were completed and technical commissioning and relevant personnel training were finished.

Tong fang Co. has organized 37 times of technical commission and personnel trainings under this project. Totally 23,202.5 class hours training were taken and 1454 persons/times were trained.

2.5 Management

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 R-32 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 Tong Fang factory - once in 2011 and thrice in 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 confirmation and conclusion.

3. Outcomes

The project has been completed and has successfully passed national acceptance in December 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 quantity. The suitability of HFC-32 technology as a viable replacement for HCFC-22 as a refrigerant in the manufacture of small-sized commercial air-source water chillers/heat pumps at Tsinghua Tong Fang Artificial Environment Co. Ltd. was established

The following are the salient outcomes of the project.

- The enterprise completed the redesign of system, components and production process in 2011.
- The performance test rig was modified to meet the requirements of testing products with flammable refrigerants in 2011.
- The prototypes were manufactured, tested and adjusted in 2011.
- Training, technology communication, and advertisement were finished in 2012.
- Equipment for modification of heat exchanger and sheet metal processing was procured in 2012.
- Product assembly line and testing facilities converted and verified in 2012.
- Technical commissioning was completed successfully and relevant personnel were trained in 2012.
- The project successfully passed national acceptance in December 2013

4. Technical performance

- R-32 has ODP of 0.
- R-32 has GWP of 675, about a third of that of R-410A.
- R-32 is a mature refrigerant with a large knowledge base on its properties.
- R-32 is produced domestically and has assured commercial availability as reasonable prices.
- R-32 is a single substance with good heat transfer capacity, volumetric refrigerating capacity and theoretical energy efficiency.
- For the same refrigeration capacity, the charge quantity for R-32 is 60-80% of that of R-22 depending on the application.
- The actual efficiency of R32 system in this project is 3%-5% higher than former R22 system, and the performance efficiency will grow along with optimizing in deeper application and promotion of compressors and other accessories.
- The cost of system is over 20% than R22 system, but the cost will reduce along with large-scale applications of R32.
- The R32 compressors of this project were supplied by several compressor companies in China. The compressors were redesigned and modified based on R410A, and the performance has potential to be

promoted.

5. Project management and monitoring

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 December 2013. The capacity of the production line has been converted to use substitute refrigerants and is capable of manufacture the converted products.

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

Milestones		Status
1st	Signing of the contract	FECO and the enterprise signed contract in January 2011
2nd	Completion of designs of products and pass the evaluation of experts	Finished in October 2012
3rd	Completion of the test facilities	Finished and verified in April 2012
4th	Prototypes are built and tested	
5th	Completion of conversion heat exchanger and metal plate process	Finished and verified in December 2012
6th	Assembly line and delivery inspection process are completed	
7th	Technical commissioning completed successfully and relevant personnel trained	Finished and verified in December 2012

5.2 Conversion cost

Total Project Costs

The total contract amount with the enterprise is US$ 1,122,870, including ICC US$ 733,530, and IOC US$ 389,340.

Incremental Capital Costs

The actual incremental capital costs for conversion was US$ 830,344.71, among which US$ 733,530 was funded by the MLF, and the US$ 96,814.71 was co-financed by the enterprise.

The details of ICC are as follows:

No	Cost Head		Actual cost (US$)
1	**System, component and process redesign**		
	Redesign	Product redesign	21,313.82
	Software	Outsourced simulation and control software	13,071.90
		sub-total	**34,385.72**
2	**Prototype testing**		
	Prototype materials	Cost of materials/process for 3 prototypes	34,596.34
	Testing	Third party laboratory testing	17,017.72
		sub-total	**51,614.06**
3	**Production line conversion-**		
	Heat exchanger processing	Dies for 7 mm diameter tubes	80,065.36
		Modification of tube bending machine	5,538.24
		New vertical tube expanding machine	208,428.10
		Degreasing furnace	-

	Sheet Metal Processing	Die for end-plate hole-punching	1,895.42
		Die for end-plate rim-bending	561.27
		Die for rim-bending	2,941.18
	Product Assembly	Suction gun Helium leak detector	74,017.65
		Charging room isolation/fire protection	84,542.11
		Two R-32 concentration sensors	56,045.75
		R-32 automatic charging machine	70,261.44
		Refrigerant recovery machine for R-32	8,006.54
	Quality inspection, finishing and testing	Testing equipment for safety performance	10,294.12
		Two R-32 concentration sensors	
		sub-total	**602,597.17**
4	**Prototype production trials and testing**		
	Testing	Modification of performance test rig	45,751.63
		Isolation of test rig room/fire protection	57,189.54
	Trial production	Cost of trial production for 3 units	20,958.54
		sub-total	**123,899.72**
5	**Process and safety training**		
	Manufacturing	Training for 233 manufacturing personnel for 86 training hours	17,848.04
	Installation and maintenance	Training for 86 installation and maintenance personnel for 30 training hours	
		sub-total	**17,848.04**
6	**Contingency**	for enterprise	**0**
ICC for enterprise		**TOTAL**	**830,344.71**
		Total fund by MLF	**733,530**
		Co-financing by enterprise	**96,814.71**

Incremental Operating Costs

The agreed total incremental operating costs calculated for one-year duration amount to US$ 389,340.
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:

1. HCFC-22 price is US$ 2.20/kg
2. HFC-32 price is US$ 2.94/kg
3. HFC-32 charge quantity for the three models is 16 kg (for 60 kW), 8.4 kg (for 30 kW) and 3.5 kg (for 13 kW)

Incremental Operating Cost Source	**Incremental Costs/Savings (US$/unit)**		
	60 kW unit	**30 kW unit**	**13 kW unit**
Compressors	236.00	118.00	96.00
Finned tube heat exchangers	(19.00)	(9.50)	(4.50)
Tube-in-tube/plate heat exchangers	(13.50)	(6.80)	(3.10)
Refrigerant	(5.90)	(2.90)	(1.00)
Electrical components (ex-proofing)	88.40	78.20	75.60
Net costs (savings)	**286.00**	**177.00**	**163.00**
Agreed	**73.93**	**45.75**	**42.13**

Incremental Operating Costs	Amount (US$)
60 kw unit: US$ 151.19/unit X 1,858 units/year	280,917
30 kw unit: US$ 75.56/unit X 858 units/year	64,827
13 kw unit: US$ 32.13/unit X 1,357 units/year	43,596
Total	**389,340**

6. Impact

The project was completed and 61.9 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 170,000 CO2-eq tonnes will be achieved, thus contributing to protection of both the ozone layer and the climate system.

The successful implementation of this demonstration project provides an environmentally safe and cost-effective alternative for enabling replication of this technology in similar applications in this sub-sector in China.

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 (^oC)	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:

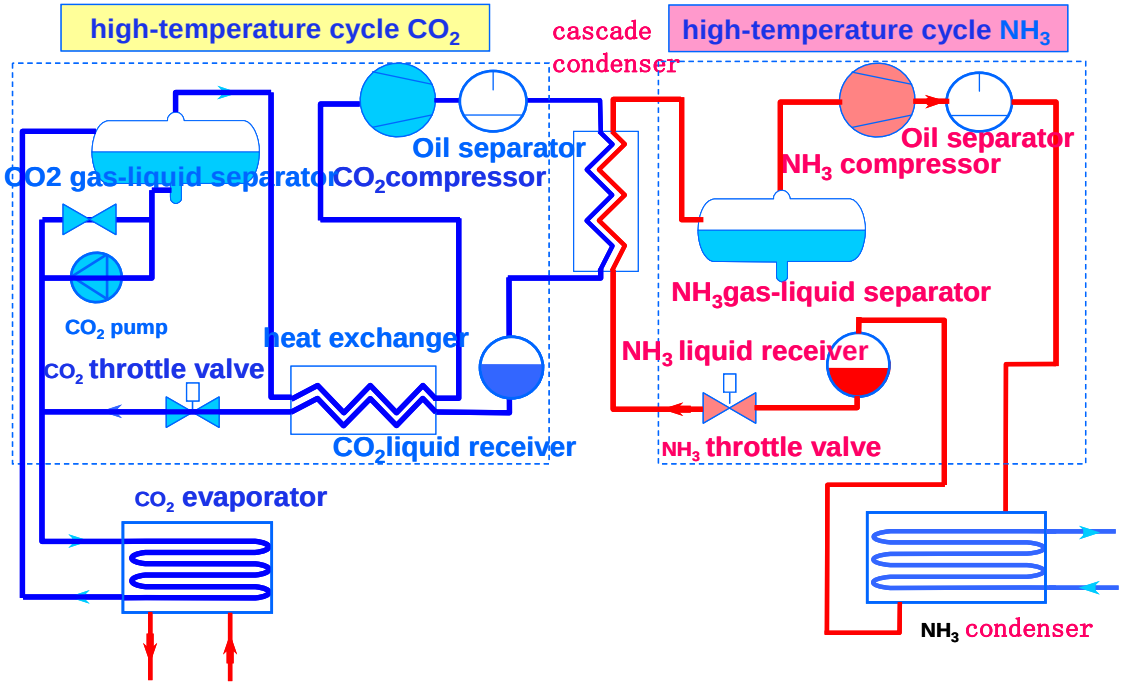


Fig 1. System schematic

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

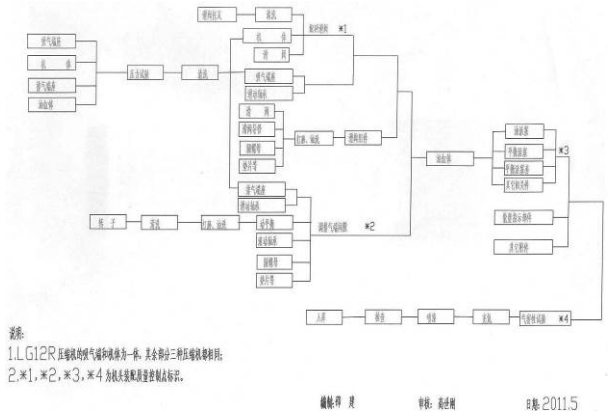


Fig 2. Technical process diagram

Fig 3. Drawings documents recording

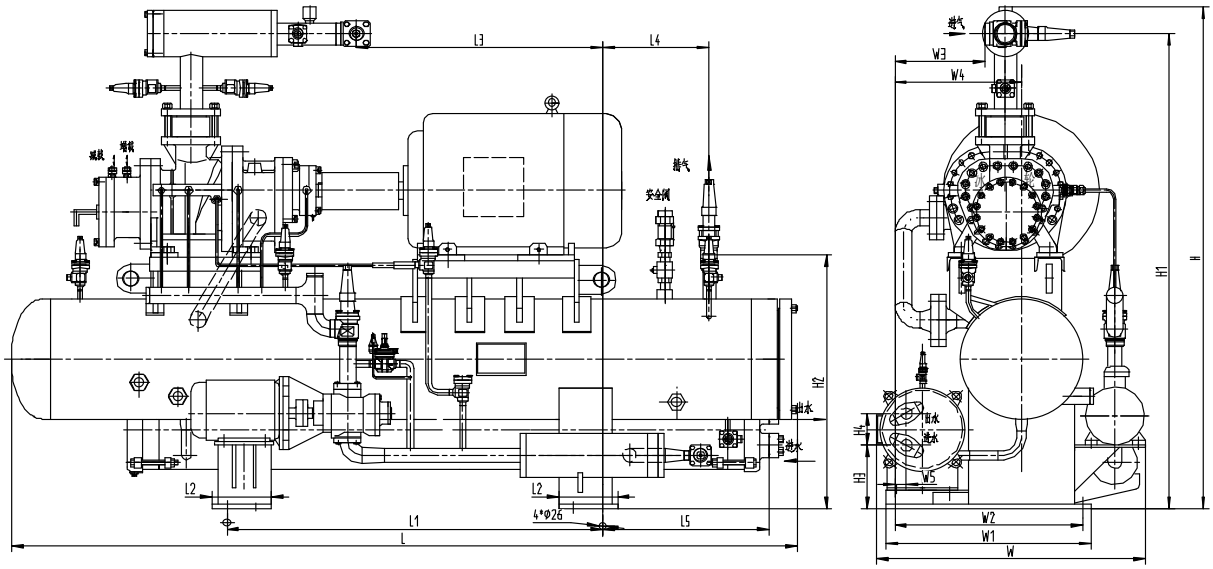


Fig 4. System structure

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, CO2 regenerator, heat exchanger for defrost, tube expander, welding and assembly for CO2 shell and tube evaporator.

As materials of tube sheet and cylinder for the CO2 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 CO2 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 CO2 refrigeration system requires new facility construction.

The modification of test equipment was completed in 2012. The test devices of CO2 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)

Tc / Te	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）

Tc / Te	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）

Tc / Te	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

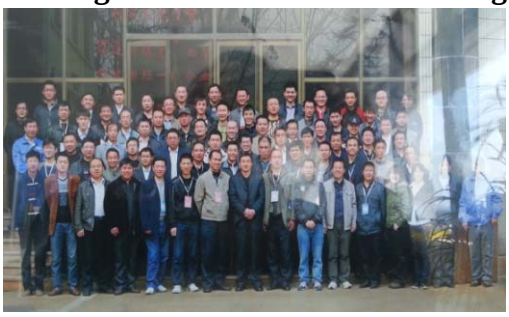
The personnel trainings were carried out during project implementing, and the trainings are including design, production, marketing and debugging. The following personnel were included in the training:

- 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.