UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Demonstration Sub-Project for Conversion from HCFC-22 to Propane at Midea Room Air-conditioner Manufacturing Company

Demonstration Sub-Project for Conversion of Room A/C Compressor Manufacturing from HCFC-22 to Propane at Guangdong Meizhi Co.

FINAL REPORT

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Executive summary

This project was developed as response to the Decision 55/43 of the Multilateral Fund Executive Committee and is part of a limited group of projects with the objective to assess new technology options that use non-ODP and low GWP refrigerants; this project was specifically approved by Decision 61/32 in July 2010.

Propane (R-290) is an environmentally friendly refrigerant, since its ODP is zero and its GWP is as low as three. With an excellent cooling performance, R-290 is considered one of the ideal alternatives to replace HCFC-22 in the Room Air Conditioning (RAC) sector. However, since this refrigerant is different from HCFC-22 in terms of chemical and physical properties, thermal performance and flammability, the application of R-290 refrigerant requires design and structural modifications of the HCFC-22-based products and production lines.

In this sense, and in order to support the implementation of its HCFCs phase-out plan in the RAC sector, China (an article 5 party) prepared, in cooperation with UNIDO, two demonstration sub-projects for the conversion of RAC units and compressors manufacturing from HCFC-22 to R-290, in two leading companies' production lines: Guangdong Midea Refrigeration Equipment Co. Ltd. and Guangdong Meizhi Co. Ltd.

In the case of Midea, the production line that has been converted is an advanced mechanized line with complete manufacturing functions, consisting of assembly line, charging equipment, vacuum pump, running test system, leak detectors, packing machine as well as other specialized machines. The products manufactured on the line include split units working with AC and DC. The baseline production is 200,000 units per year.

With regard to Meizhi, the selected production line has an annual production capacity of 1,830,000 HCFC-22-based units that are applied in split air-conditioners of 1 hp and 1.5 hp. Within the selected line there are altogether five component manufacturing departments, that is: 1) roughing and finishing of rollor, cylinder, blade, and crankshaft and bearing components of the compression structure; 2) case manufacturing department for the production of main shell and upper and lower shells; 3) Production of stator and rotor of the compressor motor; 4) Motor coil manufacturing, and 5) Assembly department for sorting, matching, assembly, painting lubricant charging, sealing, tightness, electrical and performance testing.

From these two projects the following conclusions can be pointed out:

- With an excellent cooling performance, R-290 is considered one of the ideal alternatives of HCFC-22 in the RAC sector after conversion of production lines.
- R-290 is available in the Chinese market.
- The conversion of two of the most important production lines of RAC units and compressors in China has maintained the quality and performance of the appliances produced by these two companies. Their performance is consistent with national (CCC) and international standards (IEC/CB and CE), and this has already been certified by the authorities.
- In order to obtain such improvements in the new products' performance, as well as in the system optimization, significant additional efforts were required in terms of co-financing by both companies.
- Regarding the new compressors' performance, the energy efficiency is 2%-3% higher than HCFC-22 compressors.
- Concerning the new RAC units' performance, the energy efficiency is 5%-12% higher than HCFC-22 air-conditioners.
- Further efficiency improvement both in compressors and AC units could be achieved if the charge sizes specified in international standards were relaxed, since there is a relationship between charge and efficiency. Until then, efficiency improvement is mainly dependent on the actual R&D - invested in the product in the past several years and the years to come - and also on system optimization, which was required as in most refrigeration conversion activities in the past.
- **Two types of R-290 compressors (fixed and variable frequency) with 1 HP and COP of 4.12-4.33** are available for mass production after the conversion of the production line.
- **Two types of R-290 RAC units (split/VF and portable A/C) and six different models** are also available for mass production after conversion.
- The conversion of production lines and the manufacturing of new appliances can be handled safely, despite the flammability of R-290, if appropriate measures are implemented and appropriate tools and equipment are used.
- Developments continue post-project with the aim to minimize and simplify product modifications while maintaining safety; as well as to reduce the refrigerant charge in order to expand the range of products.
- The experiments and assessments show that the possibility of fire and explosion for a wall-mounted R-290 air-conditioner is only 10^{-8}-10^{-9} per year under household use conditions in China. Nevertheless, the next stages of phase-out programme should focus on risks in the servicing and installation processes, risks at different charges, and secondary risks from a fire.

- Besides, in order to foster the introduction of this new technology in the Chinese market it is necessary to establish new policies and financial measures, as well as updated safety standards.

Incremental capital costs

- In the case of both Midea and Meizhi, the projects have had higher capital costs than the agreed project budget.

Incremental operating costs

- Regarding Midea's project, the estimated IOC for one split unit is currently US$ 41.95. Although the actual IOC is significantly higher than the eligible USD 6.3/kg, these additional costs are associated with the product initiation and expected to decrease in future, albeit not quite the level of the IOC threshold. In addition, the methodology for applying the safety measures is also being refined.
- The cost of the new compressor manufactured by Meizhi is US$ 7.57 higher than the HCFC-22 based compressor (cost already part of the above calculation). IOC for compressor for Midea was not covered by the funds provided by the MLF, instead the conversion of Meizhi compressor manufacturing line was financed.

The approval and implementation of these demonstration projects was key for the development of R290 units and was a basis for the RAC phase-out strategy in China. As a result, by now, most RAC manufacturers in China are involved in R290 conversion activities and R&D.

While these demonstration projects in China were successful, the application of hydrocarbon (HC) technology should be carefully evaluated in context of the local situation prevailing in each country. The report by no means concludes that the technology was sufficiently consolidated to be applied in all countries, and did not address issues of availability and cost in the field. Finally, interested parties must take into consideration the proprietary issues related to the technology.

1. Introduction

In 2007, the 19th Meeting of the Parties of the Montreal Protocol agreed on accelerating the phase-out of HCFCs. To achieve the compliance goal, China is implementing a HCFCs phase-out sector plan in the Room Air Conditioning (RAC) sector since 2012. In order to support the implementation of this sector plan, China prepared, in cooperation with UNIDO, two demonstration projects (hereafter, the projects) for the conversion of RAC and compressors manufacturing from HCFC-22 to propane (R-290), in two different companies: Guangdong Midea Refrigeration Equipment Co. Ltd. and Guangdong Meizhi Co. Ltd.

The Executive Committee (ExCom) approved the Midea and Meizhi projects at the 61st ExCom meeting, with a budget of US$ 4,026,507 and US$ 1,875,000, respectively. UNIDO has been the implementing international agency of the two projects, while the Foreign Economic Cooperation Office of China (FECO), which is part of the Ministry of Environmental Protection, has been the national implementing agency.

Guangdong Midea Refrigeration Equipment Co., Ltd was jointly funded by Guangdong Midea Electric Appliances Inc. (80%) and Toshiba-Carrier Corporation (20%) in 2000. Midea is a large-scale enterprise focusing on the development, production, sales and after-sales service of domestic, commercial and central air-conditioners. As one of the leading manufacturers in the RAC sector of China, Midea has altogether 75 RAC production lines and the annual production capacity amounts to 20,000,000 units.

Guandong Meizhi Refrigeration Equipment Company Co., Ltd is a comprehensive technology-oriented compressor manufacturer established in September 1995. It is owned by Guangdong Midea Electric Appliances Group (60% share) and Toshiba (40% share). Meizhi belongs to the refrigeration business group of Midea, and it is specializing in the production, sale, and R&D of domestic compressors, mainly for RAC appliances, but also for refrigeration.

Since these two companies are joint ventures shared by local and foreign companies, the budget allocated by the ExCom covers the associated costs of the projects in the same proportion as the local ownership, that is: 80% in the case of Midea and 60% in the case of Meizhi. For this reason, co-financing was needed to cover the rest of the associated costs.

The conversion projects in these two companies were developed as response to the Decision 55/43 (b) of the Multilateral Fund Executive Committee, which is intended to select projects that best demonstrated alternative technologies and facilitated the collection of accurate data on incremental capital costs and incremental operating costs or savings, as well as other data relevant to the application of the technologies. They are also part of a limited group of projects with the objective to assess new technology options that use refrigerants with zero ozone depleting potential (ODP) and low global warming potential (GWP).

2. Project objectives

R-290 is an environmentally friendly refrigerant, since its ODP is zero and its GWP is as low as three. With an excellent cooling performance, R-290 is considered one of the ideal alternatives of HCFC-22 in RAC sector. However, since this refrigerant is different from HCFC-22 in terms of chemical and physical properties, thermal performance and flammability, the application of R-290 refrigerant necessitates design and structural modifications of the HCFC-22-based products and their production lines.

Table 1. Physical properties of R-290 compared to HCFC-22

Parameters	HCFC-22	R-290
Molecular formula	$CHCLF_2$	C_3H_8
Molecular weight	86.5	44.1
Critical temperature ℃	96.2	96.8
Critical pressure (MPa)	4.99	4.25
Boiling point (℃)	-40.8	-42.1
Lower flammable limit (v%)	N	2.1
Burning velocity (cm/s)	N	39
Combustion heat (KJ/mol)	N	2217.8
GWP	1700	3
ODP	0.055	0

In this sense, these projects consist of the conversion of two HCFC-22-based production lines of both split room air-conditioners and compressors, to R-290 technology[1], with no capacity increase and quality upgrade, in order to:

- Promote the replacement of HCFC in RAC manufacturing sector;
- Demonstrate redesign of split RAC units and compressors for the use of R-290 refrigerant;
- Seek solutions and obtain experience in safe conversion of production lines, refrigerant storage and handling facilities,
- Demonstrate alternative production techniques in air-conditioner and compressor manufacturing;
- Undertake training and marketing of RAC appliances and compressors using R-290 refrigerant;
- Elaborate techniques and processes as well as to collect experience in transportation and installation of R-290 split RACs;
- Support the testing and verification of the conversion of manufacturing of HCFC-22-based compressors to R-290-based compressor and;

[1] Refrigerant R-290 is currently available in the Chinese market.

- Accumulate and disseminate experience for future technical conversion projects.

With the conversion of Meizhi's production line, the new compressors will indirectly phase out 2,196 metric tons of HCFC-22, with an impact of 121 ODP tons per year. In the case of Midea, the new RAC units will phase out 240 metric tons per year, with an impact of 13.2 ODP tons per year.

3. Implementation

3.1. Selected production lines

In the case of Midea, the production line that has been converted is an advanced mechanized line with complete manufacturing functions, consisting of assembly line, charging equipment, vacuum pump, running test system, leak detectors, packing machine as well as other specialized machines. The products manufactured on the line include split unit working with AC and DC. The production line met quality and safety requirements and its baseline production was 200,000 units per year.

The company produces most of the components, including heat exchangers. The compressors are purchased from Meizhi compressor factory.

In the case of Meizhi, among the eleven domestic RAC compressor production lines of the company, it has been converted the one with an annual production capacity of 1,830,000 HCFC-22-based units. The compressors of this line are applied in split air-conditioners of 1 hp and 1.5 hp. Within the selected line there are altogether five component manufacturing departments:

- Roughing and finishing of rollor, cylinder, blade, and crankshaft and bearing components of the compression structure;
- Case manufacturing department for the production of main shell and upper and lower shells;
- Production of stator and rotor of the compressor motor;
- Motor coil manufacturing and;
- Assembly department for sorting, matching, assembly, painting lubricant charging, sealing, tightness, electrical and performance testing etc.

3.2. Projects activities and scope of the work

3.2.1. Midea

After the project was approved in July 2010, FECO and UNIDO signed a contract in May 2011 for its implementation. After 30 months implementation, the conversion project was completed by the end of 2013, and all equipment and lab facilities were installed and tested. Midea has developed different types of A/C products for domestic and oversea markets. It entrusted the national quality supervision and inspection center and the provider of technical services TUV to carry out product test. The test focused

especially on the safety of products. The R-290 A/C has received the China Compulsory Certificate (CCC), the IEC/CB certificate, and the CE certificate.

The following activities were carried out in the implementation: production line planning, conversion of product testing unit, modification of production process, product redesign and development, set-up of prototype and training[2].

The residential air conditioner research and development center of Midea was responsible for the overall coordination and management of the project implementation.

Production line planning

Capacity of R-290 production line

The R-290 production line was converted from an existing HCFC-22 line. The capacity of this production line will be 200,000 units annually. It can produce outdoor units, including VF, for split A/C of 1.5HP and below, portable A/C, window A/C and dehumidifiers.

Location and construction plan

The old line was located in a plant with other 6 lines. Considering the flammability of R-290, the company decided to select a new production site, separated from other lines. In this sense, it was decided that the production line would be moved to the second floor of No9 plant building. The size of the new production area is 1,800 m^2, from previously around 1,000 m^2, but this increase in the operating area is not related to the flammability of R-290, neither is it to any increase in production capacity.

Conversion of production line

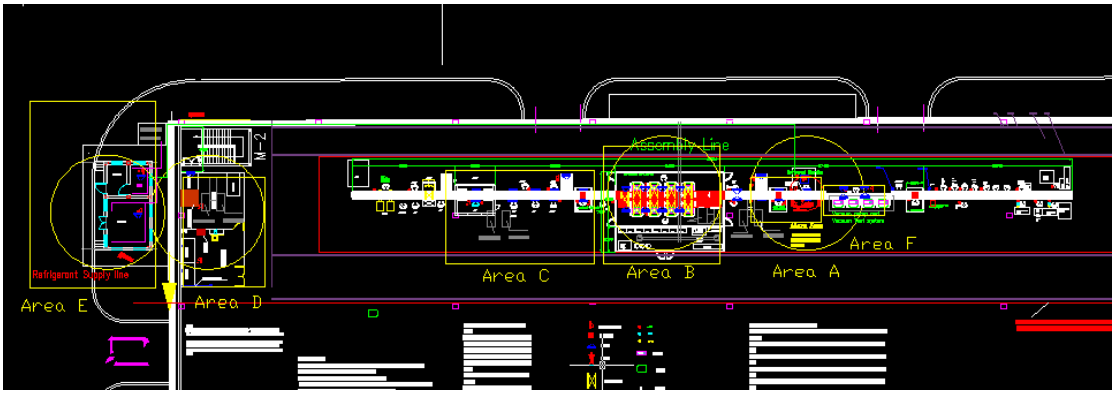
The following conversions and modifications were carried out to the production line:

[2] Transportation, installation and servicing of R-290 AC units are part of an ongoing R&D project under the Stage I HPMP of the RAC sector.

Table 2. Conversion of production line - Midea

No.	Equipment	Contents of Conversion
1	Assembly Line	• Relocation of the equipment to new site • Modification of production process (modification of line structure and work station) • Explosion-proof modification and antistatic measurements
2	Running Test system	• Function test units adjusted to the properties of R-290 • Explosion-proof modification • Modification to the operation room
3	Vacuum inspection system	• Explosion-proof modification to inspection systems • Modification to inspection program
4	Refrigerant Supply line	• Installation of R-290 supply equipment • Installation of transport piping of R-290 • New storage tank for R-290 • Lighting protection to the supply station
5	Vacuum pump	• Explosion-proof motor • Explosion-proof modification to rework area
6	Vacuum chamber helium leak detection	• Explosion-proof modification
7	Refrigerant Charging	• AGRAMKOW PROMAX-F2 charging machine, include pressure booster and safety systems
8	Leak detectors	• INFICO leak detector
9	Ventilation system	• The ventilation system was composed of 4 independent sub-systems, including product testing area, production line, operating room and refrigerant supply station. Each sub system has 2 double speed exhaust fan. When one fan malfunctioned, another fan will be switched on automatically.
10	Alarm system	• Drager alarm system. The system has 15 infrared gas detectors and sensors. It is able to detect the concentration of flammable gas of the production line, the refrigerant supply station and the product testing area.
11	Sealing machine	• LOKRING pneumatic sealing
12	Tools and fixtures	• Quick connector, improve safety level

The layout of the production line is shown in the picture below:



Picture 1. Layout of the production line.

Area A: refrigerant charging area

Area B: performance testing area

Area C: leakage detecting and final testing area

Area D: products inspection area

Area E: refrigerants supply station

Area F: other assembly

Regarding the modification of production process in the assembly line, the structure remained the same with some differences, mainly related to the safety measures required for the R-290. After the assembly of the units, there is a N2/H2 pressure and leak test to control the tightness of the assembled unit , followed by evacuation of the units. After this, charging takes place followed by a leak test, which includes a repair area. Then, there is a sealing (ultrasonic welding or Lokring) function test, followed by a leak test and packaging. In hazardous areas (charging, repair, testing areas) there are dedicated ventilation systems and enclosures to avoid spreading R-290 in case of a leak.

Concerning the running test system, a new function test room was built with R-290 indoor units, antistatic floor, proper ventilation and earthing system. Besides, as regards the vacuum inspection system, gas sensors have been installed in hazardous areas, triggering ventilation system when needed, and activating the automatic shut off only after continued leak.

Finally, regarding the refrigerant charging machines, electrical components are separated and encapsulated to avoid contact with the refrigerant. There is an enclosure at the charging area to avoid spreading R290. There is antistatic floor, there are proper earthing connections and there is ventilation in the charging station as well as in the enclosure as well as under the conveyor belt. For refrigerant supply, a dedicated storage area is located outside, next to the building.

Procurement of new equipment

The company made a procurement plan according to the implementation plan. The procurement was finished in March 2013. By July 2013, all equipment has been installed and commissioned by the company.

Product redesign and development

Dimension

Indoor unit：930x370x298 （mm）

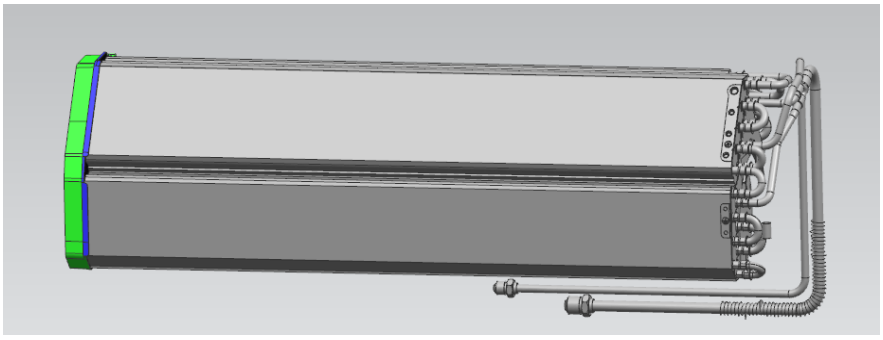
Outdoor unit：760x285x590

Picture 2. Product redesign.

Configuration

Heat exchanger for indoor unit

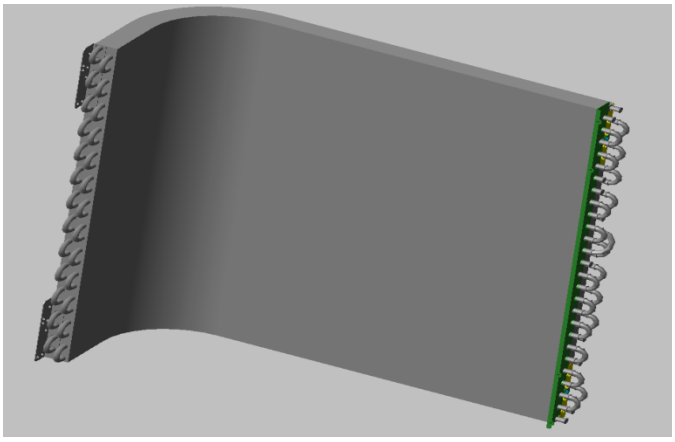
Φ7 Inner grooved copper tube, 4 input and 4 output. The main purpose of the heat exchanger modification is to reduce the charge size, and it is related to the reduction of the tube diameter. This reduced diameter may have a positive impact on the heat transfer coefficient.



Picture 3. Configuration

Condenser

Φ5 Inner grooved copper tube, 5 input and 5 output. In this case, the condenser has been changed from the former 9 mm tube to reduce the charged refrigerant mass.



Picture 4. Condenser

Compressor

Type：DD180G1C-10DZ

Discharge rate：18.0 cm^3/rev. Changed from 13.0 cm^3/rev.

Fan

Indoor：WZDK30-38G　output: 30W

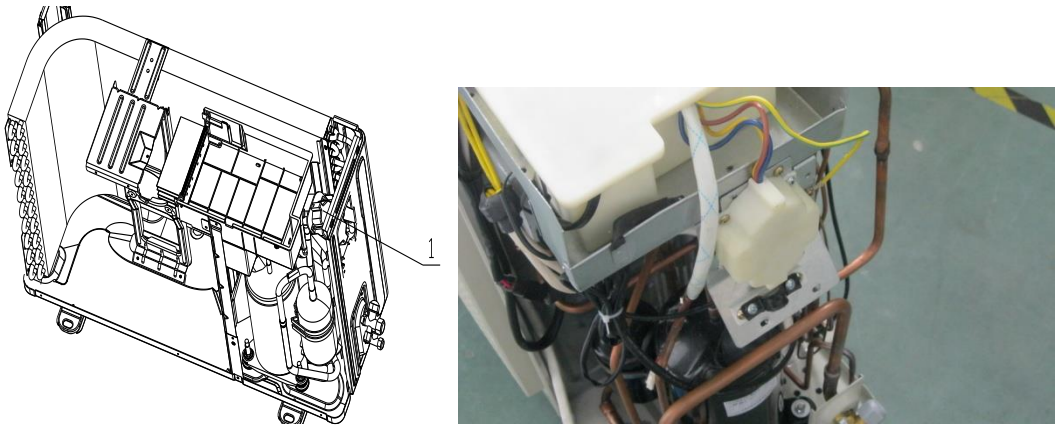
Outdoor：WZDK35-38G　output：35W

There has been no conversion in this case.

Safety measures

The terminal block of outdoor unit

A new outdoor unit structure was designed to prevent accumulation of leaked refrigerants. In addition, as an initial approach, gas detectors were fixed near the most potential ignition sources (electrical connections) to detect and alarm if there is any refrigerant leakage.

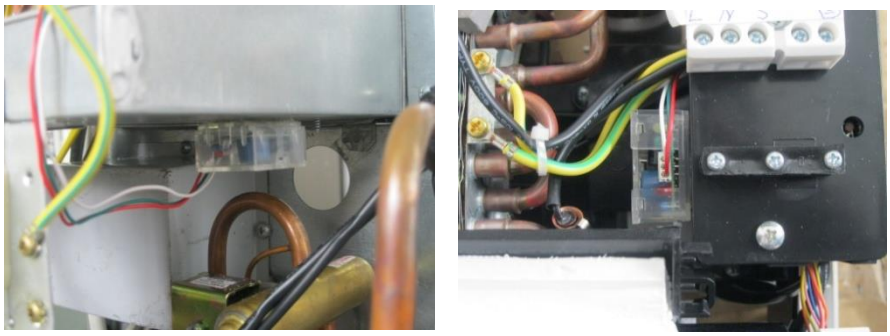


Picture 5. Outdoor units

However, the manufacturers are currently focusing more on the elimination of the ignition source rather than installing such sensors. In order to avoid ignition, electrical parts are encapsulated, the end of the heat exchanger is covered, the cabinet is designed for natural ventilation, etc. It is an ongoing process to be refined with the experience gained, nevertheless, installation of the detectors on the outdoor unit will most likely not be a future feature of smaller units.

Leak detection

Gas detectors were added for both indoor and outdoor unit. When gas leak were detected the electrical control component will switch off the machine.



Picture 6. Leak detection

Auto lock designing

Solenoid valves were placed on the tubes of outdoor unit. The leak control and testing is improved to reduce the overall leak rate.

Picture 7. Auto lock

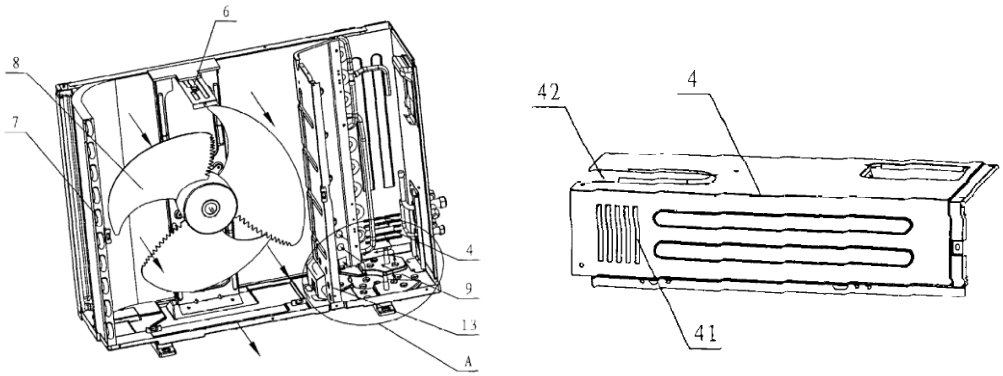
Safety design to process pipes

Locking connector was used for pipes. When refrigerant is charged, it is sealed flameless.

Picture 8. Safety design to process pipes

Prevent gas concentration

Clapboard with special structure was designed between the fan blades and compressor of the outdoor unit. It will help air flow in the space between compressor, the pipe and electrical devices.



Picture 9. Special clapboard

Destruction of HCFC-22 equipment

In November 2013, Midea destructed its HCFC-22 equipment from the converted production line. The company invited Shunde EPB to witness the disposal.

Training

Midea has organized several training workshops focused on different topics and trainees:

Table 3. Training workshops – Midea

	Trainer	Topics	Trainee	Place	Number of participants	Date
1	Daniel Colbourne	International standards	R&D engineers	Shunde	15	July 2012
2	Liu Xu	Structure of R-290 A/C and its characteristics	Process engineers	Shunde	30	October 2012
3	Li Tingxun	Selection of alternative refrigerants	R&D engineers	Shunde	100	June 2013
4	Liu Zhen	Safety protection of R-290 A/C	Maintenance engineers	Shunde	120	March 2014
5	Zhou Xiangyang	A/C with flammable refrigerants	Process engineers	Wuhan	30	Mai 2014
6	Li Tingxun	Standards for flammable refrigerants	R&D engineers	Shunde	100	June 2014

Furthermore, experience gained by Midea has been and is being disseminated at various national and international conferences and workshops:

- During network meetings;
- At the annual international conference of RAC manufacturers in China, which is held end October/early November;
- At the Atmosphere Europe event that was held in June 2013 in Vienna;
- During conferences on HCFC alternatives in high ambient conditions;
- Through UNEP webinars.

3.2.1 Meizhi

After 30 months implementation, the conversion project was completed by the end of 2013; all equipment and lab facilities were installed and tested. One prototype was sent to be tested at China Testing & Inspection Institute for Household Electric Appliances. The report shows that all required

parameters can meet national standards. The production line is ready for final commission, which is planned for November 2014[3].

The following activities were carried out in the implementation: product redesign, procurement of necessary equipment and systems, modification of tools and parts, installation, debugging and trial of production lines, training, pilot production and performance testing of R-290 compressor as well as technology dissemination.

Product redesign

Three types of compressor were designed, including both fixed frequency and variable frequency. The specifications of compressors are as below:

Table 4. Types of compressors

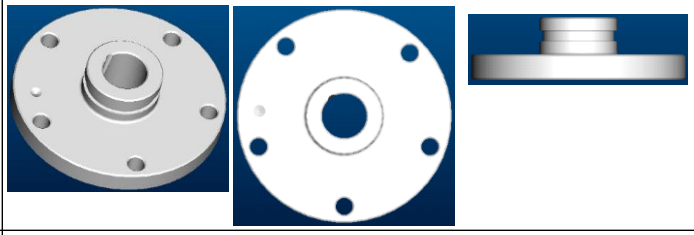
Type	Power	Capacity (w)	HP(w)*	COP (w/w)*		
				R-290	HCFC-22[1]	Minimum requirements
DSK118D10UBZ	DC INV	1700	515	3.3	---	---
DSN180V1UDZ	220/240V/50Hz	2700	820	3.29	---	---
DSM180V1UDZ	220/240V/50Hz	2700	830	3.25	3.15	3.10

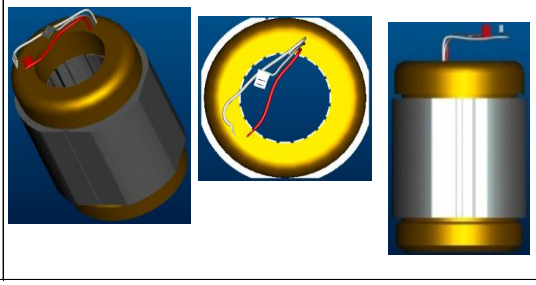
1. There are no basic R-22 models of DSK118D and DSN180V, these two models were specially designed for R-290. The DSM180V is developed based on R-22 model HSM180V, but the motor of DSM and HSM is different, so the result is only for reference.

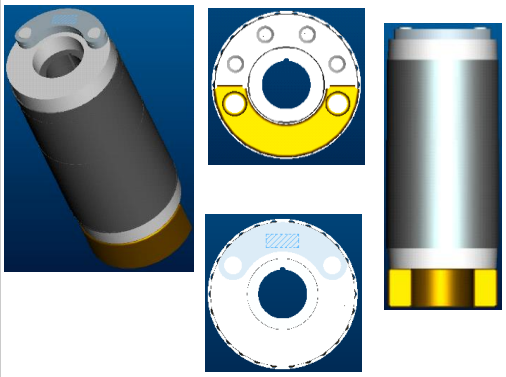
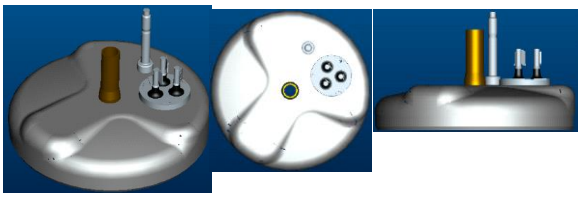
Other design changes are described and illustrated on the series of pictures of the various main parts affected.

[3] The other two prototypes will apply also the certification and the schedule depends on the market demand.

CYLINDER		Change of: Inner Diameter, Height, Position of bolt holes,
MAIN		Change of: Inner Diameter, Height, Position of bolt holes,

SUB		Change of: Inner diameter,
ROLLER		Change of: Inner and outer
BLADE		Change of: Height

CRANK		Change of: Outer diameter
STATOR		Change of: Inner and outer diameters.

ROTOR		Change of: inner and outer diameters, shape of lamination, shape of balancer
UPPER CASE		Change of: outer diameter

P

Picture 10. Design changes on different compressor's parts.

The conversion of the compressor was done with the following two objectives:

a) To increase compressor swept volume to offset the slightly reduced capacity of R-290, which has also an impact on the electromotor.
b) To optimize the compressor in order to minimize the refrigerant contained in the oil. As a result of this effort, the compressor contributed to approximately 5% charge reduction in the RAC unit and the oil quantity was also reduced.

Lubricant selection

Besides the reduction of the charge size, one of the main challenges in the manufacturing of these appliances was the development of a suitable lubricant[4] [5].

Regarding the technical aspects of oil selection, besides the basic property called for lubricant oil, the other three key points are solubility, miscibility and viscosity.

Since R-290 has very good solubility with almost all kinds of oil, the manufacturer considers that the lowest the solubility and the miscibility, the better.

[4] Due to the changed performance of the lubricant, the anti-wear treatment of some of the components of the compressor was modified. In this sense, for example, the wear of vane tip was too large after compressor left test, and this problem was solved by increase the hardness of the vane tip like use the treatment CrN or DLC coating.

[5] The supply of raw material, on the contrary, is not a challenge for the development of a suitable lubricant, since compressors manufacturers in China are working together with lubricant suppliers.

On the other hand, the very good solubility also causes the decrease of working viscosity, so it is necessary to test this working viscosity with the viscometer while the compressor is in operation.

Several companies have already made some publications on how to test oil working viscosity in compressors with a viscometer and, besides, this method can be found in the handbook of the viscometer device. Basically, it is necessary to assemble the viscometer on the compressor and run the compressor by using the test device. The working viscosity data can be read on the viscometer screen.

For the analysis of results, it is convenient to make a comparison with a baseline at the same running conditions. This baseline can be set as R-22 compressor with its oil.

However, it is to be noted that each manufacturer has its own developed compressors with components of different sizes, and this can lead to different procedures in lubricant selection.

Conversion of production line

The conversion involves 12 major parts of the production line: assembly, cylinder, roller, bearing, crankshaft, blade, sorting, upper-case, main-vessel, motor coiling, stator/rotor, inspection-tools. The activities mainly include procurement of new equipment, modification and tools and parts.

Procurement of new equipment

There are two fundamental requirements for the equipment: the performance testing equipment should be explosion-proof due to the flammability of R-290; the lubricant chargers, lubricant purifying and supply systems need to be replaced.

Equipment conversion and purchase are described as follows:

Table 5. Equipment conversion and purchase

NO.	Category	Action	Name of line	Contents
1	Production equipment	Modification	Assembly Line	fixture and tools of Cylinder centering machine
2			Cylinder Line	fixture and tools of Automatic chamfering machine
3			Rollor Line	fixture and tools of Automatic internal honing machin
4			Bearing Line	fixture and tools of Automatic internal honing machine
5			Crank Shaft Line	fixture and tools of Semi-Automatic cylindrical grinder
6			Blade Line	fixture and tools of Automatic high-speed surface honing machine
7			Sorting Line	fixture and tools of Blade Sorting Equipment

NO.	Category	Action	Name of line	Contents
8			Case Line	fixture and tools of Blade Sorting Equipment
9			Motor Coiling Line	fixture and tools of Auto rolling machine
10			Stator Varnish Equipment	varnishing tooling
11			high speed press machine	Die & control system
12			Testing tools	Testing tools
1	Performance testing equipment	Purchase	Calorie Meter	Calorie Meter
2			Life test Unit for 10 pieces	Life test Unit
3			Gas Load Test Unit	Gas Load Test Unit
4			Gas concentration alarm system	Gas concentration alarm system
5			Lubricant viscometer	Lubricant viscometer

Modification of tools and parts

The processing and machining equipment can still be used after conversion, but it was necessary to change the tools and moulds to meet the size of the parts for R-290 compressors. Meizhi designed and manufactured these tools and moulds by themselves.

Installation, debugging and trial of the production line

The equipment was delivered and installed in April and May 2012.

Training and technology dissemination

Meizhi has organized three training workshops focused on different topics and trainees:

- 6 March 2011, test operation of R-290 compressors
- 13 January 2012, designing of R-290 compressors
- 10 May 2012, HC refrigerants and its applications

The company has utilized the opportunity of meetings and exhibition to disseminate the R-290 technology. The main activities include:

- The 23rd IIR international Congress of Refrigeration: Refrigeration for Sustainable Development.
- Advancing Ozone and Climate Protection Technologies: Next Steps.

- The 2nd Regional Symposium on Alternative Refrigeration or Air-conditioning Industry in High-Ambient Temperature Countries, the Way Forward 2012.
- Chillventa
- ACREX

4. Results

The results of these two projects can be divided in three different aspects: the environmental impact of the projects, the quality of the new products and the capacity of converted production lines.

4.1. Environmental impact

The implementation of these projects will indirectly benefit the ozone layer by enabling domestic room air conditioner manufacturers to build appliances using refrigerant with no ozone depleting impact. This will prevent the release of refrigerants at two stages: during the life time of the products and at the time of discarding those products.

In this sense, considering the fact that average RAC units traditionally contain 1.2 kg of HCFC-22 refrigerant with an ODP of 0.055, the new compressors manufactured by Meizhi will indirectly phase out 2,196 metric tons of HCFC-22 with a total impact of 121 ODP tons per year, while Midea's new RAC appliances will allow the phase-out of 240 metric tons per year, equivalent to 13.2 ODP tons per year.

The use of these new products will also reduce the emission of Green House Gases (GHG) during the life time of the appliances and in the process of disposal, due to the very low GWP of R-290. The estimated greenhouse gas emission reduction in the Meizhi project is 8,852,533 MT CO_2 equivalent per year of operation of the line at the given capacity. In the case of Midea, this reduction is estimated in 967,490 MT CO_2 equivalent per year of operation of the line at the given capacity.

In addition, in view of the higher energy efficiency of the refrigerant, an indirect reduction of GHG emissions linked to energy consumption is also expected.

Table 6. Environmental impact of the projects*

Projects	ODS		GHG (MT CO2 eq.)
	Metric tons of HCFC-22	ODP tons	
Midea	240	13.2	967,490
Meizhi	2,196	121	8,852,533

* Per year of manufacturing on the lines at the given capacity

4.2. Quality of the new products

As mentioned before regarding Meizhi's project, two types of R-290 compressors (fixed and variable frequency) with 1 HP and COP of 4.12-4.33 are available for mass production[6]. The compressors have been tested under the following test conditions:

Table 7. Test conditions

Parameters	Temperature (deg C)
Condensing Temp.	54.4
Evaporation Temp.	7.2
Superheat	10.8
Subcooling	8.3

Tested by Midea under standard GB/T7725-2004.

The energy efficiency ratio of the R-290 compressor is 2%-3% higher than a HCFC-22 compressor[7]. In order to obtain such improvements in the new products' performance, as well as in the system optimization, additional efforts were required in terms of co-financing by Meizhi. This was also the case for Midea's project.

As above mentioned, the certification authorities have already certified the consistency of new air-conditioners with the standard GB 4706.32 (see section 7. Practical findings), which allows the use of flammable refrigerants in RAC products in the local market (3C certificate).

Compliance with international standards has also been certified (IEC/CB and CE).

The types and models of R-290 RAC units that has been developed by Midea is shown in the table below:

[6] The actual COP is higher than the designed COP parameter (from 3.25 to 3.30), since the new compressor is a DC INV model and the one before conversion was a fix speed compressor. In this sense, the test conditions are different and hence the results are also different.

[7] The energy efficiency of new compressors was tested with Calorie meter at Meizhi laboratory.

Table 8. Performance information for R-290 based air-conditioners*

Type	Model	Capacity (w)	R-290		HFC-410A		Minimum requirements	Certification
			Charge (g)	COP (w/w)	Charge (g)	COP (w/w)	COP (w/w)	
Split/VF	KFR-26GW/BP3DN7Y	2600	270	4.77(APF)	980(R410A)	4.75(APF)	3.5	CCC
Split/VF	KFR-35GW/BP3DN7Y	3500	360	4.73(APF)	1130(R410A)	4.75(APF)	3.5	CCC
Split/VF	MS11M-09HRFN7-QRC4	2600	310	4.0(SCOP)	1030(R410A)	4.0(SCOP)	3.3(GWP<150)	CB/CE
Split/VF	MS11M-12HRFN7-QRC4	3500	350	4.0(SCOP)	1300	4.0(SCOP)	3.3(GWP<150)	CB/CE
Portable A/C	MPPD-09ERN7-QB6G1	2600	210	3.1	430(R410A)	2.6(R410A)	2.6	CB/CE
Portable A/C	MPPD-11ERN7-QB6G1	3200	230	3.0	520(R410A)	2.6(R410A)	2.6	CB/CE

* The R290 products were developed based on R410A models, thus, there are no comparison data with R22. In addition, R290's RAC efficiency is normally 5-12% higher than R22. Charge mass is only 45% of R22.

In terms of energy efficiency, as shown in the table, the new units can reach the highest standards. Compare to the HCFC-22 based units, the use of R-290 in the new air-conditioners leads to a reduction of 5% to 12% in energy consumption[8]. According to the test result, based on tests undertaken by Midea, in order to achieve the best performance, the 450g refrigerant would be required for a 3,500W capacity (COP = 3.0) split unit, however, the standards allow maximum 350g with which the capacity is less than 3,400W and a COP of 2.8.

Further efficiency improvement both in compressors and AC units could be achieved if the charge sizes specified in international standards were relaxed, since there is a relationship between charge and efficiency, and hence also an optimal charge. Until then, efficiency improvement is mainly dependent on the actual R&D - invested in the product in the past several years and the years to come - that was not financed by the project, and also on system optimization, which was required as in most refrigeration conversion activities in the past. Furthermore, given these restrictions on charge sizes, only a change of refrigerant would have resulted in poorer performance compared to the R22 units, not to mention safety concerns. All products under the demo projects were designed for T1 ambient conditions. After the completion of the project, Meizhi has developed T3 compressors for high ambient regions as well.Capacity of production lines

[8] The energy efficiency of new AC units was tested at Midea laboratories.

The capacity of the production lines remains the same as before the conversion in both companies: 200,000 units, in the case of Midea, and 1,830,000 units, in Meizhi's production line.

With regard to the latter, more than 20,000 R-290 compressors were produced by the end of 2013, being most of them sold to other AC manufacturers different from Midea.

5. Incremental costs

5.1. Incremental capital costs

In both projects there have been some adjustments regarding the cost of equipment and tools purchased. The following is a summary of these adjustments. Besides, in annexes 1 and 2, a breakdown of these costs is presented, including explanations of the major variations from the original budget.

5.1.1. Midea

The actual cost of the combined pre-charging H_2/N_2 pressure- and leak test was US$ 74,444 compared to the approved budget of US$ 32,000. The cost of the ex-proof R-290 storage room was US$ 59,841, whereas the approved budget was US$ 32,961. The cost of R-290 storage tank and pipeline including installation amounted to US$ 132,698 compared to an approved budget of USD 64,039.

Additional items were required, which were originally not budgeted: a booster pump that ensures that the inlet of the charging machine is fed with sub-cooled refrigerant, Nitto quick couplings to avoid leaks during charging and in particular testing, as well as variable frequency power supply to facilitate 110V and 220V as required by different A5 markets. These additional items had additional costs of US$ 60,000.

Cost of the heat exchanger conversion was 3 times higher than the approved budget, however, it needs to be considered that funding was provided only for 60% of the estimated conversion costs, since the production capacity of the HE was about 330,000 unit per year (before and after conversion), while the converted production line had a capacity of only 200,000.

Cost of other items was similar to the approved budget with differences of up to +/-20%. In this sense, the cost of the equipment purchased amounts to US$ 3,938,004, out of which US$ 2,383,967 has been covered by the funds provided by the MLF in line with the approved project based on the eligible A5 ownership.

5.1.2. Meizhi

The actual costs in the case of Meizhi amounted to US$ 3,398,093 and were about 11% higher than the total agreed project budget (US$ 3,049,190). However, in these costs, investments related to R&D of the past years have not been included, which is also of significant value. High level of co-financing was required from the enterprise to cover the costs related to the 40% A2 ownership as well as the additional

investments. In this sense, the funds provided by the MLF amounted to US$ 1,875,000, in line with the approved project based on the eligible A5 ownership.

With respect to the various components, it can be concluded that costs related to the motor coiling line and the rotor & stator line were significantly underestimated in the project document, since these parts are crucial to the performance of the compressors and thus, high quality equipment is required[9]. Conversion of these two lines alone had a cost of US$ 1,416,187. Actual cost of the conversion of assembly line was about 30% more expensive than approved. Cost of the lubricant viscosity meter was US$ 31,746 compared to the approved budget of US$ 11,644. It is to be noted that selection of a suitable lubricant is essential in the reduction of the charge size.

On the other hand, investment costs related to the case line were significantly lower, since a majority of these operations have been outsourced by the company. However, it adds operating cost to the company, which is not eligible for funding. The cost of test tools was also much lower (about 20% of the approved budget) and savings could be made on the purchase of the gas concentration alarm system (1/3 of the approved budget) due to the fact that these tools were sourced domestically instead of the originally foreseen imported equipment. The cost of other items was similar to the approved budget with differences of up to +/-20%.

5.2. Incremental operating costs

IOC for compressor for Midea was not covered by the funds provided by the MLF, instead the conversion of Meizhi compressor manufacturing line was financed. The cost of the new compressor manufactured by Meizhi is US$ 7.57 higher than the HCFC-22 based compressor.

In the case of Midea, the estimated IOC for one split unit is currently US$ 41.95, as described in the table below.

Although the actual IOC is significantly higher than the eligible USD 6.3/kg, these additional costs are associated with the product initiation and expected to decrease in future, albeit not quite the level of the IOC threshold. In addition, the methodology for applying the safety measures is also being refined. UNIDO will continue to monitor the progress of the IOC as part of the RAC sector plan.

[9] The high cost of these lines was due to the high quality equipment that was required in order to fulfil the technical requirements of conversion. There was no other option for conversion and, thus, there is no difference between the cost increases resulted from performance upgrade and those from conversion.

Table 9. Incremental operating costs - Midea

Item	Incremental cost/RMB	Incremental Cost/USD	Remarks
Heat exchanger	-31.05	-5.09	40 meters of copper tube for condenser, with 7.395 RMB per meter of 7 mm and 6.61875 RMB per meter of 5mm
Refrigerant	-3.02	-0.50	1.2 kg HCFC-22 with 10.126 RMB/kg, 0.3kg R-290 with 30.45 RMB/kg
Lokring	10	1.64	One lokring costs 2.5 RMB and there is a need for four
Compressor	46.19	7.57	Data from Meizhi
Electronic parts	99.63	16.33	Electronic parts are sealed
Labor cost per unit	4.14	0.68	Based on 0.006RMB/second;
Installation	130	21.31	Installation of one HCFC-22 unit requires 4,440 seconds and an R-290 one needs 6,690 seconds, with a labor cost of 0.052 RMB/sec.
Total	**255.89**	**41.95**	

In this project, 50% of the IOC relates to additional labor costs due to the necessary safety features applied to the product.

6. Safety issues

As above mentioned, contrary to HCFC-22, R-290 is flammable and explosive refrigerant and therefore, significant changes should be introduced to the existing design and use of air-conditioners and compressors.

In the case of RAC units manufactured by Midea, these changes are introduced to reduce the amount of the refrigerant in the appliance, control refrigerant containment and prevent large leakages. Furthermore, safety measures need to be adopted in every step including production, storage, transportation, as well as installation and servicing of the appliances at the costumers.

In light of the above, to reduce hazards in the manufacturing of RAC units the following major principles are followed during the product and technology conversion:

a. The charge size of R-290 A/C should be dramatically reduced comparing to HCFC-22. In view of the excellent thermo-physical performance of R-290, especially its large latent heat and favorable viscosity, the charge amount of R-290 refrigerants can be substantially lowered without compromising on the cooling capacity of the A/C;

b. The new split units should be equipped with explosion proof components, leak sensor and a special sensor, which monitors the temperature/pressure ratio to recognize eventual refrigerant leaks and avoid formulation of hazardous air/refrigerant mixture within the room being cooled;

c. In the manufacturing, repair and testing processes gas detection, monitoring and safety ventilation systems as well as emergency power supply should be installed. The hazardous areas should be thoroughly checked and safety risks should be eliminated, e.g. all equipment in the hazardous areas should be made Ex-proof and properly grounded to eliminate risks arising from sparks in case of a potential leakage of refrigerant, the plant floor in the hazardous areas should be painted with antistatic coating for the very same reason.

d. The manufacturing, plant maintenance as well as the appliance installation and service personnel should be thoroughly trained.

e. Special tools are to be provided to the service staff for the installation of R-290 RACs.

Developments continue post-project with the aim to minimize and simplify product modifications while maintaining safety, in order to expand the range of products. In this sense, there are efforts on simplifying the safety measures - like the one mentioned on the sensor for the outdoor unit – and, furthermore, significant efforts are being made to reduce charge size without significantly compromising the system performance, as well as extending the application to larger units.

Concerning the production of compressors, the main safety measures to be considered are as follows:

a. Electric components inside the R-290-based compressor should be sealed. This results in the modifications of the electric components and structure of the compressor;

b. Flammability of the new refrigerant requires special explosion-proof performance testing machines, such as calorimeter, life test units, gas load testing unit and operation testing unit for the compressor.

Besides these principles, relevant foreign standards and practices for the production of R-290-based room air-conditioners and compressors can be a reference to Chinese manufacturers.

In conjunction with RAC sector plan, FECO has cooperated with Tianjin Firefighting Research Institute to design and conduct a research on the flammability of R-290 refrigerant in a common use scenario. Air-conditioners were installed in rooms of various sizes and refrigerant leaks and burning were tested in different conditions. The experiment report was made available in May 2013 and published in English on *International Journal of Refrigeration*. The experiments and assessments showed that the possibility of fire and explosion for a wall-mounted R-290 air-conditioner is 10^{-8}-10^{-9} per year under household use conditions, which is 1/10 of the risk of a domestic refrigerator with hydrocarbon. In June, an expert panel discussed and determined the key points of next phase's risk assessment, including risks in the servicing and installation processes, risks at different charges, and secondary risks from a fire.

7. Practical findings/Lessons learnt

With regard to the project, the main point to highlight is that its approval and implementation were essential for the development of R-290 units, and have also been a basis for the RAC phase-out strategy

in China. As a result, by now, most RAC manufacturers in the country are involved in R-290 conversion activities and R&D.

In terms of market introduction, since the local market is so relevant for both companies, the following lessons can be learnt:

- Due to the introduction of new alternative technologies in the RAC sector, modification on the existing Chinese standards as well as establishment of new standards will be a key factor for the adoption of alternative technologies.
- Technology promotion is essential for the introduction of R-290 in the local market. New policy/financial measures should be considered to help the R-290 air-conditioners' sales in the market.
- Training on the servicing and installation of the RACs with flammable refrigerants is prerequisite for the market introduction and safe use of the R-290 air-conditioners.

Regarding the standards, FECO has cooperated with the China Household Electrical Appliances Association (CHEAA) to establish 3 standards for flammable refrigerants. These are technical safety codes for using flammable refrigerants in the household and similar air-conditioners manufacturing industry, the particular requirements for transportation of room air-conditioners charged with flammable refrigerants, and technical safety codes for servicing. The draft standards are planned to be prepared in 2014, while the adoption of the standards is envisaged in 2015.

In parallel, on 1st May 2013, the standard GB4706.32 on Safety of Household and Similar Electrical Appliances – Particular Requirements for Heat Pumps, Air-Conditioner and Dehumidifier, came into effect. The standard is equivalent to IEC 60335-2-40, which allows application of flammable refrigerants in air-conditioner systems provided that they meet the specific requirements such as charging amount, labelling and electric safety measures.

Concerning the market introduction, FECO, in partnership with an association of manufacturers, has established a market promotion subsidy scheme by which those manufacturers that sell R-290 AC units in 2014 and 2015 can get a subsidy up to a level of US$50 for the first 10,000 units they produce. In 2016, this subsidy will be half of the above mentioned amount.

Besides this, since 2008 many initiatives have been launched to control and limit the production, commercialization and consumption of ODS as the HCFC refrigerants. Among these initiatives, it can be mentioned the *Circular on the Catalogue of Controlled ODS in Import &Export (5th batch)*, the *Circular on Strict Control over the Establishment of Facilities Using HCFCs* and the *Circular on Strict Control of HCFC Production Facilities*. In June 2010 it entered into force the *Regulation on ODS Management*, which was reviewed and approved in principle at the Executive Meeting of the State Council chaired by Premier Wen Jiabao. More recently, in August 2013, the MEP issued the *Notice on quota permit for the production, sale and consumption of HCFCs*. These initiatives establish a legal

framework to reduce the use of ODS and, therefore, they promote indirectly the adoption of alternative refrigerants, as for example the R-290 that has been tested in these projects.

Finally, with respect to the training on the servicing sector, a feasibility study on the certification of servicing workers has been initiated by FECO to standardize the operation of servicing workers and minimize the unwanted emission and discharge of refrigerant.

8. Conclusions

- R-290 is an environmentally friendly refrigerant, since its ODP is zero and its GWP is as low as three. With an excellent cooling performance, R-290 is considered one of the ideal alternatives of HCFC-22 in the RAC sector after conversion of production lines.
- R-290 is available in the Chinese market.
- The conversion of two of the most important production lines of RAC units and compressors in China has maintained the quality and performance of the appliances produced by these two companies. Their performance is consistent with national (CCC) and international standards (IEC/CB and CE), and this has already been certified by the authorities.
- In order to obtain such improvements in the new products' performance, as well as in the system optimization, significant additional efforts were required in terms of co-financing by both companies.
- Regarding the new compressors' performance, the energy efficiency is 2%-3% higher than HCFC-22 compressors.
- Concerning the new RAC units' performance, the energy efficiency is 5%-12% higher than HCFC-22 air-conditioners.
- Further efficiency improvement both in compressors and AC units could be achieved if the charge sizes specified in international standards were relaxed, since there is a relationship between charge and efficiency. Until then, efficiency improvement is mainly dependent on the actual R&D - invested in the product in the past several years and the years to come - and also on system optimization, which was required as in most refrigeration conversion activities in the past.
- **Two types of R-290 compressors (fixed and variable frequency) with 1 HP and COP of 4.12-4.33** are available for mass production after the conversion of the production line.
- **Two types of R-290 RAC units (split/VF and portable A/C) and six different models** are also available for mass production after conversion.

- The conversion of production lines and the manufacturing of new appliances can be handled safely, despite the flammability of R-290, if appropriate measures are implemented and appropriate tools and equipment are used.
- Developments continue post-project with the aim to minimize and simplify product modifications while maintaining safety; as well as to reduce the refrigerant charge in order to expand the range of products.
- The experiments and assessments show that the possibility of fire and explosion for a wall-mounted R-290 air-conditioner is only 10^{-8}-10^{-9} per year under household use conditions in China. Nevertheless, the next stages of phase-out programme should focus on risks in the servicing and installation processes, risks at different charges, and secondary risks from a fire.
- Besides, in order to foster the introduction of this new technology in the Chinese market it is necessary to establish new policies and financial measures, as well as updated safety standards.

Incremental capital costs

- In the case of both Midea and Meizhi, the projects have had higher capital costs than the agreed project budget.

Incremental operating costs

- Regarding Midea's project, the estimated IOC for one split unit is currently US$ 41.95. Although the actual IOC is significantly higher than the eligible USD 6.3/kg, these additional costs are associated with the product initiation and expected to decrease in future, albeit not quite the level of the IOC threshold. In addition, the methodology for applying the safety measures is also being refined.
- The cost of the new compressor manufactured by Meizhi is US$ 7.57 higher than the HCFC-22 based compressor (cost already part of the above calculation). IOC for compressor for Midea was not covered by the funds provided by the MLF, instead the conversion of Meizhi compressor manufacturing line was financed.

The approval and implementation of these demonstration projects was key for the development of R290 units and was a basis for the RAC phase-out strategy in China. As a result, by now, most RAC manufacturers in China are involved in R290 conversion activities and R&D.

While these demonstration projects in China were successful, the application of hydrocarbon (HC) technology should be carefully evaluated in context of the local situation prevailing in each country. The report by no means concludes that the technology was sufficiently consolidated to be applied in all countries, and did not address issues of availability and cost in the field. Finally, interested parties must take into consideration the proprietary issues related to the technology.

ANNEX 1. Cost of equipment purchased - Midea

No.	Area	Conversion or Procurement	Equipment	Conversion details	Budget (USD)	Budget (USD)	Actual cost (USD)	MLF financing (USD)	Company co-financing (USD)	Remark	Additonal remaks
1	Assembly Line Equipment	Conversion	Assembly Line	Assembly line relocation	117,000	117,000	227,302	140,400	86,902	Combined with Item 2 and item 16	The beneficiary has installed a new line, instead of converting the original one. This was the main reason for the higher costs. 20% beyond the budget was compensated in line with existing MLF rules.
2				Antistatic floor and ground circuit in the hazardous areas						Combined with Item 1 and item 16	
3				Power distribution explosion-proof modification for the production line							
				variable frequency power supply						Included above	
				Nitto quick coupling for the products						Additional items purchased that were required. 275 units of quick couplings were purchased for charging to avoid leakage. Frequency power supply was required since various countries have various needs and the tests have to be made accordingly	

No.	Area	Conversion or Procurement	Equipment	Conversion details	Budget (USD)	Budget (USD)	Actual cost (USD)	MLF financing (USD)	Company co-financing (USD)	Remark	Additonal remaks
4		Conversion	Function Test system	Function test units adjusted to the properties of R-290 (including Electrical safety tester and new quick connectors)	85,000	85,000	99,365	85,000	14,365	Combined with item 5, item 12 and item 30; 30test units	difference less than 20%
										30 test units	
6		Procurement	Refrigerant Charging	New refrigerant charging machines (including the transportation pump in the storage room)	100,000	320,000	352,143	320,000	32,143	Combined with item 15, item 17 and item 33	difference less than 20%
15			Leak detectors	Gas detection (IR) (included in the safety system)	-					Combined with item 6, item 17 and item 33	
16			Ventilation system	Safety ventilation system for R-290-based RAC production line	80,000					Combined with item 1 and item 2	
17			Safety System	Safety alarm system for R-	140,000					Combined with item 6, item 15 and item 33	

No.	Area	Conversion or Procurement	Equipment	Conversion details	Budget (USD)	Budget (USD)	Actual cost (USD)	MLF financing (USD)	Company co-financing (USD)	Remark	Additonal remaks
				290-based RAC production line and R290 storage room							
7		Procurement	Refrigerant Supply equipments and pipeline	Ex-proof R290 storage room	32,961	32,961	59,841	32,961	26,880		The beneficiary installed a bigger storage room than required for the one line in order to cater for the needs of additional R290 lines in future. 20% beyond the budget was compensated in line with existing MLF rules.
8				New storage tank for R-290 and New R290 pipeline installation for the production line and R290 storage room	64,039	64,039	132,698	76,847	55,851	Combined with item 9	
10		Procurement	Vacuum system and vacuum test	Ex-proof vacuum pumps	-	-	88,198	-	88,198	Combined with item 11	not eligible item
11				Vacuum meter						Combined with item 10	
12		Conversion		Vacuum measuring system modification						Combined with item 4, item 5 and item 30	
13		Conversion	Helium leak testing system		32,000	32,000	74,444	38,400	36,044		The budget approved was not sufficient and in future higher cost should be approved for a He leak testing system. 20% beyond the budget was compensated in line with existing MLF rules.

No.	Area	Conversion or Procurement	Equipment	Conversion details	Budget (USD)	Budget (USD)	Actual cost (USD)	MLF financing (USD)	Company co-financing (USD)	Remark	Additonal remaks
14		Procurement	Leak detectors	New portable R290 detectors for production line/test room/storage and new Helium leak detector for heat exchanger	80,000	80,000	83,200	80,000	3,200		difference less than 20%
18		Procurement	Sealing machine	LOKRING sealing machine	60,000	60,000	11,762	11,762	-		
19	Heat Exchanger Process Equipment	Conversion	High-speed fin stamping Press	Conversion of various parts of the high speed fin press and its stacker, fixtures and parts	103,700	417,850	1,646,337	459,635	1,186,702	Combined with item 20	The production capacity of the heat exchanger was about 330,000 unit per year (before and after conversion), while the converted production line had a capacity of only 200,000. For this reason, the approved budget was reduced according to the line capacity. However, the conversion of the heat exchanger producing equipment had to be done for the original full capacity (330,000 units) and thus, costs were consequently higher.
20		Procurement		Procurement of moulds for fin press	314,150					Combined with item 19	
21		Conversion	Hair pin tube bending machine	Conversion of the Ø9.52-sized Hair Pin Bending machine to Ø5-sized one, new tools.	24,000	24,000	62,698	24,000	38,698	Combined with item 25	
22			Connection curve bending machine	Conversion of the Ø9.52-sized connection curve bending	12,000	12,000	18,651	12,000	6,651	Combined with item 23 and item 24	

No.	Area	Conversion or Procurement	Equipment	Conversion details	Budget (USD)	Budget (USD)	Actual cost (USD)	MLF financing (USD)	Company co-financing (USD)	Remark	Additonal remaks
				machine to Ø5-sized one, new tools.							
23			Cutting machine	Conversion of the Ø9.52-sized cutting machine to Ø5-sized one, new tools.	15,000	15,000	23,810	15,000	8,810	Combined with item 22 and item 24	
24			CNC Tube Bending Machine	Conversion of the Ø9.52-sized CNC tube bending machine to Ø5-sized one, new tools.	16,000	16,000	21,746	16,376	5,370	Combined with item 22 and item 23	
25			Automatic Tube End Processing Machine	Conversion of the Ø9.52-sized automatic tube end processing machine to Ø5-sized ones, new tools.	13,000	13,000	10,397	10,397	-	Combined with item 21	
26		Procurement	Expander Presses	For small diameter of tube.	198,250	332,450	660,317	332,450	327,867	Combined with item 27	
27			Expander Fixtures and Jigs	For small diameter of tube.	134,200					Combined with item 26	
28			Welding Ring Insertion Machine	For small diameter of tube.	20,000	20,000	19,381	19,381	-		

No.	Area	Conversion or Procurement	Equipment	Conversion details	Budget (USD)	Budget (USD)	Actual cost (USD)	MLF financing (USD)	Company co-financing (USD)	Remark	Additonal remaks
29			Cleaning Machine	New cleaning machine for Ø5-sized tubes.	18,000	18,000	18,730	18,730	-		
30	Operating performance test equipment	Conversion	Ex-proof conversion	Explosion-proof modification of the function test	20,000	259,000	326,984	284,900	42,084	Combined with item 31 and 32	Actual costs confirm that the original budget was somewhat underestimated. For this reason, 10% beyond the budget was compensated in line with existing MLF rules.
31		Procurement	Capacity test	Capacity test unit suitable for R-290 RAC	159,000					Combined with item 30 and 32	
32			Life test Unit	Life test units suitable for R-290 RAC	80,000					Combined with item 30 and 31	
33	R290 recovery station	Procurement	R290 recovery station	Ex-proof recovery stations for R-290	10,000	10,000	see remarks			Combined with item 15, item 17 and item 6	
34	Tools for Installation	Procurement	Tools for Installation	Refrigerant Bottles	15,750	15,750	see remarks			To be purchased as soon as sales start and will be paid by company co-financing.	Will be additional costs and are required as eligible items
35				Ex-proof vacuum pump	180,000	180,000	see remarks			To be purchased as soon as sales start and will be paid by company co-financing.	Will be additional costs and are required as eligible items
36				LOKRINGS tools	396,000	396,000	see remarks			To be purchased as soon as sales start and will be paid by company co-financing.	Will be additional costs and are required as eligible items

No.	Area	Conversion or Procurement	Equipment	Conversion details	Budget (USD)	Budget (USD)	Actual cost (USD)	MLF financing (USD)	Company co-financing (USD)	Remark	Additonal remaks
37	Others	Delivery, insurance, installation of manufacturing equipment etc. 7.5%			189,004	189,004	see remarks	189,004	-189,004	Total cost for this line is not possible to identify due to the many items and purchases made. For this reason, the total approved budget is indicated for this line item and co-financing amount is reduced accordingly.	
38		Contingency			270,905	270,905		216,724	-216,724	Since actual costs were higher than the original budget (including A2 ownership), the co-financing amount was was reduced by the approved contingency budget.	
TOTAL					**2,979,959**	**2,979,959**	**3,938,004**	**2,383,967**	**1,554,037**	39% of the total equipment cost was company co-financing	

ANNEX 2. Actual costs – Meizhi

Activities	Total Budget US$	Actual Expenditure (USD)	MLF Actual (USD)	Co-financing (USD)	Remarks
Motor coiling line	131,285	619,048	131,285	487,763	Costs have significantly increased, since higher standard equipment was selected, as these are essential for compressor performance;
ROTOR & STATOR line	397,020	797,139	305,483	491,656	Costs have significantly increased, since higher standard equipment was selected, as these are essential for compressor performance;
Assembly Line	170,217	216,990	170,217	46,773	
CASE line	132,210	3,499	0	3,499	it has been largely outsourced, that is the reason for the under-expenditure
ROLLOR line	79,281	72,393	72,393	0	
MAIN BEARING line	33,814	29,124	29,124	0	
SUB BEARING line	33,814	33,965	33,965	0	
CRANK SHAFT line	79,282	81,892	72,804	9,088	
CYLINDER line	52,854	53,615	52,854	761	
BLADE line	6,607	4,675	4,675	0	
sorting line	11,653	3,425	0	3,425	domestic purchase reduced costs
Test tools	264,268	38,206	0	38,206	domestic purchase reduced costs
Calorie Meter	330,335	373,016	330,335	42,681	

Activities		Total Budget US$		Actual Expenditure (USD)	MLF Actual (USD)	Co-financing (USD)	Remarks
Life test Unit		488,896		552,381	488,896	63,485	Another unit will be purchased by the company outside the project budget
Gas Load Test Unit		158,561		115,714	0	115,714	purchased before the project was approved, so cost was paid as co-financing, but it is in fact and actual ICC
Gas concentration alarm system		39,000		13,270	13,270	0	domestic purchase reduced costs
Lubricant viscometer		11,644		31,746	11,644	20,102	The planned viscosity meter did not meet the requirements and for this reason another type had to be purchased
Sub-total		**2,420,741**		**3,040,098**	**1,716,945**	**1,323,153**	
Production trials	material cost	42,750		49,495	42,055	7,440	costs related to prototyping
	Labour Costs	5,750		5,750	0	5,750	cost was covered from company's budget
	Evaluation and Testing	1,750		1,750	0	1,750	cost was covered from company's budget
Sub-total		**50,250**		**56,995**	**42,055**	**14,940**	
Technical Assistance Costs	Design conversion	Redesign of products, production line, manufacturing procedures and conversion of specialized software	100,000	100,000	45,000	55,000	estimated staff costs, company's co-financing

Activities		Total Budget US$		Actual Expenditure (USD)	MLF Actual (USD)	Co-financing (USD)	Remarks
	Technical communication, survey and consulting	Technical communication with component suppliers, Technical communication with downstream companies, Expert costs	60,000	60,000	30,000	30,000	estimated staff costs, company's co-financing
	Consultant (External coordination and cooperation)	Safety test of compressorsSelection of lubricant	100,000	100,000	0	100,000	estimated costs, company's co-financing
	Test and certification	Test and certification of products Component and material tests	25,000	25,000	25,000	0	
Sub-total			**285,000**	**285,000**	**100,000**	**185,000**	
Training Cost	Training of processing staff		12,000	12,000	12,000		level of additional costs born by the company is not known
	Training of test staff		4,000	4,000	4,000		level of additional costs born by the company is not known
Sub-total			**16,000**	**16,000**	**16,000**	**0**	
Contingency			***277,199***	See remarks	See remarks	See remarks	Included in the above items
TOTAL			**3,049,190**	**3,398,093**	**1,875,000**	**1,523,093**	