1998

Our Rapid Advances Have Prepared Us for the Demands of the Future

K. Nishioka
Mitsubishi Heavy Industries Climate Control

"Our Rapid Advances Have Prepared Us for the Demands of the Future."

Address by:

Kazumitsu Nishioka, Ph.D.
Executive Vice President
Mitsubishi Heavy Industries Climate Control, Inc., Franklin, Indiana

To the
1998 International Compressor Engineering
and Refrigeration Conferences

Purdue University Stewart Center, Loeb Theater
Tuesday, July 14, 1998

"Our Rapid Advances Have Prepared Us for the Demands of the Future."

Address by Kazumitsu Nishioka, Ph.D.
Executive Vice President, Mitsubishi Heavy Industries Climate Control, Inc.,
To the 1998 International Compressor Engineering and Refrigeration Conferences

Good morning. First, I'd like to thank the organizing committees for these two conferences. Also, I want to thank Professor Raymond Cohen and Professor Robert Bernhard for the invitation to stand before you today.

I feel privileged because this year and this occasion is special for Purdue University. It marks the fortieth anniversary of the founding of the Ray W. Herrick Laboratories, a landmark event for both this school and our entire industry. If you did not tour the laboratories on Monday, I urge you to take advantage of the other opportunities to do so before you leave. I also feel honored and humbled to be here because this year is the twentieth anniversary of my introduction to Purdue University and the Herrick Laboratories as a young graduate student from Japan. And although I gave my professors plenty of reason to doubt that I would succeed, they gave me enough of their wisdom that I have been able to make a career in this field with Mitsubishi Heavy Industries.

For you young engineers, remember this lesson: You work hard for 20 years, then they make you give a speech!

With these anniversaries taken care of, I would like to welcome you to the Fourteenth International Compressor Conference and Seventh International Refrigeration Conference. We schedule these meetings in July because we know that the famous Indiana heat and humidity would scare away other conferences. One thing refrigeration engineers can do is take the heat!

I enjoy these meetings because they are always wonderful opportunities to renew friendships and relive old stories. Clearly, these annual conferences have a much more serious purpose as well to justify the time and expense involved in attending and presenting them. The papers presented here will display the state of our art and the remarkable thinking of the scientists and engineers who will push that art into the future.

This morning, I will talk about two of the most urgent challenges facing our industry: depletion of the ozone layer and global warming. These are problems that science has laid at the door of our industry. Perhaps the dramatic progress we have made with compressors and refrigeration have contributed to the conditions we see today. Certainly, the methods we have employed to make that dramatic progress will serve us well in addressing these new problems. I'm not going to give you the solution to those problems, but I am going to try to describe the choices that we must make. Further, I will make a case that our industry stands, because of the requirements and uniqueness of our technology, at a very special place in the world of engineering.

Finally, I will demonstrate, I hope, that the tradition of innovation and excellence we have established in our industry – which I believe has its heart at the Herrick Laboratories – will enable us to make the right decisions for our companies, our environment and our society.

Environmental Challenges

Our society's responsibility to protect our environment has placed immense demands on those of us who simply wish to make the world a place where our homes, our workplaces and our vehicles can be healthy and comfortable whatever the weather. That comfort, however, cannot come at the price of destroying the ozone layer in our atmosphere or producing a cataclysmic increase in the average temperature of the earth.

The Montreal Protocol of 1987 restricted production of Chloro-Flouro-Carbons and Hydro-Chloro-Flouro-Carbons As you can see, we were on quite a short track to eliminate CFC before 1996. Now we are facing a similar challenge with respect to HCFC, as this chart shows. Just five years from now, we must have an answer to this problem that will allow us to stop production of at least 35 percent of our annual HCFC output. And that answer cannot be a stop-gap. Just six years later, we have to cut back to only 35 percent of the original production level. And by the year 2020, HCFC almost will be history.

An HFC type blend refrigerant has been seen in the market as a potentially strong candidate to replace HCFC refrigerant. Mitsubishi Heavy Industries has also begun to introduce products into the market that utilize R404A, R410, R407C as opposed to R22. For example, our small-size residential air conditioner uses R410A. R410A, however, has its shortcomings in comparison with R22. The pressure level is 60 percent higher while energy efficiency is lower by 7 percent. We overcame these challenges and increased efficiency by 13 percent through optimizing the scroll profile, the thrust load compensation, and through efficiency improvements in the motor, inverter, and converter. This innovation allowed R410A to be superior in efficiency by over 5 percent. Although this is only an example, the prevention of global warming will center around efficiency improvement of Flourine-type alternative refrigerant.

Targets were established at the Kyoto protocol last December that, by 2010, emission of gas with green-house effect among the leading industrialized nations must be reduced by 5 percent of 1990 level.

The urgent challenges to us are:

- Drastic improvement of energy consumption efficiency.
- Reduced use or mandatory recovery of alternative refrigerant, since the majority of currently available alternative refrigerants are HFC-type, which faces emission restriction.

How will we choose to solve these problems? Our own history tells us that research and experimentation in this field takes lots of time. As I will relate later, my own company, Mitsubishi Heavy Industries, needed five years to conclude that using a scroll compressor would be the best choice for our products. A basic choice will be what new refrigerants should replace those that are being outlawed. Should we design and develop new synthetic chemicals, then test them exhaustively to make sure they do not harm the environment? Or should we use naturally occurring substances, such as carbon dioxide, that may require greater sophistication in technology but would carry an assurance of being environmentally benign? The "natural refrigerants" examined to date have zero ozone layer effect and an almost infinitesimal global warming effect.

Let me say that I prefer sticking with nature. The lesson of Herrick Laboratories is that we can beat the technical challenges in materials and fabrication. If we do, we will be free to continuously work on the improvement of existing technology rather than being forced, again, to step back and find new technology.

Requirements and Uniqueness of Compressor Technology

All of us deal with the basic issues of compressor technology and refrigeration every day. Touching on ozone depletion and the greenhouse effect, as important as those concerns are, can sometimes become so commonplace that we forget how complex and sophisticated our field has become. I want to take a few minutes to recall what we have accomplished.

I have worked for Mitsubishi Heavy Industries of Japan for almost thirty years. Most of that time I worked in Japan, but returned to Indiana in 1995 to open our factory in Franklin. My background is research and development of compressors for residential, automobile and commercial use. Basically, I have spent my career to date working with positive displacement compressors: reciprocating, rotary, screw, scroll and others.

Along the way, as I mentioned earlier, I had the privilege of coming to Purdue University as a Ph.D. student at Herrick Laboratories, where my major professors were Professor Werner Soedel and Professor Raymond Cohen. The laboratories were founded in 1958 under the direction of Ray W. Herrick, president of Tecumseh Products. Before Herrick Laboratories existed, our field was more art than engineering. Herrick provided the opportunity to simulate and test higher technology and mathematical analyses of motion and valves; applying thin shell vibration and examining the concepts of flow and dynamic coefficients.

Over the past 40 years, Herrick Laboratories has become the Mecca of the compressor, HVAC and refrigeration technology world. So it is appropriate that we consider here the assignments that our customers have given us in advancing the engineering, and art, of compressors and refrigeration. In attacking the environmental situation we now have, we also must be sensitive to a whole list of significant additional issues:

- Safety
- Energy conservation
- Recycling of natural resources
- Noise reduction
- Durability and reliability
- Size and mass reduction
- Economical and efficient manufacture

Satisfying all these priorities calls on the most advanced techniques and investigative skills in the world of technology. That's because what happens in a compressor is a marvelous intersection of theory, design and manufacturing.

The volume of a compressor, whether residential or vehicular, is about a gallon. About 16 cubic inches of gas is contained in the cylinder. The mechanism itself is relatively simple but the phenomenon that it induces is tremendously complicated. Here are the terms: fluid dynamics; thermodynamics; heat transfer; dynamics, vibration; phase change (from liquid to gas or vice versa); materials strength; and so on. It's hard to imagine any area of expertise in physical, chemical and mechanical studies that is not involved in compressor research.

As an example of how complicated our world can be, let's just look at compressor tribology (that is, lubrication of pistons, cylinders and bearings), with that of other machinery. I draw here on products of my own company, Mitsubishi Heavy Industries in Japan. Mitsubishi Heavy Industries is one of the leading producers of electric power generators, both conventional and nuclear; huge seagoing tanker ships; rockets and satellites; submarines and jet fighter planes.

Velocity and pressure, in addition to temperature, sea water depth, and degree of vacuum conditions are other factors determined by the bearing design. Operational conditions are finalized on the basis of trade-off with cost and size etc. Comparing our compressors to those products, what I make looks kind of small, simple and cheap.

Some of the special characteristics of compressor bearings include:

- Refrigerant may be dissolved or migrated in the lubricant. Refrigerant tends to evaporate when sent through the bearing.
- Excessive load of 600 pounds per square inch, if compressed in a form of liquid, may change to 2,000 pounds per square inch or more.
- Depending on the compressor size, shaft may become thinner and bend.
- Foreign material from abrasion, etc. accumulates.

The bearing is used in somewhat extreme conditions, as I just mentioned, where some degree of solid-to-solid contact occurs due to boundary lubrication. In other words, today's compressor is able to retain long-lasting high performance thanks to countless simulations of pressure and oil film thickness, which were calculated based on measuring the cylinder's internal pressure as well as taking into consideration the deformity of shaft and bearing.

Unlike changing the oil in your car, which is done often during the life of a vehicle, compressor oil for automobile and residential air conditioning, which is used under much more severe and extreme conditions, is rarely replaced. This fact alone speaks for a major technical accomplishment from Tribology perspective.

It is no exaggeration to suggest that simple, low cost, and precise bearings along with tribological capabilities are the critical force in supporting the advancement of today's compact and high-performance compressor. The reason I chose to mention Tribology out of a number of compressor engineering methods is that I strongly feel that the commercialization of alternative refrigerant, whether synthetic or natural, will soon materialize with continued improvement on existing technology and innovative design ideas.

I'm not sure even our Mitsubishi submarine boat engineers want to deal with 200 atmospheres. But this tricky analysis and simulation – just to study lubrication in a compressor – bumps up against the most complex engineering requirements in the whole technology universe. Truly, what we do with that little cylinder is amazing. And although what we will be asked to do in the future looks daunting, we have proven our capacity to meet challenges through our art of engineering. We will do it again.

Research and Industrialization

As an example, I'll tell you a little about our experience at Mitsubishi Heavy Industries Climate Control, Inc. Our company made a significant investment in researching the optimal compressor type for automobiles. We looked, over a ten-year period, at scroll, rotary piston and swash plate designs – and others.

We selected the best compressor type to develop for automotive use through mathematical simulation and prototype testing, Some of the major requirements of competitive automotive air conditioning compressors are:

- High efficiency
- Compactness
- Light weight
- Low noise and vibration

This is the efficiency level for each type of compressor. Refrigeration capability is indicated as a non-dimensional coefficient at High and Low pressure of 207 and 30 pounds per square inch with 1,500 rpm. We call this Coefficient of Performance. Superiority of the scroll compressor is apparent. It can also be verified that the scroll type has the lightest weight of all types, in addition to having the lowest noise character.

Now I would like briefly to touch on the mechanism for the scroll type compressor. The scroll is rotated through a shaft which is rotated by a clutch pulley attached to an engine belt. The scroll is made of a special type of aluminum. The scroll mechanism consists of two scrolls: one is fixed while the other moves in orbiting motion.

The main reason for the high efficiency of the scroll compressor is the order in which compression occurs. This keeps the pressure difference between each compression room small and minimizing gas leakage through the cylinder. Friction loss, also, is maintained at a low level through the relative motion comprised of rolling and sliding. One reason for the low noise performance is due to a small orbiting radius, which is only one-fifth inch. Another factor contributing to low noise is 800 degrees of compression cycle, which is 4.4 times greater than that of the swash plate type.

This, combined with symmetrical compression rooms erasing each other's force, allows a long and smooth compression. Again, two scrolls positioned symmetrically small orbiting radius contributes to compactness and light-weight of the compressor, with long product life. We found that the scroll type compressor had the potential for the greatest efficiency and the lowest noise. In addition, the scroll design offered relatively light weight and high reliability.

Scroll compressors already were gaining popularity in HVAC system use and refrigeration. Our challenge was to raise our technology to take advantage of the features of the scroll design and then bring that technology to the United States market. We established Mitsubishi Heavy Industries Climate Control in 1995 and broke ground in Franklin in April, 1996. The first compressor rolled off the assembly line in November, 1996, just one year later. We began mass production in January of 1997.

Last October, we received our QS 9000 registration. We now are doubling capacity to 400,000 units a year and are building a climatic wind tunnel, which will be completed this summer. It will generate 100-mile-an-hour wind velocity and temperatures from minus 20 degrees Fahrenheit to 130 degrees Fahrenheit. It will also have a 4-wheel drive chassis dynamometer. Our assembly area features a clean room, which allows us to control temperature and humidity and keep out dirt and dust.

Looking back, we can see that we have moved very quickly. We have opened a new facility and brought it to full production; begun expansion; moved an assembly operation in and earned our QS 9000, pretty much all at the same time. We also took a little time to accept the General Motors and Mitsubishi Motors Manufacturing America Supplier of the Year awards.

Conclusion

We have discussed the development of automobile air conditioners since 1980 and the history of our plant in Franklin. I hope that my recollections will assist your studies or your work.

At the time that I graduated from Purdue, which was in the spring of 1980, you rarely heard disputes about global warming or ozone layer protection. However, F.S. Rowland and M.J. Molina had raised the question of ozone layer protection in a Nature magazine article back in 1974.

Now, 24 years later, we are urgently searching for an alternate refrigerant, synthetic or natural, as I have discussed. And I will concede that although I hope for a natural solution, I realize that using carbon dioxide will require pressures of as much as 120 atmospheres, and that means we have a lot of problems to solve.

Remember, however, that we have solved serious problems in the past. We can do it again. For example, the interior phenomena of compressors has been heavily researched. We hear of new successes frequently, and we may expect more in this conference. The pressure requirement alone is not unique. Bulldozers operate with oil pressure above 150 atmospheres.

Even in automobile air conditioners, migration or "slugging" sometimes results in pressures above 120 atmospheres. To analyze the interior phenomenon of compressors, experts from many disciplines are needed, but when you look at these problems one at a time, analysis and solution becomes easier.

In this conference, where many professionals and learned men assemble under the leadership of the Herrick Laboratories, we may find ways to solve these technical problems within a short time period. Earlier, I called Herrick Laboratories the Mecca of compressor technology. Looking toward Mecca was one reason why Mitsubishi Heavy Industries chose to locate its United States production plant in Franklin, Indiana. Franklin is on Interstate 65, just about an hour and a half south of Purdue.

Another, major, reason was the location of our market. Eighty-four percent of the United States automobile industry – that's our market – is located within an 625-mile radius of our plant. Our location is convenient to our customers and to our suppliers. What we have put in Franklin is the realization of a personal and company dream. We have built an advanced compressor company in the United States.

I will say this to Professor Cohen and to my major professor, Dr. Soedel: I may not have been the best student, but I hope you see that I retained what you taught us in the best training ground, Herrick Laboratories, your classes and research projects.

After I graduated from Purdue, it took six years until the first automobile scroll compressor was put into the market. It took another ten years until we started production in the United States, here in Indiana.

What we have accomplished really is symbolic of the whole industry. Given time, determination, need and expertise, we have accomplished what we set out to do. I believe that in the future I will be able to say the same thing about the tasks now before compressor and refrigeration engineering as an industry. Facing a challenge to protect our environment, we used our time well, worked with determination and innovation and met the need.

I hope all of you find your time at this conference this week to be time well spent. Much is happening and the aggressive, innovative minds that have gathered in this room, along with the resources here at Purdue, promise to produce a better world for everyone.

Thank you.