"Making a Comfortable and Better Way of Life"

–From Residential Air Conditioners to District Heating and Cooling Systems–

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1.Introduction

Air conditioning has become essential to create comfortable spaces in residences and offices for human living, while refrigeration has become indispensable to frozen food and cold storages for keeping food fresh. In order to meet various customer needs, MHI produces an extensive range of products as an all-round manufacturer of air-conditioning and refrigeration equipment. These products include such items as air-conditioners for residences, air-conditioners for offices and stores, automobile air-conditioners, centrifugal chillers and absorption chillers for large scale buildings and district heating and cooling plants in the air-conditioning field, refrigerators for cold storage, and truck and marine refrigeration units in the freezing and cold storage field, amongst others. MHI's refrigerating equipment business has its origin in the production of refrigerated cargo carriers and ice-making machines for ships before World War II. After the War, MHI has developed and produced many products ever since it first made electric refrigerators and ice cream freezers for the Occupation Forces, playing a leading role and advancing with the progress of the refrigeration and air-conditioning industry in Japan.

The Air-Conditioning & Refrigeration System Headquarters of MHI is continually striving to develop many products that are high in efficiency, low in noise, and friendly to the environment. The aim is to create a healthy and comfortable living space for people while protecting the global environment under the motto "Take pride in letting people around the world feel comfortable and rich through our air-conditioning and refrigeration products." Moreover, MHI is intent on fulfilling recently expanding customer needs concerning reliability and service. In order to cope with rapid changes in the business environment, such as the emergence of China and Korea, MHI is emphasizing its effort to strengthen the business fundamentals that will enable the company to compete successfully in an increasingly severe and competitive environment, by enhancing its ability to develop new products, prepare and implement sophisticated marketing strategies, improve sales efficiency, and establish superlative, high-quality production bases.

2. Past

The past of the air-conditioning and refrigeration business of MHI can generally be said to reflect a history of successful expansion of market, and the overcoming of difficulties such as oil shocks and cool summers through the development of new products, all the while matching or contributing to the pace of Japanese industrial progress since the end of the War. The following is a description of the major products developed by MHI, from the beginning of 1960s to the present, during which time remarkable growth has been achieved in the air-conditioning and refrigeration business which started from the application of refrigeration and cold storage.

The authors will be most grateful if this article in some small way helps contribute to a better understanding of the cooling and heating equipment business of MHI through a review of the past and look at the future of the business.

2.1 Room air-conditioners

During the ten-year period from 1955, air-conditioners were called coolers and used exclusively to cool rooms. At that time, in advance of others, MHI advocated that the use of a heat pump would make air-conditioning more comfortable and efficient, and as a result promoted the spread of heat pump systems throughout the Japanese domestic market. Heat pumps had been defined as lacking in any warming feeling because of its low air outlet temperatures. However, the Warp 60 put on the market by MHI in 1987 demonstrated that a warming feeling could also be attained by heat pump systems if they produce a breeze with an outlet temperature as high as 60°C.

As heat pump systems became leading products in the air-conditioner market and the number of hours that they were used increased each year, the major concern of users shifted to realizing ever-better energy-savings in air-conditioners. Accordingly, MHI developed a DD scroll compressor that was characterized by high efficiency and

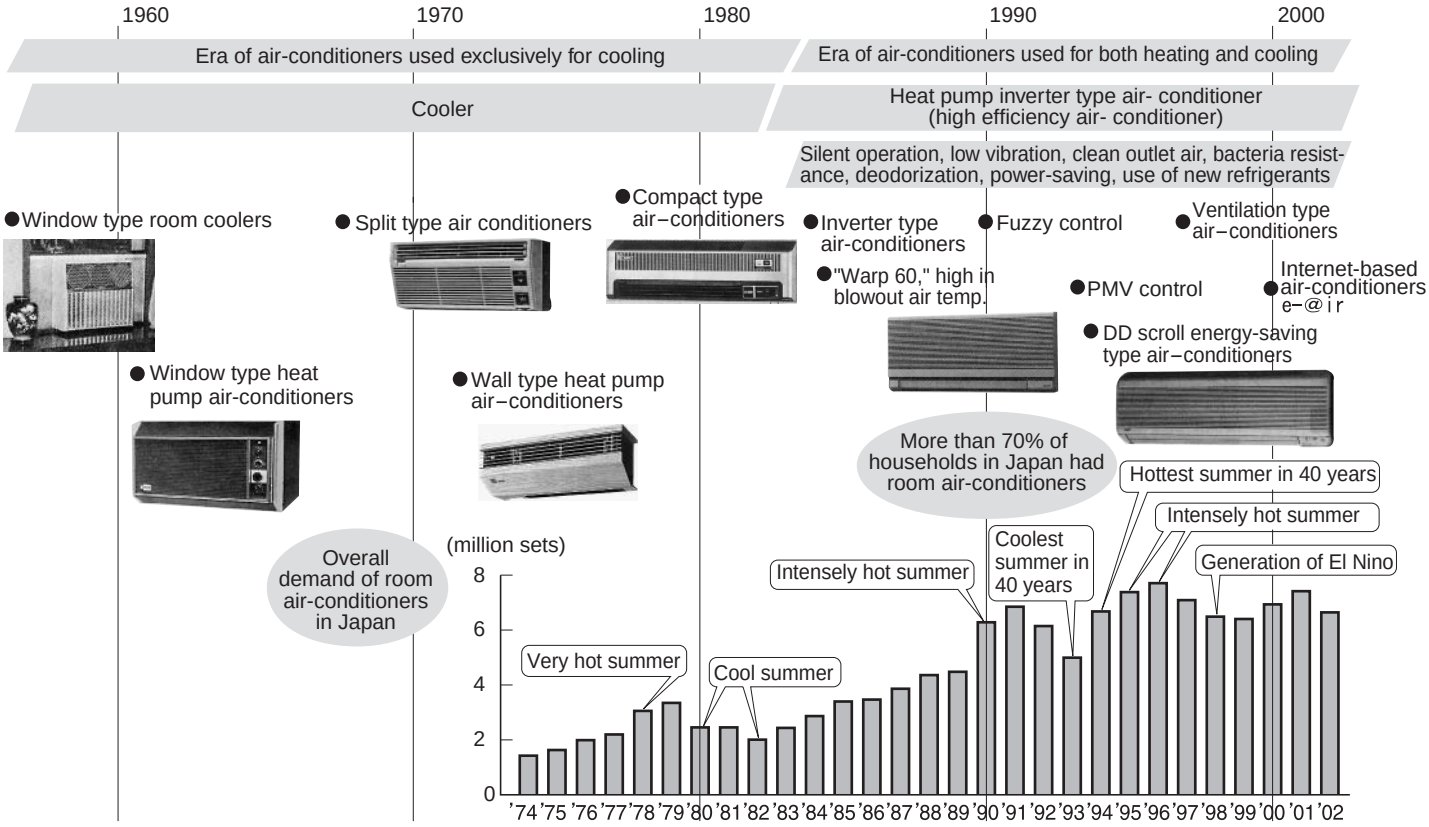

Fig. 1 Progressive history of room air-conditioners

low noise in order to realize the compatibility of comfort and low energy consumption. As a result, the excellent energy-saving capabilities of the unit were highly regarded and recognized in the awarding to MHI of prizes by the Director of the Agency of Natural Resources and Energy at the Energy Conservation Center Japan in both 1996 and 1997. **Fig. 1** shows an overview of the progress of development of air-conditioners at MHI.

2.2 Packaged air-conditioners

Packaged air-conditioners began to spread into restaurants and department stores in the ten years from 1955. Demand for the units soon also expanded to offices and stores, as coolers became indispensable in the summer. In order to reduce the space occupied by a packaged air-conditioning unit, MHI developed new space-saving types of units, such as ceiling pendant and ceiling recessed types of units. This resulted in the affixing of the nickname “MHI of ceiling types” to these types of units that have become the main stream in present-day packaged air-conditioners.

Because the spread of air-conditioners raised the peak levels of electric power demand in the summer, MHI undertook research into ice thermal storage type air-conditioner that utilized electric power at night during off-peak time periods in an attempt to level off electric power loads throughout the day. MHI successfully commercialized packaged air-conditioners that were equipped with an ice thermal storage for peak cut and peak shift based on the results of joint research by Tohoku Electric Power Co., Inc., Tokyo Electric Power Co., Chubu Electric Power Co., Inc., The Kansai Electric Power Co., Inc., Chugoku Electric Power Co., Inc., and Kyushu Electric Power Co. This new type of unit made it possible to realize large reductions in peak electric power consumption. Owing to this development, MHI received a prize from the President of the Japan Machinery Federation in the 1996.

2.3 Large sized refrigerating machine

Large sized refrigerating machines equipped with centrifugal chillers have been successively delivered by MHI not only for high rise buildings but also industrial plants since the beginning half of 1960s. In fact, MHI came to be the dominant player in the field of large sized refrigerating machines in Japan. In particular, MHI has been developing large capacity chillers ever since the company delivered chillers for the first district heating and cooling systems for the first time ever in Japan at the site of the world exposition fair in 1970 and at Senri New Town. As a result, MHI delivered the world's largest capacity steam turbine driven centrifugal chiller with a capacity of 10 000 tons of refrigeration (RT) to the Makuhari Shintoshin District Heating and Cooling Plant of the Tokyo Gas Co., Ltd. in 1990. This was followed by delivery of the world's largest absorption chiller with a capacity of 5000 RT to the Minato Mirai 21 District Heating and Cooling Service Co., Ltd. in 1999. The latter was highly evaluated and recognized for its highly efficient performance, resulting in MHI being awarded the prize of the Director of Agency of Na-

tional Resources & Energy at the Japan Machinery Federation in the 2000 and the technology prize of Japan Society of Refrigerating and Air Conditioning (JSRAE).

2.4 Automobile air-conditioners

The development of air-conditioners for use in cars and similar motor vehicles began in nearly 1957. However, MHI's full-scale advance into this market started in 1968, when MHI passenger cars took a considerably high share of the market and taxi air-coolers began to spread. During the last half of the 1970s, MHI developed automatic air-conditioners for cars that could automatically control the temperature in the passenger cabin, so that comfortable air-conditioning became enjoyable throughout the four seasons of the year. From the beginning of the 1980s, MHI developed scroll compressors for car air-conditioners that were characterized by their high efficiency and low noise levels. In 1990, MHI developed the first scroll compressor in the world capable of preventing excess cooling using capacity control. This scroll was awarded the technology prize of JSRAE.

2.5 Low temperature physical distribution system

Since about 1963, low temperature physical distributing systems began to spread and facilities for freezing and cold storage for retaining the freshness of food began to be installed in food producing districts, transportation systems, and in food consuming districts. Semi-hermetic refrigerators for freezing and cold storage as well as refrigerating units for prefabricated freezing and cold storage have also been developed by MHI. At present, these facilities are major products of MHI's low temperature business. Since 1968, MHI developed truck refrigeration units and completed a series of such units of various sizes and applications ranging from use in compact cars through to large sized vehicles. In 1979, MHI developed under-mount type units driven by diesel sub-engines for large sized vehicles. The low fuel consumption and excellent car body stability features of these units made them a hit product and helped position MHI as the top manufacturer in this field.

MHI began to produce marine refrigeration units in 1956. After that, as containerization progressed, flush-mount type refrigeration units were developed in 1971 and super-thin end wall type units developed in 1973. The latter satisfied user demand for storage capacity to be made as large as possible within a limited container volume. These units have come to be the present foundation of the marine refrigeration unit business of MHI.

3. Present

3.1 Room air-conditioners

In developing room air-conditioners, MHI has always striven to reduce loads on the global environment, such as global warming and depletion of the ozone layer. Since 1997, MHI began to exchange HCFC for HFC refrigerants as part of measures to protect the ozone layer. The exchange is scheduled to be completed before the target date

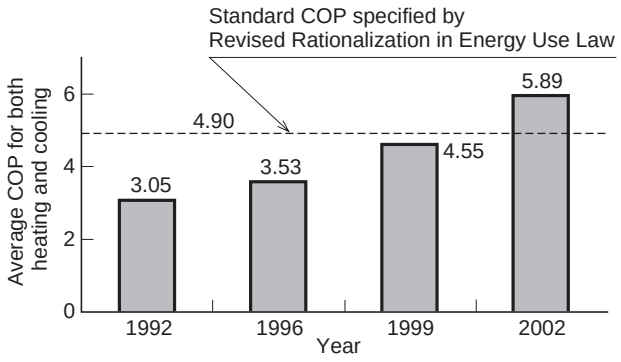

Fig. 2 Trend in average COP of heating and cooling for MHI air-conditioners (2.8 kW class)

of 2010 in Japan for the complete abolition of HCFC refrigerants used in new products. Bearing in mind that the improvement of efficiency is one of the most important points of concern in preventing global warming, MHI has already cleared the standard heating and cooling average COP (Coefficient of Performance) of 4.90 specified to be achieved in the 2004 stipulated in the revised Energy-Saving Law. As can be seen in **Fig. 2**, present day air-conditioners have reached a level of efficiency that is about twice what it was about ten years ago.

The SE series of high quality units was developed to meet the need for superior air-conditioning performance, especially for realizing true comfort in terms of temperature, humidity and cleanliness of the conditioned air.

In terms of comfort and excellent performance, the position of these units in the top class of this industry has been achieved by the adoption of a JET air current that applies jet engine technology as well as high accuracy temperature control.

- JET & warp

  An ideal wind path design can make a room comfortable within a very short period of time. This is because a large amount of cool or warm air can be spread into all corners of the room efficiently with less power consumption. For instance, such an approach would make it possible to heat a room from 10°C to 20°C in only three minutes at an outside temperature of 2°C. In addition, the operating sound of the indoor unit has been reduced to 19 dB in the silent mode of operation thanks to a special design that aims to achieve operation which is so silent that no sound is noticeable even at night. **Fig. 3** shows an

Fig. 3 External view of indoor unit of air-conditioner (2.8 kW class, high-end machine)

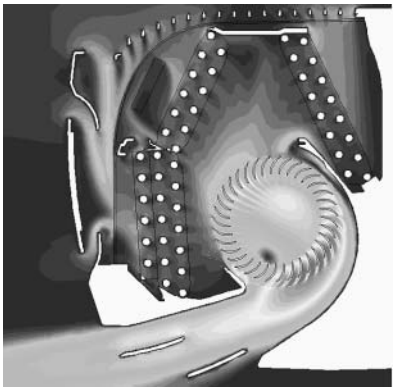

Fig. 4 Air flow of indoor unit

external view of a 2.8 kW class high quality unit, while **Fig. 4** shows the flow of air with such a unit.

The various following means are adopted in order to improve the cleanliness of the air.

- Powerful disinfection by enzymes

  MHI has developed the first air filter in the world for use in an air-conditioner. It disinfects mold and bacteria by enzymes in order to always keep the insides of the units and room clean.

- Cleanliness by ventilation

  Based on experience gained over a five-year period as a pioneer in ventilation type air-conditioners, MHI has developed a new ventilation type air-conditioner that keeps the indoor environment healthy through the use of a ventilation fan that discharges CO_2, formaldehyde, and other chemical vapors that are impossible to remove by a filter.

- Negative ions

  MHI has developed a system for supplying negative ions that are thought to be effective in mental therapy.

  In addition, MHI has developed an air-conditioner provided with advanced "e-@ir" technology that makes it possible to control air-conditioners via a remote controller using IT or a portable telephone.

3.2 Packaged type air-conditioners

MHI produces a wide range of packaged type air-conditioners. These include store air-conditioners, building air-conditioning units, ice thermal storage units, and gas heat pump (GHP) type air- conditioners. All these units use the HFC 407C refrigerant, which does not deplete the ozone layer, as one means of protecting the global environment.

3.2.1 Air-conditioner for stores

MHI has developed "Hyper Inverters" for store air-conditioners that have the features described below.

- Highly efficient and energy-saving operation

  Highly efficient and energy-saving operation has become possible in all operational ranges, thanks to the adoption of a hybrid type controller, in which the control range of the inverter driving the compressor is divided into both low speed and high speed ranges. As a result, the COP reaches 4.40 in a 2.5 HP unit, which is the top level in the air-conditioner industry, and attains an energy-saving rate in which annual electric power consumption is reduced by 47% compared with that of conventional 5 HP MHI units.

- Low noise

  Noise levels during operation have been remarkably reduced by 6 dB in an outdoor unit and 4 dB in an indoor unit, in comparison with the noise levels of conventional units.

- Adoption of powerful enzyme-based disinfecting filters

  Filters impregnated with special enzymes have been adopted in room air-conditioners to remove mold and bacteria in order to realize clean air-conditioning. This is the first unit of its type in Japan.

- Remote controller equipped with weekly timer function

  MHI has developed a remote air-conditioner controller with functions that can be set one week in advance that is the first of its kind in Japan.

  The figure in the headline shows external views of both an indoor and outdoor unit equipped with the "hyper inverter".

3.2.2 Air-conditioning systems for larger buildings

Recent buildings are often built as integral structures, in which offices and stores are combined. As a result, the air-conditioning system for such buildings is divided into small cell units and each cell unit works differently in terms of operation time, settings, and the like, so that individually distributed air-conditioning is required. The adoption of intelligent systems increases the amount of OA equipment used, so that both cooling and heating functions are often operated simultaneously in the same building. MHI has completed the multi-KX2 series system to accommodate such diverse operational conditions in air-conditioning. These systems have been adopted not only in Japan but also overseas in Korea, China, and Europe, and have become one of the main products of MHI. The major features of the system are briefly summarized below.

- Plenty of variation in indoor units

  A very wide variety of indoor units are available, including ceiling recessed type, ceiling recessed compact type, and duct type units. Individual units with capacities ranging from 0.8 through 10 HP can be combined.

- Large capacity outdoor units

  In addition to integral type units that range from 5 to 16 HP, large capacities from 18 through 40 HP have been realized by the combination of 8 and 10 HP units.

- Simultaneous heating and cooling operation

  Heating and cooling functions can also be freely selected and operated simultaneously with a single outdoor unit such as multi-KXR.

Fig. 5 External view of inverter type multi-KX2 outdoor unit (32 to40 HP)

Fig. 5 shows an external view of an outdoor unit of multi-KX2 for buildings.

3.2.3 Ice thermal storage systems

Ice thermal storage system utilizes ice or hot water produced by less expensive electric power during the night for air-conditioning during the daytime. MHI offers both series of large capacity Multi-HiCoP Ice 60 and HiCoP Ice 90 systems. The major features of these systems are briefly summarized below.

- High efficiency

  The icethermal storage systems developed by MHI have achieved a daily COP 2.2 or more in total of electric power consumption for ice thermal storage during the night, and that for cooling rooms using ice thermal storage during the daytime. This high efficiency, the highest level in Japan, has been obtained by improving the performance of both the ice making heat exchanger and the outdoor unit.

- Peak cut and peak shift method

  In the HiCoP Ice 90 series, the compressor of each outdoor unit is stopped during the time zone from 1 pm through 4 pm in the summer, when power consumption peaks, so that 90% of the power consumption is cut. During other time zones, 35% of the power consumption is shifted by subcooling the refrigerant. These cuts in power consumption and use of lower rates make it possible to realize substantial savings in the amount paid for power. **Fig. 6** shows an operating pattern for peak cut and peak shift. In addition to the HiCoP Ice 90 series, the HiCoP Ice 60 series has also been commercialized. This series achieves reductions in power consumption of as much as 60% and 40% by peak cutting and peak shifting, respectively.

- Heating by use of heat accumulator

  Strong market needs have led to the addition of a hot water type heat accumulating mode to the ice thermal storage system. Heat is accumulated by holding hot water at about 35°C in a heat accumulating tank using less expensive electric power during the night. The heat accumulated is then used for heating during the daytime. A "heating capability- raising mode" has become applicable to increase the heating capability of the heat accumulator.

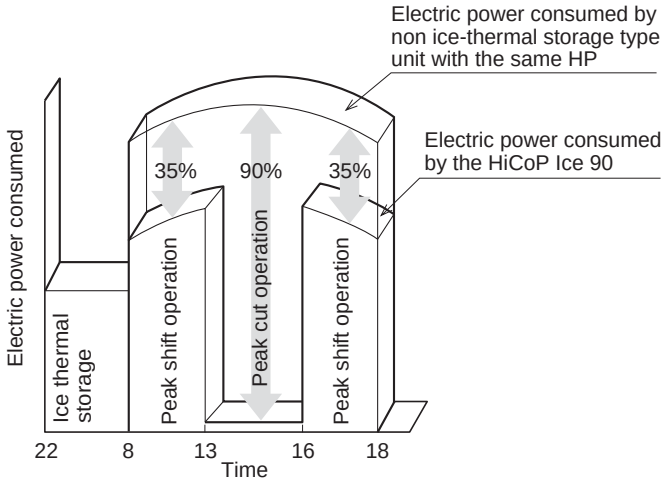

Fig. 6 Illustration of ice thermal storage system (HiCoP Ice 90) operation pattern (for cooling)

3.2.4 Gas heat pump (GHP) type air-conditioners

The GHP type air-conditioner series ECO-5 using a new refrigerant has been developed to satisfy the following customer needs.

- Energy-savings

  Efficiency has been increased by about 20% compared with conventional units by the improvement of the efficiency of the engine, the application of electronic control, and the adoption of low-pressure loss refrigerant circuitry originated by MHI. As a result, the COP value for these units reaches 1.31 on average for cooling and heating, which places them in the top class in Japan.

- Reduction of environmental load

  The emission concentration of NOx (nitrogen oxides) has been reduced by 40% through the application of electronic control and improvements to the EGR (Exhaust Gas Recirculation) system, in which a portion of the exhaust gas is recirculated.

- Low noise

  The operational noise level of each unit has been reduced to 60dB through the application of a double vibration-isolating system using a liquid seal type engine mount originally developed by MHI, optimized design of the engine suction and exhaust system, and improved cabinet noise-isolating performance.

- Improvement of serviceability

  A maintenance interval of as long as 5 years or

Fig. 7 External view of outdoor unit of gas engine heat pump type air-conditioner

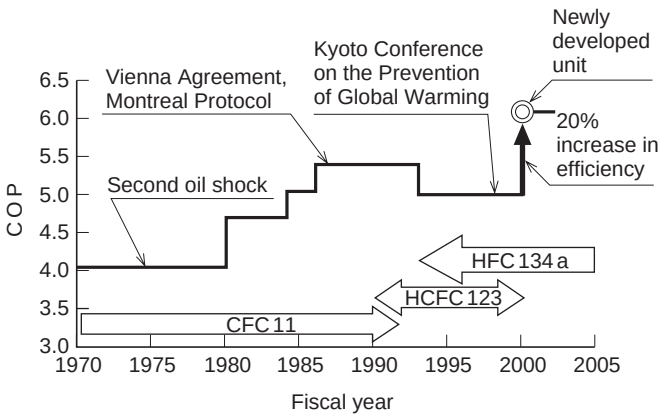

Fig. 8 Trend of COP of electric motor driven turbo chillers

10 000 hours has been realized with the use of improved engine oil.

Fig. 7 shows an external view of an outdoor ECO-5 unit.

3.3 Large sized refrigerating machine

Typical large sized refrigerating machine products include electric motor driven turbo chillers, steam absorption chillers, and district heating and cooling plants. The electric motor-driven turbo chillers are used for the cooling of large-scale buildings, clean rooms in IT plants, and district heating and cooling plants. The NART series of electric driven turbo chillers realizes a COP of 6.1, the highest efficiency rating in the world, through the use of HFC134a refrigerant. As a result, the series contributes not only to reductions in CO_2 emissions at electric power stations, but also to reductions in running costs. This machine was highly praised for its high efficiency and was awarded the prize of the President of the Japan Machinery Federation in 2001. **Fig. 8** shows the trend of COP levels for electric motor driven turbo chillers. **Fig. 9** shows an external view of a NART turbo chiller.

In an effort to increase the capacity and efficiency of steam absorption chillers, MHI has realized the world's largest absorption chiller with a capacity of 5000 RT and a steam consumption rate of 3.9 kg/h･RT. Using steam generated by heat exhausted from a gas turbine used for cogeneration, the chiller in a district heating and cooling plant supplies chilled water to buildings in the area served by the plant.

These chillers are controlled by a microcomputer control panel with a color liquid crystal display developed originally by MHI. The microcomputer control panel is applicable to various building systems such as LonWorks(R), as an option, and can be used to control the number of operating units so as to support the daily operations of the customer. Furthermore, it can also be connected to a "Hot Support" remote control system, so that the chiller can be monitored 24 hours a day so that MHI can offer suggestions on preventive methods and

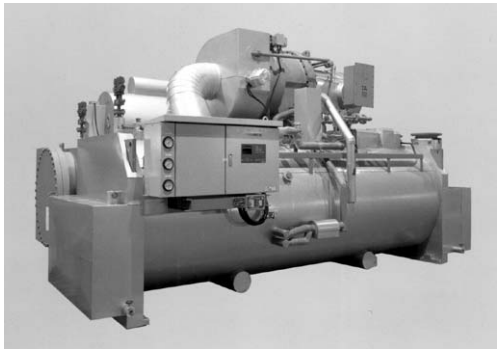

Fig. 9 External view of turbo chiller (NART series)

prompt measures that can be taken to address any troubles or difficulties in addition to advice on energy-saving operation and planned maintenance.

MHI is currently constructing a district heating and cooling plant at the east entrance area of the Shinagawa station. The plant will use a combination of an electric motor driven turbo chiller and a steam absorption chiller that fully utilize the advantages of MHI. An ice thermal storage system using night electric power and gas turbine for cogeneration are to provide a stable supply of chilled water at low cost to buildings such as offices and hotels in the area.

3.4 Automobile Air-conditioners

Automobile air-conditioners must be compact, because the space in a car is limited due to the increase of onboard devices such as audio sets and car navigators. At the same time, the car air-conditioner must satisfy a variety of needs for improving comfort, saving power, reducing fuel consumption, protecting the environment through reduced use of refrigerants, and ensuring users of further higher reliability and safety.

Accordingly, MHI is striving to improve the performance of the major components that constitute a car air-conditioner in the following ways.

MHI has adopted scroll compressors from the past because they have the advantages of high efficiency, low noise, low vibration, and high speed. As a result of various improvements, a new profile (stepped profile) has been adopted, so that the performance and reliability of

Fig. 10 Profile of new scroll (stepped profile)

the scroll has been greatly increased as a result. **Fig. 10** shows an external view of the stepped profile of a scroll.

The excellent heat transfer performance and remarkable weight reductions in heat exchangers have been realized by providing numerous dimples on the surface of the refrigerant side of the tubes, instead of attaching inner fins as has been the case until now, as well as by optimizing the air side fins. In addition, in order to reduce the required space and amount of refrigerant needed, the performance of the heat exchanger has been improved (increased in density) and reduced in thickness. **Fig. 11** shows an external view of evaporator plates.

In the case of HVAC air-conditioning units, MHI intends to enhance the performance, reduce noise, minimize the size, prevent reheating due to the hot water heater, and optimize the arrangement of the heat exchangers, air paths, and damper to reduce pressure loss. Power savings have been achieved by improving the performance of the controller, without losing comfort in the cabin room.

MHI has also been successful in producing blowers of high performance, high reliability, and low noise through the adoption of advanced blade profiles and rear edge serration of the fan, and by optimizing the three-dimensional profile and operation points of blades by CFD and FEM.

3.5 Refrigerating physical distribution system equipment

3.5.1 Truck refrigeration units

The truck refrigeration units are divided into the direct-coupled type and sub-engine type, depending on the method used to drive the compressor. The direct-coupled type is used for compact and medium sized cars, while the sub-engine type is often used for medium and large sized vehicles. MHI provides a wide lineup covering all units for light cars through large sized vehicles.

MHI takes great care to ensure observance with all environmental regulations such as those dealing with the use of CFCs (chlorofluorocarbon), noise, and gas emissions. With regards to the ban on the use of the CFC family of refrigerants, for example, MHI has already

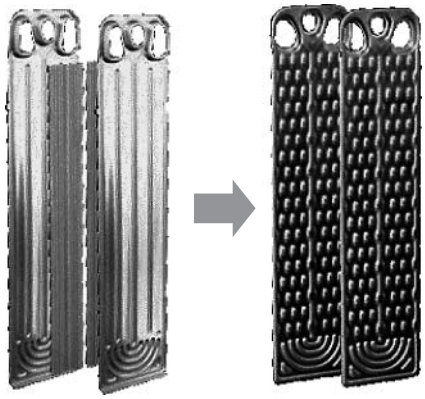

Fig. 11 External view of evaporator plates

finished replacing all CFCs and HCFCs with HFCs.

The improvement of the quality control of transported food, changes in national dietary habits from home to restaurant, an increase in dependence on ready-made foods, and the increase in the number of convenience stores are accelerating the need for ever more effective temperature controlled transport and storage environments. These include expansion of the light car market, and the simultaneous transport of products in different temperatures using multiple evaporator systems. MHI has been very active in developing new products to meet these needs.

MHI has developed the TUJ80D which is a combined evaporator and condenser refrigeration unit using the sub-engine method, the first of its type in Japan. In this unit, the evaporator and condenser are both contained together in a single container, so that engine noise is reduced by 8dB compared with the noise level of conventional machines. The reduced noise reaches a level that permits conversation in front of the power unit; that is, the TUJ80D is a silent refrigeration unit that is also friendly to the environment. The refrigerant used for this unit is HFC404A, which does not deplete the ozone layer. In addition, the refrigeration capacity of the unit has been increased by 10% over conventional units in order to accommodate the increase in the size of car and truck bodies. **Fig. 12** shows an external view of the unit carried on a refrigeration truck.

Fig. 12 External view of truck refrigeration unit

3.5.2 Marine refrigeration units

A marine refrigeration unit consists of a chiller unit used to refrigerate a marine container. Hence, it needs to be highly reliable and durable enough to withstand such severe conditions as tropical zone, frozen regions, seawater, vibration, and impact.

In particular, it has been recently advocated by some that the durability of such units be increased further and that the maintenance that is normally carried out periodically is to be abolished or minimized in order to reduce operating costs.

The most critical issues regarding durability are corrosion of the compressors and air-cooled condensers used in ocean circumstances. Accordingly, MHI has developed a new, original painting method which is known for its excellent corrosion resistance. Applying this newly developed painting method, the operating lives of these machines have been extended by up to three times of that of conventional units.

Backup functions, such as making emergency manual operation possible in the event of failure of the controller or refrigerant-regulating valve and transmitting operational data stored in the controller during voyages, have been fully completed as part of measures to increase reliability. **Fig.13** shows an external view of a marine refrigeration unit.

Fig. 13 External view of marine refrigeration unit

4. Future

The subjects to be considered and products to be targeted in the future are described as follows:

4.1 Protection of global environment

It is the basic policy of MHI to place top priority on protection of the global environment. In this regard, converting the CFC and HCFC family of refrigerants to HFC refrigerants, increasing efficiency, utilizing natural refrigerants as a means of preventing global warming, and accelerating the recycling of waste materials including the recovery of refrigerants upon the repair and scrapping of refrigeration equipment are all issues of vital importance to MHI.

4.1.1 Protection of the ozone layer

The depletion of the ozone layer has become an environmental problem of great international concern. This led to the conclusion of the Montreal Protocol to protect the ozone layer in 1987. As a result, the production and use of CFC and HCFC refrigerants became restricted. MHI intends to accelerate the conversion of conventional refrigerants to HFC refrigerants that do not deplete the ozone layer, and to complete this conversion before the international deadline for scheduled complete restriction.

4.1.2 Prevention of global warming

(1) Increasing efficiency and saving energy

It is the intent of MHI to further improve the energy saving performance of room and packaged air-conditioners in order to reduce power consumption. One result of these efforts is the contribution thus made to preventing global warming through the reduction of CO_2 emissions caused by power generation. Based on its top priority on developing high efficiency products, MHI is always striving to improve the efficiency of the refrigeration cycle as well as of all major components such as compressors, heat exchangers, blowers, and inverters.

In the field of large sized chillers, MHI is working to develop a steam absorption chiller that utilizes the exhaust heat of a gas turbine as well as utilize exhaust heat directly from gas engines, as products that effectively use exhaust heat.

A suction gas-cooling system, commercialized by MHI as a new product, is to be spread to the market. The output of a gas turbine decreases as the air temperature increases in the summer. In order to compensate for this decrease in gas turbine output, a suction gas-cooling system is used to cool the suction gas of the gas turbine. This system uses chilled water that is supplied from an absorption chiller driven by steam produced by the exhaust heat emitted by the gas turbine. In the field of thermal storage, MHI is planning to spread a PCM thermal storage system. In this system, heat can be storaged in high density at a temperature level that is equivalent to the extent to which the temperature of the chilled water is higher than ice (0^{o}C). Both the suction gas-cooling and PCM thermal storage systems can not only be installed in newly built plants, but in existing plants, as well. **Fig. 14** shows an external view of the first PCM thermal storage tank in the world installed at New Tokyo International Airport.

(2) Use of natural refrigerants

At the third session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (i.e. the Kyoto Conference), six kinds of gases including HFCs were defined as being greenhouse gases. Accordingly, MHI has moved to accelerate the commercialization of products using natural refrigerants that have little, if any, greenhouse effect.

Fig. 14 PCM heat accumulator installed at New Tokyo International Airport

Fig. 15 External view of CO_2 compressor

Fig. 16 Test car for CO_2 system

MHI's experience with automobile air-conditioners shows good prospects that efficiencies can be increased and the weight of heat exchangers and compressors can be decreased even when carbon dioxide is used as a refrigerant. As a result of practical car testing on this prospect, it has been confirmed that a car air-conditioner using carbon dioxide has a refrigerating capability equivalent to a system using HFC134a. **Fig. 15** shows an external view of CO_2 compressor and **Fig. 16** a test car for CO_2 system.

In addition, MHI intends to develop an electric motor driven turbo chiller in which ammonia is adopted as a refrigerant in large sized chillers. Current technology for improving efficiency will also be incorporated in the system.

(3) Leveling of electric power demand

Another goal of MHI is to increase the performance of a packaged air-conditioner provided with an ice thermal storage and a chilling unit provided with an ice thermal storage even further. This would solve problems due to peak demand for cooling at midsummer by using electric power that is stored during the night. In addition, MHI is planning to propose optimum air-conditioning systems with improved efficiencies for a given requested condition for gas air-conditioning systems (gas heat pump type air-conditioners and gas absorption chillers) that do not consume electric power.

Utilizing its advantage as an all-round air-conditioner manufacturer, MHI always strives to propose the best choices to its customers and clients. For instance, a gas type air-conditioning system might be the best choice for a school that has limited electric power source capacity, while an ice thermal storage air-conditioning system might be optimal for a factory that is ISO 14001 certified.

4.1.3 Recycling recovered waste material

In order to control the amount of waste and save limited global resources, MHI consistently strives to develop environmentally oriented designs. This might include extending product life, pursuing resource-saving effects through reductions in product sizes and weights, finding ways to facilitate easy separation and disassembly, reducing the numbers of kinds of plastics, and using recycled materials.

In the field of room air-conditioners, MHI has already achieved a level that far exceeds the standard recycle rate specified by Law for Recycling of Specified Kinds of Consumer Electric Goods that came into force in April 2001. Even so, the company is continually seeking ways to extend the recycling concept to all cooling and heating products that it produces.

4.2 Utilization of IT (Information Technology)

With the great progress in IT that has been seen in recent years, the use of IT is accelerating ever more quickly in both business and ordinary households as the infrastructures for high-speed networks are built and come on line. MHI is looking to be the first commercialize internet-based air-conditioners for households, and intends to apply intelligent system design to the management of buildings for business purposes. As a result, energy-savings and serviceability will be improved through the use of remote monitoring, control and diagnosis of the states of the air-conditioning systems and equipment used by users.

4.2.1 Energy-savings

The internet-based air-conditioner known as “e-@ir” can control a maximum of 255 sets of air-conditioners through wireless communication between a personal computer and the respective air-conditioners. As a result, multiple air-conditioners in houses, as well as in dormitories, schools, and companies can be easily and conveniently controlled. The internet air-conditioner can be switched on or off, and room temperature, humidity, and external temperatures can also be monitored. Required temperatures can be set from a long distance away, so that forgetting to switch the system off or excessive cooling or heating can be prevented no matter where the user is. Moreover, each air-conditioner in a house will be connected in the future to the internet via a personal computer in the house. This will make on-

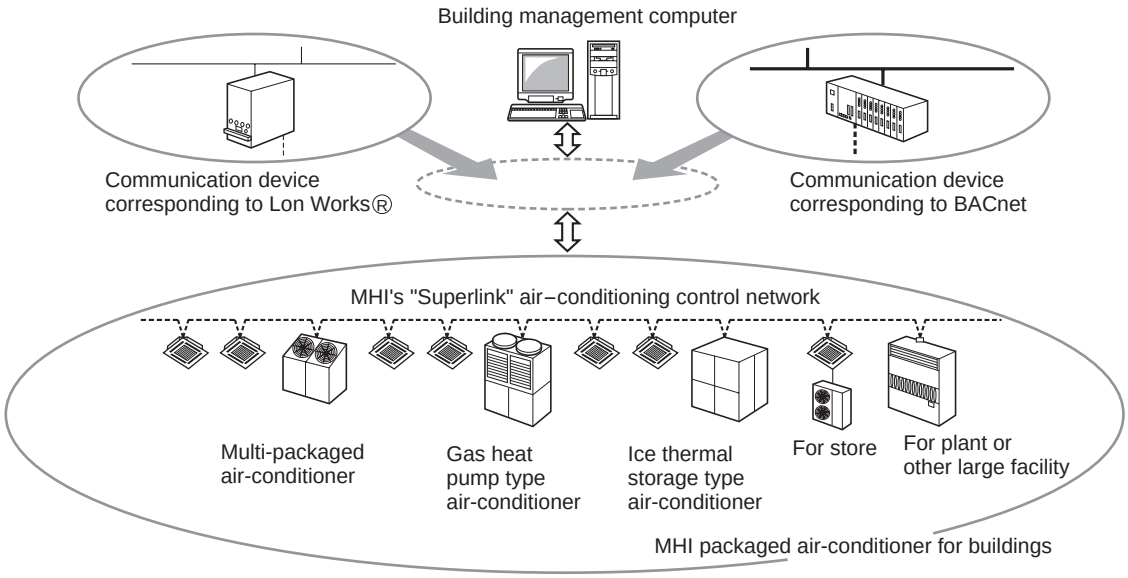

Fig. 17 Scheme of MHI's plan for the opening its packaged air-conditioner system

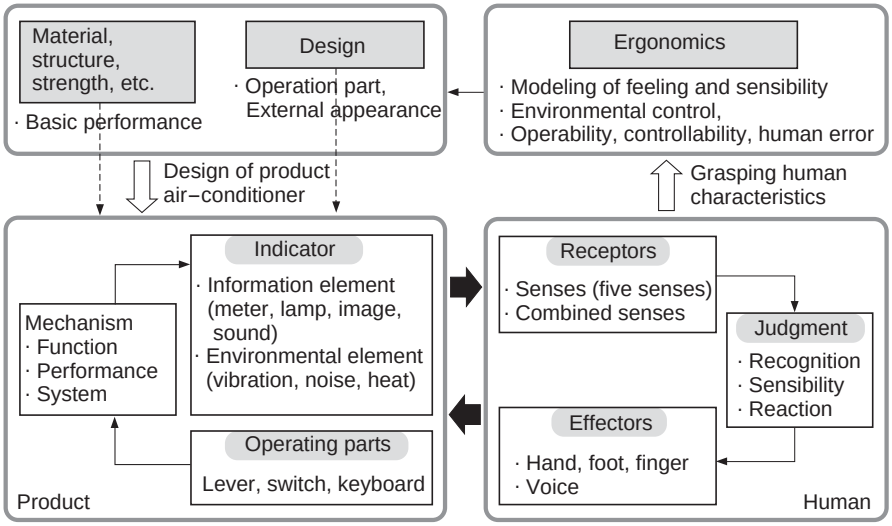

Fig. 18 Position of ergonomics

demand control such as changing the set temperature or temporarily stopping the system during power peaks in midsummer possible by monitoring the extent of power consumption from a great distance. Thus, the energy-saving effect of utilizing IT is expected to be significant.

4.2.2 Improvement of serviceability

MHI was the first company to develop an air-conditioning control network known as "Superlink" for a building management system, which is capable of controlling several ten sets of indoor and outdoor units. In addition, the opening of communication protocols, as represented by LonWorks(R) and BACnet, for building management has been spreading recently. This network can communicate with building management systems that are connected among different venders. In fact, the trend now is towards achieving overall management of not just the interior of a specific building, but also to expanding such control to provide consistent management over several buildings at the same time. District control based on this approach has even begun to appear recently. MHI has already developed communication devices that correspond to both LonWorks(R) and BACnet, in order to accommodate the realization of intelligent building management systems. **Fig. 17** shows a MHI plan for opening such a system based on its packaged air-conditioning system.

Based on these experiences, MHI is striving to improve its services and solve defects and faults quickly through the operation monitoring system known as QSS-net (Quickly Service Support System network). As an all-round air-conditioner manufacturer, MHI is accelerating the pace of completion of networks for use in remote monitoring systems, fault prevention systems, and the like with the ultimate goal of achieving the complete satisfaction of its customers of both software and hardware products and services.

4.3 Improvement of usability

ISO13407, "Human-Oriented Design of Interactive

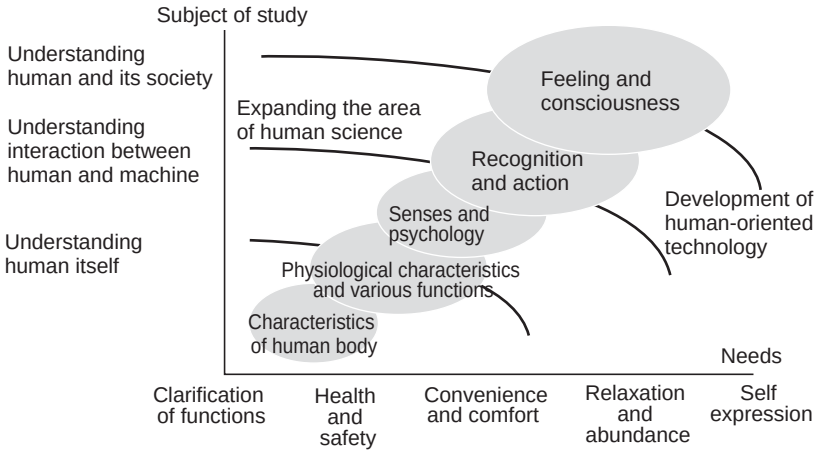

Fig. 19 Development of ergonomics

Systems," was established in June 1999 as an international standard. MHI has striven to improve the design of all new air-conditioners in keeping with the principles of this standard, continuing its tradition of placing major emphasis on both performance and reliability. This being said, however, usability will become an ever more important subject of concern in the future, as well.

The marketability of MHI air-conditioner products has continued to improve, as human technology is applied more and more in their development and design from the perspective of comfort and ease of use (**Fig. 18**). In the future, as can be seen in **Fig. 19**, MHI intends to extend such ergonomics even further from the viewpoint of customer's needs. This will include contributing to the progress of air-conditioning systems by introducing new functions and further facilitating ease of use. Particular attention will be placed on the following points in these efforts:

- Usability will become an ever more important to customers as a selection factor, complaint factor, and differentiation factor from other competitive products.
- Easy use is becoming ever more strongly expected by users.
- Consideration needs to be given to convenience, suitability, for and ease of use by aged and disabled persons.

5. Conclusion

This article presented a summary introduction to the past, present, and future of heating and cooling products of the air-conditioning and refrigeration system business of MHI.

The market of air-conditioning and refrigeration systems is extremely large. Moreover, the market is a field in which future growth is expected. In particular, a high GDP (Gross Domestic Product) rate is expected in Asia because its population is large and the economy is growing, overall. As houses and buildings are completed as part of the social infrastructure, air-conditioning systems will inevitably become more important as a means of improving the comfort of living spaces. Related systems will also become increasingly essential to both freezing and refrigerating storage that is closely related to food distribution. Both these areas promise significant growth as important markets in the future.

Protecting the irreplaceable global environment and grasping customer's needs exactly, MHI is continually striving to provide equipment and services to the market that delight customers and satisfy their needs completely. To this end, the company is actively conducting research and development and is always seeking ways to improve the quality of its services ever further.

In the future, MHI will also strive to contribute to the creation of an abundant and comfortable human life throughout the world, with an extensive product mix ranging from local air-conditioners through to district heating and cooling systems. Understanding the intention of MHI, the authors would like to express their appreciation to all interested parties for their further guidance to and support of MHI in these activities.

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