Historical Review of R&D in NKK

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It is not possible to discuss this issue without referring to the achievements of Kaichiro Imaizumi. Our company was founded in 1912 by the combined efforts of Motojiro Shiraishi, who was in charge of the business side, and Kaichiro Imaizumi, who led the technology side of the operation. Kaichiro recognized the importance of technological development from the outset and formed the Technical Research Department in 1935. He was already 68 years old at that time, and yet he took the position of the first general manager of the research department. The establishment of an organization dedicated to R&D based on the perspective of developing technologies long into the future was epoch-making, particularly considering the fact that Japanese steel production at that time was at a level of only 2 million tons per year. We can imagine his devotion and enthusiasm for technological development. The white, 3-story, Research Center Annex building constructed at that time to accommodate the research department still exists in the Watarida area of the Keihin Works and is currently the office of NKK Tubes (**Photo 1**).

NKK originally started as a seamless steel pipe producer, but acquired a neighboring shipbuilding company, Tsurumi Steelworks & Shipbuilding, in 1940. This transformed NKK into a compound business company engaged in the two business fields of steelmaking and engineering, as it remains today. The research department was expanded into the Technical Research Center in 1948, which led NKK's technological development in the postwar era. The organizational transition since the establishment of Technical Research Center is shown in **Fig.1**. The basic philosophy underlying this transition was always Kaichiro Imaizumi's spirit of being autonomous and challenging, which has been passed down from generation to generation. NKK's R&D activities have been characterized by its unique and integrated R&D system that aims to create synergistic effects by combining steel production technology with engineering technology. In 1978, the Technical Research Center was reorganized into the Research and Development Division, which has been maintained to the present.

In the 1970's, various world-first technological developments came to fruition in rapid succession. For example, the continuous casting molten steel level meter (eddy current detector), NKK-CAL for continuous annealing, and snow and ice technologies, as represented by the construction of the Antarctic expedition ship. NKK's R&D activities have reached notable achievements that are second to none in the industry. Evidence of this includes the prestigious prizes and awards that the Company has received in recent years, such as the Okochi Memorial Prize (**Table 1, Fig.2**) and the National Invention Award (**Table 2, Fig.3**).

Photo 1 Former Technical Research Department Building (currently NKK Tubes Office)

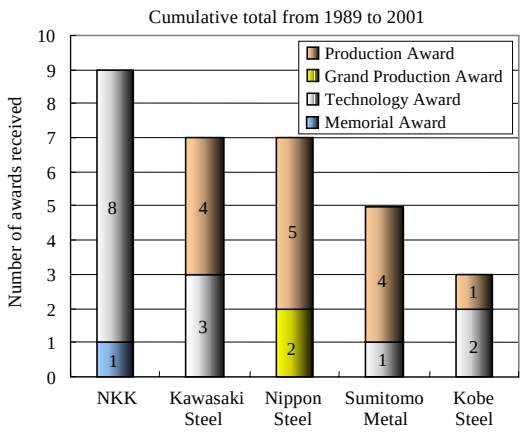

Fig.2 Number of Awards of Okochi Memorial Prize Japanese steel companies received since 1989

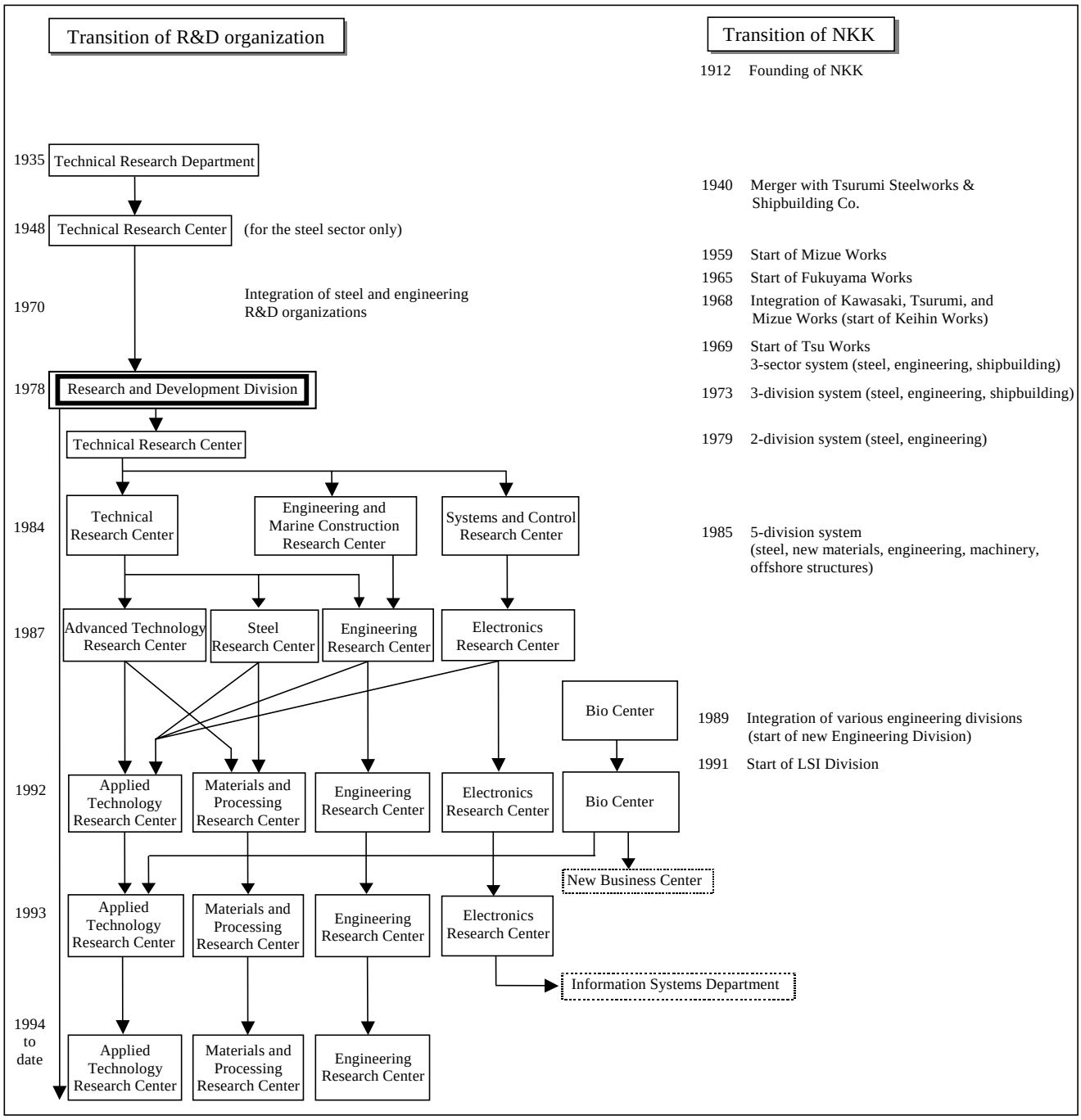

Fig.1 Organizational transition since the establishment of Technical Research Department

Table 1 Awards of Okochi Memorial Prize NKK received since 1990

Year	Theme	Prize
2001	Development and application of automatic surface flaw inspection using 3-channel polarized light	Technology Award
2000	Development of environment-friendly, new steelmaking process	Technology Award
1998	Development and application of environmentally friendly regenerative burner system	Memorial Award
1997	Development and application of high-performance rapid steel analyzer	Technology Award
1996	Development of mass-production technology of 6.5%-silicon steel sheet	Technology Award
1994	Development of manufacturing and application technology of ribbed steel pipe for steel and concrete composite structure	Technology Award
1993	Development of high-quality, rolled, clad steel plate manufacturing technology using sandwich type assembled slabs	Technology Award
1991	High strength steel with high seismic performance for building structures	Technology Award
1990	Production technology of new, high quality agglomerate (Hybrid Pelletized Sinter)	Technology Award

Table 2 National Invention Awards NKK received from 1989 to 2001

Year	Theme	Award
2000	Invention of environmentally friendly regenerative burner heating system with low-NOx combustion	Japan Federation of Economic Organizations (Keidanren) Chairman's Award
1998	Mass-production technology of 6.5%-silicon steel sheet by continuous chemical vapor deposition	JIII (Japan Institute of Invention and Innovation) Chairman's Award
1996	Energy-efficient ship with off-center propeller shaft	MITI (Ministry of International Trade and Industry) Minister's Award
1994	High speed rotating arc automatic welding technology	MITI Minister's Award

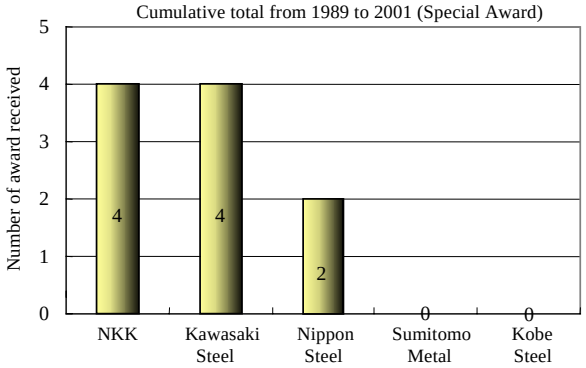

Fig.3 Number of National Invention Awards Japanese steel companies received since 1989

The transition of NKK's annual R&D investment since 1980 is shown in **Fig.4**. Annual R&D investment reached a peak in the period of 1990 to 1993 because large amounts of investment were allocated to new business fields such as semiconductors and electronics, new materials, and biological research subjects. Since 1993, investment amounts in these fields have decreased. As a result, the total amount of R&D investment has also decreased annually, and in recent years, it has remained at a level of about half of that in 1990. However, the achievements of R&D activities in the core business fields such as steel production are no less than those in the period around 1990.

In July 2001, the Research and Development Division staged an event to promote IR (Investor Relations), where NKK introduced their recent R&D achievements to representatives of financial organizations and other institutional investors. **Table 3** shows the achievements divided into two categories: technological fields where NKK is the top runner in the industry (NKK's top-running technologies), and NKK's automotive steel sheet technologies. Of the various technologies introduced in the table that originated from the synergistic effects of steel production and engineering, three representative achievements are discussed below. The first is DME (dimethyl ether), a much anticipated, next-generation, clean energy source. This new energy technology was developed by combining chemical plant technology in the engineering sector with numerous technologies in the steel sector related to coal and coke, such as gas refining and waste gas treatment. The second is the waste gasifying & direct melting furnace. This environmental technology was achieved by combining high-temperature melting technology from the steel sector with the fluidized-bed combustion technology from the engineering sector. The third is the earthquake-resistant line pipe NK-HIPER, a new steel product created by combining the earthquake-resistant design technology from the engineering sector with material properties control technology from the steel sector. NKK's top-running technologies also include: steel production process technologies, as represented by the zero-slag steelmaking process; high-value-added steel products such as electrical steel sheets, chromate-free coated steel sheets, and weathering steel for coastal use; numerous environment- and energy-related technologies established based on engineering technologies; a group of steel and engineering products with high workability and safety for constructing social infrastructures such as piles and bridges; and automotive steel sheet technologies represented by high tensile

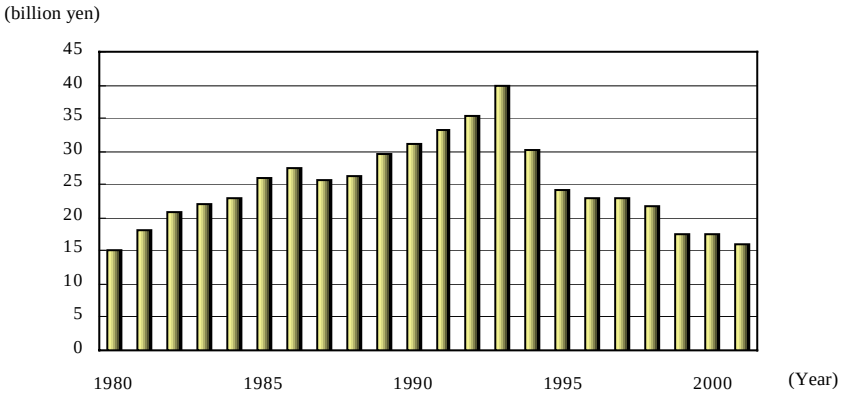

Fig.4 Transition of NKK's annual R&D investment (1980 to 2001)

strength steel, GA (Galvannealed) or GI (Galvanized Iron) sheets with high press formability, analysis and forming technologies, and DELTA-EYE quality assurance technology.

Four key words express the characteristics of NKK's R&D activities that realized these achievements, as shown in **Fig.5**. These are "Professional" (advanced professional skill), "Synergy" (integration and fusion of common technologies in the steel and engineering sectors), "Flexibility" (flexible research management system for raising the challenging spirit), and "Responsibility" (research in line with business strategy). These characteristics have been cultivated since the Company was founded to support the integrated R&D system in keeping with the compound management.

Table 3 NKK's recent technologies introduced at the R&D IR event

Category	Group	Technologies
NKK's top-running technologies		
	Steel production processes	・Energy saving and life prolongation of blast furnaces (hot stove combustion control) ・High-rate pulverized coal injection (massive PCI) ・New high quality agglomerate (hybrid pelletized sinter) ・ZSP (Zero slag process) ・High-speed continuous casting ・Steel flow control by travelling magnetic field ・On-line accelerated cooling (*SUPER*-OLAC) ・Regenerative burner heating system ・Advanced quality assurance technology by inclusion inspection for high-grade can-making steel sheets
	Steel products	・Ultra-low sulfur electrical steel sheet for high-efficiency motors (NKB-CORE) ・6.5%-silicon electrical steel sheet (SUPER-E-CORE) ・Chromate-free coated steel sheet for electrical appliances (GEO-FRONTIER-COAT) ・Thin organic composite coated, 55%Al-Zn alloy coated steel sheet with high corrosion resistance (SUPER-GENIOUS-COAT)) ・Prepainted 55%Al-Zn alloy coated steel sheet with good formability and corrosion resistance (GALFLEX-COLOR) ・High earthquake-resistance line pipe (NK-HIPER) ・New weathering steel products (weathering steel for coastal use, rust stabilizing treatment CAPTEN-COAT-M)
	Environment and energy	・DME (Dimethyl ether) direct synthesis ・Waste incinerator (hybrid combustion control system and operator training simulator) ・High-temperature gasifying & direct melting furnace ・New waste incineration and ash treatment stoker furnace with maximum energy efficiency and minimum environmental load ・Environment-friendly and economical arc furnace (ECOARC) ・Dioxins reduction technology (HIGH-CLEAN-DX) ・Dioxin precursor analyzer ・Automobile shredder dust recycling (THERMO-BATH process) ・Waste plastic container recycling system with rapid bottle sorting ・CHS (Clathrate Hydrate Slurry) for energy-saving air-conditioning system ・Mathematical model for design and operation of advanced biological wastewater treatment system ・Unique sewage treatment system using microorganism immobilization technology (BIO-TUBE)
	Infrastructure & applied technologies	・Steel framing method (NKK-FRAME-KIT) ・New applications of iron and steelmaking slag (MARINE-BLOCK for artificial reef, slow-release potassium silicate fertilizer) ・Environmentally friendly, earthquake-resistant, and labor-saving pile products (wing-shaped screw pile, hybrid steel pipe and soil cement pile, connection of steel tube column to concrete-filled pipe) ・Wind-resistant design for low-cost, cable-stayed bridge ・Non-excavating pipeline laying method with fully automated spoil slurry transportation system (NKK-FAST) ・Gas pipeline operation support system (WIN-GAIA) ・Simulation for optimal design of mechanical systems ・High-speed rotating arc automatic welding technology
NKK's automotive steel sheet technologies		
	Advanced material	・Ultra-high tensile strength steel sheet produced by CAL-WQ process ・Super-fine grain, high tensile strength steel sheet (SFG-HITEN) ・NANO-HITEN ・Non-oriented high carbon steel sheet for automobile transmission parts
	Surface treatment	・Galvannealed steel sheet for outer panels ・Galvanized steel sheet for outer panels
	Forming & analysis methods	・FEM analysis for optimizing material, structure, and tailor-welded blanks ・Arc-laser hybrid welding
	Quality assurance	・Steel sheet automatic surface flaw inspection and marking system (DELTA-EYE)

With the business consolidation of NKK and Kawasaki Steel, R&D activities will start under the new organization in April 2003. I hope that the spirit of Kaichiro Imaizumi, which has been cultivated since NKK's corporate foundation, will be maintained regardless of the changes in organization, and that the JFE Group will continue to create numerous new technologies that lead the 21st century.

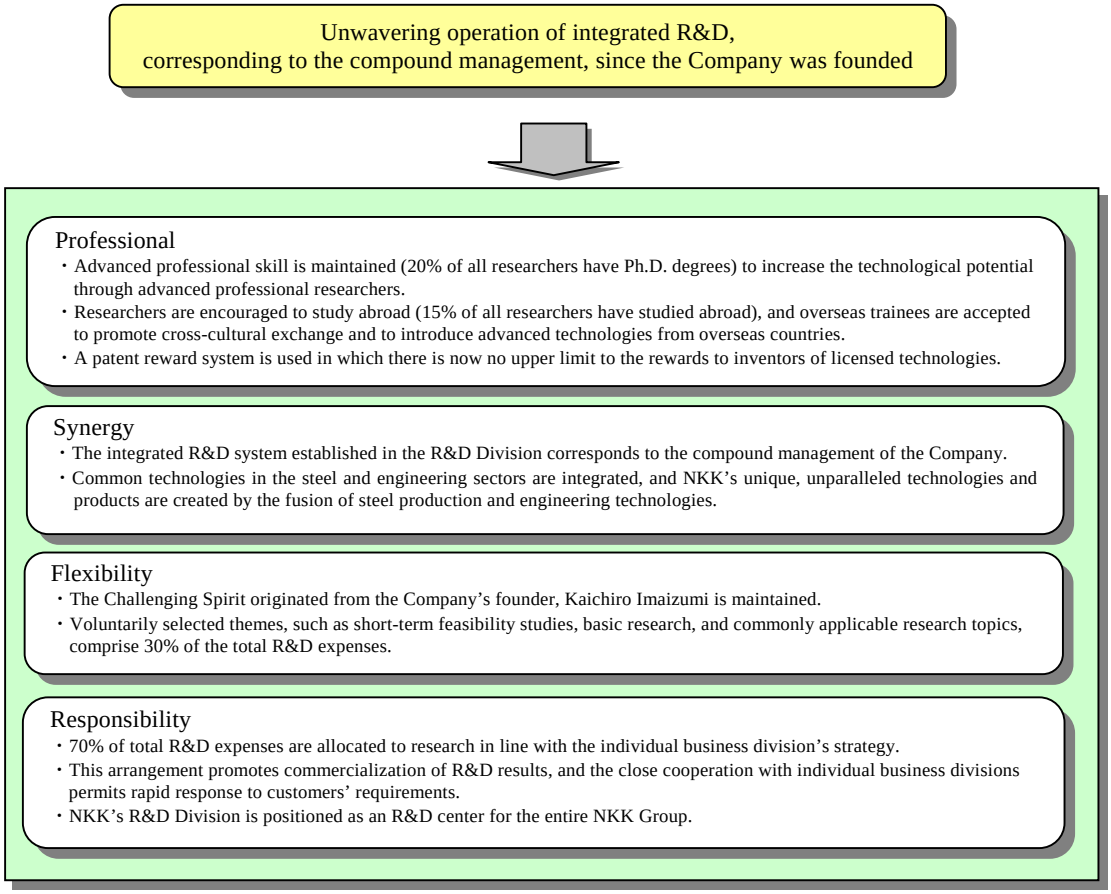

Fig.5 Characteristics of NKK's R&D activities expressed by four key words