Heat Transfer Engineering, 34(5–6):409–419, 2013

ISSN: 0145-7632 print / 1521-0537 online
DOI: 10.1080/01457632.2012.721314

heat in history

The Heat Transfer Society of Japan, the 50th Anniversary: Retrospect and Prospect

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The Heat Transfer Society of Japan (HTSJ), herein "the Society," was founded in 1961. A series of events have been held to commemorate its 50th anniversary during 2011–2012. I participated in the events, talking and writing on the history of the Society. This article is based on the materials I collected for my roles in the events, my recollections of the past, and my personal considerations about the Society and heat transfer research. Throughout the article I attempt to explain the Society's history in the light of organizational, technological, and industrial developments that have proceeded in the universities and the industry in the past 50 years. The Society made its start as a nationwide coalition of study groups organized by the founding academics. A symbolic feat of heat transfer research at the time, known as the Nukiyama curve, is briefly described. The evolution of the Society in subsequent years mirrors the industrial developments in Japan. The Society's commitments to the international heat transfer community are summarized. Also, the issue of industry/academia collaboration is discussed. Finally, a short discussion on the present and future generations of HTSJ members concludes the article.

INTRODUCTION

The Heat Transfer Society of Japan (HTSJ), herein "the Society," was founded in 1961. To commemorate its 50th anniversary a series of events has been held in 2011 through 2012. The events are the Special Session at the National Heat Transfer Symposium in Okayama (June 1–3, 2011), the Commemorative Heat Transfer Seminar in Yokohama (September 30–October 1, 2011), the 50th Anniversary Ceremony in Tokyo (November 26, 2011), and the Special Session at the National Heat Transfer Symposium in Toyama (May 30–June 1, 2012). In addition, two international conferences were dedicated to the anniversary: the 4th International Conference on Heat Transfer and Fluid Flow in Microscale in Fukuoka (September 4–9, 2011), and the Asian Symposium on Computational Heat Transfer and Fluid Flow in Kyoto (September 22–26, 2011).

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At the Special Session in Okayama I was invited to present a summary view of the Society's evolution over the past 50 years. The Commemorative Heat Transfer Seminar in Yokohama had presentations by the colleagues on the developments of heat transfer science and engineering in the past 50 years. The topics and the presenters were Boiling and Condensation (M. Shoji and H. Honda), Radiation (R. Echigo), Forced and Natural Convection (Y. Nagano and H. Ozoe), Bio Heat Transfer (K. Tanishita), and Heat Transfer Equipment (W. Nakayama). The seminar was a full-day event webcast in Japan, followed by free discussion sessions that went deep into the evening in a casual and free-spirited atmosphere. The ceremony in Tokyo proceeded as follows: an address by Professor Nobuhide Kasagi, 2011/2012 HTSJ president; congratulatory addresses by the representatives of the government ministries, the Science Council of Japan, the Japan Society of Mechanical Engineers, and the Japan Society of Refrigeration and Air Conditioning Engineers; reading messages from Professor Richard J. Goldstein, representing ASME, Professor Graham de Vahl Davis, representing ICHMT, Professor Avram Bar-Cohen, representing the Assembly for IHTC; reading messages from two prominent scholars of the earliest days of HTSJ, Professors Kaneyasu Nishikawa and Naotsugu Isshiki; and presentation of distinguished service commendations to 157 HTSJ members, including 6 from overseas, 2 publishers, and 3 administrators. The eldest among the commendation recipients was Professor Itaru Michiyoshi, Professor Emeritus, Kyoto University, who addressed the audience on behalf of all the recipients commenting on the blessing he enjoys for his good health and spirit in his mid eighties. Professor Akira Nagashima, Professor Emeritus, Keio University, made the keynote presentation. He discussed the sustainability of the HTSJ, recalling his studies on heat transfer and thermophysical properties.

The earthquake that hit northeastern Japan on March 11, 2011, affected various aspects of our life and work. Particularly, those colleagues in the hardest hit region experienced a period of extreme agony and inconvenience. The tragedy was amplified by what happened in Fukushima Dai-ichi nuclear power plant. The accident was triggered by the earthquake, and the crisis was heightened by the subsequent onslaught of a tsunami. The public confidence in nuclear power has been shattered since then. The development of nuclear power has been one of the major motives for heat transfer science and engineering. We are now asking ourselves what roles the HTSJ can play in the relief effort for the damaged plant in particular, and in the national effort to restructure the energy supply chain for a better future in general. The sessions to discuss this urgent agenda were held at the symposia in Okayama and Yokohama, and was held again in Toyama. Professor Shigenao Maruyama has been taking the initiative in organizing the sessions and setting the agenda, as the location of his home university, Tohoku University, made him a natural choice for the task. As if administered by Mother Nature, these sessions awoke our consciousness about the missions of heat transfer science and engineering in the midst of the celebratory atmosphere of the anniversary.

In writing this article I used some of the materials from my talk in Okayama, but felt the need to write anew for international readers. The sections are arranged as follows. The next section, "In the Beginning," describes how the Society was started, and one of the prominent achievements of heat transfer research that is now known as the "Nukiyama curve." In the section "Evolution of the Society in Perspective" I project the growth of the Society onto the charts of industrial developments in Japan. The section "International Relations" summarizes the functions of the Society as a window to the international heat transfer community. The section "Industry/Academia Collaboration" describes the changing environment for the heat transfer research in the industry and the university campuses. In "Concluding Notes" I present a short essay on the present and future generations of HTSJ members.

IN THE BEGINNING

It may be appropriate to insert an introductory remark about the Japanese university system, which has undergone adjustments to changing social environments. Japan's modern educational system was founded a few years after 1868, the year marking the start of Japan's modern-era government. During the period from the late 19th century to the early 20th century the centers of higher learning and research were established by the government in major metropolitan areas; their names indicate the locations of the universities, such as Tokyo, Kyoto, Tohoku, Kyushu, Hokkaido, Osaka, and Nagoya. They were called the "Imperial Seven." Tokyo Institute of Technology also has its origin in a technical college established by the government in the late 19th century. Keio and Waseda universities had their origins in the schools established in the 19th century by the prominent leaders in business and politics. There are more schools that have earned their prestige since the early years. Commonly adopted in these schools was the "koh-za" system, which had its origin in German schools of the 19th century. The "koh-za" is composed typically of a full professor, an assistant professor, and a few assistants, and it had autonomy in choosing research topics and conducting research. After World War II the university system underwent a shakeup, and many universities were born mostly from those that had formerly been technical colleges. In spite of such changes at the national level, the "koh-za" system had been retained in the old universities until later years. In the early years the source of research fund for the "koh-za" was the Ministry of Education, and the outlay was sufficient enough for a professor to run the laboratory on that professor's own terms. The funding situation gradually changed during the 1980s and the 1990s, and the need to diversify the sources of funding has increased. With a certain phase lag from the change of funding situation, the "koh-za" system has been replaced by the current system, which is designed to encourage young faculty members to assume independence from their seniors and to take more initiatives in launching research programs.

The "koh-za" was the basic organizational unit in many engineering schools when the Heat Transfer Society was organized. I think the initial growth of the Society could be attributed partly to the "'koh-za" system, which fostered personal bonds among the professor, research staff, students, and alumni. Those of younger generations came around their mentors to help the startup efforts. In addition, the former imperial universities served as the conduits of technological modernization in postwar Japan. The professors in these universities understood what needed to be done in basic engineering research to help renovate the industrial base. Heat transfer research was recognized as one of the urgent needs for rebuilding the industrial base. However, such general understanding did not lead to any research project of national scale. The "koh-za" system tended to leave researchers holed up in their own laboratories. Meanwhile, researchers felt the need to make sure that their research programs fit in the national industrial needs. Information sharing in a loosely bound study group was perceived as the most desired form of collaboration between researchers. In 196l, the plans for such study groups sprang up spontaneously in Tokyo and Kyoto/Osaka areas. The two plans were eventually merged into a nationwide organization. On November 22, 1961, the Society was inaugurated, and Professor Akira Kobayashi, then director of Toyota Central Research Laboratory, was elected as the first president, along with the first-term officials. The officials, who were in essence the executive committee members, included five professors from the University of Tokyo, two from Kyoto University, one each from Osaka, Hokkaido, Tohoku, Kyushu, Tokyo Institute of Tech, and Nihon, and four from the different government laboratories. The role of auditor was entrusted to two individuals from the industry.

These founding members agreed to develop the Society into something different from the existing professional societies in several respects. The bureaucratic overhead was reduced as much as possible. The administrative jobs were handled by the key members in turn. Here, the "koh-za" provided convenience in assigning secretarial chores to its secretary or assistants. The autonomy of the regional groups was respected; that is, the central authoritative atmosphere had to be eliminated. Informal and frank discussions were encouraged at seminars and symposia. These characteristics of the Society have been inherited to this day. The Japanese name of the Society was literary "study group" (*kenkyuu-kai*). The later growth of the Society together with the need to strengthen the relationships with other societies and the Science Council of Japan led to the adoption of a more formal name "Society" (*gakkai*) in 1991. In 1995 the HTSJ was formally registered among other science and engineering societies in the list of the Ministry of Education, Science, and Technology.

Most of the founding members were vigorous youths when they started HTSJ. Before them, there had been several scholars who left their footprints in heat transfer science and engineering. Most notable among them was Professor Shiro (pronounced *Shiro-h*) Nukiyama, shown in Figure 1. Professor Nukiyama was a professor at Tohoku University when he and his team conducted their landmark experiments during 1929–1933.

Figure 1 Professor Shiro Nukiyama (1896–1983).

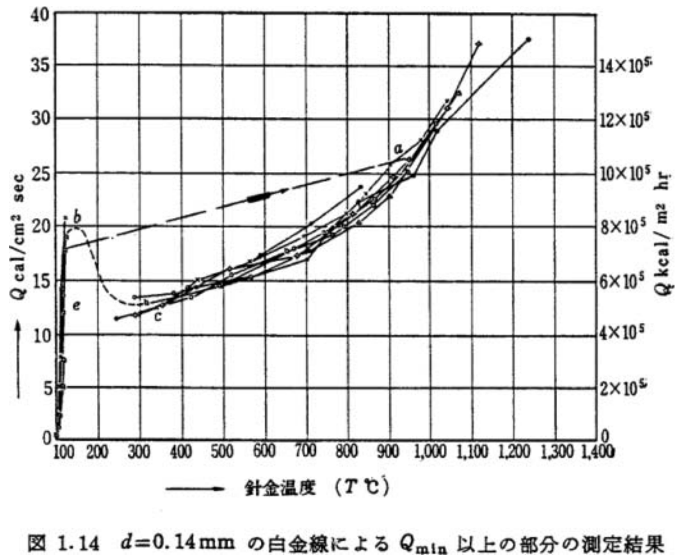

Figure 2 A Nukiyama curve obtained with a 0.14-mm-diameter platinum wire in saturated water. The horizontal axis is the wire temperature in °C, and the vertical axis is the heat flux in cal/cm^2-s (left) or kcal/m^2-h (right). (1 cal/cm^2-s = 4.187 W/cm^2, and 1 kcal/m^2-h = 1.163 W/m^2.) The figure caption in Japanese reads "Fig.1.14 Measured results for the portion above Q_{min} obtained on a d = 0.14 mm platinum wire" [1].

Figure 2 shows one of the graphs published in the *JSME Journal* in 1934 [1]. The graph shows a complete boiling curve covering the nucleate pool boiling regime, the burnout point, and the film boiling regime. The data were obtained with a thin (0.14-mm diameter) platinum wire immersed in a pool of water and heated by passing electric current. I had an opportunity to learn some details of the experiment when I prepared my talk for the history session of the ASME/JSME Thermal Engineering Joint Conference in Honolulu in 1991 [2]. There was a book that collected the papers and memoirs of Professor Nukiyama. It was edited by Professor Yasusi Tanasawa and published by the group of of Nukiyama koh-za graduates in 1969 [3]. I found this book greatly helpful to my work for Honolulu conference. The use of a thin wire of high-melting-point material was a key to the success of obtaining the data beyond the burnout point. Cooling on a relatively large surface area of a thin wire helps to suppress the maximum temperature in the wire. In addition, the high melting point helps to avert melting of the wire. The concept seemed a natural one, but no one had made the actual attempt before Professor Nukiyama. Although the concept was logically sound, however, its implementation was another matter. I quote from what Professor Tanasawa reflected in [3]. This part was written in English, and hence, the quotation is verbatim.

> On reflection, I remember we made some experiments on the point of maximum boiling rate from 1929 till 1933. Mr. Kisuke Kurose, our assistant, who was in charge of our experiment, threw light on nickel wires and platinum wires in a thick glass vessel generally used for a storage battery with a flash light in hand, walking around on the water splashed concrete floor in rubber boots. Professor Nukiyama in a white robe gazed at

steam bubbles generating from thin wires. It was regrettable that many fine wires were burnt out before the maximum point was reached. A thick glass vessel heated through sand bathing was sometimes broken into two with cracks. Every time a vessel was broken, several reels of oscillogram were wasted. But in the course of repeated failures, we grasped somehow a knack of difficult experiments and could verify the existence of the maximum point and the minimum point as we had expected backed up with many experimental data.

Professor Tanasawa further reflected that the experimental program was conceived out of scientific curiosity without any application in mind. At the time they reported the data around 1934 in Japan, few people paid serious attention. But the researchers were caught by surprise when they learned that their data received attention elsewhere. Again, a quotation from Professor Tanasawa's recollections:

Immediately after the 2nd World War, an American chemist, Dr. Fox, called on Professor Nukiyama. Dr. Fox asked him earnestly how the research on the point of maximum boiling rate had been developing in Japan and what results were obtained. At that time, Professor Nukiyama and I, who happened to sit with him, could not understand what Dr. Fox meant by his question and had to answer him that we had stopped the research. We learned, however, after a considerable time after our meeting, that an extensive study on the boiling heat transfer was being conducted in the U.S.A., because the cooling performance of a boiling water type nuclear reactor was restricted at the point of maximum boiling rate, but that a complete solution had not yet been obtained.

Many heat transfer researchers outside of Japan came to know this experimental feat through the textbook *Heat Transfer* authored by Professor Max Jakob and published in 1949 [4]. Professor Tanasawa continued: "In his book [4] on page 655, it was written: 'Nukiyama [1], using a platinum wire, 0.14 mm in diameter, seems to have been the first to succeed in obtaining a substantially complete boiling curve with a maximum boiling rate at $\theta_s \approx 45°C$.'" The entire curve came to be called the "Nukiyama curve." Professor Nukiyama received the ASME Max Jakob Memorial Award in 1968.

From the 1950s onward, the boiling heat transfer research picked up momentum in Japan partly because the development of nuclear power reactors became a national endeavor. At Tohoku University some of the graduates of the Nukiyama "kohza" resumed and expanded boiling research programs. Professors Tanasawa and Takeo Takeyama were senior members of the Tohoku group. Elsewhere, the University of Tokyo and Kyushu University were early strongholds of boiling heat transfer research. Because of its historical role as a national center of technology developments, the University of Tokyo provided the government with the service of engineering faculty members as overseers of nuclear technology developments. Professor Hideo Uchida played a key role in the early phase of this effort. Later, Professor Yoshiro Katto joined the faculty, and he and his graduate students established a long tradition of boiling heat transfer research there. At Kyushu University the research was motivated mainly by the development of high-temperature, high-pressure boilers for fossil-fuel-powered plants. Professors Kiyoshi Yamagata and Kaneyasu Nishikawa formed a senior/junior pair that played a key role in establishing the tradition of boiling heat transfer research in Kyushu.

The Heat Transfer Society of Japan established the Nukiyama Memorial Award at the juncture of its 50th anniversary in memory of our outstanding pioneer. The first award was presented in 2012.

EVOLUTION OF THE SOCIETY IN PERSPECTIVE

The HTSJ started with 170 members plus 3 corporate support members in 1961. As of 2011, it has 1,118 members and 43 corporate members. The growth of membership over the past 50 years is shown in Figure 3, where the data are normalized by the membership of 2000. The years when the major events were held are also indicated. Among the events, the legal matters concerning the Society's name and registration were already mentioned in the previous section. The first national heat transfer symposium was held in Kyoto in 1964, with 29 presentations and 235 participants. Since then, the symposium has been held every year, rotating the meeting location around the major cities. The annual symposium is the most popular event of the Society. The first major international event for the Society was the fifth International Heat Transfer Conference (IHTC) held in Tokyo in 1974. The first Japan–U.S. Heat Transfer Seminar was held in Tokyo in 1980. The IHTC will return to Japan in 2014.

From the curve of Figure 3 we observe that the Society has undergone two phases of growth; a high growth phase that spans the 1960s to the 1980s, and a flat growth phase of recent years.

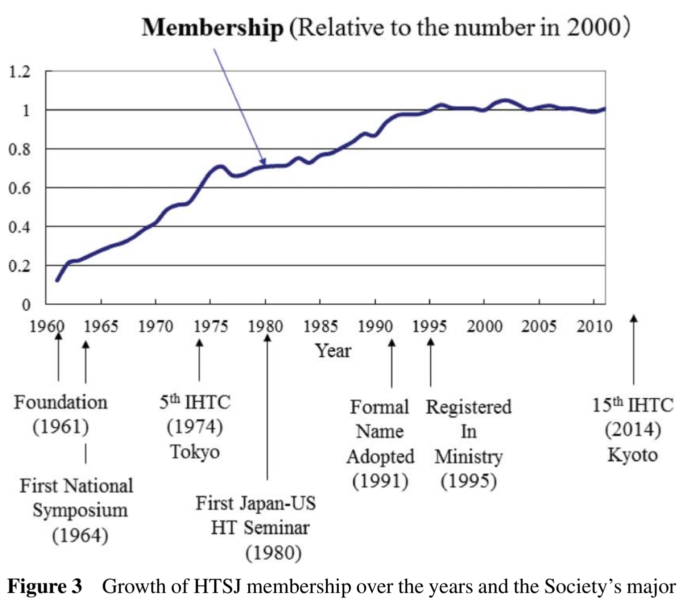

Figure 3 Growth of HTSJ membership over the years and the Society's major events. (Color figure available online.)

The general feature of the membership curve coincides with that of Japan's population curve. Hence, the arrival of the flat phase appears inevitable in this respect. A more fundamental factor is the diversification of technological and scientific interests that has been accelerated in recent decades. The Society for basic science and engineering like heat transfer has had to see human and funding resources being diverted to other emerging sectors. When the Society started, the development of the nation's industrial base was a major objective of basic science and engineering.

In Figure 4 the curves representing two base industries are superposed on the membership curve [5]. One of the curves shows the production volume of petrochemical products. The other is the power generation by nuclear reactors. Both data sets are normalized by the respective numbers of 2000. The design of large systems requires the accumulation of basic science and engineering data. For example, the development of boiling-type nuclear reactors needed the data on boiling heat transfer on fuel rods. Petrochemical plants are in essence large heat exchanger systems, and their design is based on fundamental understanding of forced convection and phase-change heat transfer. Besides these two examples, fossil-fuel power plants, power delivery networks, steel mills, coal mines, and transportation systems needed renovation and upgrading. Buildup of these heavy industries became the national priority. The engineering schools bore the responsibility of supplying engineers for the national effort. Heat transfer was regarded as one of the key disciplines, and the heat transfer "koh-za"s of various universities became popular destinations for students to perform graduate and postgraduate studies. The growth of the Society's membership in the 1960s and the 1970s resulted from the growing population of heat transfer engineers in the industry, as well as that of researchers in the universities and the government laboratories.

Once the industrial infrastructure reached a certain level of maturity, the consumer industries were the next driver of economic growth. Refrigerators and air conditioners became the necessary items for households. The curve showing the production volume of air-conditioners is superposed on the membership curve in Figure 5. According to the statistics [5], the production volume of air conditioners increased fivefold from 1970 to 1980. Automobiles also became the rapidly growing items, and their production doubled during the same period. The design and production of compact heat exchangers held the key to the competitiveness of these consumer products. The efforts to make heat exchangers more compact were sustained by engineers, many of whom were the graduates of heat transfer "koh-za"s. In this period several manufacturers in the air-conditioning and refrigeration industry came to join the Society as corporate support members. The representatives of these companies were the alumni of heat transfer "koh-za"s, and they served as the industry/academia liaisons, transmitting industrial needs to their academic colleagues through the Society's seminars and committees.

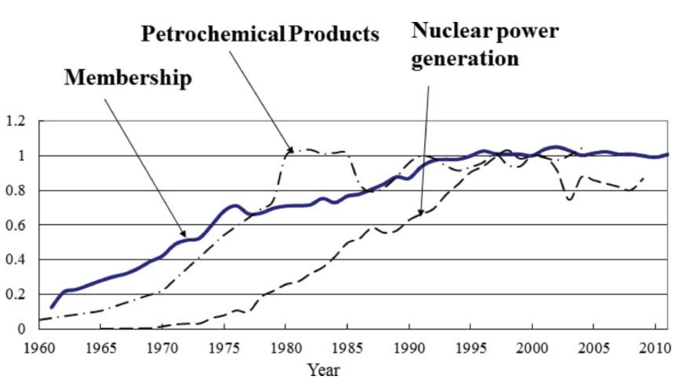

Figure 4 Production volume of petrochemical products and the capacity of nuclear power generation in Japan, superposed with the HTSJ membership curve. (Color figure available online.)

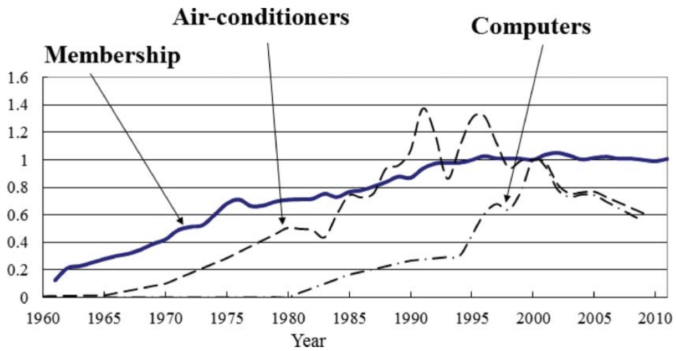

Figure 5 Production volume of air conditioners and that of computers, superposed with the HTSJ membership curve. (Color figure available online.)

Arrival of the information age brought wide and deep impacts on various aspects of our life and work. The most visible benefit for science and engineering was brought by the development of large-scale high-performance computers that enabled the analysis of complex physical processes and the design of large complex systems through numerical simulations. With increasing speed and capacity of calculations rendered by these computers, the heat generation rate had increased. In the 1980s the problem of heat generation in computers became so serious that cooling computers emerged as one of the key areas of heat transfer research. Meanwhile, advances in electronics technology engendered various classes of electronic devices and equipment for diverse applications. Desktop computers, laptop computers, and mobile phones came into being as the tools of everyday use. So-called embedded devices made refrigerators, air conditioners, automobiles, and other machinery more efficient and smooth-running. Proliferation of electronic devices and equipment has led to diversification of heat transfer problems arising from them. Researchers and engineers working on thermal management of electronic equipment have rapidly increased. Figure 5 includes the curve showing the production volume of computers. From the comparison with the membership growth curve we surmise that by the time the industry needed human resources to tackle diverse heat transfer problems, the population of heat transfer engineers has grown to a sufficient level owing to the investments made earlier in the heat transfer "koh-za"s. The session for electronics cooling papers has become a regular feature at the national heat transfer symposium since the 1980s.

From Figures 3–5 we observe that the various growth curves are flat to the right of around 2000. For the production volumes of industrial products, their saturations can be partly attributed to the shift of manufacturing facilities to overseas locations. Another major factor is the stagnant economy after the bust of the bubble economy at the start of the 1990s. Such economic developments were overlapped by the emergence of new professional societies that carved out their own shares from the population of scientists and engineers. Some of these new societies are offshoots of the traditional societies but more focused on specific areas of research: a society of multi-phase flow, that of thermophysical properties, and that of flow visualization are some examples. Others are the responses to the developments of new frontiers of science and technology such as micro- and nanoscale technologies, or renewed needs for energy-related research, such as solar energy utilization. Thus, for the existing societies the environment has changed a great deal, and the membership saturation is not a problem of the HTSJ alone. To think about the future of the Society we first accept the environment we are placed in, then consider the meaning of growth in years ahead. In my talk at the symposium in Okayama and in the article for the *HTSJ Journal* I proposed my view on the issue of "how the Society will adapt to a changing environment." The following is an excerpt.

- The Society will not get back on the fast growth track. This is not a pessimistic view, but recognition of the historical consequence. We had passed the phase where the primary objective of research was aligned with the development of basic industrial infrastructure. The design of large systems constituting the industrial infrastructure required solid understanding of the physics involved in their operations. Such industrial needs provided an environment for the academics to pursue scientific interests in narrowly defined modes of heat transfer phenomena. The "koh-za" was often identified with the mode of heat transfer on which its research was focused, such as forced convection, boiling, condensation, radiation, etc. Furthermore, long term research was permitted in the era of heavy industry developments. The "koh-za" system served well in conducting long-term research. When the professor reached the retirement age, the assistant professor took over the "koh-za" and continued their research. In this way the theme and the methodology of research have been carried over from one generation to the next. In the meantime, the "koh-za" produced graduates, and some of them chose to pursue academic careers in the expanding university system of the 1960s through the 1980s. Many of them continued to work in the same field of research of the "koh-za" where they came from. The national heat transfer symposium still has many presentations in the mode-specific sessions such as forced convection, boiling, condensation, radiation, etc. As pointed out in the previous paragraph, several factors converged to end the era of quantitative expansion, including the membership of HTSJ. Also, the "koh-za" system had been dismantled over a period of about ten years since the mid-1990s. Obviously, we have no luxury of assuming the future as an extension of the past.
- The end of quantitative expansion is not the end of progress. Ample opportunities for heat transfer research are opening up in various emerging fields of science and technology. New materials, renewable energy, biotechnology, and novel electronic devices are some samples of rapidly growing fields which cannot be developed without the commitments of heat transfer researchers. The HTSJ already has many members who have been working on the topics of these emerging fields. The national heat transfer symposium has seen the increase of the sessions devoted to new subjects. Since the 1990s the session on "Molecular Dynamics Simulation" has become a popular feature of the national symposium. Also, the sessions for solar energy, environment-friendly refrigerants, heat transfer in micro-gravity, biotechnology, food processing, and agriculture have been introduced. These subjects are interdisciplinary in their nature. In an attempt to participate in the development of new science and technology one has to acquire at least introductory knowledge of the emerging field of one's interest, and develop a research program which responds properly to the arising needs for heat transfer research. A joint research program involving researchers and engineers of different disciplines is becoming a common format of collaboration. In such environment one finds few seniors to whom one solicits guidance as in the "koh-za" era. Instead, researchers have to chart their own course of research by absorbing interdisciplinary knowledge and through consultation with their colleagues in other fields. Communications between scientists and engineers of different disciplines are gaining unprecedented importance. Just as different parts of the world are increasingly integrated by the Internet, different disciplines of science and engineering are going to be more tightly coupled. We are now in the phase of horizontal integration after we came through the phase of vertical growth. Obviously, we need a new measure of growth or success in place of the quantitative growth curve which has served as a central measure in our value system for so long. We have not yet worked out any concrete idea about a measure of growth in the new era. Neither have we worked out an action plan by which we stimulate the growth of HTSJ on a possible new measure of success. However, one thing is obvious and assuring. That is, the importance of heat transfer research will never diminish but increase in diverse fields of science and engineering. The HTSJ can play a role of the information hub where diverse proposals for heat transfer research flow in and research results flow out in different directions for potential applications. At the national symposium in Toyama (May, 2012) a special session was held to discuss the future of the Society.

INTERNATIONAL RELATIONS

In the postwar economic situation an overseas trip was an extremely expensive venture for Japanese researchers. The currency rate was fixed at 360 yens per U.S. dollar until 1971. At the first International Heat Transfer Conference held in 1951, in London, Professor Tokuro Mizushina, Kyoto University, was the only presenter from Japan. In the 1950s helping hands came mainly from the United States in the form of scholarships for Japanese researchers. The Fulbright scholarship sent many scholars to the United States. Also, Germany and France provided the opportunities for overseas study through their funding agencies. By the time the HTSJ was founded the economic situation had improved somewhat, and the Science Council of Japan (SCJ) had some budget to promote international interactions. Since the HTSJ was registered as a subordinate branch of the SCJ at the outset, it received a dividend of improved situations. Overseas stays or trips to meetings in the postwar era gave the HTSJ founding members the opportunities to get acquainted with their seniors and peers in the United States and Europe. Thus, the developed personal bonds led to the early admittance of Japan into the international heat transfer community.

It was a few years before the fourth International Heat Transfer Conference (Paris, 1970) that the Assembly for the IHTC ("the Assembly") was formed. From Japan, professors Niich Nishiwaki, University of Tokyo, and Tokuro Mizushina, Kyoto University, joined the Assembly. Later, the Assembly voted for Tokyo to be the site of the fifth IHTC in 1974. The organizing committee was formed under the umbrella of SCJ in order to smooth the process of fund raising and other preparations. The committee members were the key members of HTSJ: chair, Niichi Nishiwaki (Tokyo); vice-chairs, Hideo Uchida (Tokyo), Fujio Tachibana (Tokyo), Tokuro Mizushina (Kyoto); secretary, Yoshiro Katto (Tokyo); paper review, Yasuo Mori (Tokyo Institute of Technology); program, Satoshi Sato (Kyoto); proceedings, Mitsunobu Ogasawara (Osaka). There were other well-known professors who participated in the organization efforts through various functions or as the representatives of the collaborative societies such as Nuclear Energy, Space and Aeronautical, Air Conditioning and Refrigeration, and Architecture. The conference was held in Tokyo during September 3–7, 1974, with 8 keynote presentations, 330 paper presentations, and 649 participants. The HTSJ has continued to serve as an organizational window for the IHTC Assembly to this day.

In 1961, the same year as the HTSJ founding, the Agreement of Science and Technology Cooperation was signed between Japan and the United States. Twenty years later the heat transfer researchers of both countries used this channel to stage the first Japan–U.S. Heat Transfer Seminar in Tokyo. The funds came from the Japan Society for the Promotion of Science (JSPS) and the U.S. National Science Foundation (NSF). Figure 6 is a group photo taken on that occasion. Only those professors on the front row are identified here: from left, Nishikawa, Westwater, Sato, Rohsenow, Katto, Yang, Mori, Goldstein, Ueda, and Aung. Other well-known professors were seen in the back rows. The meeting, entitled "Heat Transfer in Energy Problems," was held during September 29–October 2, 1980, in Tokyo, with 57 participants from Japan and 13 from the United States. Since this first meeting the Japan/U.S. Heat Transfer Seminar has been held on various themes, and has become an additional channel of international interactions for HTSJ members.

As noted previously, the initial development of international relations for the HTSJ depended much on personal contacts

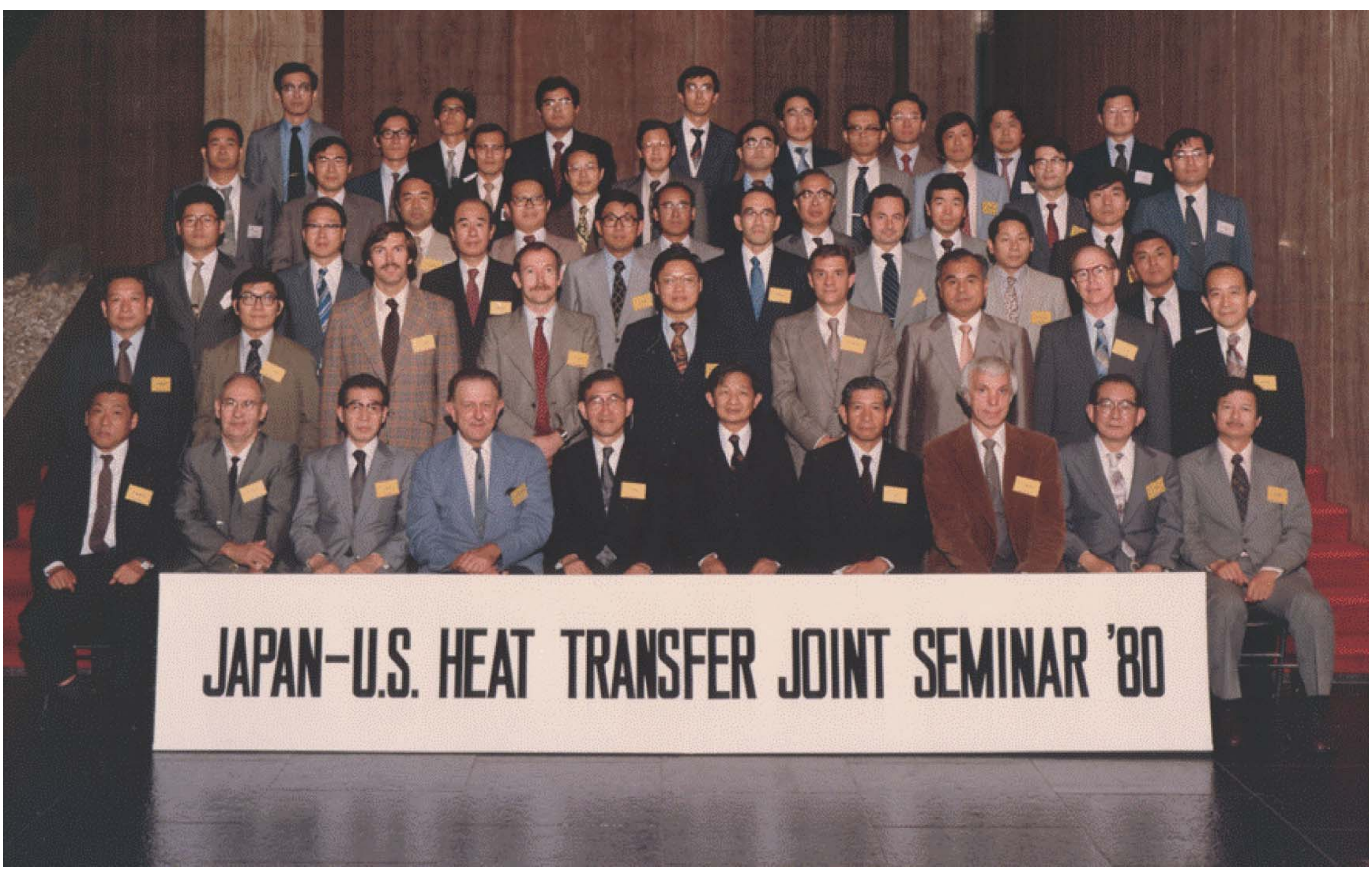

Figure 6 A group photo at the first Japan–U.S. Heat Transfer Seminar, Tokyo, 1980. (Color figure available online.)

cultivated between the Japanese and U.S. researchers. Some U.S. researchers came to stay in Japan for extended periods on various occasions, and contributed to building up networks of researchers in both countries. Notable among them were Professor Warren H. Giedt, University of California at Berkeley (later Davis), and Professor Wen J. Yang, University of Michigan. Professor Giedt came to stay at the University of Tokyo for 6 months in 1963. His name was already known to Japanese researchers through his textbook *Principles of Engineering Heat Transfer* [6] translated by Drs. Susumu Yokobori and Osamu Kuga. Professor Giedt came back to Japan several times, and also hosted the stay of more than 10 Japanese researchers at his laboratory over the years. Professor W. J. Yang had an experience of graduate study in the laboratory of Professor Fujio Tachibana at the University of Tokyo. His proficiency in Japanese language won him the acquaintance with a broad range of heat transfer researchers in Japan. Many researchers came to stay in his laboratory at the University of Michigan. He served as an international bond not only for Japanese researchers but also those in other Asian countries. He and Professor Yasuo Mori, Tokyo Institute of Technology, organized the first ASME/JSME Thermal Engineering Joint Conference in Honolulu during March 20–24, 1983, with 250 papers and 360 participants. With participants from Asian countries the conference became a first of the Pan-Pacific conferences that are now routinely held on various themes. Professor Yang established the HTSJ Young Researchers Prize in 2001.

For the International Centre for Heat and Mass Transfer (ICHMT), originally established in Yugoslavia and now located in Turkey, the Japanese researchers made commitments in the early phase. A letter from Professor E. A. Brun, University of Paris, then President of the IHTC Assembly, to Professors Nishiwaki and Mizushina inquired about the commitment of Japanese researchers to the summer seminar planned in Yugoslavia in 1967. The HTSJ became the official interface with the Yugoslavia seminar. Shortly after, the seminar grew into a center with an overseeing structure named the Scientific Council. Professor Masaru Hirata, University of Tokyo, performed an important function of communication with the center organizers and made the arrangement within HTSJ. In 1971 professors Mizushina, Mori, and Nishiwaki formally joined the Scientific Council. Professor Mori served as president of the Scientific Council during 1990–1994. Professor Kenjiro Suzuki, Kyoto University, served as chairman of the Executive Committee (2004–2006), and Professor Nobuhide Kasagi is serving as vice-president (2010–2014). Currently, Japan has 19 members in the Scientific Council.

The achievements of Japanese researchers have been internationally recognized by prominent awards: ASME Max Jakob Memorial Award, to S. Nukiyama (1968), N. Nishiwaki (1979), and Y. Mori (1988); ASME Heat Transfer Memorial Award, to Y. Mori (1982) and W. Nakayama (1992); Luikov Medal, to Y. Mori (1988) and M. Hirata (2004); ASME Melville Medal, to A. Sakurai, M. Shiotsu, and K. Hata; ICHMT Fellowship Award, to W. Nakayama (1996) and K. Suzuki (2002); ASME Touloukian Award, to A. Nagashima (2000) and K. Watanabe (2009); the Nusselt-Reynolds Prize, to M. Shoji (2005); and the William Begell Medal, to N. Kasagi (2010).

The HTSJ has introduced the international session at the national heat transfer symposium since 1995. The invited speakers at the 1995 session were Professor Z.-Y. Guo, Tsinghua University, China, and Professor J. M. Hyun, Korean Advanced Institute of Science and Technology. In 1996, Professor S. H. Winoto, National University of Singapore, and Professor G. J. Hwang, National Tsinghua University, Taiwan, were invited. In subsequent years invitations have been extended to renowned scholars in other countries. The HTSJ also initiated the International Forum of Heat Transfer in 2004 and has made it an annual event. The 2004 forum was held in Kyoto, with 8 keynote presentations and 150 paper presentations. This forum is focused on hot topics such as nanoscale heat transfer, and is designed to promote intimate discussions between participants in a Japanese-style informal atmosphere.

INDUSTRY/ACADEMIA COLLABORATION

Scanning through the issues of the *HTSJ Journal* I am impressed by how the issue of industry/academia collaboration has occupied the minds of members in both academia and industry. Many articles on this issue have been written by various authors over the years; the first issue of the journal already had one. In the early years direct collaboration was difficult, at least on the surface. In the postwar atmosphere of the Japanese campuses, academic independence was given top priority, and any overt commitment by the faculty to a corporate sponsored research project had to be avoided. Furthermore, as mentioned previously, the "koh-za" system guaranteed autonomy in research; hence, if one chose, one could do any research without regard to the industrial needs of the day. However, there were collaborations in broader interpretations, rather than direct joint research efforts with industrial partners. In the era of industrial infrastructure development the results of basic research produced by the academics were useful in some ways to engineers who needed heat transfer data in the design of large systems. Furthermore, some of the academics were recruited by the government ministries to serve on the committees that oversaw the national industrial development efforts. On the committees they could hear research needs from the industrial members and acquired information on the technologies in need. Such knowledge was fed to the plan of research programs in the campus. Most importantly, there were personal bonds fostered by the "koh-za" system between the academics and their former students. In the Japanese engineering schools everyone has to belong to a particular "koh-za" at his/her fourth year of undergraduate studies and experience a one-year research term. (This system is still kept, even after the "koh-za" was disbanded to current more atomic units.) Thus, every engineer feels personal bonds to his/her mentor, research staff, and those seniors, peers, and juniors who came through the same "koh-za." It has been common that those in the industry come back to their home "koh-za" and ask for technical guidance from their former mentors. Such personal interactions do not entail any financial commitment on the part of the industrial employer, let alone legal arrangement for information sharing. Informal interactions were relatively easy in the early years when the technical information was concerned with basic heat transfer physics; hence, the interaction involved least the possibility of conflict of proprietary right.

The situation has changed gradually since around the mid-1970s. Consumer markets grew, and the competition between manufacturers intensified. Protection of proprietary information has become a matter of concern for researchers and engineers in the industry. Meanwhile, the industry developed its research potential thanks to the expansion of graduate schools since the 1960s. Major manufacturers developed their pool of heat transfer researchers, and the work for current products could be handled by in-house research. The results of research are often reported at the national heat transfer symposium, but after the patent filings are processed, to protect proprietary information. For the academics, heat transfer problems arising from consumer products are often difficult to work on due to involvement of many factors. Constraints by manufacturing and assembling technologies and cost considerations need to be understood. Actual geometries of heat transfer surfaces and coolant paths are complex, so that modeling methodologies need to be developed. The situation makes it difficult to design research programs to be completed in a year or two. This is particularly challenging for a professor who has to assign research programs to fourth-year undergraduates who come to experience one year of research. On the other hand, the funding situation for the academics has changed. The days of free funding for the "koh-za" are gone. Instead, one has to apply for funding with a proposal of a specific research program. There is a way to get large funds from the Ministry of Education, Science, and Technology: that is, to form a group with colleagues and propose a large umbrella project. The referee committee of the ministry is staffed largely by those in the fields of basic science, mostly physicists and chemists. Naturally, proposals on basic science subjects are assumed to have advantages. Besides, the interest in fundamental physics has been a strong undercurrent in the minds of engineering faculty members since the era of industrial development, and it is now strengthened by the rapid growth of nanoscale sciences. Today, there are many research topics reported at HTSJ meetings and symposia that border on those of fundamental physics. Such a bent on physics is viewed favorably by those researchers in the industry who look for revolutionary ideas for future product development. On the other hand, there are engineers who need solutions to somewhat more mundane engineering problems. For them the current trend of increasing weight on fundamental physics seems to mirror a widening gap between industry and academia. In an attempt to promote industry/academia communications within the HTSJ I proposed in 1994 the formation of a committee named Forge Industrial Liaison to Generic Academic Problems (FILGAP). The objective is to encourage industrial members to make efforts in narrowing the industry/academia gap. The reason for asking industrial members to make steps toward academia is that they are in a position to do the job of tailoring actual engineering problems into those suitable for academic studies. Some colleagues have taken my proposal seriously, and have stimulated discussions among the HTSJ members through the FILGAP committee activities. The job is understandably quite challenging, and will need some more time for various ideas to converge to any concrete action plan.

While the industry/academia gap seems widening as described in the previous paragraph, there have been developments that act to close the gap. One of the developments is the increasing migration of researchers from the industry to teaching jobs in the campus. The population of heat transfer researchers in the industry had increased during the 1960s through the 1980s almost in phase with the growth of HTSJ membership (Figure 3). Since the late 1980s onward an increasing number of researchers have reached their fifties. The mid-fifties is the age customarily set for Japanese companies to arrange the relocation of their mid-level employees to somewhere outside the company. It has become a customary pattern that a researcher who made enough research records in the industry finds a teaching job in a university. By the time such migrations became possible, the campus atmosphere had drastically changed from that of the 1950s and 1960s. It became more hospitable to corporate funding of academic research. Particularly in the bubble economy of the late 1980s, the amount of corporate donations to universities increased. For those researchers who landed teaching jobs, an arrangement was often made to attach research funds from their former employers for several years after the job landing. In this way, the knowledge flow from the industry to the campus has been increased, but the beneficiaries are mostly students who experience the work on topics carried over by their mentors from the industry. Interactions between those arrivals from the industry and those home-grown individuals are less likely, as far as research work is concerned. However, there are some cases where a group project involves both industry-bred and home-grown researchers, necessarily promoting their dialogue.

There are still some other channels through which the academics can learn the state of the art of technologies in the industry. The Japanese graduate schools have traditionally admitted the application of a doctoral thesis from an individual in the industry without requirements for school attendance. The thesis is examined by the panel of examiners in the light of its academic merit, and the applicant undergoes oral examinations and thesis defense sessions. The occasion of thesis examination is also the opportunity for the examiners to learn the industrial needs, as the thesis contains background information of the work in the industry. This type of interactions has been enhanced by another doctoral program that has become popular since the mid-1990s in many engineering schools. In the recent program the applicant is required to come to work at the thesis adviser's laboratory in hours of one's convenience, and at the same time attend requisite classes. The interactions between the applicant, the adviser,

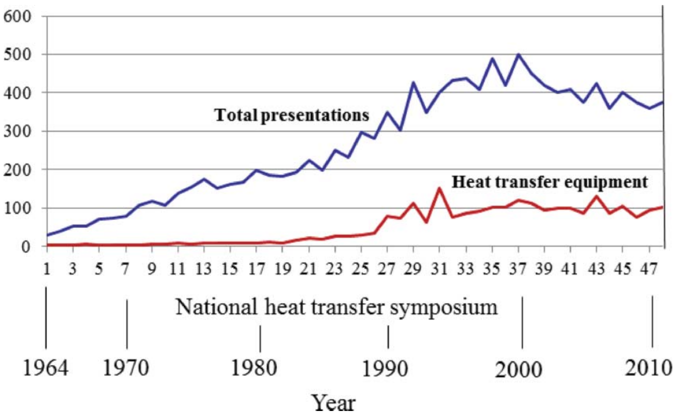

Figure 7 Number of presentations at the annual Heat Transfer Symposium: the total number and the number of reports on heat transfer equipment. (Color figure available online.)

and the laboratory staff become personal, and in many cases the laboratory work involves a few graduate students, giving them a taste of industrial research work.

Today, the presentations at the annual national heat transfer symposium spread over a wide range of topics, from fundamental physics of nanoscale heat transfer to thermal design of industrial products. Figure 7 shows the trends of presentations at the national symposium. In phase with the growth of HTSJ membership, the number of total presentations rose until the mid-1990s, and has settled at a level of 400 in recent years. Among these the reports on heat transfer equipment amount to around 100. The ratio 4 to 1 is considered to indicate the current level of interests in engineering heat transfer problems held by Japanese heat transfer researchers.

CONCLUDING NOTES

In 1961, I enrolled in the graduate school of the Tokyo Institute of Technology, and joined the "koh-za" of Professor Yasuo Mori. Racing my thought from the past to the present I have an impression that the most impressive are the advances in research tools. I remember the work I did with a couple of fellow students in one summer. We worked as research assistants for Professor Mori to solve the problem of forced/natural mixed convection heat transfer on a flat plate. The equations are nonlinear, and the Runge–Kutta method was employed to obtain numerical solutions. The tools available for us were several manually operated calculation machines. After this experience, rapid evolutions of calculation tools have followed in the subsequent years. Calculation machines driven by electric motors came and went. Carrying a box of punched cards to the computer center was the next experience. Today, my desktop computer can do almost all the calculations I need to perform for my research work. My thesis work involved the measurement of air velocity of the order of 1 m/s and less [7]. I found a Chattock tilting pressure gauge in the dusty attic of the laboratory building, cleaned it, and connected it to a Pitot tube. It was extremely sensitive to atmospheric temperature and pressure. The building admitted external air leaking through the ill-fitted windows and doors. I had to construct an elaborate structure around the gauge to shield it from temperature and pressure fluctuations. Today, the laboratories of the mechanical engineering departments of the Tokyo Institute are housed in a modern building and have stable internal environment. In addition, the advent of particle image velocimetry has made the measurement of complex low-speed air flow a far more efficient undertaking. In my student days I often wandered into the engineering department's library in search of literature. The library was located in the basement, and the air was damp, making the search work sometimes uncomfortable. Today, I can download a paper published decades ago to my laptop anywhere I work.

Convenience, efficiency, and comfort brought by the technological advancements are certainly welcome and joyous experiences for the researchers of my generation. I wonder, if I were born into the current generation of graduate students, how would I perceive things around me? I would take these fruits of technological development for granted. I would be used to the acceleration of changes in almost everything in the sphere of my life and work, so I would expect more changes to come. Floods of information on emerging fields of research would let me wonder whether there is any more fascinating research area than the one I am currently committed to. When I focus on a specific area of research, I would be overwhelmed by a flood of related papers published in journals or presented at numerous conferences, and anticipate tough competition waiting ahead in my career. In the meantime, the urgency in solving global energy and environmental problems would make me conscious of the need to work faster. Articles forecasting the world population, the depletion of fossil fuels, the aging of the Japanese society, and other worrisome issues would incite uneasiness in my mind. I would harbor in the corner of my mind anticipation that some big hurdles, social as well as technological, would loom tall in 20–30 years from now. Immersed in such environment full of rapid changes, mounting challenges, and uneasiness, I would find myself thinking and behaving differently from earlier generations.

The HTSJ will be the society for those people belonging to the era characterized by dynamism, urgency, globalization, interconnectedness, and more. The Society has to adapt to generational turnover of its members, which brings in different ways of thinking and working. The Society's future will be the subject of continuous discussion in years ahead. I hope that the Society's history summarized in this article will serve as one of the reference materials in thinking about the future. Like many other histories, the history of HTSJ is about the people and their achievements. In addition, the history is the record of developments produced interactively by the people and the ever-changing social and technological environments. This is a subject of study, equally as fascinating as the subjects of heat transfer science and engineering. To me, most fascinating are the people. While writing this article I recalled the avuncular faces of the senior scholars from whom I received guidance and inspirations, and with whom I enjoyed talking and drinking. Many of the early-generation scholars have left this world, and some have been in ill health. Also, the bright faces of young colleagues flashed up from time to time. We are all bound to the surface of the fourth dimension called “time” that is relentlessly marching in one direction. I feel my great luck in having lived through the period of HTSJ evolution and getting acquainted with people of different generations along the way.

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