(Keynote article)

A Hundred Years of Technology and Product Development at Kobe Steel

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For 100 years, ever since its foundation in 1905, Kobe Steel has been one of the world's leaders in the development and commercialization of new technologies and products. As well as continuing the development of the technologies and products featured in its original business, the company quickly extended its scope into totally new technologies and products leading to new business opportunities.

In 1905, it was National Policy to grow the Steel and Heavy Industries in Japan. In this social climate Kobe Steel started to manufacture steel and industrial machinery as its first steps as a material and machinery company. The technical and commercial synergies produced by these separate undertakings in the material and machinery fields created opportunities for new products, which over the years have grown into Kobe Steel's current, diversified, business.

In this article we describe how the progressive development of our technologies over the last hundred years has led to our current products and technologies, and we outline our view of the intended direction of our future R&D effort to support our core businesses and develop new businesses.

1. Milestones in the last 100 years

Kobe Steel began on the first of September 1905 as the Casting and Forging Division of Suzuki Shoten (a partnership trading company) at the Wakinohama district of Kobe city. The domestic steel industry in 1905 was still in its early developmental stage, and lagged far behind western countries in terms of technologies and experience. It took us three months of struggle before we succeeded in discharging our first melt from the 3.5t open-hearth furnace. By the 1920s we had accumulated operational know-how and had introduced state-of-the-art equipment, including a 1200t forging press, the largest in the country at the time of installation in 1913. This technical innovation enabled us to produce large-size cast and forged steel products. We received a bulk order from the Kaigun-Koushou (Naval Arsenal), then regarded as the most stringent customer in quality requirements. The Casting and Forging Division grew continuously and built up, through in-house development and acquisition, technologies to produce the world's largest propellers at that time for supertankers. In 1976 we introduced an 8000t forging press, one of the world's largest, and since then have led the world in the area of large-size cast and forged steel products with high reliability.

In 1959 the Kobe Works achieved a major milestone with the 'blowing-in' of its No.1 blast furnace, and we made the first step from an open-hearth manufacturer toward an integrated, blast furnace, steel manufacturer. Now, the Kobe Works is one of the world's largest plants specialized in the production of wire and rods, and produces high-quality, high-strength wires used for automotive valve-springs, suspension springs, various gears and bearings, and also suspension-bridge cables.

In the 1960s the Japanese steel manufacturing industry was becoming the supply base of the world with its annual crude steel production approaching 100 million tons. To meet growing demand for steel, we inaugurated the Kakogawa Works and blew-in the No.1 blast furnace there in

8000t forging press

1970. The No.1 blast furnace, with its capacity of 2,843m^3, was the first of the large-capacity blast furnaces and provided the basis to establish the burden material and operation technologies such as high pellets ratio operation and burden distribution control. The Kakogawa Works produces plates, sheets and wires, including distinctive products characterized by its own technology, such as high-tensile strength steel plate (High-Ten), TMCP (Thermo Mechanically Controlled Process) plate for high heat-input welding, Ni-containing weathering steel, steel cord for tires, and high-purity bearing steel.

Shipbuilding technology in Japan achieved a breakthrough after the Second World War, and progress in welding technology was the key to the breakthrough. In 1943 we inaugurated a welding rod production plant at Hidaka (Hyogo prefecture) and started production of high quality welding rods by exploiting the technology of steel wires. This was followed by the inauguration of plants at Fujisawa (Kanagawa prefecture) and Ibaraki (Osaka prefecture), which established supply bases for a variety of welding materials. At the same time we developed various new technologies including one-side automatic welding and vertical-down welding, and have become an all-round supplier of welding materials for both domestic and overseas markets.

From early on we recognized the significance of metals that would grow in importance alongside steel in the future. We started production of aluminum alloy sheets, bars and shape extrusions in 1939 at the Chofu Plant in Shimonoseki city. Subsequently, we started production of castings and forgings at the Nagoya Plant (currently the Daian Plant), and sheet and plate at the Moka Plant (Tochigi prefecture). The Moka Plant owns one of the largest broad-width rolling machines and is a supply base for the aluminum sheet used for beverage cans, magnetic recording disk substrates and other products. Recently there have been increasing demands for panel sheet and under-body forged parts made of aluminum, which contribute to the weight reduction of automobiles. Copper and brass were first manufactured in 1917 at the Moji Plant. We inaugurated the Hatano Plant (Kanagawa prefecture) in 1967 to meet the demand for the copper tube used in air-conditioning equipment. In 1973 we started the development of the semiconductor lead frames which have become one of the major items in our electronic products range.

Titanium is a symbolic material in the history of the company. We were the first company in Japan to succeed in the mass production of titanium, by establishing a stable melting technology of scraps, and by developing coil rolling technology. We have since led the titanium industry in Japan.

When we established our position as a cast and forged steel manufacturer, we also took our first step as a machinery manufacturer. First we started the development of an air compressor, which was a significant challenge for the technology of the time. After successfully, independently making a machine domestically, we formed an agreement for technical cooperation with Peter Brothers of the UK in 1915 and came to be regarded as a capable manufacturer of large-size air compressors. Introduction of foreign technologies, along with our original development, made us an all-round manufacturer of compressors covering a range from application-specific compressors to multi-purpose compressors. Above all, the screw compressor is a product of our own engineering effort, which included design of the screw profile, and structural, vibration and acoustic designs, resulting in high performance with low vibration and noise. Our high-pressure equipment is the result of technical synergy between machinery and material technologies. The pioneering machine was a metal-working hydraulic press built in 1921. This was followed by a variety of high pressure equipment including an ultra-high pressure press for diamond synthesis and a hot isostatic press (HIP) used for powder forming and sintering. We also established our position as a tire equipment manufacturer, starting with technical cooperation on the vulcanization equipment with McNeal Machinery of the USA in 1957, followed by a series of technical alliances with foreign manufacturers on mixers and tire-testing equipment. After the technical alliances in tire equipment had all been ended in 1986, we developed equipment on our

Integrally geared type compressor

own such as the vertical hydraulic tire vulcanizer and high-throughput, high-dispersion, 6 blade, rotary mixer which won a good reputation all over the world. Those technologies were utilized in the design of plastic processing equipment and led to the development of our own characteristic equipment such as the twin-screw extruder used for plastics molding.

The construction machinery business began in 1930 with the production of an electric excavator, the first construction machine built in Japan. In 1955 we started a technical cooperation with P&H of the USA and commenced manufacturing high performance cranes, including all-hydraulic crawler cranes. We have also developed hydraulic excavators and now supply a wide range of construction machines to the world through our group companies, Kobelco Construction Machinery Co., Ltd. and Kobelco Cranes Co., Ltd.

Our experience and know-how in the construction and operation of our own steel plants enabled us to start our business of engineering plant construction. The first large-scale enterprise was a fertilizer plant built in East Pakistan (currently People's Republic of Bangladesh) for which we received an order in 1958. This was the first export of a large-scale full-turnkey-base plant from Japan. After that, we developed a process to reduce iron ore without using a blast furnace and now have the world's largest market share in direct reduction iron-making plant.

We also started an environmental equipment business in 1973 and have added to our menu such plants as municipal waste incineration and high-performance sewage processing. The business, currently taken over by our group company Shinko Eco-Solutions Co., Ltd., is based on technologies established by our group companies, including the processing, combustion and water treatment technologies used in steel making.

Our success in supplying and installing the cables for long and wide suspension bridges including the world's longest, the Akashi Strait Bridge, depends heavily on the technical combination of our material and structural-design technologies. A similar combination of technologies can be found in the vessels for radioactive material storage and transportation, in which our large-size steel-forgings technology and structural design technology are combined.

Our R&D activity played an important role in supporting the business activities described above and we have constantly improved our R&D framework. Our research laboratory started in 1932 as an analysis group in the inspection department, and has carried out research since the late 1930s on the products which currently comprise our main business lines such as cast and forged steels, wires, pressure vessels, steel plates for high-heat input welding, and steel powders. The laboratories, originally dispersedly located at Wakinohama, Iwaya and other districts, have been relocated one after another to the Seishin district since 1987, and are now united as the Corporate Research Laboratories consisting of the Materials Research Laboratory, Mechanical Engineering Research Laboratory, Production System Research Laboratory and Electronics Research Laboratory. At the same time we revised the roles of the technical development groups of the corporate headquarters and the operational sectors, and decided that the operational sectors would take the lead in development work directly connected to on-going manufacturing and products. As a result, we relocated the laboratory researching iron and steel to the Kakogawa Works in 1992.

Akashi Strait Bridge

The following section of this article describes how the accumulation of our past technologies is utilized in our current business, by referring to examples of some of our distinctive, characteristic products.

2. Characteristic products and technologies

[Materials]

2.1 Blast furnace operating technology

Since the blowing-in at the Kobe Works in 1959, we have made several new developments in blast furnace operation. In 1963 we developed our own self-fluxed pellets of pulverized ores, and started using the pellets as the main raw material of the No.3 blast furnace at the Kobe Works. The pelletization enabled the use of pulverized ores, which cannot be sintered, as the raw material. In 1983 injection of pulverized coal (PC), used as the supplement fuel, became operational as the KOBELCO-PCI system. In the system, a portion of the coke is charged at the center of the furnace throat during the PC injection to optimize the ratio between the ore and the coke volumes and to stabilize the operation. This led the No.1 blast furnace of the Kakogawa Works to achieve the world record of monthly PC ratio in 1998.

2.2 Steelmaking technology

Since our beginning as an open-hearth manufacturer, we have developed specific steelmaking technologies for our various products. In order to reduce the impurities in steel to the minimum, the dephosphorization of hot metal was put into practice by using a converter-type, dephosphorization furnace in 1983 at the Kobe Works. Also, we developed our original top-and-bottom-blown converter which can cover production from ultra-low carbon to high carbon steels. In continuous casting, we introduced electromagnetic stirring technology to produce defect-free castings and developed a technology, in 1989, to use the tundish repeatedly while still hot, which allows an efficient production of high-mix, low-volume products.

2.3 Ultra high-strength wire

The high-strength wire which is one of our representative products is mainly used for the valve springs of automotive engines. Since the valve spring is used under one of the severest conditions among automotive parts, there is a requirement for an extremely high reliability and an increasing demand for higher strength. To meet this requirement, we established production technologies for long-life, super-high strength, wires by establishing purification technologies, including the removal of non-metallic inclusions, and by intensive research on the alloying content and spring fabrication technology. Currently we hold 50% of the worldwide market share of the high strength steel wires for automotive valve springs. Steel cord for tire reinforcement is another of our main wire products. Steel cord not only increases the life of tires but also improves the drivability and steering stability, and is now used in almost all tires. As in the case of valve spring wires, there is an increasing demand for higher strength for the steel tire cord and currently we are producing ultra-high strength steel cord having tensile strength as high as 4,000 MPa.

2.4 High strength thick plate for high heat-input welding

The "oil shock" in the 1970s forced the shipbuilding industry in Japan to build larger and more energy-efficient ships at lower cost using high strength steel plates. However, the high strength steel plate at that time required a larger number of welding passes with lower heat input compared to mild steel. This is due to the higher carbon equivalent content, which causes deterioration in toughness of the welded joint and the heat affected zone (HAZ). In order to solve this problem, we developed a technology to improve the toughness of the HAZ by adding a small quantity of Ti to disperse fine particles of TiN in the alloy. Also developed for the same purpose was the thermo-mechanically-controlled-process (TMCP) technology to control the microstructure of the alloy by applying on-line water cooling immediately after the rolling process. More recent development of a technology called the "Low Carbon Bainitic Substructure" refines the microstructure of the HAZ, enabling one-pass welding of 590MPa class high-strength steel plates with thickness up to 100 mm without sacrificing the toughness of the HAZ.

2.5 High strength steel sheet for automobiles

Since early on, we have continued to develop our original high tensile-strength steel sheet (High-Ten), recognizing that the use of High-Ten in automotive body parts is very effective in reducing the thickness of the parts and thus in reducing the weights of vehicles. Our technical potential in High-Ten technology started to gain reputation when we developed a 980MPa class cold-rolled complex steel with high ductility called "100kg High-Ten". When we started the development work in 1984, the ductility of the steel was only slightly more than 10%, however, a new technique for producing solid-solution hardening by additional Si resulted in the successful development of a 980MPa class steel with ductility of 20%, which can endure the complex and severe press-forming used in the production of the door guard bars or the reinforcement members of automotive doors. Various other High-Ten products were developed including ductile, retained-austenite, steel using the transformation induced plasticity (TRIP) effect and hot-dip galvannealed alloy steel having good spot-weldability and coatability.

2.6 Special chemical-conversion treated steel sheet

We have commercialized a special chemical-conversion treated electro-galvanized sheet on which an extremely thin chemical coating is applied with a chromate layer substrate to add corrosion resistance, fingerprint resistance, conductivity and workability. The growing concerns about environmental issues limit the use of environmental burden materials, including hexavalent chromium, and led us to develop a chromate-free steel sheet in 1998 for the first time in the steel industry. Since then we have eliminated the chromate process from the electroplating factory and, by the end of 2004, had established a completely chromate-free factory environment. This owes much to the development of our unique technologies including a special chemical-conversion coating in which nano-particles such as rust inhibitors are dispersed homogeneously in the thin film.

2.7 Marine crankshaft

The crankshaft for marine vessel engines is one of our main items in the cast and forged steel business. We are the only manufacturer of cast steel crankshafts in the world. Cast steel has a higher productivity compared with forged steel because of its near-net-shape forming capability, however, a special care has to be taken of its fatigue strength. We have improved the fatigue strength of cast steel crankshafts to the level of forged ones by adding compressive residual stress to the surface through roll forming and by optimizing the alloying elements. As the result of this technical development we currently hold the world's largest market share of crankshafts.

2.8 Aluminum products for automobiles

Our contribution to the weight reduction of automobiles is not limited to the production of High-Ten but also extends to the production of aluminum sheets, extrusions and forgings. Recently the use of wrought aluminum, in addition to conventional cast aluminum, is expanding to such products as sheets for exterior panels, including the hood, and extrusions including the bumper beams and forgings for the under-body parts. As an all-round supplier of automotive aluminum products in various forms, we continue research and development to satisfy a wide variety of requirements including material strength, formability, surface characteristics and weldability. Also included in our work are peripheral technologies such as the analysis of collision characteristics (crash worthiness) and development of welding technology.

2.9 Aluminum sheet for beverage cans

Use of aluminum beverage cans in Japan has increased dramatically since the first application of the all-aluminum DI (Draw & Iron) can in 1971. Nowadays, more than 30% of aluminum sheet shipped domestically is used for beverage cans. We kept improving the formability of the material to meet the ever increasing speed of the integrated mass production lines of can manufacturers. We also developed, for the first time in the world, a bake-hardening-type, high-strength, aluminum sheet using a rapid heat-and-cool process. We maintain a high level of stable quality and productivity by combining advanced rolling-control technology and lubrication technology. Recently the demand for the aluminum bottle-can has increased very rapidly. The radius reduction at the neck of the bottle-can is nearly 5 times more than that of the conventional beverage can, providing a challenge for metal forming technology. We have developed materials that can endure such severe forming conditions.

2.10 Hard disk substrate for high density magnetic recording

We hold 60% of the worldwide market share of aluminum alloy sheet and punched-out blanks for memory disk substrates. In order for the memory disk to achieve high recording density, the substrate requires a very smooth, defect-free surface. In order to provide such a surface, we control the amount of impurities in the alloy such as Fe and Si to the very minimum and thus reduce the amount of intermetallic compounds which can appear on the disk surface and cause recording errors. To meet

Memory disk

the demand for increased recording density, we have developed high-precision manufacturing technologies including precision rolling to achieve good flatness of the blanks and precision grinding technology.

2.11 Copper alloys for electronics parts

With the growth of the IT industry, the copper alloys used for the lead frames and connectors of electronics components have become one of our main products. The KFC® (Kobe Ferrous Copper) was first put into production in 1976, and has won a very good reputation from customers because of its well balanced general properties of strength, conductivity, elongation and heat resistance. Nowadays our copper alloys represented by the KFC® are used in almost all the transistor lead frames and have become the global standard for materials for semiconductor components and connectors.

2.12 Titanium products

In 1949 we became the first company in Japan to develop titanium products. Since then we have established production technologies such as melting and rolling, and have developed products characterized by the three important inherent properties of titanium; lightness, strength and corrosion-resistance. One of the applications of titanium is in the super-size heat exchangers (condensers) of power plant where seawater is used for cooling. Another application is in seawater desalination plant. In those applications, thin-wall heat-transmission tubing of pure titanium is widely used because of its extremely high resistance to corrosion by saltwater. More recently, applications in commodity goods such as eyeglass frames and golf clubs are increasing because of titanium's corrosion resistance, weather resistance and designability.

2.13 High performance arc welding wires

There are three major purposes for the research and development of welding technologies; the streamlining of the welding process, improvement of welded joint properties and improvement of the welding environment. To increase the productivity of solid wire welding, which has become the major arc-welding method, we have developed products such as wires without copper plating, for improved feedability, and wires for high heat-input welding. A number of products with improved joint properties have been developed including wires for off-shore structures built in low-temperature ocean areas, solid wire for 950MPa class high tensile-strength steel and fine flux-cored wires (FCW) for stainless steel sheet. Other products developed for environmental improvement include low-fume, low-spatter, FCW. We have also focused on the development of the welding robot and have commercialized arc-welding robots which provide high-throughput, high-quality welding of steel frames for buildings, construction machinery and industrial machinery.

[Machinery]

2.14 Screw compressors

The development of compressors, which we started immediately after the foundation of the company, has continued to the present day and, as an integrated compressor manufacturer, we have a comprehensive line-up of products. Today we hold approximately 40% worldwide market share of application-specific screw compressors. Our flagship machine is the only machine in the world that can compress up to 6 MPa. We also hold the largest market share in Japan and Southeast Asia of multi-purpose screw compressors, for which several unique technical developments were made including a direct motor drive structure and inverter control. One of the main innovations of our screw compressor is its unique screw design, which reduces vibration and improves overall performance. The design of the screw employs state of the art optimization technologies including vibration analysis and performance simulation. Another feature is its low noise, which is a result of our study of noise reduction technologies. The reduced pressure pulse noise and rigid casing design which minimizes sound radiation, enable the installation of the compressor close to office areas without enclosure acoustic insulation.

2.15 High pressure technology

Our high pressure technology started with the introduction of multilayered containers for ammonia synthesis and has extended to the manufacturing of the large-size reactors commonly used in the petrochemical industry. We also developed solid super-high pressure equipment including a 10GPa class press machine for diamond synthesis, and fluid pressure equipment including isostatic extrusion machinery, cold isostatic press (CIP) and hot isostatic press (HIP). The isostatic extrusion machines are used for the extrusion of materials which are difficult to form, such as superconductive materials, and the CIP and HIP of 100 to 1,000 MPa are used for consolidation, forming and sintering of hard powder materials. Other high pressure equipment which we have developed include pressure food-sterilization equipment and supercritical pressure-extraction equipment used for the extraction of useful organic components.

2.16 New iron production plant

The main stream of the modern iron making process is the blast-furnace/converter. However, direct-reduction iron-making plants have a valuable role, mainly in natural gas producing countries, because they require neither the large capital investment nor the coke required in the blast furnace process. In 1978 we delivered a direct-reduction iron-making plant based on the MIDREX® process to Qatar. Our MIDREX process, now installed at several locations in the world, produces 64% of the directly reduced iron of the world. After this, we developed a new process named FASTMET®, which substitutes less expensive coal for natural gas. Also developed was a process named FASTMELT which takes the hot charge of iron, directly reduced by FASTMET, and refines it by removing ash and sulfur.

Recently we have developed a new iron making process named ITmk3® based on a totally new concept, which we regard as the third generation iron making process. In the ITmk3 process, pulverized ore and coal are granulated into pellets which are charged into a rotary hearth furnace where the pellets rapidly separate into iron nuggets and slag. The process allows the use of a variety of cheaper raw materials including general coal and low grade ore. Another important feature of ITmk3 is its low environmental burden.

Direct-reduction iron-making plant

2.17 Vessels for storage and transport of radioactive materials used in nuclear power generation

There is a national need for safe and economical vessels for the storage of spent nuclear fuels and for the transportation of radioactive materials. The vessels are required to have important safety features such as cooling, shielding and criticality prevention capabilities, because the radioactive content radiates a considerable amount of gamma and neutron radiation, along with up to tens of kilowatts of heat. We have worked on the development of such vessels since the late 1970s and have developed criticality prevention materials including aluminum alloys and stainless steels containing boron (which absorbs neutrons efficiently). We have also developed special materials which shield neutron radiation effectively and have optimized the manufacturing process of the vessels including melting, forging and assembly. In addition to developing new materials, we have established safety analysis technologies including structural analysis, heat analysis, shielding analysis and criticality analysis, and have used these in the design of our vessels.

[New business]

2.18 PVD equipment

The material and equipment design technologies combined and extended in the field of high pressure technology, lend themselves to the development of PVD (Physical Vapor Deposition) equipment using vacuum and thin-film technologies. The AIP (Arc Ion Plating) equipment, of which we started production and sales in 1986, produces dense and hard film with good adhesion, and is used for the hard-coating of cutting tools and sliding parts. Its application is increasing in a variety of industrial products including automotive parts, machinery parts, metal molds and surface decoration. In 1998 we developed UBMS

(UnBalanced Magnetron Sputtering) equipment for the first time in Japan. The equipment allows bombardment of high-density nonequilibrium plasma against the work piece in an unbalanced magnetic field, and enables deposition of such films as DLC (Diamond Like Carbon), which is eminently suitable for sliding surfaces because of its hardness and low friction coefficient.

2.19 Sputtering target materials

Our sputtering target material resulted from an accumulation of technologies on a variety of metals. The sputtering target provides the material for the thin film deposited by the sputtering method. This process is used widely in the production of liquid crystal display (LCD) panels and optical disks. In the late 1980s we started development of sputtering target material for the wiring in LCD panels and have developed an Al-Nd alloy having low electrical resistance and high thermal resistance. Nowadays this alloy is used in approximately 80% of the LCD panels for TV. The technology employs a special processing technique called spray-forming in order to achieve the fine, homogeneous, segregation-free, microstructure required for the target material. More development work is continuing for further applications including the target for larger, high-performance LCD panels and reflectors.

2.20 Superconductor technology

Our continuous research and development on superconductivity since 1964 has led to our current business of NMR (Nuclear Magnetic Resonance) magnets and superconductor wires. Our Nb_3Sn superconductor wire has a high critical current density and enables downsizing of the superconducting magnet without compromising the magnetic field. The achievements in technologies such as coiling, superconductor joint, and cryogenics have led to the commercialization of a 930 MHz magnet for NMR, which recorded the world's highest magnetic field of 21.9 T (Tesla) which equates to approximately three hundred thousand times the global magnetic field. We also achieved in 2005 the world record of 15.5 T for a cryogen-free magnet which is more compact and easier to use.

Sputtering target material

3. Our Future Research & Development

The core businesses of Kobe Steel are, and will continue to be, the production of steel, aluminum and other materials by the materials divisions, and industrial equipment and the provision of engineering services by the machinery divisions. The main emphasis of our research and development will continue to be to provide strong support to these core businesses but we will also strive to help to develop new businesses based on new technologies.

Firstly, we will continue R&D to ensure competitiveness of the existing businesses by understanding and reflecting the diverse user needs into our activity and by developing novel products that satisfy our customers' requirements. Especially, we will focus on energy and environmental issues and respond in a timely way to social needs by developing new products such as automotive weight-reduction materials, including High-Ten and aluminum alloys, and energy-saving equipment including high-efficiency compressors. It is also important to continue our effort to improve the inherent features of materials to their maximum values. More sophisticated technologies are needed for microstructure control, analysis and evaluation of materials, as the control of material structure progresses from the "micro" level to the "nano" level, and as thin film technologies progress to the "atomic" level. Innovation in those areas will bring about new business opportunities in functional material products as well as in conventional structural material products. At the same time it is essential to establish efficient production systems for stable and economical production. We will keep upgrading our routine production technologies such as process control and production planning. In the machinery and engineering field we will continue improvement of our characteristic technologies inherited from the past, such as compressors, by utilizing advanced elemental technologies including flow, vibration and acoustic analyses. Also we will continue pursuing business development and advancement of technology in the areas where we can exploit the technical synergy of our experiences and knowledge.

Secondly, we will continue to develop new products in the peripheral area by focusing on world technical and market trends and by analyzing the correlation with our business assets. Recently, the technical expertise required for each segment of materials, parts and final-products have become more specialized, and the value added by each segment tends to vary widely. We will define the goal of each development by exploring how our technical skills in materials and machinery fit together and work to their maximum in each business segment. A good example is our sputtering target for LCD, which made a very successful entry to a totally new business area.

It is also important to keep abreast of new technologies by predicting their usefulness in the future even when their current status for business may be premature. In the area of nanotechnology and new energy, although it is difficult at this time to foresee the future and it will take time before the technologies prosper, we will consider development of new products at an early stage in relation to our strength in the relevant business and technology. We will clarify the direction of the development, not only by ourselves, but by cooperating with universities and other public institutions.

Our environmental management policy is not limited to the environmental–burden reduction activities in our own production, but has extended to our products and services including chromate-free steel sheet, high-efficiency screw compressors and vinyl-chloride recycling plant. We will continue the development of materials and equipment which will contribute to energy saving and environmental burden reduction.

The maintenance and reinforcement of technical capabilities are essential for manufacturers and we will continue adding new technologies to our existing technical assets through our steady effort in the future. In order to utilize the results of research and development in a timely and effective manner, we will need to utilize more advanced simulation technologies along with supporting tools such as quality engineering. With the increasing need for new development at business interfaces, we will also need an agile and flexible cooperation, not only within our own business sectors but also with other companies including our own group companies.

It is our strong intention to strive to satisfy society's future needs for new products and technologies through continuing our R&D effort to extend our technical assets accumulated over our first hundred years of existence.