Compact, High-Efficiency Multi-Air-Conditioner LX

MASAHIKO SASAKURA*1
TOYOTAKA HIRAO*2
MASASHI MAENO*2
SHIGEKI OSEKI*2

Multi-Air-Conditioner LX for 2004 needs 52% less installation space and has a 24% improved coefficient of performance (COP), as compared with the conventional KX2 series of 20 horsepower class. The compact design and higher COP have been realized by reduction of pressure loss in duct by four-side suction structure of the heat exchanger, optimization of fan and duct, and DC compressor motor, and all models conform to the standard values of the Energy Conservation Law of Japan. The maximum piping length has been extended to 160 meters, the longest in the industry, and by improved collection of running data, installation and maintenance have been made easier.

1. Introduction

In the field of packaged multi-air-conditioners, regulation of coefficient of performance by the Energy Conservation Law of Japan takes effect in 2007, and the Law on Promoting Green Purchasing is also applied to promoting purchase of environmentally friendly machines and products by Japanese government offices. The market is encouraging development of law-compliant products and is competing to conform to the requirements earlier than scheduled.

At the time of development of new models, the refrigerant was changed from HCFC22 to HFC407C as alternative refrigerant to prevent depletion of the ozone layer, but as lower pressure loss and higher efficiency are required in multi-air-conditioners for buildings, like the air-conditioners of rooms or shops, the refrigerant is being changed to HFC410A with higher pressure and higher density.

Mitsubishi Heavy Industries, Ltd. (MHI) has developed the LX series using the HFC410A refrigerant in succession to the KX2 using the alternative refrigerant HFC407C and KX3 (8 and 10 horsepower) conforming to Energy Conservation Law. The capacity ranges from 8 to 24 horsepower, and in combination, a wide range of models are available up to 48 horsepower. Features of the LX series are described below.

2. Features

2.1 Compact design

All models from 8 to 24 horsepower are built in an integral module structure. Every model has a width of 1 350 mm, as in the conventional KX series, and a depth of 720 mm. Because the area of installation is the same, the restriction in area of installation is minimized and an outstanding compact design has been realized. In the 20 horsepower class, the space required for installation is only half that of the conventional counterpart. This improvement contributes to greening of the outdoor environment and has other added values. The depth of 720 mm is the smallest in the industry, and the unit can be installed on the verandah of a building. Further, the unit width dimension has been unchanged for 13 years, and the anchor bolt holes of former models can be used with only minor changes. **Fig. 1** shows a comparison of the space for installation of the new model and conventional model in the 20 horsepower class.

The compact design has been realized by changing from the conventional structure of heat exchanger one-side layout + oblique upward diffusion fan of the KX2 to a new structure of heat exchanger four-side layout + straight upward diffusion fan, thereby expanding the heating area and reducing the air pressure loss. In addition to the compact design, high efficiency is also

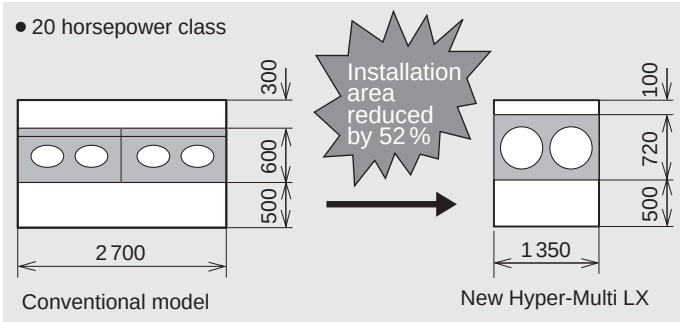

Fig. 1 Comparison of installation area of 20 horsepower class
As compared with the installation area of conventional KX 20 horsepower models, only about half the area is needed for the new LX 20 horsepower model.

*1 Air-Conditioning & Refrigeration Systems Headquarters
*2 Nagoya Aerospace Systems Works

achieved in this series. Details are discussed in paragraph 2.2.

The machine room accommodating the compressor has also been modified by optimum refrigerant piping design in order to save space. To determine the piping design, the strength has been analyzed beforehand by the originally developed piping design system. By using this system, quality engineering (Taguchi method) is applied to take account of fluctuations of piping shape and others, and the piping specifications are determined. An example of the piping layout obtained by the analysis is shown in **Fig. 2**. As a result, vibrations and stress can be controlled to within allowable values in the entire range of rotating speed of the compressor, with compact design.

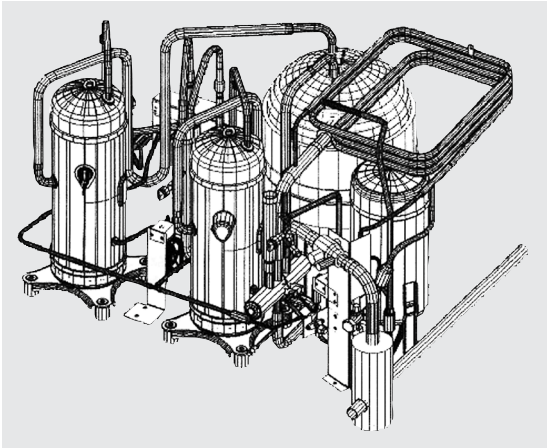

Fig. 2 Piping structure of machine room
Piping structure has been simplified, and machine room is compact.

2.2 High efficiency

The LX series satisfies the 10 horsepower standard of the Energy Conservation Law in all models including the one-body type and combined type. In the 20 horsepower class, as shown in **Fig. 3**, the COP has been improved by 24% over the conventional model. In the entire series, the 16 horsepower class shows the highest improvement rate of COP of 35%. To achieve higher efficiency, the following points have been modified.

(1) Use of high-performance compressor

It is intended to improve the compressor performance by 4.1% in the average of heating and cooling as compared with the conventional machine for HFC407C. This is realized by using a DC motor and optimizing the design pressure ratio suited to HFC410A.

(2) Improvement of heat exchanger and air flow (in comparison with 10 horsepower prototype)

- Increase of heat exchange area and air flow rate, and optimization of duct structure (The improvement is realized by four-side layout of heat exchanger on the top of the unit.)
- Use of DC motor for outdoor fan motor
- Use of new high-efficiency fan

Improvement of the heat exchanger and duct structure is discussed together with increase of fan efficiency and suppression of noise. To improve the air flow, this is limited by modifying the fan alone, and it should be regarded as a total heat exchange system in consideration of the effects of the heat exchanger and other structural components.

As a result of computational fluid dynamics (CFD) of conventional units, it has been disclosed that the fan suction flow is biased, being accompanied by increase of pressure loss and noise level, by the one-side layout of the heat exchanger. The presence of compressor and electricals box adds even further to the worsening tendency. In the new unit, the following points are being studied to bring about improvement.

(a) Four-side layout of heat exchanger

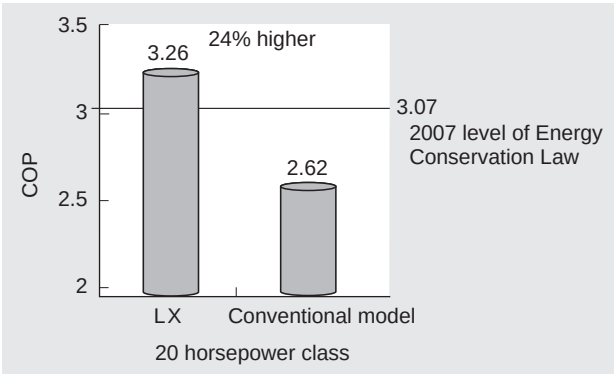

Fig. 3 Improvement in COP of 20 horsepower class
As compared with conventional KX 20 horsepower models, COP has been improved by 24%, reaching 3.26, which is well over the 3.07 level required in 2007 by the Energy Conservation Law (10 horsepower standard).

(b) Separation of machine room and heat exchanger room

(c) Higher performance of fan

Mutual effects have been investigated, and further CFD has been attempted in a bid to solve the problems. As a result, as shown in **Fig. 4**, in a comparison of the conventional unit and a new one, use of a DC motor and improvement of fan efficiency has realized a remarkably lower input in spite of substantial increase of the air flow rate.

A comparison of fan performance is shown in **Fig. 5**, where the fan is designed in a longer chord, the vane load is decreased, disturbance on the vane is suppressed, and serration is formed in the rear edge, so that high efficiency is realized.

By comparison of fan characteristics and unit characteristics, it is known that 20% out of 50% of reduced input of the fan motor depends on fan efficiency improvement and the remaining 30% on the use of a DC motor.

As a result of these improvements, the COP has been improved by 24% in the 20 horsepower class as

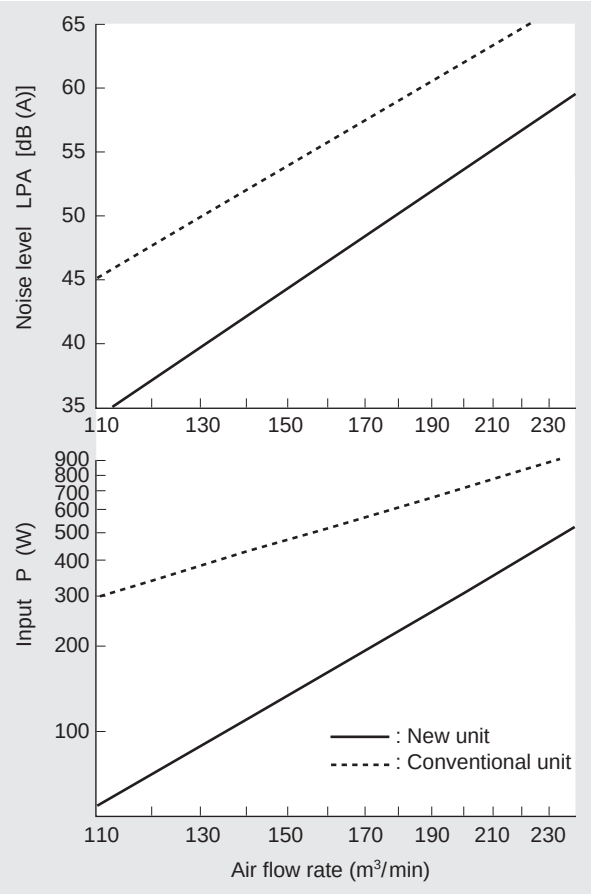

Fig. 4 Comparison of blowing characteristics of units
Substantial improvements and high performance have been realized in the new LX series.

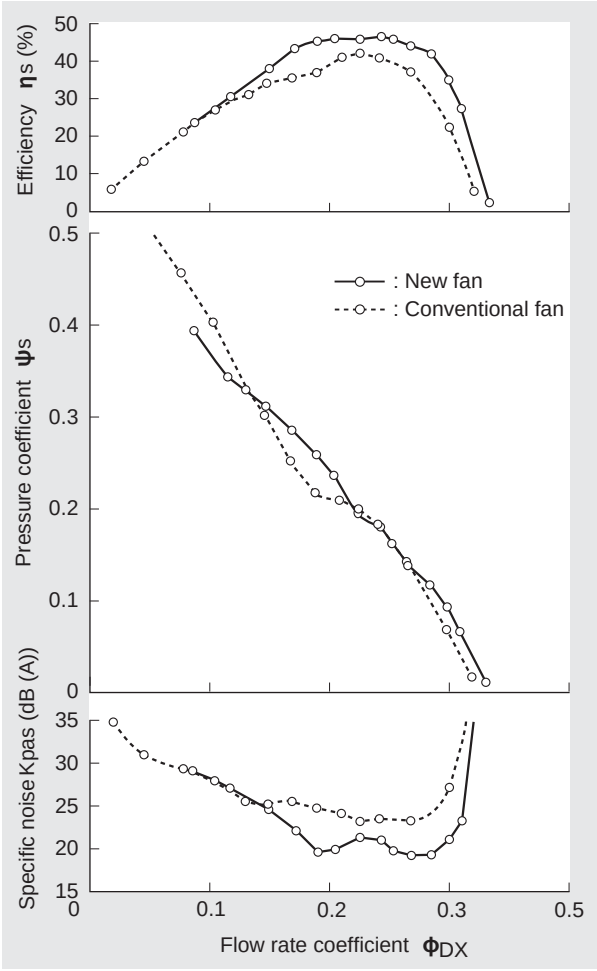

Fig. 5 Comparison of fan characteristics
By modification of the fan shape, uniform distribution of heat exchange air flow, increase of suction area of the heat exchanger, and use of a DC fan motor, the noise level has been lowered and efficiency increased.

compared with the conventional model, and the COP of all models in the new series exceeds 3.07 (the standard value for 10 horsepower class by the Energy Conservation Law).

2.3 Expanded range of use

It is also intended to expand the usable range of the new air conditioner as compared with conventional units. Points of improvement are as follows.

(1) Extension of limit of connection piping length

In very large shops, the inner and outer connection piping length often exceeds 100 meters. The piping length of the new air conditioner has been extended from the conventional 100 meters to 160 meters, the longest in the industry, and the limiting conditions on installation have been eliminated. The total piping length is 510 meters, and the applicable range has been expanded remarkably.

For extension of the piping length, it is important to know the oil discharge amount from the compressor, conduct oil recovery, and measure the oil holding volume in the piping. **Fig. 6** shows the oil circulation rate (oil circulation amount/oil and refrigerant circulation amount) discharged from the compressor (oil separator) into the refrigerant route, expressing 80 Hz as 10. From this diagram, the oil discharge amount – which differs according to condition of unit operation – is calculated precisely, and execution of oil recovery operation is determined.

The oil recovery operation is controlled specifically to collect the oil securely and quickly in consideration of the piping diameter and head difference between indoor and outdoor units. The control contents are verified by using the high head different testing equipment at Yokohama Building of MHI (33 stories, 151.9 meters in height).

(2) Expansion of lower limit ambient temperature of heating operation

In heating operation, the conventional lower limit ambient temperature is −15°C. This has been lowered to −20°C, and applicable districts have been expanded.

To verify the application expansion, improvement of anti-frost performance was studied by using a straight fin heat exchanger. Validity was also investigated for control of compressor and expansion valve to assure compressor oil at start, recovery operation control of compressor oil during operation, and equal

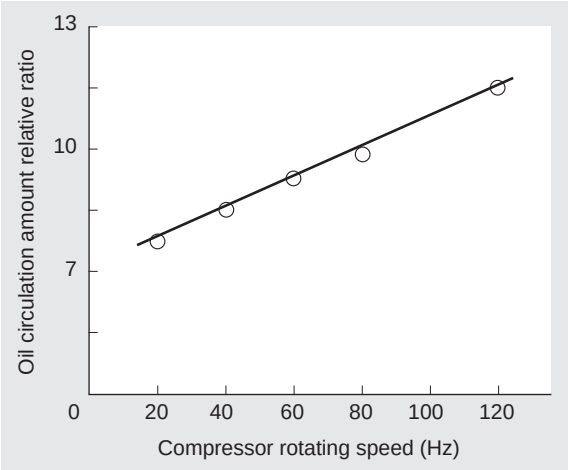

Fig. 6 Compressor rotating speed to oil circulation amount relative ratio
By precise analysis of the oil discharge amount from the compressor, oil recovery control is determined and high reliability is achieved. In the diagram, the oil circulation volume at 80 Hz is shown as 10, and the oil circulation amount ratio is shown in terms of compressor rotating speed.

Fig. 7 Seven-segment display of outdoor controller
Operation data including temperature, pressure and control status of the unit can be checked on the seven-segment display of the outdoor unit controller, and convenience in trial runs and servicing has been improved.

oil operation control, and reliability was confirmed.

Thus, by extending the piping length and expanding the usable range of ambient temperature, it will be possible to apply the new system in a greater number of buildings.

2.4 Improvement of service

Principal items of service improvement are shown below.

(1) Operation data can be read and checked from outdoor unit by using a personal computer.

(2) In case of trouble, the running data before outbreak of abnormality is stored automatically for 30 minutes. As a result, the cause of trouble can be found and removed promptly, and operation can be resumed more quickly.

(3) Operation data such as temperature and pressure can be observed by seven-segment display of outdoor controller (**Fig. 7**).

(4) The outdoor unit is separated into machine room and blower room, and servicing or trial run can be realized while the panel is open.

(5) Pipings of the heat exchanger have been moved from the rear to the front side, and servicing of the heat exchanger is easier.

(6) By means of a pump-down switch, automatic pump-down operation has been realized by using a low pressure sensor, and the refrigerant recovery work is easier and shorter.

3. Conclusions

The new Multi-Air-Conditioner LX has been substantially improved, as compared with the conventional KX2, in various aspects including structure, efficiency, usable range, controllability and service. These improvements result in considerable merits for end users, design offices, installation firms, service companies and others. All models conform to the COP standard values of the Energy Conservation Law. By reducing the piping diameter, the refrigerant amount has been decreased, packaging is wood-free, and the new series is friendly to the global environment.

Further efforts will be concentrated on development of new air-conditioners to meet the needs of the market and users in a timely and appropriate fashion.


Masahiko Sasakura


Toyotaka Hirao


Masashi Maeno


Shigeki Oseki