Discussion

Those Days of Our Fight against Heat

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We invited former leading researchers and development managers in the field of refractory materials who set the foundations for Nippon Steel's refractory technology, and listened to their views on the attractions and satisfaction of R&D into refractories for steel production, recollections of their challenges in the 1940s to 1980s, the need for more efficient R&D, as well as their dreams and expectations.

The Host: Thank you very much for joining this talk. On the occasion of this special edition of the Nippon Steel Technical Report on refractories some 20 years after the last one, we thought it would be opportune to allow those of you who led the refractory development activities of the entire company to share your recollections. To begin with, would each of you please tell us what you have been doing lately?

HIRAGUSHI: As part of my lifelong learning, I am tackling mineral chemistry and re-learning foreign languages. Besides these, I began to compile my personal history, and as one element of that, I requested a copy of my graduation thesis from my university. The subject was the pyrolysis of lead rhodanate ($Pb(SCN)_2$), and I was thrilled to receive a copy of my handwritten thesis on 36 A4 sheets from 53 years ago. As for foreign languages, I have been translating technical papers for the Journal of the Technical Association of Refractories, Japan, into English for 27 years, but I find that approaching native-speaker level is extremely difficult. Besides English, I am relearning conversational German, French, Korean and Chinese. NHK's radio courses are very helpful for me.

YAMANAKA: It has been 22 years since I left Hirohata Refractory Development Dept., and 10 years since I finally retired. I feel honored to be here today, and I recall the good old days when I devotedly worked with my seniors, fellow engineers and people in related organizations to develop new refractory materials and their application in the field. Now, I act as a manager of the residents' association of my neighborhood community in the city of Himeji, taking part in social security activities and conservation of local culture. Another contribution to local society is that I have been working as a volunteer guide for visitors to Himeji Castle for the last eight years, and enjoy walking and talking with visitors from different corners of the world.

IKEDA: I left Nippon Steel nearly 20 years ago, and after that, worked for three related companies, but was no longer closely engaged in refractory. After leaving the last of those companies, far from being academic, I have been enjoying my private life playing tennis, mountaineering, and traveling in and outside Japan. Once every two years, I attend a gathering of the ex-members of refractory development at the R&D Lab and Hirohata Refractory Development, and hear from present researchers what is happening at the laboratories, but after such a long time away from the steel industry, I understand only a little of what is talked about. So, I am not sure if I can be of any help today.

SHINOHARA: I left Nippon Steel in 1998, and then joined Harima Ceramic and Krosaki Harima Corporation with responsibility for technical management and sales until 2002. Then in 2003, I was requested to work for the Japan Refractories Association, and now I am serving as its executive director. I remain in good health, but feel like retiring completely to enjoy life while my aged body still allows it.

HORIO: Immediately after retiring, I bought a PC and learned how to use it. The purpose was initially to edit my video recordings. Then, as a pastime, I thought it would be a good idea to acquire a specialist skill, and learned the skill of making *kakejiku* (cloth framing for a picture in a scroll). I have already made more than 200 frames, mostly for ink paintings of my wife and her friends. Another pastime is golf. I have played golf since my days in Yawata Refractory Development, but my score does no justice to my long experience. I continue playing it for my health and for the golfing get-togethers of former refractory-related people in the region. The PC, *kakejiku*, and golf are the main pillars of my everyday life.

SAWANO: After retiring from Nippon Steel, I have been working for Micron Co., Ltd. a subsidiary of Nippon Steel Materials, and am responsible for technical management. The company is a leading manufacturer of fine spherical ceramic particles used mainly as the filler for semiconductors. The production process is derived from the flame-gunning method that Nippon Steel developed originally for hot repair of refractories. So, I am living off past experiences. The knowledge and experience of fine ceramics that I acquired in Nippon SteelÅfs laboratories (presently Advanced Technology Research Laboratories) proved very helpful, too. I am still pretty busy with the development of new products and processes.

The Host: While we endeavor to sharpen our competitive edge, enhance our capability in terms of high-end products and remain at the technical forefront to secure our position at the top of the industry, we are often so busy with our daily work that we fail to see our position in the whole picture. Now, what did you find exciting and attractive in the development of refractory for steel industry, and during your days from the late 1940s to the early 80s, what caused you trouble or brought you satisfaction?

HIRAGUSHI: Refractory researchers in the steel industry are almost akin to medical doctors. In an integrated steel works, especially, refractory is used in virtually all production processes from blast furnaces to heat treatment lines, and there is no end to technical problems related to it. For example, up to the late 1950s, refractory engineers were blamed for any non-metallic inclusions from brick-induced defects to slag inclusions and deoxidation products, but zircon tracer made it clear that refractory was only responsible for less than 10% of all that, and the blots on our names were erased. As another example, silicon carbide grinding stones were used for slab finishing after scarfing; but many surface defects caused by the hard grinding material of silicon carbide were found at the annealing process; so we changed the grinding material to alumina, and the problem disappeared to the satisfaction of all concerned. Fire clay bricks were used for blast furnace hearths until the early 1950s, and a campaign life was five years at best, with pig iron production of 2 million tons or less. Use of carbon blocks extended the campaign life to 10 years or longer and the pig iron production during a campaign increased to more than 30 million tons. This is largely due to the high melting point, good volume stability, erosion resistance, thermal conductivity and high cooling efficiency of carbon blocks. In addition to these factors, the micro-pore effects due to the addition of Al, Si and Ti greatly contributed to the high performance. This is a typical example of success achieved by collaboration between researchers in the fields of mechanical and heat conduction engineering and refractory manufacturers under the leadership of refractory researchers.

In relation to high-temperature hot stoves, there were many problems, such as refractory creep that became apparent when the blast temperature was raised, walking of refractory walls due to different thermal expansion rates for straight and curved walls, and stress corrosion cracking of the dome shell due to the high blast temperature. Countermeasures against all these problems were worked out, again, through close collaboration with researchers in the fields of mechanical, heat conduction and corrosion protection engineering.

The technology for ceramic coating has advanced together with the development of jet engines, but the steel industry began to apply the technology to the coating of rolls with tungsten carbide in the late 60s. It was also applied to the alumina coating of copper tuyeres for blast furnaces at a spraying rate of 1 kg per hour. Later, we at Yawata developed a flame spray gun with a capacity for 10 kg per hour, ten times the capacity of similar equipment then available in the world, and in spite of a considerable risk of failure, Mr. Yamanaka, the then head of Coke Plant Technical Section of Hirohata Works, decided to use it to repair the walls of coking chambers actually in operation. After that, its use expanded to the refractory repair of molten steel ladles, vacuum degassers and converters. I think this is a typical example of developments achieved through the initiative of refractory researchers in the steel industry.

Furnaces are composed of refractories and a steel shell ? the frame to hold it in place. Furnace operation involves technologies such as heat conduction and chemical erosion resulting from operation. Industrial furnaces are expected to play quite an important role in environmental measures such as waste treatment. I believe refractory engineers will be kept busy for a long time yet.

YAMANAKA: I think the attractiveness, or satisfaction, of working in the field of refractories is that the steel industry is typically a high-temperature industry, and the advance of refractory technology constitutes the basis for the development of the steel industry. Typical examples are blast furnace hearth bricks (CBD series) in ironmaking, MgO-C refractory for converters, and sliding-gate nozzles and flux powder for continuous casting in steelmaking, and refractory and heat insulators for reheat furnaces in rolling. With respect especially to the widespread use of unshaped refractory such as the plastic lining of reheat furnace walls, vibration forming and microwave drying of ladle lining, I am sure we have been far ahead of our competitors. These innovations in the refractory technology significantly contributed to the extension of the service lives of plant facilities and vertical integration of steel production processes.

On the other hand, Nippon Steel began its new materials business in the early 1980s under its business diversification programs. In this field, too, we successfully commercialized some plant facilities applying technologies derived from refractory development. When I was transferred from Hirohata Refractory Development to New Plant Engineering Dept. with responsibility for the construction of a plant to produce the material for the sealing compound for ICs, and then, for the construction of a pilot plant for carbon fiber production, I was strongly backed by the Hirohata refractory people. Now, the period of initial loss is over and all those plants are operating profitably. Refractory researchers may well be confident and proud to be at the technical forefront of the steel industry.

Talking about the joys and fears of R&D in the 1980s, I worked in Hirohata Refractory Development only for three and a half years from April 1981. At that time, to help improve steel production processes in any possible way, the organization, then nine years old under the newly organized Plant Engineering Bureau, launched a 10-year plan to tackle subjects in quite a wide variety of fields in response to requirements for energy and manpower saving, and automation and environmental measures, besides refractory development. Those subjects included analysis and handling technologies for powder and granular materials, high-functionality ceramics, measurement technologies in addition to refractory analysis and furnace design technologies.

The department was very big with 28 expert engineers and 50 seasoned field workers, 85 people in total. Everyone was well motivated and the atmosphere was just great. As head of the department, I felt responsible for maintaining this progressive atmosphere, and for a while, enjoyed a fruitful period of significant achievements one after another. But, gradually the economic conditions worsened, and the so-called restructuring of R&D organizations began, and my days of joy turned into bitter negotiations concerning mergers with other organizations. Now, I am very glad to see my old department reorganized as the Refractory Ceramics R&D Lab.

IKEDA: It would not be an exaggeration to say that refractory determines the fate of steelmaking technology. This has long been my strong belief and the source of my motivation. I joined the company in 1963, when the RH degasser was introduced from Germany, and I was engaged in bringing it to commercial use from the refractory technology side. At the beginning, the equipment could seldom process more than five consecutive heatings, and I often had to argue with steelmaking people blaming each other for a poor manner of operation and too short refractory life. Gradually, the number of consecutive heatings approached a satisfactory level thanks to operational improvements and development of new refractory containing chromium oxide. This was the first time that I felt satisfaction through my job.

As the RH treatment ratio increased, hot metal leakage from ladles occurred more often because of the longer residual time of the molten metal and slag in the ladles and consequent deformation of stoppers. This was a very serious problem. Through many field studies, we found that the cause was thermal stress cracking of the stopper sleeve bricks. The development of double-layered sleeve bricks solved the problem. The massive computer that had just been introduced for production control proved to be of great help. It enabled us to carry out multiple regression analysis of refractory-damaging factors, thermal stress calculations, etc. in a dramatically shorter time. I was impressed by the advance of technology that affected our job.

As a radical solution to the problem that eliminated the use of stoppers, we tried to develop sliding-gate nozzles, which we learned about from foreign texts, by ourselves. We set up prototype nozzles to test ladles and carried out many trials at the Electric Furnace Plant, but we could not finally solve the problem of metal solidification inside the nozzle. A few years later, a countermeasure technology was introduced from outside. When we saw it together with the steelmaking people, I was beaten by a feeling of defeat due to a lack of resourcefulness.

I do not think most present-day steel engineers know what an open hearth furnace is like, but many of them were still in operation when I was young. As blowing oxygen into the furnaces became common practice, damage to ceiling bricks increased, and we were told to do something to make the bricks last longer. We sometimes had to climb onto hot furnace ceilings or go into still hot hearths not long after the last tapping to sample bricks and investigate their damage. It was tremendously hot and dangerous, too, but those efforts led to the field use of direct bond bricks, and looking it back, I now

NSC-THYSSEN TM SC-5a (The 6th REX-Meeting) NOV·7~8·1983. at H·R·D feel rewarded. This and the development of refractory for the RH degasser are among the main events of my past fight against heat.

Later, I was assigned to head Hirohata Refractory Development after 10 years of working in different fields, but in that office, I seldom had to face heat personally in the frontline as I had used to before. Instead, the people in my department fought against heat day and night in projects such as the blast furnace hearth structure tests using a 3-t electric furnace, and development of a top-and-bottom blowing system for converters, to achieve satisfactory results. I still vividly remember one of my engineers, Mr. Andoh, who was regrettably killed later in a traffic accident, returned one evening from the hot blast furnace cast house after a successful field application test of resin-bonded tap-hole mud, shouting, “We did it,” and left the office for rounds of toasts together with the analysis staff with whom he worked on the project. That was an unforgettable case of the joy of development engineers.

SHINOHARA: Every new steel technology is backed by the development of a new type of refractory. Seeing a new steel process being put into practice thanks to refractory development is the bliss only refractory R&D engineers are privileged to experience. I joined the refractory R&D for the first time in 1981 when I was assigned to the Plant Engineering & Technology Center in Tokyo. My responsibility for the next 10 years was planning and coordination, and for three years after that, the start-up of the Refractory Ceramics R&D Lab just after its organization. Therefore, I have little experience of actually working in the forefront of R&D.

What I did in the planning and coordination position was to secure the budget and human resources so that the laboratory people could do their jobs without worrying about them. For that, I thought it was important to select subjects of interest for the whole company as development themes, and publicize the fruits of R&D activities adequately. Presidential commendations and other in-house prizes are, of course, encouraging and important, but I thought commendations by outside organizations were more objective and appealing, and actively applied for them. As a result, the technology of flame gunning for refractory repair won the Production Award by the Ohkochi Memorial Foundation as the first award of the Plant Engineering & Technology Center, and high-durability carbon blocks for blast furnace hearths won the Award of the Director-General of the Science and Technology Agency recommended by the Japan Institute of Invention and Innovation. Besides these, the technologies for poured casting of ladle lining and high-performance burned magnesia brick were commended by the Institute, too. In applying for these outside commendations, how to prepare application documents comprehensible to the jury, who did not specialize in refractory technology, was a difficult task.

The jury often asked what advantage our technology held in comparison with similar ones of other companies. Unit consumption is a valid indicator in many cases, but its value changes depending on operating conditions of the plant in question, and may not be effective in every case. So, I always tried to place emphasis on the novelty of the developed technology. I have the impression that our argument was persuasive probably because most of the refractory technologies for the steel industry at that time had their origins in Nippon Steel. I was busy every day with applications for budgets and explanation of development subjects. But, perhaps because the refractory group was viewed as a minor party in the company, the related people were cooperative, or rather sympathetic, and our achievement ratio per budget allocation was not too bad.

HORIO: Personally, I worked in R&D of the blast furnace process, operation of ironmaking plants and refractory development; that is to say, I have worked in three different fields related to blast furnaces, and in each of them, I was met by technical challenges stemming from the needs of the time. In the field of R&D for the blast furnace process, I tackled subjects such as measures against the powdering of self-fluxing sinter during reduction, and development of the injection of heavy oil, which was then economical, into blast furnaces. When in charge of the ironmaking operation, I had to resolve damage to blast furnace tuyeres, start-up the first hot stoves made of silica bricks, and implement environmental measures for sintering plants. Furthermore, in refractory development, I worked on enhancement of the durability and reliability of refractory for blast furnaces and hot stoves, hot repair of coke ovens, hot stoves and converters by flame gunning, introducing ceramic fibers and other new materials to the lining of reheat furnaces and soaking pits for energy conservation, and the preservation of hot stoves made of silica bricks through cooling at blow-off of the blast furnaces, etc. etc. Every one of these tasks was very tough.

Looking back on those days, I frequently recall my field activities, like repairing the hot blast port of a hot stove by flame gunning on an elevated work platform on a cold winter day, and wracking my brain about how to repair the ceramic fiber lining of a reheat furnace on a hot summer day. One aspect that is common to all those problems is that laboratory test results cannot be applied to problems in the field without suitable modification. We were frequently surprised by the difference between the two. In this regard, it is important to correctly grasp the facts of field practice, repeat tests simulating the facts, and evaluate alternatives based on the results obtained. This may sound too obvious, but, to do this, it is essential to look carefully at the actual field practice, and listen attentively to the people in the production field to collect information from as many viewpoints as possible. As we are all well aware, many things in our daily life were invented through careful study of everyday matters that we see around us but seldom question. I mean, it is essential to always be problem-conscious.

While I worked in R&D, I very often felt relieved of a heavy burden when a solution was worked out, but I was seldom excited. On the other hand, I am very glad when I hear that what we developed has been introduced and become part of our daily practice. I cannot help smiling inwardly when I hear people mentioning things like, “High-blast-speed tuyeres are now standard equipment for blast furnaces,” “Any steel works can cool down hot stoves made of silica bricks without problem,” or “Field maintenance staff would have all sorts of trouble if ceramic fiber were not used for reheat furnaces.”

SAWANO: Refractory directly contacts steel in production processes, and is considered an important material. Dealing with refractory has always been as exciting as the so-called mainstream steel technology for me. Meanwhile, we have seen many R&D reports in the field of refractory manufacturing, but in comparison, there have not been many studies on its use, and much seems to be still left unknown. For example, the work methods of casting, drying and stress dispersion in the use of unshaped refractory can be improved significantly if researchers turn their eyes more to these things. On the other hand, as far as seed technologies are concerned, thanks to our predecessors, Nippon Steel has a rich heritage of outstanding technologies to its credit such as flame gunning, microwave drying, and carbon blocks for blast furnace hearths, and these have positively contributed to the performance of the company. They form a firm foundation for many more innovations to evolve.

About 30 years ago, soon after joining the company, I worked for seven years trying to develop a system for automatic repair of damaged portions of converter lining; the system was characterized by non-contact measurement of lining thickness using microwaves (mm wave), position coding, and flame gunning. It was quite an ambitious attempt, perhaps a little ahead of the time. The microwave oscillators at that time were for military use only and not available in Japan, and the processing speed and capacity of computers were far from sufficient, and naturally, the performance of programs was limited. In spite of all these limitations, and after testing the system overnight several times, we brought it up to a trial on a real converter. At the end of the day, regrettably, the system was not put to commercial use. However, knowing that a similar concept led to development of the current hot repairing system of coke ovens, fills me with some emotion.

My attempt did not succeed in practice, but the world of refractory technology is wide and deep, and there is no end to the wonders it shows us. This will be the same in the future, too.

The Host: To further stimulate R&D activities and enhance their efficiency, Nippon Steel is now actively cultivating strategic alliances with leading steelmakers outside Japan and cooperative relationships with academic and public institutes. How do you view this policy?

HIRAGUSHI: I live in a western suburb of Kitakyushu City, and, because the Kitakyushu Science and Research Park (a joint research organization between Kyushu Institute of Technology, the University of Kitakyushu, Waseda University and Fukuoka University), founded a few years ago, is only about five or six minutes' drive from my home, I often go to the library there and read the latest issues of the NSTR. I have read all the papers on the development of carbon blocks with the addition of Ti, that of stave coolers of copper casting, the advances in super-conducting materials, ceramic fiber, ceramics of ultra-low thermal expansion, the construction of a new coke oven battery, new technologies for blast furnace relining work, etc. on the R&D results in the field of refractories. All these update me with information on the technical advances that have occurred during the 24 years since my retirement, and I am impressed by the depth of research activities and their high technical level in response to current demands.

YAMANAKA: I am not well informed about the latest activities of the Refractory Ceramics R&D Lab, but generally speaking, strategic alliances with other steelmakers and industrial-academic cooperation are not easy if the culture of the partner is different from ours. Rather, Nippon Steel is an overall organization covering R&D, equipment engineering, operations and maintenance; it is an ideal cooperative partner within itself. I mean, close cooperation with related organizations inside Nippon Steel is effective and fruitful. In this relation, we have to bear in mind that fostering mutual confidence with works and other laboratories is very important, but not always easy.

IKEDA: I think such alliances and cooperation with outside organizations are very good. No doubt, the steel industry has matured and R&D activities must target higher efficiency. I remember we became a member of the International Joint Research Association on Ultra-fine Particles in the late 1980s. Through activities under this framework, we could obtain information from various research institutes worldwide, which was very helpful in advancing our technologies for unshaped refractory materials.

SHINOHARA: I am afraid my view may not be relevant as I have been away from the R&D forefront for a long time, but what do you think about the recent lack of interest in refractory seen amongst many universities? Joint research utilizing the fruits of R&D in a wide variety of technical fields may be necessary to benefit refractory technology, but I believe more efforts should be made to conduct joint research with universities into the very fundamentals of refractory.

HORIO: The importance of industrial-academic cooperation has been emphasized for quite a while. I was engaged in some of those projects, too. What is important in that type of activity is that all the parties can maintain interest in the subject and enjoy the benefit equally. In the field of steelmaking, a subject like fostering a seed technology or clarifying the mechanism of a phenomenon seems suitable for industrial-academic cooperation. I do not know specifically what subjects are being pursued under the framework, but if a difficulty that a single organization cannot overcome is cleared through cooperation between companies or between industry and academy, that will be very meaningful.

SAWANO: I believe alliance with outside organizations is indispensable for more efficient R&D. On the other hand, modesty aside, we may well claim that Nippon Steel's refractory technology is among the best in the world, and it will not always be Nippon Steel that gets the most benefit from such cooperation; the contrary may often be the case. But, what is important is to remain in the top tier throughout, and for that, it is necessary for us not to get lost in strategic alliances with other steelmakers but be sturdy to learn from their merits.

As for the cooperative relationships with academic and public institutes, we must be able to correctly evaluate the technical and academic expertise of each partner. At any rate, setting ourselves up properly is the essential requirement for any alliance and cooperation with outside parties.

The Host: To conclude, please tell us your expectations or dreams for the future, advice for our researchers or candid comments on our activities.

HIRAGUSHI: The current situation is very different from our days, as most researchers now joining the company are better qualified with master's degrees or suchlike, so this may seem like teaching my grandmother to suck eggs, but I would like them to bear in mind that learning is a life-long challenge, and to tackle their tasks promptly and in a thoroughgoing manner.

Our generation could not clarify the mechanisms of enrichment of K in priority to Na inside blast furnaces and the formation of iron whales in blast furnace hearths, and although they may be of small practical meaning now, it would be very nice to see them clarified by our successors.

YAMANAKA: The role of refractory in the steel industry is to secure product quality at each production process, and it is refractory technology that ensures our cost competitiveness. Therefore, refractory engineers are expected to follow the changes in steel production processes flexibly. How about research into composite materials to make refractory last longer, that is, use of FRP to combine and support different kinds of refractory? Carbon fiber, especially, is resistant to heat, strong and lightweight, and has excellent properties as a support material. Selective use of different kinds of FRP according to application will offer wider possibilities.

IKEDA: How about a new type of refractory that the longer you use it, the better the product steel quality becomes. You may think I am already demented. You do not have dreams unless you are keen about something. Now that I am no longer after any new kind of refractory, I am not qualified to talk about dream refractories. But, I believe steel technology will continue to progress forever, and refractory development will support that progress, just as it has done so far. I would like to see my fellow refractory researchers lead innovations of steel technology yet further.

SHINOHARA: It has been five years since I left the Nippon Steel group. Seen from outside, I am afraid the latest state of Nippon Steel's refractory technology is somewhat vague. We seldom see articles on Nippon Steel's refractory-related activities in industrial and economical newspapers. I rarely see the names of Nippon Steel staff, either, in the tables of contents or indexes of refractory-related journals.

I think the fact that Nippon Steel leads the technology of refractory for steel industry in Japan, or rather, in the world, should be more widely known. This will help attract competent researchers for the future of this field.

HORIO: In technical development, we hit a thick wall somewhere sooner or later. In the case of thin walls, they are broken by someone else beforehand, and we are untroubled by it. Our task is how to break the thick walls. To do this, all of us must be thorough and full-time thinkers, and in the midst of pursuing a subject day and night, a hint sometimes reveals itself. Honestly, I have some difficulty imaging R&D full of dreams. Instead, I believe that hard work to bring what lies beyond dreams into reality is the essence of R&D, and this is the thick wall that we must break through with all our strength.

SAWANO: Talking of R&D in terms of dreams is one thing, attaining it is quite another. Flame gunning, application of microwaves, and carbon blocks, all these were realized through long and dogged efforts in pursuit of dreams. It is more easily said than done. Sometimes you will have to fight against suggestions or pressure from people around you to quit. It is meaningless to discuss if anything is worth continuing. It is more meaningful to think how to do it than wonder if it will be successful. I think this is the key point in proceeding with R&D activities.

The Host: Thank you very much for your time. Your valuable words will serve as guidelines in our efforts to keep our banner of "the world's top refractory experts at Nippon Steel Laboratories in Futtsu," and make further progress.


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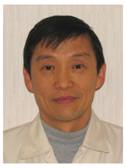
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