Trends and Perspectives in HVAC & R Technology in China

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ABSTRACT
The development of HVAC & R industries and market in China is described. The current trends in HVAC & R products mainly focuses on energy saving, environmental protection and comfortable healthy products. The manufacturers in China produce mainly split room air conditioners, refrigerators, VRF multi evaporator systems for commercial and residential users, air-source heat pump type water chiller, screw chillers, centrifugal chillers and absorption chillers. The energy labeling system for HVAC & R has contributed to increased energy savings in China. The national standards and certification systems have given impetus to the HVAC & R market sustained growth. With the increased awareness of the importance of R&D, the Chinese industry, the organizations and universities have promoted the development and even pushed the R & D of HVAC & R products. This is slowly changing the perspective in the HVAC&R domain from “made in China” to “developed or innovated in China”. Various new research works are highlighted in this paper.

1. INTRODUCTION

China is the largest developing country in the world and has a varied climate that can be divided into five climatic zones. These zones include areas which are:

- Severely cold e.g. Heilongjiang province, where heating is very important for the most part of the year;
- Cold e.g. Beijing, where heating is necessary from Oct. to March, while cooling in summer is not a big problem;
- Hot in summer and cold in winter e.g. Shanghai and nearby provinces, where cooling in summer and heating in winter are necessary;
- Warm e.g. Guangdong and Fujian provinces, where heating is not necessary and cooling is needed in summer time;
- Hot e.g. Hainan province, where cooling is needed all the year.

With the recent rapid development of the Chinese economy, heating and cooling has become more and more important in real life. The statistics on energy consumption shows that buildings have contributed up to 25% total energy consumption in China. Out of this, 60% was used for heating and cooling, while 15% for residential hot water (Jiang,2005).

The fast economic development and the increasing living standards of people in China have prompted a new wave of building construction. Since the year 2000, 1.5 billion m² area of buildings are built every year, and this is projected to continue until the year 2020(Qiu,2007). This increase in buildings has a direct effect on the national energy consumption, and therefore the Chinese government has taken energy management into serious consideration. Two laws, Renewable Energy Law and Energy Saving Law, provide the main guidelines for building energy systems and HVAC & R industries. The Renewable Energy Law was enacted in 2005 and started to be enforced in 2006, whereas the Energy Saving Law will be issued in 2008. Energy saving for air conditioning systems and refrigerators has been in consideration for many years. Energy saving labels has been used for most of residential electric appliances, especially for room air conditioners. It is a known fact that air conditioning consumes
more than 40% electricity in summer peak time in some big cities such as Shanghai. The recent cold winter has also caused problems of electricity shortage in some big cities.

The China HVAC & R industry has developed rapidly in the last 20 years, and currently China is a big manufacturer of HVAC & R products. Both the Chinese national companies and the international companies have contributed to the growth of the industry. China is now slowly changing focus from “Made in China” to “Designed in China”, and “Researched & Developed in China”. The government and other associations have been encouraging the industries to move a step further to “Innovated in China”. Many big and well known companies have established research centers in China in the last five years and the Chinese HVAC & R products are not only available on the local market but also on the global market.

This paper shows the market development of HVAC & R in China, the market shares of various types of products, and also the intensified researches and developments of building energy systems in China.

2. HVAC & R INDUSTRIES AND MARKETS IN CHINA

The HVAC & R industry has developed rapidly in the recent years and the market for HVAC & R products has been expanding consistently. In 2007, the total production of HVAC & R products accounted for 90.8 billion RMB Yuan. The total sales were 85.9 billion RMB Yuan and the benefits were 5.43 billion RMB Yuan. It is estimated that the rate of increase in the total production and sale of HVAC & R products will be 10-20% in 2010, which is 1.5 times that of 2006. By the year 2020, the main index is projected to double in comparison with that of 2010.

The recent increase in building construction has prompted the market of air conditioning systems. Many urban centers have come up in the countryside, which has helped to extend market for HVAC & R. The automobile industry has also been growing at a high rate. The total production of automobiles reached 7 million units in 2006 and 8.8 million in 2007, hence resulting in increased demand for automotive air conditioning systems. Even though currently the automobile industry supplies mainly the local market, it is expected that within the next few years, it will also supply the world market. The continuous increase in the number of supermarkets and shopping malls provides impetus to the growth of the market for commercial refrigeration and cold chain equipments. This therefore makes certain the fact that the HVAC & R industries in China will suffer many changes and expansion in the next 5-10 years.

2.1 Room air conditioners

China is the biggest supplier of room air conditioners (RAC) in the world. The annual total production has reached close to 30 million units. Fig.1 shows the changes in production of room air conditioning units from 1997 to 2007(Aircon http://, 2008). In 2007, 28.4 million units were sold, which accounted for 68 billion RMB Yuan. Fig.2 shows the Unit price changes from 2001-2007(Aircon http://, 2008).

![Fig.1: The production unit changes from 1997 to 2007.](image1)

![Fig.2: The averaged unit price changes from 2001-2007.](image2)

The main producers of room air conditioners can be classified into three grades based on the production output. Grade 1 (>2 million units per year) includes Gree, Media, and Haier, which are all Chinese manufacturers. Grade 2 (between 1 and 2 million units per year) includes Hisense, Panasonic, Kelong, Glaze, Aux, Chigao, where only Panasonic is from outside China. Grade 3 (< 1 million units per year) includes Mitsubishi, Samsung, Changhong, Chunlan, TCL, Daikin, Hitachi, Sharp, Fujitsu General, Sanyoo, LG etc., in which only Changhong, Chunlan and TCL are Chinese companies. It is worth mentioning that Changhong and Chunlan were once the main manufacturers
of room air conditioners, but they later diversified to manufacture other products. Fig. 3 shows the changes in RAC market share (in units) in China market from 2003 to 2007 (Aircon, http://, 2008). Grade 1 manufacturers have consistently had an increase in the market share for their products.

If the market is classified by regions in China, 33.9% of the market is in East China (mainly the triangle Yangzhi River, Shanghai and its environs), 18.64% in North China (Beijing and its surrounding areas), 16.78% in middle China (Wuhan and the nearby areas) and 16.10% in South China (Guangdong, Fujian provinces etc.). The market in North East, North West and South West of China accounted for less than 15% market.

2.2 Centralized air conditioners
The centralized air conditioning systems had a total market of 26 billion RMB Yuan in 2007, however the market share for these products has dropped down to the lowest point since 2003. This is perhaps related to the controlled construction of public buildings in China. However, this is likely to change in the next few years due to the market needs for Beijing Olympics in August 2008 and Shanghai world EXPO in 2010, in addition to several other big projects. There are mainly 8 dominating brands of centralized air conditioners, which can be classified as “5+3”. The “5” consists of Daikin, York, Carrier, McQuay, Trane, whereas the “3” consists of national brands Media, Haier and Gree. The market increase rate for the “5” brands is 16.58%, while for the “3” brands is 27%.

The overall market share for air conditioning systems (based on sale values) are shown in Fig. 4 (Aircon, http://, 2008). The centrifugal chiller, screw chiller, LiBr-water absorption chiller, VRF heat pump, and air/ground source heat pump occupy 8%, 14.7%, 7%, 19.6% and 2.8% of the market respectively. Whereas, room air conditioners (others) comprise close to half the AC market.

Centrifugal chiller: The Centrifugal chiller market is dominated by four American brands (York, Carrier, Trane and McQuay), which command 95.8% market share or 96.6% of total sales. Chinese companies such as
Media, Haier and Gree have paid attention to this product, and are making efforts to have a significant share in the market in future. It should be noted that since 2006, McQuay has become a subsidiary of Japanese Daikin Company.

**Screw chiller:** Screw chiller has a total market sales of 14.7%, in which water cooled screw chiller accounts for 72%, whereas the air cooled screw chiller accounts for 28%. The major market share belongs to international brands, however Chinese products are increasingly entering the market and the situation may be different in 5-10 years as Chinese companies already have a good command of the technology.

**LiBr-water absorption chiller:** It was estimated to have a market share (sale value) of 10-15%, but the shortage and the increase in cost of natural gas has slowed down the market share of this product to 7%. This has made many small Chinese companies to stop production of absorption chillers. At the moment, the market is mainly dominated by Shuangliang, Broad, Sanyoo, Ebara, Carrier, and LG. Shuangliang, Broad, and Sanyoo brands were the main dominants 5 years ago, but currently, Ebara’s share has reached a market share of about 20%. The main market of LiBr-water absorption chillers is in northern China due to the relatively low price of natural gas, and because it has a high heating efficiency. The future designs of absorption chillers is expected to factor in waste heat utilization as energy saving is increasingly becoming one of the main concerns in China. The demand for single effect absorption chiller and absorption heat pump may therefore increase in the future, besides the currently double effect products.

**VRF heat pump:** Also referred to as VRV, MDV, HRV by different companies. The market for this product has increased rapidly, and is mostly suitable in the East China market for cooling and heating purposes, and especially for small to medium office buildings. The CBD high rise buildings also use such systems according to the demand of different floors or companies. Daikin brand has dominated the market with a share of 43.3%, whereas the shares for the other brands are: Hisense Hitachi 13.4%, Haier 5.7%, Mitsubishi Heavy Haier 5.0%, Media 4.7%, Gree 11%. Other various small brands comprise 22.1%. The multi-evaporator inverter systems are dominated by Japanese brands with 84% of the market share. The market share for Samsung, Gree and Media is likely to increase rapidly in the next 3-5 years because the manufacturing companies have cooperated with Emerson to use digital scroll compressor. Currently Gree, Media, Samsung, McQuay are also focusing on VRF heat pump products as they think that such products have advantages when used as heat pump at ambient temperature lower than -10 °C. There are potential market needs in the northern part of China for such products.

**Ground source heat pump:** a kind of water source heat pump which extracts heat from the ground through a water-soil heat exchanger. The market for this product has been increasing for the last 3 years, and mostly is in the north of China. The winter heating and summer cooling for residential buildings can be nearly balanced, such systems are quite suitable for use in Beijing, Tianjin, Shandong provinces and its environs. The application in Yangzi river triangle region (Shanghai and its surrounding areas) and Zhujiang triangle region (Guangzhou and its environs) have also started. However there are problems in the near future due to the unbalance of heat in the ground. Ground source heat pumps have been used also in commercial buildings, although they may be restricted in downtown areas of cities. Currently there are no standards which have been issued for these products. Small companies have started to compete against big, international companies.

### 2.3 Refrigerators

The number of refrigerators produced in China has increased a lot from 1991 (4.7 million units) until 2006, at an annual rate of 11%, which is somehow is higher than the GDP increase rate (Ma,2007). In 2005, the total number of refrigerators produced was 24.76 million units, with 10.71 million units sold within China. This accounted for 23.8 billion RMB Yuan, the average unit price was only 2,220 RMB Yuan in China. In 2006, the total number of refrigerator produced increased to 30.79 million units (which is already 30% total worldwide production), in which 14.27 million units were sold in China.

The statistical data in 2006 showed that the major producers of the refrigerators were Haier, Xinfei, Meiling, Media, Rongsheng, Little Swan, Hisense, TCL, Rongshida, which are all Chinese brands. Their products had accounted for 90% of Chinese market, for refrigerators with capacity less than 210 liters. The foreign based brands Siemens, Bosch, Electrolux, Panasonic, Sharp, LG, Samsung dominated for high capacity refrigerators.

### 3 ENERGY LABELS AND HVAC & R PRODUCTS

Energy saving for HVAC&R products came into focus 20 years ago. However, the real national wide movement was initiated in 2005.
Room air conditioners (RAC), as the main consumers of electricity, had an EER between 2.2 to 3.3 in 2003 in China. Most of the products (made from Chinese companies) of split room air conditioners had EER of between 2.2-2.5, which was far below that of international standards. In 2004 the new standards for room air conditioners and unit air conditioners were issued (GB12021.3-2004, GB19576-2004). The implementation of these standards began in 2005. Table 1 and 2 shows the energy efficiency level of RAC and unit air conditioners, respectively, classified into 5 grades. When the energy efficiency grade level of RAC was issued in 2004, there were 30% RAC with efficiency level lower than grade 5, thus the real enforcement of the standard was postponed to 2005(Ma, 2007). In 2007, most of market products were labeled as grade 5 and 4, and few products have grade 1 or 2 labels. However, new upgraded standard will be executed in 2009, in which the original grades 5, 4 and 3 will not be allowed in the market. These new upgraded standard is currently under discussion and it will possibly set the original grade 3 as the new start point in place of grade 5. Besides, there are several companies such as Hisense who have paid more attention to inverter RAC production, which have showed a high EER, and also high SEER. The inverter RACs have been influenced by Japanese technologies and products, and are increasingly getting into the market.

In table 2, the air conditioning system is usually a centralized system with refrigeration power larger than 7000W and the multi evaporator VRF heat pump is not included. The standard for VRF energy efficiency grade level will be issued in China in 2008. For the above energy label standards, heating is not yet considered. The energy efficiency grade level standards for inverter type air conditioner and multi evaporator VRF heat pump are yet to be issued. These standards will indicate the replacement of EER by SEER for the above fixed frequency systems. The IPLV method will be used to evaluate the multi evaporator VRF products into 5 grade levels.

Table 1 the energy efficiency grade level of room air conditioners

<table>
<thead>
<tr>
<th>Type</th>
<th>Rated refrigeration power (CC,W)</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packed</td>
<td>-</td>
<td>2.3</td>
<td>2.5</td>
<td>2.7</td>
<td>2.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Split</td>
<td>CC≤4500</td>
<td>2.6</td>
<td>2.8</td>
<td>3.0</td>
<td>3.2</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>4500&lt;CC≤7100</td>
<td>2.5</td>
<td>2.7</td>
<td>2.9</td>
<td>3.1</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>7100&lt;CC≤14000</td>
<td>2.4</td>
<td>2.6</td>
<td>2.8</td>
<td>3.0</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Table 2 The energy efficiency grade level of unit air conditioners(CC≥7000W)

<table>
<thead>
<tr>
<th>Type</th>
<th>Energy efficiency grade (EER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan coil</td>
<td>2.4, 2.6, 2.8, 3.0, 3.2</td>
</tr>
<tr>
<td>Wind tunnel</td>
<td>2.1, 2.3, 2.5, 2.7, 2.9</td>
</tr>
<tr>
<td>Water cooled</td>
<td>2.8, 3.0, 3.2, 3.4, 3.6</td>
</tr>
<tr>
<td>Wind tunnel</td>
<td>2.5, 2.7, 2.9, 3.1, 3.3</td>
</tr>
</tbody>
</table>

Table 3. The energy efficiency grade level of water chillers (GB19577-2004)

<table>
<thead>
<tr>
<th>Type</th>
<th>Rated refrigeration power (CC,kW)</th>
<th>Energy efficiency grade (EER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air cooled or evaporative cooling</td>
<td>CC≤50</td>
<td>3.2, 3.0, 2.8, 2.6, 2.4</td>
</tr>
<tr>
<td></td>
<td>50&lt;CC</td>
<td>3.4, 3.2, 3.0, 2.8, 2.6</td>
</tr>
<tr>
<td>Water cooled</td>
<td>CC≤528</td>
<td>5.0, 4.7, 4.4, 4.1, 3.8</td>
</tr>
<tr>
<td></td>
<td>528&lt;CC≤1163</td>
<td>5.5, 5.1, 4.7, 4.3, 4.0</td>
</tr>
<tr>
<td></td>
<td>1163&lt;CC</td>
<td>6.1, 5.6, 5.1, 4.6, 4.2</td>
</tr>
</tbody>
</table>

Table 3 has shown the energy efficiency grade level of water chillers, which had been enforced in 2005 together with the public building energy saving standards (GB50189—2005).

For the refrigeration products, the energy label with 5 grades was issued in 2003 (GB12021.2-2003). A basic limit load $E_{max}$ was fixed for Grades 1, 2, 3, 4, 5 to represent $0.55, 0.65-0.66, 0.66-0.80, 0.81-0.90, 0.91-1$ of that of $E_{max}$, respectively. Currently most of the refrigerators are in the grade 2 and 3 levels. More and more of refrigerators in the market have reached grade 1 level (Ma, 2007).
There are no energy efficiency grade level standards currently available for LiBr-water absorption chillers. However, the national standard Bureau requested manufacturers to ensure that all the products have a COP of at least 1.1. Most producers claim that their products have a COP of about 1.3, and some even more than 1.4. The municipal government of Shanghai has started a program to promote the use of high efficiency gas fired absorption chillers. The local energy efficiency standards are expected to be issued in 2008 in which it requires that absorption chillers have a COP of at least 1.2. The municipal gas company is expected to issue different prices of natural gas according to the COP of the integrated systems in buildings. This regulation may bring manufacturers, customers and designers together to share the responsibilities. One of the main difficulties in preparing the energy efficiency grade standards is lack of standard criteria of measuring COP because the real running conditions are usually different from the fixed rated conditions. A recent research done by SJTU and Shanghai Gas Company showed that most of the LiBr-water absorption chillers currently in use have a system COP of between 0.8-1.3 (Hu et al., 2007). The producers therefore need to work harder to improve the efficiency, especially by proper control of gas burner (from on/off control to multi-stage or no stage) and the good match between the burner and the stove.

4 REFRIGERANTS

Refrigerants fluids play an indispensable role in HVAC & R products. Because of the global environmental issues, China phased out the use of R12 in 2007 and now most of the refrigerators use mainly R134a and R600a. Also, some HVAC & R equipments use R22, although international regulations require that China should phase out the use of this refrigerant by the year 2040. Chinese companies mainly use R22 for RAC (for China market), but they also produce R407c RAC for EU market. The Chinese producers of RAC also have considered the possibility of using R410A, but they face the problems of IP rights. Some of the RAC producers from Japan use R410A and have also penetrated the Chinese market. Research on refrigerant blends has been going on and refrigerants such as Tsinghua 3 refrigerants (THIR03) have been developed and are believed to be potential substitutes for R22 (Shi et al., 2000).

Most of the automotive air conditioning systems use R134a refrigerant, however there are some research on CO₂ systems going on, but currently are at the prototype development stage (Wang et al., 2007).

R134a and R123 are accepted in China as the refrigerants for Centrifugal chillers. There are strong competitions from the producers regarding environmental and energy saving problems.

5 RESEARCHES AND DEVELOPMENTS OF HVAC & R IN CHINA

5.1. Research & development organizations

Company based research centers have played an important role in the development of HVAC & R products in China. Before the year 2000, Chinese refrigeration companies were very weak in terms of R & D as there were no PhDs and masters graduates who were interested in working in these companies, especially the graduates from the several outstanding universities such as Shanghai Jiao Tong University (SJTU) and Xi’an Jiao Tong University (XJTU). After 2000, there were many changes as many good companies developed interest to have Enterprise Technology Centers and to host a post doctor programs supported by the state government. Typical examples these companies are Media, Haier, Xinfei, Gree and Shuangliang. Many PhD graduates joined these companies through the enterprise and universities jointly supported post doctoral programs.

In Feb. 2004, Trane founded its R & D center in Shanghai. All the R & D engineers and scientist usually worked in Shanghai downtown area, but they were occasionally requested to work in the Trane factory near Shanghai. Trane has now more than 200 employees. York founded its Asia pacific R & D center in Nov. 2004 in Wuxi near Shanghai. The R & D center is located together with the York factory. Currently, York has its business center with about 100 research engineers in Shanghai. The newly built Carrier R & D center started to function in 2006. The center was created jointly with Carrier University and the Research Center of UTC in Shanghai. It is located in Jinqiao of Shanghai Pudong developing area, very close to Shanghai PVG airport. Carrier is different from other companies in that it has several manufacturers in Shanghai. Thus the R & D could be related very closely to its manufacturers. The Research Center has currently 150 employees. The competition between the above 3 USA based companies is very strong, especially for the human resources. This is likely to makes the market for R & D of HVAC & R to grow quickly.

A big competitor of Carrier and other companies is Daikin. The Japanese company has reformed a lot in the last 3 years into a big international company. In 2006 Daikin took over McQuey which allowed it to cover nearly all HVAC & R products. The annual sale of Daikin is the biggest in China HVAC & R market according to the
estimation of market share in 2007. Daikin is ambitious to be No.1 HVAC & R Company in the world by 2010. Currently Daikin has several manufacturers in China, but the R & D center is still in Japan. In 2003 Daikin started the program to collaborate with Chinese Universities and Research Institutions. One sub R & D center was founded in Beijing in cooperation with Tsinghua University, which distributes various R & D projects to selected universities and research institutes. The other program is the joint research work with Shanghai Jiao Tong University which covers HVAC, Noise, Vibration, Materials science and engineering (welding, deforming etc.).

5.2 Universities

Universities are thought to be the R & D partners of companies in China. Most of the Chinese universities can not only to teach and do research, but also to develop products. Professors and laboratories are very closely related to industries. This was mainly caused by the lack of R & D resources in Chinese companies. There are more than 120 universities involved in teaching and researching or possibly developing HVAC & R technologies. The strongest universities are Shanghai Jiao Tong University (SJTU), Xi’an Jiao Tong University (XJTU) and Tsinghua University (THU). SJTU and XJTU were one university before 1958, originally called Jiao Tong University (JTU) which was located in Shanghai. The Refrigeration division was founded in 1956 in JTU. Both SJTU and XJTU are strong in refrigeration and HVAC equipments.

SJTU has now 28 faculty members (14 full professors) and about 200 graduate students. The main areas of research and development include simulation of refrigeration and air conditioning systems, sorption refrigeration and desiccant cooling, CCHP, LNG and cryogenic technologies, indoor air, solar systems, automotive AC. SJTU has made the following products commercially available: heat pump water heater, adsorption chillers, desiccant cooling system, and simulation software for refrigeration systems. In addition green building energy systems are among the new contributions. Currently most of graduates of SJTU joined the R & D center and business units of Carrier, Trane, York and also Daikin.

XJTU is good in compressor systems and has helped several industries to design and develop compressor products. Typical products include screw compressors, and scroll compressors. XJTU is also good in cryogenics, especially for large cryogenic liquid systems and its space environment simulation. XJTU has produced a lot of high quality graduates to the Chinese based R & AC companies.

THU is good in building energy saving and indoor air. Currently the developed liquid desiccant cooling system has been commercialized. The THU based Tshinghua Tongfang stock holder company is a national strong company especially on heat pumps. THU has been involved in various building energy saving programs, including building energy label for Green Olympics in Beijing 2008. THU has a demonstration building on energy saving to promote new HVAC technologies.

5.3 Standards and Approval Organizations

The Chinese standards for HVAC & R products are mainly dominated by the Chinese Association of Refrigeration (CAR, similar to ASHRAE), the Chinese Refrigeration and Air Conditioning Industry Association (CRAA, similar to ARI) and the following three testing and approval organizations.

1. Hefei General Machinery Research Institute (HFGMRI) (HGMRI http://,2008): is a multidisciplinary and a comprehensive national class A scientific research institute. HFGMRI mainly engages in the design, development, manufacture and inspection of general machinery. It also plays a big role in corresponding engineering contracting, engineering supervision and equipment integration. It has National Standards Committee of R & AC Equipment/compressors/valves/boilers/pressure vessels/pumps, etc. Most of such products can be tested and inspected by this institute. The institute can also send technical staff to provide onsite services to manufacturers of big or bulky refrigeration systems. They also provide services to novel products for which no national standards are available.

2. Guangzhou Electric Apparatus Institute (GEARI) (GEARI,http://,2008): is a national level research institute integrated with R&D, testing and certification services for industries. GEARI hosts Guangzhou Testing & Inspection Institute for Household Electrical Appliances which is a national level quality supervision, testing, inspection and certification accredited by the Chinese National Accreditation Board for Laboratory (CNAL). Its services are based on a variety of standards, such as GB, IEC, EN, UL and ISO etc. GEARI also hosts Guangzhou Electrical Apparatus Research Institute Weathering Testing Center, in which its testing and environmental adaptability evaluation work is recognized worldwide.

3. China Academy of Building Research (CABR) (CABR http://,2008): which has a national center of quality supervision and inspection and testing for air conditioning equipment (NCSA). This agency is one of the first
national quality supervision centers established in 1985 by State Standard Administration of China (SAC). NCSA has developed the specification and supervision of almost all national product standards in HVAC ranging from conventional air conditioner to solar heating system. They have also came up with design, engineering, commissioning and auditing procedures for assorted air conditioning components ranging from vent, radiator, duct, humidifier to various construction energy saving criteria. Currently, NCSA carries out a wide scope of functions including product certification for national standards, quality issue arbitration, high quality technology/product promotion and distribution and national-wide product inspection.

6. CHINA REFRIGERATION EXPO

China Refrigeration Expo (CR, http://,2008) was initiated in the year of 1987 and has been serving the industry for 21 years. It is generally recognized as one of the leading HVAC&R exhibitions in the world. It is certificated by the International Association of the Exhibition Industry (UFI) and the Foreign Commercial Service (FCS) of the U.S Department of Commerce. With the 21-years of experience in serving the industry, China Refrigeration Expo has become a significant partner of the HVAC&R companies. It features a wide range of exhibits, with the latest advances in technologies reflecting the most significant developments and achievements in the industry.

China Refrigeration Expo is usually organized every two years alternatively in Beijing and Shanghai. The fast growing market and industry have made it difficult to do the exhibition in 2007 in Beijing due to lack of a big exhibition hall. Therefore the China Refrigeration 2007 exhibition took place in Guangzhou. And about 1000 exhibitors from 30 countries and in different regions of the world displayed their products and technologies. The total displaying area in Guangzhou was more than 60,000 m² and more than 380,000 visitors attended the show.

The China Refrigeration 2008 was hold in Shanghai with 67,000 m² exhibition area, most of the worldwide brands had their exhibition on new HVAC & R products in the exhibition. There were more than 50 technical seminars in parallel with the exhibitions. China Refrigeration Expo has been now recognized as a high quality trade show and it has had a strong push to boost the HVAC&R industry in China.

7. PERSPECTIVES OF CHINA HVAC & R

7.1 Energy efficiency equipments and their applications

Since the implementation of energy label in China, there has been a lot of market competition for various types of products (split room air conditioner, water chiller, VRF multi connection air conditioning system). The selection of a suitable air conditioning system is critical for building energy saving.

Room air conditioners are cheap and convenient to use, and are quite suitable for residential users and offices with flexible working time such as universities. In order to achieve a high building energy saving, the use of grade 1 and grade 2 room air conditioners, and also inverter room air conditioners is recommended.

For office buildings with divided air conditioning zones, the multi evaporator VRF inverter air conditioning system is recommended. Its energy efficiency label is expected to be available in the year 2008. However, the multi evaporator VRF inverter system may be limited by its capacity since the higher the capacity, the less efficiency it may have. The copper tubes used for refrigerant flow are usually limited below 100 m. VRF should have an optimized air conditioning area. For example, if a building has an area of 2000 m², VRF systems might not be efficient, and a building with 5000 m² air conditioning area might require a centralized water chiller.

Air cooled heat pumps are suitable for buildings in the Yangzhi triangle region near Shanghai. It might be efficient for the buildings with 1000-5000 m² and with the requirement of heating and cooling. Its main advantage is that it can be used for both cooling and heating, although its system COP is low.

In order to achieve a high cooling efficiency the use of water cooled air conditioning systems is recommended. Large size screw type or centrifugal type water chillers are usually adopted for large commercial buildings and hotels, for such buildings, heating is usually done by a gas boiler. Such HVAC water chiller usually has a high COP (5–6 or even higher). However, the HVAC system requires pumping and ventilation and 30-40% energy might be used by these additional components.

In south China, heating is not needed for the whole year, thus water cooled air conditioning systems are the best choice. Water-Loop heat pump using water to cool the condenser has been thought as a reasonable product. Such system could be used in room air conditioners (individual systems, but all condensers are cooled by a water loop connected to a cooling water tower). Its COP can be as high as 4 which is much better than the conventional split room air conditioners.
The CRAA and CAR should collaborate with some HVAC manufacturers like Carrier and Daikin to develop some guidelines for HVAC & R equipments used in buildings. Currently both Carrier and Daikin have products covering all air conditioning needs and their customers might provide good samples for such studies.

7.2 Refrigerants

Refrigerators: the use of R12 refrigerant was prohibited in refrigerators in China in the year 2007 and was replaced by R134a and HCs refrigerants.

Room air conditioners: R22 can be still used in China until 2040, although the products from joint ventures from Japan (Daikin, Panasonic etc.) have changed into R410a. The compressor manufacturers in China can supply products for R22, R410a and R407c. The THU-01/THU-02 developed in China are potential R22 substitutes. Moreover, there are negotiations regarding IP rights for the use of R410a and others. It would be possible that R22 would be prohibited to be used in 2020.

Water chillers: R134a and R123 were promoted by Carrier and Trane respectively. This will not be changed in the coming years. China is weak in large chiller design and manufacture, thereby with less consideration about that. However the “Green” Beijing Olympics have brought chances for Carrier and York.

Natural refrigerants have been extensively studied in China. Water is surely welcomed but now limited to absorption chillers with a current market share for air conditioning of 7-8% in China. There has been lack of R & D for LiBr-water absorption chillers in the last 5 years, this has shrank the Chinese brand product market share to about 20%. Currently there is a lot of research going in local universities on CO₂ automotive air conditioning and heat pump water heating. CO₂ heat pump water heater are widely available in Japanese market, but it seems to have no chance in China as HCFCs heat pump water heater is much cheaper, in addition, the Chinese people prefer showers whereas Japanese people likes bath. NH₃ might be widely applied for adsorption refrigeration systems. Prototypes are available now and some industries have been involved for R & D. It is expected that ammonia adsorption refrigerators might be used for industrial refrigeration applications with efficient use of waste heat.

7.3 Heat pumps

Northern parts of China have cold and severely cold regions with air temperature less than -15°C in winter. Heating during winter is thus needed from October to March. Coal based centralized heating systems used in cities or towns have caused serious air pollutions resulting from the burning of coal and hence the need for an alternative. Natural gas heating seems to be expansive. In the last five years the ground source heat pump has been welcomed on the market for new residential houses and even business buildings in north China. A lot of newly established companies are actively involved in this business. The use of ground source heat pump technology has also spread rapidly from north to south China. Although there has been lack of onsite test for several years regarding the proper use of ground source heat pump, these products have performance well in north China to solve winter heating problem and also to get high efficiency cooling in summer. This is because the heat release in summer and heat absorbed in winter are nearly in balance. But the ground source heat pumps are not suitable in east China and south China because the heating need in winter is much smaller than heat release in summer, and when the ground source heat pumps operate for several years, the summer cooling COP will be obviously reduced due to the increased temperature in the ground soil in these areas. It is clear that air source heat pump is more reasonable for east and south China areas.

In efforts to find a substitute for centralized heating or ground source heat pump, there are newly developed products which can overcome the difficulties of air source heat pump operated at ambient temperature below -15°C. Media, Gree and Samsung companies have collaborated with Emerson to develop the novel products of air source heat pump which uses Emerson digital scroll compressor and can be operated efficiently below -15°C or even lower than -25°C. Daikin has also introduced a new air source heat pump product to use a two stage compressor (Yamamura et al., 2008), which has better efficiency though somehow expansive. It seems that the market for heating in China has become a hot point for competition.

Heat recovery heat pump capable of producing chilled water and hot water simultaneously has been available on the Chinese market for many years. These products are suitable for newly constructed economic hotels, which has given a market chance for some small local companies. There are some examples of efficient heat recovery heat pump systems. One such system is in Haiku, Hannan island which is in tropical hot zone and needs all year air conditioning. The heat recovery heat pump has supplied both cooling and hot water for a hotel. Both the cooling and the heating requirements are in good balance.

Air source heat pump water heaters (ASHPWH) have been in the market for the last five years, and the market for this product is expanding slowly. The first interested manufacturers for such technology were solar water heater
producers, whereas the involvement of room air conditioner manufacturers started only two years ago. As reported by the International Copper Association Ltd. China, the annual market had reached 620 million RMB Yuan in 2006, the estimated data for 2007 has reached up to 1020 million RMB Yuan (International Copper Association Ltd. China, 2007). Optimistic estimates show that the total heat pump water heater sales will reach 500,000 units in 2010 in China. At the moment, there are no big RAC manufacturers involved in mass production of the ASHPWH. A residential 150 L heat pump water heater may cost 4,000-6,000 RMB Yuan. The national standard specifications for the ASHPWH products are currently being developed and are expected to be out by the end of 2008. Zhejiang Jinjiang and Jiangsu Huayang companies are the main producers of ASHPWH for residential uses, while Jiangsu Tianshu Company is the main producer of ASHPWH with large capacity (1 m³ to 100 m³) which can be used in hotels, etc. The economic ASHPWH uses a heat pump integrated or connected with a water tank in which the condenser is a copper coil immersed in a thermal insulated water tank. The high standard ASHPWH which is more reliable uses water cooled condenser in which water in a storage tank is circulated. Various means should be used to get high COP of heating in which the mass flow should be easily controlled with the increase of water temperature in the tank and also with the change of ambient temperature. The compressor should not be over pressure for long time application. Fig.5 shows the products of air source heat pump water heater for both residential and commercial uses.

![Fig.5: The air source heat pump water heater for residential and commercial uses.](image)

7.4 System innovation
There are big changes in building energy systems for residential uses. More and more residential buildings and apartments are now fully furnished by the developer, which means that the suppliers of air conditioning systems, hot water system, etc. will have to meet the requirement of the developer at first. Only one supplier can provide all energy needs for the building or apartment. The supplier should be engineering based with the capability of doing system integration. A good integration will be cheap and reliable and with high energy efficiency.

There are some examples for R & D and demonstrations with innovated energy systems for buildings in China.

7.4.1 AHU with liquid desiccant dehumidification and heat pump combined system
This system was patented by Tsinghua University, and its prototype had been used in Shanghai green building demonstration project, now it is commercialized by Beijing Huachuang Refine Co. (Sinorefine http://,2007). This concept uses a heat pump for cooling purposes, the low temperature side-evaporator can produce chilled water (about 17-20 °C), while the high temperature side-condensing heat with temperature about 70-80 °C is used to regenerate a liquid desiccant dehumidification system (Liu et al., 2004). With a proper matching of the liquid desiccant stages with heat recovery, the overall total COP can reach 5.5 and therefore this system has great energy saving potentials. Now a union has been established to push the market of the novel cooling and dehumidification system. Fig.6 shows the outlook of the system.

The AHU has an air flow rate ranging from 2,000-50,000 m³/h, with cooling capacity of 39-980 kW, heating capacity of 26-650 kW, dehumidification rate 40-1000kg/h, and humidification rate 13-320kg/h. There are several demonstration projects which used such system, even for green residential buildings.
7.4.2 Combined system of electric driven vapor compression system and desiccant dehumidification system

In such system one or two desiccant rotors are used for dehumidification which undertakes the latent heat of cooling, while the vapor compression cooling system can be operated with evaporation temperature of about 15 °C which undertakes sensible heat of cooling. Such system may save electric consumption of about 20-30% (Jia et al., 2007). If the condensing heat (about 45-55 °C) can be used to regenerate the desiccant rotor, the energy saving could be much higher. This combined system has been used for demonstrations, in which solar heating is used for the regeneration of desiccant rotor (Ge et al., 2008). Fig.7 shows the newly developed hybrid system with the use of solar energy. Research has shown that such a desiccant cooling system (dehumidification + water evaporative cooling) itself could reach a thermal COP over 1, the desiccant material used is a combination of silica gel and LiCl₂.

Fig.7: The newly developed desiccant evaporative cooling system with the use of solar energy.

7.4.3 Heat pump building energy center
Heat pumps can perform both cooling and heating, thus chilled water and hot water can be obtained. A well organized system can provide hot water, heating and cooling, and thereby can be used all the year. The end uses may be (1) hot water production (42-50°C), floor radiation heating in winter (45°C hot water) or ceil cooling by cold plate (15-20°C chilled water), in such case passive dehumidification could be used by pasting desiccant materials on the wall; or (2) hot water tank to store hot water (42-50°C), fan coil unit for heating or cooling. The option (1) has higher potential due to energy saving and commodity, though the initial investment is currently still high. Fig.8 shows the test room in SJTU with floor radiation heating/ceil cooling and fan coil heating/cooling as end uses, while the heating and cooling sources are provided by a solar water heating/solar adsorption chiller, or by a heat pump building energy center.

7.4.4 Other building energy centers such as micro CCHP
As is shown in Fig.9 in which gas is used as the energy source, the micro CCHP can supply electricity, heating and cooling with high primary energy efficiency (70–85%) (Huangfu et al., 2007). SJTU has demonstrated such systems driven by natural gas for 4kW, 16kW and 260kW respectively, selection of the suitable chillers and also the proper energy management are the main problems (Wu et al., 2006). Cheaper prime movers (gas engine etc.) should be provided, which may need the expertise from automotive industry.

The Solar integrated energy system could be another building energy system as is shown in Fig.10, though such system is still expensive, it can provide electricity, heating and cooling simultaneously. If solar PV is not included, the solar integrated building energy system capable of heating, cooling, hot water supply and even enhancement of natural ventilation in Shanghai could provide 50-60% building energy needs with 4-8 years pay back period (Zhai et al., 2007).

7.5 Renewable Energy based HVAC & R
The use of renewable energy is encouraged now in China. The issued Renewable Energy Law has promoted a plan aimed at achieving 15% total energy renewable use in China by 2020. There were 80 million m² solar collectors in
use in China in 2005. The government has planned to increase this to 150 million m$^2$ by 2010 and 300 million m$^2$ by 2020. The new residential buildings and public buildings will be required to have solar energy systems, and is expected to increase the solar heating, cooling and hot water supply market. Solar systems have been successfully used in residential high rise buildings. One good example is one residential area in Shanghai where 2500 apartments (Fig.11a) were provided with solar water heating system (3 m$^2$ solar collector on the balcony for each apartment). There are two other residential areas with installation of air source heat pump water heater in high rise apartment buildings. Fig.11 shows several examples to install solar water heating systems and air source heat pump water heater.

![Fig.11: Examples to install solar water heating systems and air source heat pump water heater. (a)-balcony solar collector, (b)- rain shielding solar collector, (c)-heat pump water heater.](image)

Ground source heat pump market is steadily growing in China. A combination with solar energy can be a good option to save electricity and to get a wider range of applications in different climate zones where thermal management is important.

Heat pump water heaters have been accepted by more and more people after 5 years experiences on the market. The government has agreed to use heat pump water heater in parallel with solar water heater. Some cities and provinces have introduced peak and off peak electricity price which helps to promote heat pump water heater and storage water tank.

Solar air conditioning is now appreciated by many peoples, the many demonstrations have attracted investments for the potential market. Solar and gas combined systems used to drive LiBr-water absorption chillers have been accepted for use in business buildings. Such systems works on the double effect mode therefore have a COP of more than 1.2 which needs parabolic through solar collector. For the buildings integrated with solar energy systems, evacuated tube collector is the best choice. Thus, the adsorption chiller (silica gel-water) with a thermal COP of 0.4 – 0.5 may be feasible when driven by hot water at 65°C. Another solar cooling system uses a solar air collector to generate desiccant dehumidification evaporative cooling, and has a thermal COP is about 1. It is still not matured for the R & D of solar cooling, but the potential market is available.

An important aspect of solar systems with thermal storage is that no matured products are available on the market. Thermal storage using hot water tank is popular, however, big size tanks may be needed if the system is large. Thermal storage with PCM materials is also attractive. The needed product could be PCM at phase transition temperature of about 50°C (for hot water supply), PCM at phase transition temperature of about 70-80°C (for sorption cooling), and those of about 100°C (for single effect LiBr-water absorption cooling) and 150°C(for double effect LiBr-water absorption cooling).

### 7.6 Free Cooling

The development of west China (where 1/2 total area with 20% population) needs a lot of constructions equipped with air conditioning. In most regions of Western China, during summer, the temperature is high but the relative humidity is low (~20-30%), as is shown in Fig.12. In this case evaporative cooling is reasonable as it consumes water and very little electricity, which is thereby also called free cooling (Huang, 2007). In some places, a water cooling tower could be used to provide chilled water for cooling in buildings. There is more than 15 years of experience in free cooling in west China, but the HVAC industries seem not to be involved. Fig.13 shows one example in Xinjiang Shihezi city(Huang, 2007).

The engineers from both design institutes and HVAC industries are not well trained on free cooling and usually prefer to use the conventional HVAC systems. Since there is already a market for free cooling, we need more designers and manufacturers or even politicians to promote this solution.
7.7 Waste heat recovery refrigeration

With the issuance of the Energy Saving Law in 2008, the efficient use of waste heat is expected to receive more attention. Waste heat with temperature ranging from 80 to 500 °C can be obtained from industries (petroleum industry, metallurgy industry and electric power industry) which could be used to drive sorption cooling systems for air conditioning or refrigeration.

The market for LiBr-water absorption chillers has extended to include waste heat recovery water chilling. The current 20-30% market of LiBr-water absorption chillers are based on waste heat utilization, and this may still increase in the near future.

There are needs for industry refrigeration (-10 to -20 °C), in which ammonia-water absorption refrigerator could be used. The other option for waste heat driven refrigeration is chemical adsorption refrigeration in which CaCl₂-NH₃ can be used as the working pair. Such system can obtain a refrigeration thermal COP of about 0.3-0.4 at -15 °C (Wang et al., 2006). The studies have shown that a thermal driven adsorption refrigeration system could even have a COP over 1 by the use of double effect and two way adsorption refrigeration cycles (Li et al., 2007).

In thermal-electric (or mechanical) power transmission movers (internal combustion engine, gas turbine, stirling engine etc.), 60-70% of thermal energy from exhausted gases or jacket water cooling is wasted. This could be used to drive sorption cooling systems. The potential markets could be adsorption ice maker for fishing boats and sorption air conditioning systems for transportation vehicles. Research has shown that heat pipes could be efficiently integrated in sorption systems and thus adsorption refrigeration could be closely related to solar energy and waste heat utilization (Wang, 2008; Wang et al., 2006).

China is the main producer and developer for LiBr-water absorption chillers, and now is one of the leading countries doing R & D on other sorption cooling systems. Fig.14 shows the silica gel-water adsorption chiller (5-15 °C chilled water) which could be operated with 60-90 °C hot water to obtain chilled water, and also the adsorption refrigerator (-10 to -25 °C with refrigeration capacity of 6-10 kW) using compound adsorbent-ammonia powered by 150 °C vapor.
8. CONCLUSIONS

China refrigeration and HVAC industries have been developing rapidly in the last 10 years. China is now the biggest manufacturer of room air conditioners and refrigerators, one of the main manufacturers of absorption chillers, and a growing-up manufacturer of centralized air conditioning systems in the world. The high economic growth rate and the increasing building construction have helped the booming of HVAC & R applications. China has now established its own standard and certification system to evaluate the HVAC & R products which can meet most of the needs for world market.

R & D in HVAC & R has being changing a lot in the last five years. The Chinese dominating companies have established their own R & D centers and they are becoming experienced. Most of the world’s main HVAC & R companies have established their Asia-Pacific research center or laboratories in China. The main universities have involved deeply in the research of new technologies of HVAC & R which will help Chinese government with the aim of switching to “researched and developed in China” from the current “made in China”.

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ACKNOWLEDGEMENT

This work was supported by Natural Science Foundation of China under the contract No. 50736004 and also National Key Technologies R&D Program under the contract No. 2006BAA04B03. The author thanks Mr. Jin HQ (Chinese Association of Refrigeration) for supplying some reference documents.