

Roundtable Discussion

Aiming to Realize Both a Comfortable Vehicle Interior and Energy Savings

—Delivering Electric Compressors to Four Corners of the World—

Electric compressor series



■ What Is an Electric Compressor?

In a car air conditioner, a refrigerant (liquid) is cycled throughout an air-conditioning system in a repeated process of vaporization (evaporation), liquefaction and re-vaporization, and the vaporization heat generated during this process is used to keep the vehicle interior comfortable. The heart of a car air conditioner is the compressor. Unlike other types of compressors that derive power from the engine, electric compressors draw power from the battery, allowing the air conditioner to run during an idling stop of HVs and other electric-powered vehicles.

As a leading manufacturer of car air-conditioning compressors, Toyota Industries develops electric compressors for HVs, PHVs and other electric-powered vehicles that match the needs of customers. We are making ongoing efforts to expand sales of electric compressors not only to Toyota Motor Corporation (TMC) but also to automakers around the world.

In 2012, we commenced sales of the ESA34 electric compressor. In addition to such features as enhanced fuel efficiency and lighter weight, the new compressor makes it easier to mount in vehicles. For this roundtable discussion, four key members of the development project respectively from the development, production engineering, quality assurance and manufacturing departments got together to look back on the three-year collaboration effort and talked about the future of Toyota Industries' electric compressors.

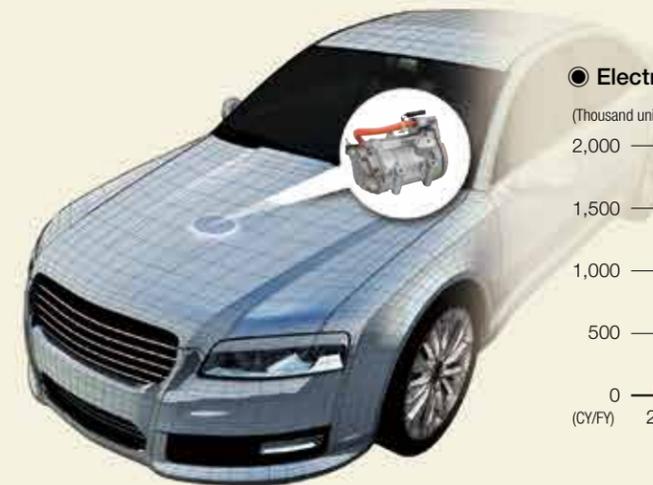
HV: Hybrid vehicle
PHV: Plug-in hybrid vehicle
EV: Electric vehicle



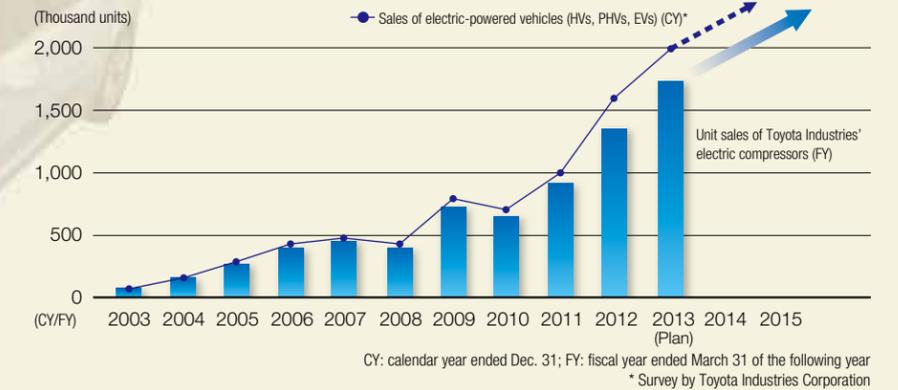
● Electric Compressor Series

Vehicle Size	2003	2005	2007	2009	2011	2013	(Year)
Large class			ES34  Significantly improved quiet operation for luxury vehicles		ESA34  Easier to mount on vehicles by placing inverter on the side		
Medium class		ES27  Smaller and lighter through industry-first integration of inverter			ESA27  Easier to mount on vehicles by placing inverter on the side		
Compact class	ES18  World's first mass-produced electric compressor			ES14  Even smaller and lighter			

Receipt of Silver Prize in 2013 Aichi Environmental Awards Through the serialization of electric compressors, Toyota Industries realized reductions in size and weight as well as higher operational efficiency. In recognition of their contribution to improving fuel efficiency of vehicles and reducing CO₂ emissions, Toyota Industries received the Silver Prize in the 2013 Aichi Environmental Awards.



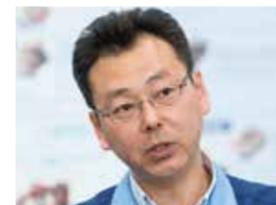
● Electric Compressor Sales



Ken Suito
Assistant General Manager,
Engineering Office No. 3, Engineering
Department, Compressor Division



Takayuki Nakase
Group Manager, Electric Assembly
Group, Assembly Production
Engineering Office, Production
Engineering Department,
Compressor Division



Masashi Abe
Group Manager, Production Quality
Group, Quality Assurance Office
No. 2, Quality Assurance Department,
Compressor Division



Takashi Watanabe
Supervisor, Assembly Section,
Manufacturing Department No. 1,
Compressor Division

Positions and departments as of March 31, 2013

Product Strengths Incorporating Technologies, Ingenuity and Teamwork

Suito: Let's look back on the development phase. In the engine room where the car air-conditioning compressor is mounted, many other devices are also installed including the engine. In recent years, more space must be set aside in the engine room to ensure safety in the event of a collision, requiring compressors to be even smaller and lighter. On the other hand, an electric compressor must be equipped with a motor and an inverter that controls the motor's revolutions, which makes the compressor bulkier. To address such issues, we integrated the inverter with the compressor and made the motor smaller. For the ESA34, we changed the placement of the inverter to make it easier to mount the compressor in a vehicle, thereby realizing a more compact, lighter-weight and more highly efficient compressor that fully utilizes Toyota Industries' long-accumulated technologies. One of our strengths, I believe, lies in the fact that we develop and produce motors and inverters in-house.

The ESA34 is also the world's first electric compressor to adopt a mechanism to control inner pressure of the compressor, which contributes to further improving fuel economy.

Abe: This mechanism is effective in attaining significant fuel efficiency, but it is revolutionary in an unprecedented way in other areas as well. Consequently, fully understanding the development concept and functional impact of the compressor was required in all phases from development to manufacturing as well as thoroughly

analyzing and taking measures for every potential flaw in each process. That's why the relevant departments got together and conducted meticulous discussions from the earliest phase of the development.

Suito: By gathering all related personnel from the relevant departments from the very first phase of development for these so-called conference room activities and sharing information every step of the way, we were able to not only realize speedier development but also ensure quality and productivity.

With HEVs, the running sound of the compressor tends to be more noticeable than internal-combustion vehicles because the engine stops rotating when the car comes to a stop. That makes quiet compressor operation all the more important, and the ESA34 displays its excellence in terms of quietness. In this aspect as well, we fully leveraged our long-standing technologies for quiet operation required for compressors to be fitted in luxury vehicles.

Car air-conditioning compressors must operate under a variety of difficult conditions, including temperature fluctuations, humidity, dust and vibrations. We believe the trend toward electric-powered vehicles will continue to accelerate, and we are undertaking our work with the pride that it is we who can assure the quality expected of in-vehicle devices because we have been involved in car-related businesses for a very long time.

Nakase: In the production engineering phase, we adopted the shrink-fitting technique, which utilizes the difference between heat-induced expansion and shrinkage to join together two parts made of different metals. This required a process of trial and error under various conditions,

including sensitive temperature adjustments as well as the thickness and shape of materials. In the end, we succeeded by making use of the computer simulation system produced internally.

Suito: These efforts led to a fewer number of components, which resulted in a reduction in production processes. I believe it was a significant achievement that we were able to contribute to cutting costs and making the compressor lighter while at the same time attaining better fuel economy.

Launch of Compact Production Line Responsive to Fluctuations in Production Volume

Nakase: In addition to enhanced product appeal, establishing a production structure responsive to fluctuations in demand is equally important in recent years. At Toyota Industries, we launched a more compact production system that is one-third the size of conventional production lines. This was the first endeavor for the Compressor Division. We aimed to halve the production area allocated for each compressor unit and reduce the number of processes. To that end, we made a prototype production line built to actual size and methodically verified the positioning of workers and operation efficiency in a real-time production setting.

Toyota Industries is working to prevent the outflow of manufacturing know-how by internalizing the design and production of such primary facilities as production equipment and inspection devices. In order to realize this compact production line, it was necessary to review the size of equipment and change work processes, but our hard work paid off and we succeeded in creating the production line in-house.

Abe: Actually, obtaining pre-approval from automakers is required when we adopt a new production process or quality assurance method. To do so, we started preparations quite early on.

Nakase: For the creation of this compact production line, we worked together on preparations transcending borders among production engineering, quality assurance, manufacturing and other relevant departments. In this regard, I believe it was an excellent experience for all

departments involved because we were able to consolidate tasks and processes while ensuring a high standard of quality.

Watanabe: This compact production line can be applied to the manufacture of non-electric car air-conditioning compressors as well. As such, we are proactively installing the line at production sites outside Japan. In order to handle future fluctuations in global demand, we are confident this production line will exert its potential to the full extent.

Dedicated Initiatives to Ensure High Product Quality

Suito: Currently, companies are globalizing their production activities and standardizing components. That means quality is all the more important. In the Engineering Department, we have been engaging in new development challenges while utilizing technologies accumulated in the development of car air-conditioning compressors for internal-combustion vehicles. I believe each department has been similarly making various efforts to ensure quality.

Watanabe: In the Manufacturing Department, we created and will continue to upgrade a procedures manual that specifies how a single act or omission in a process will have an impact on our customers and engage in daily work accordingly. We also hold a meeting every morning. This involves confirmation of the previous day's issues, no matter how minor they are, and immediate implementation of countermeasures in cooperation with personnel tasked with production engineering, quality assurance and equipment maintenance.

Abe: At the Quality Assurance Department, we faithfully follow the concept of "jikoutei-kanketsu (built in quality with ownership)" to incorporate quality in each process to ensure that only the best-quality products are sent to the post-processes. We believe everything we do both on the production floor and in our daily work is based on this premise.

In fact, when it comes to quality, our compressors are highly regarded by automakers not only in Japan but also in the United States and Europe.

High product quality was not the only factor for automakers in choosing our ESA34 electric compressor.

Through a process inspection on the production floor, they also came to appreciate the ingenuity built into the production line, our thinking behind quality assurance and the skill levels of our workers. I feel the trustworthiness of our products is backed up by our track record that our electric compressors are fitted in every single Toyota HV.

Nakase: In the Production Engineering Department, we are striving to create an environment where employees in the Compressor Division and the Electronics Division, which engages in the development of inverters and other components, share the same expertise in our efforts to further ensure product quality.

Abe: In my department, we are trying to raise the overall skill levels of employees through a comprehensive training program spanning from development to manufacture of electric compressors. Carrying out efforts in a holistic way for one project deepens one's knowledge and enables us to gain a broader perspective, which I believe will lead to the growth of our human resources.

Fully Committed to Further Sales Expansion

Suito: Since our mass-produced electric compressors were fitted in Toyota HVs for the first time in the world in 2003, we have broadened our customer base of automakers and increased the number of vehicle models installed with our products, which resulted in unit sales growth all around the world. As we expand sales, however, we must thoroughly meet the more diverse and demanding needs of our customers. For example, there is particularly strong demand for quiet operation among Japanese automakers, while in the United States outstanding operation of car air-conditioning compressors under harsh conditions is expected due to the country's vastness. Meanwhile, Europe is the world's most demanding region for excellent fuel economy. What's more, paying close attention to the heating capabilities of car air conditioners is equally important for HVs, in which the engine stops during an idling stop, as well as for EVs, which are not equipped with an engine in the first place. We are also expected to make use of eco-conscious refrigerant from the standpoint of curbing global warming.

Being the world leader in unit sales of car air-conditioning compressors* entails extensively and

accurately understanding and meeting the needs of both automakers and customers who drive their cars.

We will continue to devote our efforts toward developing both hardware and software, working closely with the Electronics Division and manufacturing production equipment internally. Through such comprehensive capabilities, we are confident that we can meet the various needs of automakers while making a range of proposals.

We are determined to realize the continued development of fuel-efficient and high-performance electric compressors and contributing to customers' businesses.

Nakase: In the Production Engineering Department, I believe the launch of this compact production line enabled us to accumulate know-how on how to respond to fluctuations in production units. So that we can more flexibly respond to demand fluctuations on a global basis, we will work to raise the potential of this compact production line and proactively apply the know-how to production lines to be set up in the future in and outside Japan.

Abe: No matter how diversified customer needs become, or no matter how much production units increase, for us quality will always remain our lifeline. I consider it our responsibility to continue meeting the expectation of customers while delivering high quality products.

Watanabe: As we expect the manufacture of compressors to keep increasing at production sites around the world, it is of the utmost importance that we maintain the best quality regardless of where compressors are produced. To do so, we are devoting efforts toward the training of human resources for Group companies outside Japan by designating production sites in Japan as mother plants.

Suito: Today, members from each department involved in the development of the new ESA34 electric compressor got together to look back on the creative efforts and talk about the future direction of compressors. I believe this occasion turned out to be a perfect opportunity to share the sense of fulfillment in creating a great product and to further motivate us to continue to offer even better products for our customers.

In step with more widespread use of HVs and EVs, we remain fully committed to helping to provide our customers with an energy-efficient and comfortable driving experience.

* Survey by Toyota Industries Corporation

● Vehicles Equipped with Our Electric Compressors

