Review of refrigeration compressor developmental trends

Jaroslav Wurm

Abstract

Over the past few years, some significant developmental efforts have been devoted to design, performance and manufacturing modifications and improvements of rotary and reciprocating positive displacement, as well as dynamic compressors. Some, such as carbon dioxide (CO₂) machines, progressed to the introducing of new and mature products to the marketplace. Twin-screw compressors are making successful inroads into transport (truck and bus) systems.

While single-screw machines have found their steady marketplace (particularly in large ammonia applications), it appears that the trochoidal compressors are being forgotten. Progress has been noted in compressors and applications of mixed refrigerant cycles.

The market statistics indicate that, overall, the refrigerating compressor market is starting to be dominated by the rotary machines. This tendency has also been reflected in the respective orientation of R&D work, specifically related to automotive applications.

The new developments, supplemented by an updated compressor market review, are the subject of this article.

Keywords: compressors, refrigeration, transport refrigeration, market review

Introduction

This paper is a continuation in part of the presentation prepared and published under the same title for the Compressors 2004 conference. Its objective is to update the market and technical information with data reflecting the industry’s progress.

20 years ago, the AC&R industry engaged in extensive research and development, and this has had a healthy influence on the industry’s progress. The R&D activity still continues to be strong and the world market position of almost all segments of the HVAC&R industry, including refrigerating compressors, demonstrates this. In the compressor area, progress has been noticeable in new approaches to design, use of alternative refrigerants, and in many new producers coming into manufacturing.

Market update

To substantiate the production volume estimates for refrigerating compressors we examine first the industries and products using them (i.e. HVAC&R in general). As given throughout the references of the first paper, demand predictions (at least for the RAC and PAC segments) indicated a bold increase of 6-10% for the years 2004-2006. Examination of the following Tables 1 and 2 shows that the increase was more modest for the major producers (i.e. China, USA and Japan), as shown in predictions for 2007-2008 [1-6]. The production increase is mainly due to progress in the rest of the world.

An interesting supplement to the market size (below) is the tabulated prediction of the residential/commercial air conditioning and other refrigerating equipment demand growth for the major US producers. This forecast is shown in Table 2 [8].

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2004</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Units (thousands)</td>
<td>Production value (billions of USD)</td>
<td>Units (thousands)</td>
</tr>
<tr>
<td>Residential / commercial air conditioning</td>
<td>46,840</td>
<td>33.5</td>
<td>59,877</td>
</tr>
<tr>
<td>Mobile air conditioning and refrigeration</td>
<td>100,000</td>
<td>38</td>
<td>102,000</td>
</tr>
</tbody>
</table>

Table 1 – estimate of demand market size of air conditioning equipment

NB: mobile air conditioning and refrigeration includes equipment for passenger cars, trucks, trailers and buses. The numbers and values are based on the 2004 prediction for the Japanese Market.

For residential / commercial air conditioning equipment, the production values are based on a BSRIA assessment (compared with estimates based on Japanese and US data shown in the first paper)
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</tr>
</thead>
<tbody>
<tr>
<td>Room AC</td>
<td>8032</td>
<td>8000</td>
<td>8400</td>
<td>8450</td>
<td></td>
<td>4.6</td>
</tr>
<tr>
<td>Packaged AC</td>
<td>5515</td>
<td>6417</td>
<td>5200</td>
<td>5700</td>
<td>5950</td>
<td>7.9</td>
</tr>
<tr>
<td>TOTAL</td>
<td>13,597</td>
<td>14,503</td>
<td>13,200</td>
<td>14,100</td>
<td>14,400</td>
<td>5.9</td>
</tr>
<tr>
<td>Plus heat pumps</td>
<td>15,483</td>
<td>16,640</td>
<td>15,072</td>
<td>16,126</td>
<td>16,482</td>
<td></td>
</tr>
<tr>
<td>Plus dehumidifiers, refrigerators freezers</td>
<td>33,979</td>
<td>35,502</td>
<td>33,889</td>
<td>35,231</td>
<td>35,820</td>
<td></td>
</tr>
<tr>
<td>Plus, commercial freezers and ice machines</td>
<td>34,669</td>
<td>36,177</td>
<td>34,600</td>
<td>35,957</td>
<td>36,564</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Table 2 – predictions for US AC&R shipments and imports of residential and commercial equipment (in thousands of units)

Although the overall world production of air equipment is predicted to grow at a healthy rate (of about 10% per year), the European product demand growth is more modest [6, 9], and so is the situation for US and Chinese production.

Compressors, as basic components of AC&R technologies, had to be available to sustain market progress. Yet, they constituted components requiring substantial redesign – a process that has continued up until now. Nevertheless, this activity has been successful in providing solutions to new environmental requirements while sustaining the industry’s growth. This is documented, eg. in graphs such as those of Figure 1, showing the production histograms for residential/commercial AC [10].

![Figure 1 – trend in air conditioning compressor production by type and volume (Source: BSRIA / JARN)](image)

This assessment is still considered valid (relevant updated statistics were to be published by BSRIA and JARN in early 2007). What is important to note, however, is that the histogram shows the progress in the family of air conditioning compressors only. For the overall production, the quantity as well as the distribution are substantially different.
For instance, in 2005 the overall production (by the individual categories) was as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>Production (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hermetic reciprocating</td>
<td>105,000,000</td>
</tr>
<tr>
<td>Semi-hermetic reciprocating</td>
<td>650,000</td>
</tr>
<tr>
<td>Open shaft reciprocating</td>
<td>30,000</td>
</tr>
<tr>
<td>Rotary</td>
<td>80,000,000</td>
</tr>
<tr>
<td>Scrolls</td>
<td>13,000,000</td>
</tr>
<tr>
<td>Screw – twin</td>
<td>120,000 (estimated)</td>
</tr>
<tr>
<td>Screw – single</td>
<td>20,000 (estimated)</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>6000 (estimated)</td>
</tr>
<tr>
<td><strong>Total world production in 2005</strong></td>
<td><strong>198,826,000 units</strong></td>
</tr>
</tbody>
</table>

In a major manufacturing shift, the Japanese, American and major European makers are creating a manufacturing powerhouse in China, known as the “Supply Center for World Demand,” and expanding their manufacturing activities in South-east Asia, Singapore and Central and Eastern Europe. Increased activity is also noted in India.

**Technical developments**

The elements of essential efforts in refrigerating compressor developments are well summarised in Reference 2.

In this article, only a brief summary of significant issues is presented to illustrate the technical progress that has substantiated the expanding market. The most important and key elements of manufacturers’ success have been perceived (by compressor buyers) as supply stability, price, production level and efficiency. Additional elements such as environmental effects, operating range, capacity and size, simplicity and ease of maintenance, all would reflect in the design, operating and manufacturing concepts pursued.

**Refrigerants**

On the legislative front, an important decision was made by the EU Parliament when it reversed the position taken by the EU’s Environment Committee on banning products using HFCs. The Parliament endorsed, however, the approach of practical reduction of emissions via containment and monitoring. This has been considered as a very rational decision, also supported by ARI as well as by the European Partnership for Energy and the Environment (EPEE), as many world companies have adapted various HFCs as a practical substitute to HCFCs.

The HFC refrigerants most often used are: R134a, R410A, R407C (Japan), R404A and R507A (low temperature).
As a response to the EU’s intent to initiate phase-out of R-134a in automotive applications by 2011, DuPont has announced that its new alternative with a global warming potential (GWP) lower than 150 will be commercialised.

The highly visible trend remains, however, the attention paid to “natural working fluids,” above all R744 (carbon dioxide). In this area, research and development is currently gaining momentum at manufacturers’ research centres, mainly for transport and automotive AC. It is still clear, however, that before CO2 can be adopted on a larger scale, problems related to manufacturing costs, design of components, servicing and maintenance will require some time to resolve.

Significant progress has been reported from Japan on the market success of their CO2 heat pump/water heaters.

This trend is illustrated in Figure 2 for the ECO CUTE system. As this product is considered to be rather expensive, it might still be interesting for CO2 developers to learn that there are “14 brands involved in heavy competition in the ECO CUTE market” [2]. Of five major Japanese manufacturers, Sanyo happens to be the most significant of them, and is planned to increase the production of compressors used in ECO CUTE systems to 300,000/year in 2006.

Figure 2 – shipments of carbon dioxide heat pumps / water heaters (ECO CUTE System, Japan)

Progress in adopting other “natural refrigerants,” namely isobutane (R-600a) and ammonia (R-717), cannot be overlooked.

For instance, in Japan and Europe, almost all home-use refrigerators newly launched on the market use R-600a [2].

Major design efforts

The worldwide orientation to energy saving has led the compressor industry towards the development and greater use of inverter and digital technologies. While in Japan more than 90% of RAC machines are inverter driven, in China the percentage is still in single digits, and in Europe it has increased to about 30%. Use with larger capacity, and even with centrifugal compressors and screw chillers, has appeared on the market.

Competing with inverters are digital compressors, such as Copeland’s digital scroll. This technology, that offers up to 40% improvement in effectiveness (versus the traditional single-speed systems), is now being adopted by Korean and Chinese companies. Hitachi has introduced this concept to its horizontal refrigeration machines used for display cases and freezers.

The same driving force of higher efficiency has been seen in the efforts of many companies. Two of them, Toshiba-Carrier with its two-stage hermetic, reciprocating design for non-fluorocarbon refrigerators, and MHI with its “3-dimensional scroll”, have been referenced in the literature as examples of those efforts.

Throughout the references cited, there is ample exemplified information for private review presented on other efforts of “key movements” of the industry (mentioned above).

We will conclude this review with an abbreviated reference to concepts marked as “unique”. The first concept of this group is a linear motor-driven, free-piston Stirling cooler. It deserves to be mentioned here that this product of Japanese Twinbird Industry is the result of about 35 years of development in the USA. Conceived by Professor William Beale in Athens, Ohio, it was originally developed as a residential heat-activated heat pump.

Several variants of this machine were later developed and marketed by Sunpower Co.

Other unique machines to be mentioned are larger capacity semi-hermetic scroll compressors introduced by Glyn Tech, Taiwan; J&E Hall’s new line of very low footprint, single-screw compressors; Copeland’s second-generation, high
efficiency scrolls; Bock’s highly compact and quiet series with frequency converter as an option; Fu Sheng’s inverter-driven screw compressors; and Samsung’s digital variable compressors with options of R600a and R134a refrigerants offered.

Conclusion

In this article, we summarised the progress of the refrigerating compressor industry over the two-year period since the 5th International Conference on Compressors and Coolants of 2004, where the first part of this presentation was published. The updated market and technical information were again gathered through the trade literature, meetings, conferences and private communications. Assessing this information makes it possible to offer conclusions that are similar, yet not identical, to those of the first paper presented at the 2004 conference:

- The AC&R industries succeeded, mostly at their own expense, in sustaining their growth while improving the quality of service to mankind;
- The demographics of manufacturing continued to change;
- The industry’s dedication to becoming “environmentally friendly” has not diminished as exhibited by the size, scope and speed of research and development related to the technology of natural refrigerants;
- Absorption and adsorption technologies are finally becoming more understood as commercially viable options and are making recognisable inroads into specialised applications worldwide.

References


About the author

Jerry Wurm is a former Director of Energy Systems and Business Analysis at the Gas Technology Institute, US. He is a member of the US National Committee for the IIR and of Commission E1 of the IIR and he was active in several Technical Committees of ASHRAE (TC 3.5 and 8.1).

He was a founding member of the Technical Group that later became TC 7.4, serving as Research and Handbook Subcommittee chair. Dr Wurm worked for 10 years in the compressor industry, then 33 years in research and development.


Dr Wurm received a degree in Mechanical Engineering and a PhD from the Czech Technical University of Prague. He continued his graduate studies at the Illinois Institute of Technology, Chicago. Besides being a member of ASHRAE, Dr Wurm is also a member of DKV, the Czechoslovak Society of Heating, Air Conditioning, and Ventilating Engineers; the American Solar Energy Association (ASEA) and an Honorary Member of the IIR. At the IIR Congress in 1983, he was elected President of IIR Commission E1 (Air Conditioning).

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