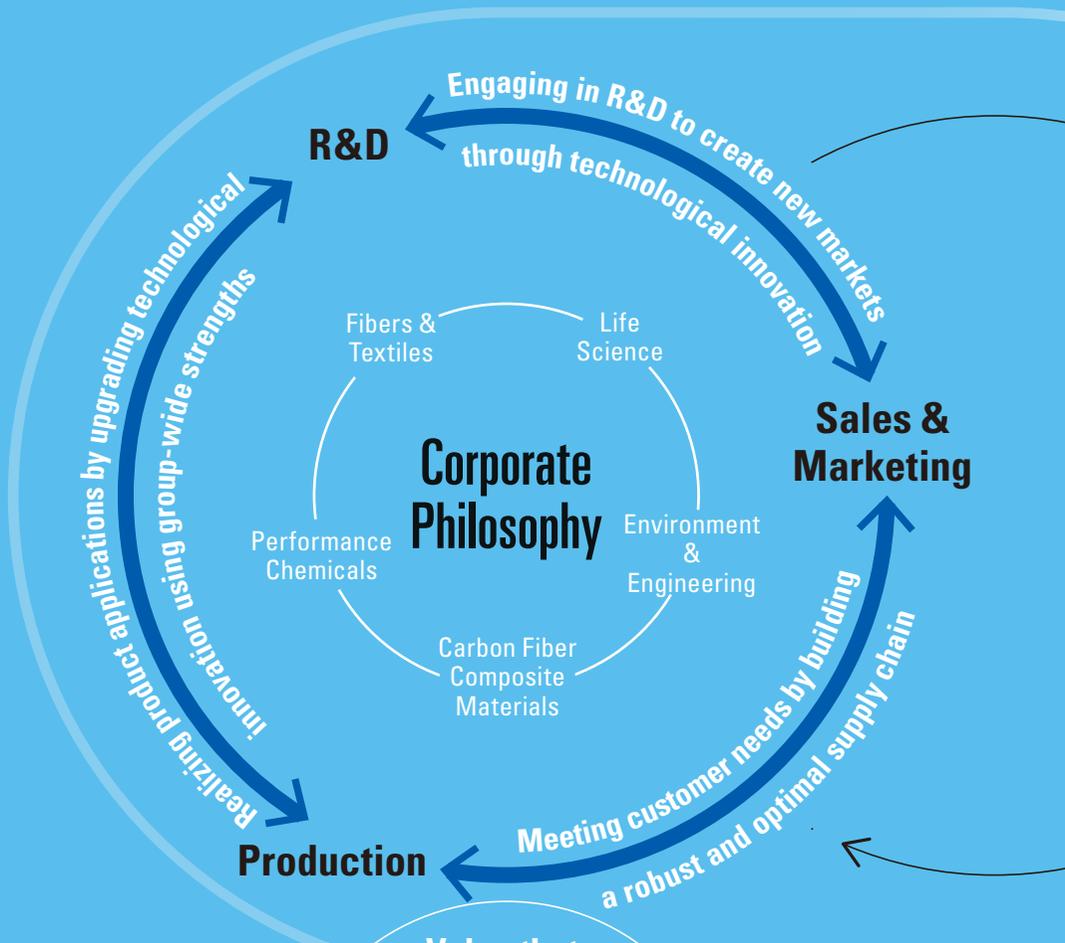


# The Toray Group Value Creation Process

Value Creation



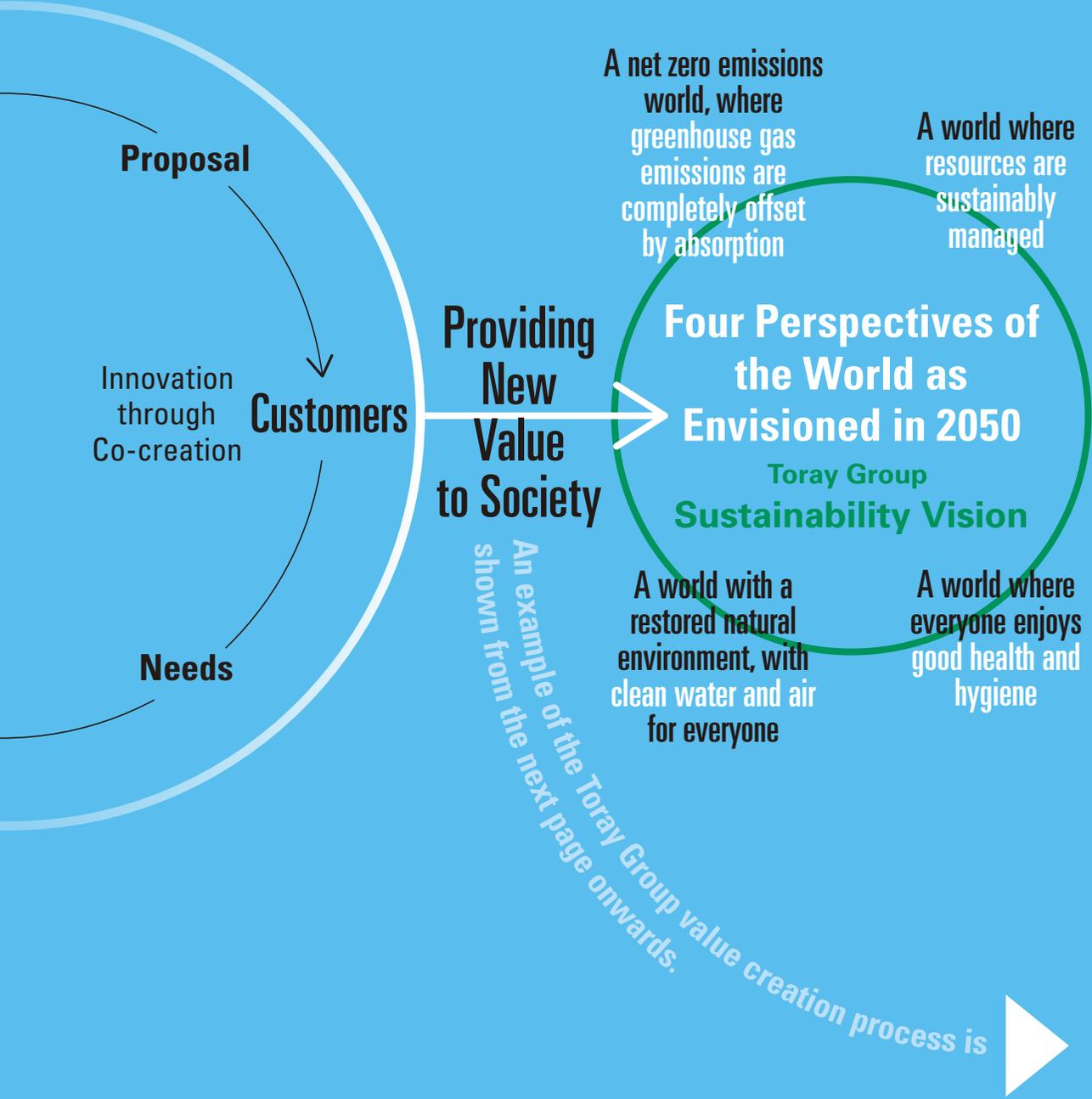
**Value that we cherish as management core value**

Contributing to society through business activities

People-centric management

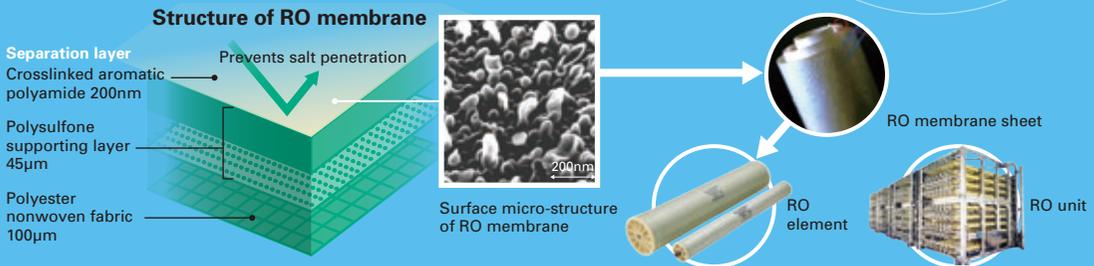
Management from a long-term perspective

Under TORAY VISION 2030, we will continue to provide new value in society through mutual cooperation in R&D, sales and marketing, and production, the key strengths of Toray Group, based on the core values of “contributing to society through business activities,” “management from a long-term perspective,” and “people-centric management.” At the same time, we will focus on fostering co-creation with our customers and supply chain partners, starting at the materials stage. In this way we will contribute to the realization of the four perspectives of the world as outlined in the Toray Group Sustainability Vision.



# STORIES OF THE CREATION OF NEW VALUE WITH INNOVATIVE IDEAS, TECHNOLOGIES, AND PRODUCTS

# RO MEMBRANES



## HISTORIES OF TORAY'S RO BUSINESS EXPANSION AND R&D

### R&D started in the U.S.A. and at Toray

In 1960, following a speech by J.F. Kennedy, the U.S.A. promoted a desalination project using Reverse Osmosis membranes (RO membranes) as a national project, and developed Cellulose Acetate membranes (CA membranes).

Toray began research on RO membranes in 1968 and has been developing RO membrane technologies, expanding its business for over 50 years, and introducing numerous RO membranes to the world.

### Basic research, establishment of fundamental technologies and start of production

The history of Toray's RO membrane business can be divided into two periods: the emergence period from the start of research until around 2000, and the global business expansion period after 2006.

In the emergence period, Toray conducted R&D of membrane itself and developed manufacturing technologies, such as the assembly of membrane elements. In 1980, Toray started CA membrane production in Shiga, Japan, and in 1985, a full-scale RO production plant for polyamide composite membranes was completed in Ehime, Japan.

With the completion of the Ehime Plant, RO membranes for brackish water desalination were commercialized and sales were started.

Although CA membranes had been shipped for the original purpose of seawater desalination for small seawater desalination systems for remote islands in Japan, the demand was still small. The market for brackish desalination and wastewater treatment had not yet grown sufficiently, and the business situation remained severe.

### Continuation of business with RO membranes for ultra-pure water production process and start of the seawater desalination business

In the 1980s, the semiconductor industry had grown into a huge market, leading the growth of the Japanese industrial sector, and RO membranes were used for the production of ultra-pure water used in semiconductor manufacturing.

However, as the semiconductor manufacturing hub shifted to the Republic of Korea and China, Toray decided on full-scale entry to the seawater desalination membrane, which was its original intention.

In 1991, Toray commercialized polyamide composite membranes for seawater desalination and received an order for membranes for the Okinawa seawater desalination Plant (40,000 m<sup>3</sup>/day), the largest plant in Japan at the time. However, the demand for seawater desalination were small in Japan, where water was basically in plenty, and Toray decided to enter the overseas market in earnest.

# Value Creation Process 1

## ENTERING THE GLOBAL MARKET AND ESTABLISHING THE GLOBAL SALES TEAM (GST) SYSTEM

### Entering the U.S.A. market and Organizing the Global Sales Team (GST)

In 2000, Toray Membrane America, Inc. (TMA) was established as a joint venture with IONICS (an engineering company that was later acquired by GE) in the U.S.A., which was the world's largest RO membrane market at the time. TMA began producing RO elements by importing seawater desalination RO membranes produced in Ehime and started sales of those elements. TMA supplied membranes to the Trinidad and Tobago Seawater Desalination Plant which was the biggest in the western hemisphere in 2002, and the Sulaibia Wastewater Treatment Plant in Kuwait which was the largest in the world, in 2005. Later, TMA was dissolved and Toray Membrane USA, Inc. (TMUS) was established as a wholly owned subsidiary of Toray. From TMUS, Toray Group established production, sales and Marketig, and development bases in various regions around the world, and during this time, Toray formed the basic concept for expanding its water treatment business.

Specifically,

- The quality of the feed water for water treatment (seawater, river water, etc.) differs from country to country and region to region, and the requirements for water treatment also differ. In order to

grasp the needs of customers accurately, local sales representatives who are familiar with the local situation are necessary.

- In many cases, global giant water business companies and construction companies execute water treatment projects of large-scale seawater desalination in the world, so in order to respond to global business schemes such as borderless inquiries and procurement, it is necessary to have sales offices around the world and a global coordination system for each office.
- In addition, in order to reflect market trends and customer needs in products and services, it is necessary to have local development, production, and sales bases.

Based on this principle the GST was organized by inviting the finest people in the water treatment industry to each sales base as managers and hiring people with local sales experience.

The decision to make a full entry into the global market and the establishment of the GST system enabled Toray to directly grasp the actual situation of the market and customers, and it became a source of accelerating the creation of new value for the Company, which had previously conducted sales and marketing in overseas only through trading companies or distributors.

### Interview

#### The reason for the establishment of TMUS and the situation at the time



**Tatsuya Tamura, General Manager of RO Membrane Product Dept. (MC)**

In this discussion, we have Mr. Steven Cappos and Mr. Kwak Soon-chul, who have been with us since the beginning of the GST. First, we would like to hear from Mr. Cappos, who was the plant manager when TMUS was established in 2006 and is currently the president of TMUS, about the situation at the time of the company's launch and the key points of sales in the Americas since then.



**Steven Cappos, President of TMUS**

When TMUS was established, experts of the RO membrane industry not only from the U.S.A. but also from around the world gathered. All of them knew the characteristics of the RO market in the U.S.A. and the needs of customers, and due to their experience, they were able to move around the U.S.A. to contribute to the sales expansion of TMUS. The U.S.A. has a wide range of applications for RO membranes and is the world's leading RO membrane market in terms of both business and technology, so we quickly captured the needs of the market and

communicated them to GST members around the world. For example, we have captured the needs of membranes for boiler pure water for industrial use, and for food industry and drinking water, and utilized them in the development of TMUS's own products. In addition, the market for brackish RO membranes for industrial water is quite large in the U.S.A., and we formulated a business strategy for brackish RO that is different from that for large-scale seawater projects, and we have been constantly competing with large-scale competitors. Since the early stage of the launch of GST, we have accurately grasped the market information and have taken several measures, which have led to our current business expansion.

### Sales by GST: Winning the Shuaibah project

**MC** One of the purposes of forming the GST was to win large projects through global collaboration. I would like to ask Mr. Kwak, who was mainly in charge of winning large seawater projects, about the situation and strategy at that time.



**Kwak-Soon Chul, President of Toray Asia Pte. Ltd. (TAS)**

In those days, I was mainly in charge of acquiring orders of large-scale projects. Since Toray was a new player in the RO membrane market for large-scale projects at the time, our primary target was emerging engineering companies that did not have strong relation to existing membrane manufacturers. One of the first successful examples of a large-scale project was the Shuaibah project in Kingdom of Saudi Arabia (KSA).

In this project, concerned parties were scattered around the world, as the operating company and the commission company were located in KSA, the investor was in KSA, the plant construction company was in the Republic of Korea, the plant design company was in the U.S.A., and the consultant was in Dubai, in the United Arab Emirates (UAE). In order to deal with this, each party worked together to negotiate and win the order. For example, TMUS handled the U.S.A., Toray HQ handled Republic of Korea, and TMEU handled KSA and Dubai in UAE. Since we were able to negotiate closely in each region, we were

able to conduct sales activities by grasping the needs of customers in each area.

### Entering the Singapore Market

**MC** Mr. Kwak, after winning the Shuaibah project, you moved to Singapore as the President of TAS in 2008, and now you are the GST Chairman. Could you tell us about the status of project acquisition in Singapore at the time?

**Kwak** Singapore is an island nation where water is limited, and it depends on Malaysia for most of its water supply, so securing water is important for its national security. For this reason, Singapore has been actively promoting seawater desalination and reuse of wastewater (NEWater), in order to promote self-sufficiency of water resources. Since around 2006, GST has been working to win orders for RO membranes for large-scale plants to be constructed in Singapore, which we have targeted as our most important region for the RO membrane business. At that time, Singapore was aiming to become a global water technology hub and was trying to research and incorporate water treatment technologies from around the world, so we collaborated with a local university and established Toray Singapore Water Research Center (TSWRC) as a new water treatment research base for the Group. We also developed sales activities to win orders for large-scale projects by utilizing the GST network around the world, and the knowledge we gained from winning the Shuaibah project was very useful.

### Entering the Chinese market, establishing JV

**MC** In China, which is currently the world's largest market for RO membranes, Toray BlueStar Membrane Co., Ltd. (TBMC) was established as a joint venture with ChemChina in 2009, and started production and sales activities in 2010. Mr. Gao, who has been a GST member since TBMC's establishment, as well as Chairman and President of Toray Industries (China) Co., Ltd., will talk about the situation at the time of TBMC's establishment and its subsequent sales activities.

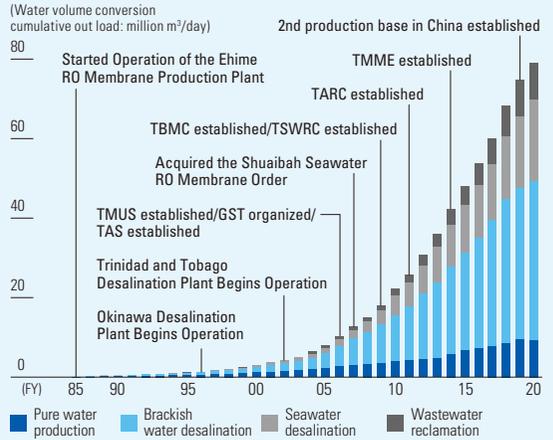


**Gao Zhiwen, Director of the Board & Vice President, Toray Industries (China) Co., Ltd. (TCH)**

TBMC was established as a joint venture in accordance with Toray's policy for establishing overseas production bases: the existence of a market, the availability of raw materials, the presence of governmental support from both countries, and the presence of a strong local partner, etc. As you know, China has its own culture and rules. Unless you understand them well, you cannot capture the needs of local market and customers. When TBMC was established, sales leader with foreign nationality started to develop the Chinese market, but couldn't achieve satisfactory results because the person did not understand the market characteristics. In 2015, I was entrusted as the leader of the sales team. Based on the management up until that point, we gradually expanded our business by conducting sales and technical service activities by the Chinese peo-

ple who were very familiar with the Chinese culture and market, and who have a good network of contacts, thus gaining the trust of customers.

**Sales Volume of Toray RO Membranes Based on Cumulative Water Production Rate and History of Expansion of the Water Treatment Business**



Cumulative water supply of 91,400,000 m<sup>3</sup>/day: equivalent to 8% of the world's population, or 640 million people (as of March 31, 2021)

## Value Creation Process 2

# DEVELOPMENT OF NEW TECHNOLOGIES AND PRODUCTS THAT MEET THE NEEDS

### Interview

#### Development of high boron removal membrane for seawater desalination

**MC** By interacting directly with customers, GST has been able to accurately capture the different needs of each country, region and customer, and based on this information, R&D and technical departments have been able to develop new products, and in particular, there have been many cases of dramatic improvements in technology and product value. Mr. Cappos, could you give us examples of this?

**Cappos** I would like to mention the development of technology to improve boron removal performance.

In 2006, in accordance with WHO's Boron Guidelines, the tightening of its regulation value had a major impact on the operation and management of water utilities around the world and on the designs of plant manufacturers. In addition, the actual boron concentration setting values are determined by each country where the plant is installed, and the required removal performance varies from country

to country. In order to respond to these changes, it was important for the GST to work closely with each region, government and users. The GST shared this information, as well as information on the market trends of each country and region, and collaborated with HQ to set targets for membrane development and consider how to respond to each project.

**MC** Due to tightening boron regulations, improvement of boron removal performance was required, and the technical department was subjected to quite challenging demands at the time. Let's hear about the difficulties from the General Manager of the Global Environment Research Laboratory and the General Manager of the membrane technical department, who were in charge of technological development.



**Koza Takahashi, General Manager of Global Environment Research Laboratories**

The performance requirements for RO

membranes have always been high rejection rates, high permeability (low operating pressure), high durability, maintaining water quality of desalination process, and developing materials for low cost, but regulations are becoming stricter as issues of environmental sustainability, pollution prevention, and health maintenance become important issues.

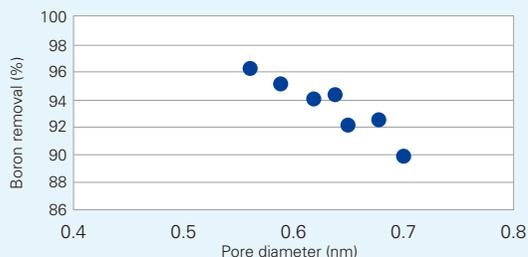
For example, in the case of seawater desalination, the WHO's regulation on boron concentration has become stricter due to the problems of reproductive abnormalities and withering of citrus plants caused by boron.

Seawater contains around 5 ppm of boron. Since the water produced by newly constructed desalination plants must comply with these regulations (0.5~1.0 ppm or below), higher boron removal performance was required for RO membranes.

Since boron has a small atomic diameter, RO membranes, which are based on filtration separation by size, are required to have smaller and uniform pore size. In order to develop such a new RO membrane, it is necessary to measure the pore size of the membrane, but there was no way to measure the pore size of organic matter at the sub-nanometer level.

Therefore, in collaboration with Toray Research Center (TRC), a subsidiary of Toray that has one of the world's leading analytical technologies, we investigated a method to measure the pore size distribution of RO membranes using Positron Annihilation Lifetime Spectroscopy (PALS), and developed a technology to measure the membrane pore size (the size of the pores in the membrane) at the nanometer level. The measurement results were correlated with the boron removal rate, and the required pore size of the RO membrane was determined, and finally a high boron removal RO membrane was obtained on a bench scale.

**Correlation between Boron Removal Ratio and Pore Diameter\* of Membrane**



\*Pore size is measured by PALS (Positron Annihilation Lifetime Spectroscopy).



**Takao Sasaki, General Manager of Membrane Technical Department**

Specifications of final products are defined and mass production technology is established at the Membrane Technical Department. The specifications for the high boron removal membrane were clarified at the Global Environment Research Laboratories, and the target RO membrane was obtained on a bench scale. Taking over this technology, the Membrane Technical Department started to study the production conditions for the actual production machine. In order to control the pore size and obtain uniformity of membranes, we analyzed the factors of membrane production conditions, and after repeated prototyping and evaluation, we finally developed the target product. We followed up on the operation of the prototype RO membrane in an actual plant, confirmed its initial performance stability and durability, and launched it as a new product.

**MC** The technology obtained through this development was not only for the development of high boron removal RO membranes, but also for the uniformity of pore size control of the entire RO membrane, which greatly improved our subsequent research and new product development capabilities. This has been the driving force behind the expansion of our global market share to more than 60% of seawater RO membranes.

**Development of highly durable brackish water desalination membrane (Tough Membrane)**

**MC** The development, production, and sales of RO membranes for seawater desalination, which require state-of-the-art high performance, has been the concept since the start of the business, but the demand for large-scale seawater desalination plant construction fluctuates greatly from year to year depending on the global economic situation. In order to realize a stable expansion of business, it was necessary to focus on the area of RO membranes for brackish water applications, where the market is large and the needs are stable. The market share of brackish RO membranes has expanded to the point where it is now competing for the top share in the world market, but please tell us about the events that triggered this expansion, Mr. Gao.

**Gao** The RO membrane market in China has grown to be the largest in the world, and is a market in which membrane manufacturers around the world are competing. At that time, our two competitors were competing for the top share. Toray established a new local JV company, TBMC, and started full-scale sales of brackish RO membranes, but faced major problems in around 2011. The customer's plant experienced a number of troubles that caused the water quality to drop within a relatively short period of time after the start of operation. We investigated the plant, but couldn't find the cause. The HQ investigation concluded that it was probably an operational error where chlorine came into contact with the RO membrane during operation. We replaced elements, but the situation did not improve, and rumors spread that Toray RO was not durable enough, and TBMC was facing a critical situation. So we asked HQ to conduct a thorough investigation again.



**Masahide Taniguchi, General Manager  
of Water Treatment Technical Department**

At the time, brackish RO membranes were sold all over the world. We obtained the degraded RO membranes from the customer and investigated them. As a result, we found that the degradation of performance was due to oxidation of the membrane surface, and we thought that the oxidation was caused by chlorine contact due to operational errors by the operator.

In response to repeated requests for investigation from TBMC, we dispatched a technical service team from HQ to the customer in China. As a result of thorough investigation, including parallel operation with another company's RO membranes, we found that there was an issue with our membranes when chemical cleaning method was used. This cleaning method, at the time, was becoming mainstream in China.

TBMC immediately asked the customers who were experiencing problems to improve their chemical cleaning methods and started development at the Global Environment Research Laboratory to enhance the durability of the membrane against chemicals.

**Takahashi** We started development to enhance the chemical durabilities (oxidation tolerance) of brackish RO membranes by establishing a proj-

ect structure with sales and marketing, technical, and research departments becoming as one. Membrane performance is affected by the minor constituents in the raw water, so in order to determine the durability of the membrane, we repeatedly conducted durability tests using various prototype membranes with different formulations and using Chinese water at Toray Advanced Materials Research Laboratories (China) Co., Ltd. (TARC), our research base in China. As a result of promoting the development of highly durable RO membranes as a project team, we were able to develop a brackish RO membrane that is more durable than competitors and launch it into the market.

**Sasaki** These internal relevant departments analyzed the phenomenon, researched new products, and improved operational technology, while the Membrane Technical Department established manufacturing technology of new products.

**Gao** By quickly reporting requests from users to the R&D team, conducting joint evaluation and cause investigation by the Global Environment Research Laboratories and TARC, and developing technology to enhance durability based on the findings, we were able to develop a brackish RO membrane with strong chemical durability that surpassed that of competitors. We named this product "Tough Membrane" and launched it, which rapidly expanded sales and led to a large increase in market share in China.

**Cappos** The sales volume of Tough Membranes greatly expanded not only in China where performance of RO membrane easily deteriorated, but also in the U.S.A. and Europe, where there were no occurrences of such deterioration, and they grew to become a representative product of Toray Brackish RO membranes. In addition, Toray developed and launched a series of new products (Tough Series) that added new values to Tough Membrane, such as high productivity, energy saving, and low fouling, and became a driving force for Toray to compete for the world's top share in brackish RO.

**Kwak** The GST learned a lot from the development of the Tough Membrane as well. The Tough

Membrane eventually became a very easy to use RO membrane for our customers due to its enhanced chemical tolerance. We came to realize through this case is the fact that customers don't say anything does not mean they are satisfied, but they just think this product is the way it is. By materializing such hidden problems and needs, we were able to improve customer satisfaction. I recognized that it is very important for GST and technical service teams to work together to uncover the hidden needs of customers.

**MC GST receives a complaint, and the technical service team conducts various investigations and tests at the customer's plant to determine the cause of the performance degradation problem, which is then passed on to R&D. Then, in the process of evaluating and analyzing the developed membrane at the customer's plant in collaboration with GST, the customer and the technical service team, we gained the customer's trust by responding to various information and questions from the customer, and as a result, though it looks troublesome at a glance, we were able to smoothly proceed with the development of the Tough Membrane.**

**Taniguchi** In order improve customer satisfaction with GST members at each base, currently, we have placed technical service teams at GST locations around the world and organized them as Global Technical Service Team (GTST) under the control of HQ to strengthen our capabilities. The role of the GTST team is to design RO membranes

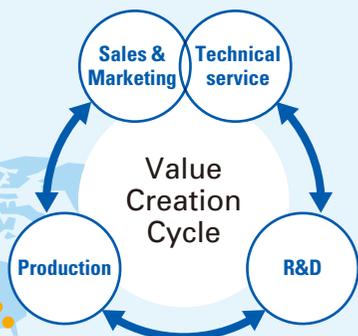
for large-scale seawater desalination projects and reuse of sewage wastewater, start-up and support operation of plant, investigate the causes of customer complaints and defects, identify product weaknesses and provide feedback to the R&D department, and evaluate the performance of new products. Regarding the RO membrane plant, in particular, as our business expands, the number of new requests including energy conservation, complaints and requests for cooperation from customers has also increased. Our company develops and sells high-performance membrane products, but we believe that it is important to get deeply involved with our customers in terms of usage rules and operational technology to let them handle the product perfectly. By cooperating and communicating with our customers, we can understand their true needs that even they are not aware of, and give an advice and make a proposal to them. Reflecting the knowledge acquired in new development themes, and "create new value" in cooperation with our customers. Taking advantage of GTST which is the strong point of our water treatment business, I would like to further strengthen such an initiative.

### About the value chain in the company

**MC** In terms of value creation in the RO business, which is the main objective of the roundtable discussion, Toray Group's value chain has also made a significant contribution. Toray provides cutting-edge materials all over the world, and advanced materials such as tricort made from Toray's nonwoven polyester fabric Toray AXTER™

### Global Expansion of Water Treatment Business

1. Identify customer needs and propose solutions through our global sales and technical service network
2. Development of new products that match customer needs through our global R&D system
3. Reliable supply of high quality products by global production network



and Toray TETORON™ are also used in key components that affect the performance and production cost of RO membranes. In addition, TRC, a wholly owned subsidiary of Toray, possesses one of the world's leading analytical facilities and technologies, which are essential for analyzing the used products, as well as for developing new products and technologies that pursue the ultimate limits of recent years.

And for RO production facilities, the Engineering Division, a group of professionals in equipment development and design, works together with the technology development department of the Water Treatment Division to develop, design, construct, and maintain the facilities. The engineering department contributes to the realization of highly competitive production facilities that include not only product performance and production capacity, but also ease of operation and maintainability of the facilities.

**Sasaki** Functional polymer is used as a base material for RO membranes, and it helps to maintain the strength and durability of RO membranes and RO elements. When RO membranes were first developed in the U.S.A., taffeta, which is used for yacht sails, was used as the base material, but today, staple nonwoven fabrics (paper-formed nonwoven fabrics) are the mainstream.

As a manufacturer of fibers and textiles materials, Toray supplied fibers used as raw materials for taffeta and nonwoven fabrics, but in order to meet the needs for enhanced pressure resistance due to the high-pressure operation of RO membranes in the desalination of high-temperature, high-concentration seawater in the Middle East, Toray worked on the development of base materials.

The key point in developing the technology to use the filament nonwoven fabric AXTER™, which is overwhelmingly superior in terms of strength and cost to the staple nonwoven fabric that is the industry standard, was the technology to equalize the thickness across the entire membrane surface (longitudinal and width directions) so that the chemical solution applied on the substrate would not leak. Toray's technology development departments of fibers and textiles and nonwoven fabrics, the Global Environment Research Laboratories,

and the Membrane Technology Department worked together to develop AXTER™, a filament nonwoven fabric that can be used as a base material for RO membranes, through repeated facility modifications and trial evaluations, and were able to significantly strengthen the competitiveness of seawater RO membranes.

**MC** Toray's sales organization (GST), which grasps information on markets and customers and responds closely to them, and its technical service organization (GTST), which digs deeper into the activities of the GST from a technical perspective and identifies essential issues, have been creating new value by analyzing issues that have been obtained and by the technology development department, which creates new technologies and products, in cooperation with the internal value chain.

Thanks to the accumulation of such value creation, sales of RO membranes have expanded steadily, and in recent years, with the successive acquisition of large-scale seawater projects by Toray Membrane Middle East LLC (TMME) in the Middle East region, we have acquired a global market share of more than 60% for seawater RO membranes, and have expanded our business to compete for the top share in the world for brackish RO membranes.

Let's further strengthen these efforts and continue to create new value, aiming to ensure world's top share in RO during the current Medium-Term Management Program, AP-G 2022, as well as exceed 50% of world's market share which is the target of the Long-Term Corporate Vision, VISION 2030, so that we can realize our determination of "providing safe, secure, and affordable water to people suffering from water shortages around the world" at a higher level.

**Sales of RO Element for Industrial Use** (FY 2013 is set to an index of 100)

