Chapter 13

Research and Standardization of Sampling Method and Analytical Testing Method

Prof. Ishikawa had enormously contributed to the development of industrial world from 1951, by researching the sampling methods and the analytical testing methods of bulk materials as industrial raw materials such as coal and iron ore. In addition, he made an effort to standardize results of the research. In 1951, he founded “Sampling Research Group” in the Union of Japanese Scientists and Engineers, promoted industry-government-academia joint research as the secretary-general, abolished the previous empirical sampling method, and established the scientific method based on statistical methods. The results of this research are a part of his thesis in 1958, “Research on Sampling of Coals.” From this research, the precision in sampling and analytical method for bulk industrial materials has greatly improved. As a result of the improvement the bias has minimized.

In 1952, based on results of the research, the Professor enacted and revised the Japanese Industrial Standards (JIS) related to the sampling method and analytical method of coal, coke, iron ore, nonferrous metals such as manganese, copper, ferroalloy, and other industrial wastes as a temporary member and an Expert Committee member of the Japanese Industrial Standards Committee. He established a system of the Japanese Industrial Standards on sampling in this way. This has greatly contributed to the Japanese industry, which imports a large amount of those materials. It also shows how superior his research was, because of these standards surpassing the international level, and also the contents of international standards (IS standards) legislated afterward were almost identical to the Japanese Industrial Standards which were enacted and revised by the chairman Prof. Ishikawa and other professors.

In all, there were as many as 27 Japanese Industrial Standards related to sampling, whose legislation and revisions the Professor participated in as a member of the Planning Committee.

Although Japan joins the International Organization for Standardization (ISO) as a

Council member, TC 102 (the Technical Committee on Iron Ore) and its SC 1 (the Subcommittee on Iron Ore Sampling) are the subcommittees for that Japan became the first secretariat country, in the ISO. The Professor, as a TC 102 National Mirror Committee member and the chairperson of the Technical Committee for Sampling, made his effort in legislating international technology exchange and an international standard. Thus the Japanese sampling method was approved internationally and has enhanced the international status of the Japanese Industrial Standards. Besides, the Professor contributed to enact seven ISO Standards.

In 1976 the Fuel Society of Japan awarded him the Fuel Society Award, and in the same year the Iron and Steel Institute of Japan gave him the Asada Award for his achievement and contribution toward quality control in the iron industry. Additionally, in 1954 the Nikkei Quality Control Literature Prize was given to his book, *Sampling in Factories* (Maruzen), published in 1952.

From the late 1960s to 70s, pollution became a major social problem in Japan. Therefore the government and local authorities took steps with various regulations. Amidst such regulations, articles like "X ppm of environmental concentration and emission concentration of various substances relating to an environmental hazard" were frequently seen on newspapers and so forth. It was extremely ambiguous, however, to determine the sampling method and measurement method to obtain such data. Professor Ishikawa carefully studied such situations, and thus established the Environmental Preservation Sampling Committee in the Union of Japanese Scientists and Engineers in March 1971 as a common studying place for academic society, industries, research members at government offices, engineers and statistic scholars, and extended his positive activities as the Steering Committee Chairman.

Note: "Prof. Kaoru Ishikawa Profile (Prof. Kaoru Ishikawa Conferral Commemoration)" was referred to for writing this article.

13.1 Professor Ishikawa and Sampling Research

Despite almost ceased operations immediately after the War, the heavy and chemical industries in Japan had reactivated with the Korean War as a turning point.

Taking the steel industry as an example, imports of iron ore and coal had sharply risen according to the rapid increase of black copper production. As their prices were determined by their quality of the principal components (iron % in the former case, ash content % in the latter case), their estimating method — the sampling and the analysis

method — was an important issue that affected a factory's profitability, which is still important at present. In those days, however, there were no standards related to sampling, and the JES standards (prior to JIS) had been used as the analysis method. It was a custom to determine prices based on analysis value: for iron ore, at a port of discharge in Japan, and for coal, at a shipping port.

The starting point of Professor Ishikawa's "Research on Sampling" was to determine how to overcome problems of sampling methods in those days. An outline of a sampling method in those days is as follows.

When a ship carrying iron ore arrived at a port somewhere in Japan, a sampling method was determined by negotiating between a person responsible for sampling from the factory side and an observer (an officer from an inspection agency) representing the shipper's mining side. It was a primitive method. To begin with, they chose a hatch, made a hole with a grab bucket, etc. and made a section of iron ore. Then both parties inspected it and mutually decided the ratio of large, medium and small lumps and powder. This is due to the difference of the iron content in each lump. Supposing they agreed to the ratio as 3:3:4, they would collect 300kg for large lumps, 300kg for medium and 400kg for small, and then mix them together to make a large specimen. This method was called "estimation" at that time, however, it was obviously inaccurate and constantly resulted in a bias from the unloaded stockpile usage record (almost equal to 100% inspection). Namely, if we compared an average iron content percentage at discharging time to an integrated iron value of daily analysis at blast furnaces, there was always 1 – 2% of bias, the latter value being lower.

This attributed its reason to the fact that an observing officer for the "estimation" (mostly from American inspection agencies) under the Occupation Time had a strong influential voice, and there were officers who directly ordered Japanese workers to pick up more large lumps (more iron contents) during unloading time at night. It was the fact that no countermeasures could be taken from the factory side.

It was Professor Ishikawa who considered changing this kind of situation, and strived to replace the then method of an "estimation," which is more appropriately expressed as a "guesstimation," with the JIS Standards based on the modern sampling method. This was one of the Professor's excellent achievements in his early days, as he upheld his policy of acting always at the forefront instead of enclosing himself in an ivory tower.

Professor's research comprises the basic theory of estimating the quality of bulk materials as well as iron ore with precision. It also consists of the establishment of a rational and practical sampling method derived from analysis results obtained from

experiments based on the theory. These became an important part of his doctoral thesis "Research on Sampling of Coals."

The most important research among Professor's sampling studies was Increment Sampling. It was absolutely necessary to revive the steel industry for the recovery of Japan at that time, however we had no alternative but to rely mostly on imports in the extreme shortage of domestic iron ore yield. Therefore, a quality estimation of iron contents of iron ore was always needed for every full load of a ship for making the settlement. Iron ore has its form in lumps and in powder, and the lumps tend to be higher quality, whereas powder was lower. As mentioned above, the ratio between lumps and powder was determined by eye-sight; therefore there was a tendency in the sampling for vendors to choose lumps whereas buyers would pick powder. In order to rationalize this point, anybody can hit on an idea to apply the sampling theory in the field of mathematical statistics. In other words, if ones agree on an accuracy target by deciding how much error is tolerated at estimation, and they calculate the necessary samples for achieving precision by a method of mathematical statistics, a rational sampling method would be established. However, there is a problem of how to fix the size and the number of samples. Should this not be done in a rational manner, the mathematical statistics would be absolutely useless. Then Professor Ishikawa carried out a vast amount of experiments, and showed that the unit volume for one action of collection for samples (termed as increment) caused variation between increments. As a result, he induced a fixing method of increment size for more rational sampling, and furthermore he devised an idea to use a special shovel so that this result could be easily put into practice at the work place. Although his doctoral thesis was for coal, this is a widely applicable method and can be applied to all bulk materials. Additionally we cannot forget that, on top of his contribution to sampling, this result has a by-product that has cultivated a way to apply mathematical statistics to the analysis of quality problems, such as sample preparation (increment division) of bulk materials.

The Professor reflected these research results in JIS M 8100 (Particulate materials — General rules for methods of sampling). This Standard can be described as the Professor's compilation of study, and even though many years have passed after its enactment, it is still the important document constantly cited for any case related to international standardization. After the completion of JIS, Japanese steel industry could clearly write "sampling method to be performed under JIS" at the time of contract, and as a result of changing to the rational sampling method, they estimated their cost reduction of around 2 billion yen as the value of that time.

Indeed there are many statisticians inside and outside the country, and there are

some researchers who choose sampling as the research theme. Yet, Professor Ishikawa was a rare scholar in the world to have contributed to the industrial development on a global level through theory and practice.

Furthermore, his investigation did not stop at just the sampling method research, but extended the research to the analysis method for securing rational analytical precision. The research for analytical precision at that time was performed by analytical chemistry engineers with their own technical approaches, but he made significant contribution to the outcomes by adding the full use of statistical methods to this, especially the design of experiments. In this way, Professor Ishikawa was the first person in Japan to apply the statistical methods effectively and practically to enacting standards. We can say that Prof. Ishikawa is a pioneer in the world.

(Toshimi Fujimori)

13.2 Bulk Material Sampling Research / JUSE Sampling Research Committee

(1) Activities of the Sampling Research Committee in the Mining and Manufacturing Industry

Considering that sampling was the biggest problem in the grade estimation of coal in the midst of increased production (called “priority production” in those days) as the driving force behind Japan’s post-war recovery, Prof. Kaoru Ishikawa selected sampling methods as the research theme. It was essential to study the analysis method itself for the research, therefore the Sampling Research Committee was established in December 1951 with Union of Japanese Scientists and Engineers (JUSE) as its secretariat to promote the study of sampling and analysis methods on a nationwide basis.

Its members were recruited from the industrial world with an annual membership fee of 36,000 yen and from universities and public research institutes for free. They started collaborative research activities.

The Committee’s chairman was Mr. Ichiro Ishikawa and Prof. Kaoru Ishikawa served as a manager or a secretary general from its inception until his death. He attended the working group meetings as long as time permitted and contributed to the establishment of operational policies and the promotion of research activities.

From the late 1950s to 1960s, he often conducted collaborative experiments to prepare JIS draft on the analysis and sampling of coal. Moreover, he accompanied coal mine on-site observation tours in Hokkaido and Kyushu. The results of these studies are

still active at present as JIS M 8810 – M 8814.

The names of Expert Committees that compose the Research Committee are as follows:

SA: Iron Ore Expert Committee
SB: Nonferrous Metal Expert Committee
SC: Coal and Coke Expert Committee
  SC1: Sampling Subcommittee
  SC2: Analysis Subcommittee (now "Coal and Coke Analysis Expert Committee")
SD: Salt Expert Committee
SE: Sulfide Ore Expert Committee
SF: Pharmaceuticals Expert Committee
SG: Ceramics Expert Committee
SH: Steel Material Expert Committee
SI: Statistics Expert Committee
SJ: Analysis Expert Committee
SK: Equipment Expert Committee
SL: Storage Salt Appraisal Expert Committee

Most of them were dissolved after achieving their respective objectives, however, three Expert Committees (SB, SC and SK) have continued their activities for 35 years up to the present time. In particular, SC 2 has concurrently served as the national committee for ISO/TC 27 since its establishment in November 1971, with examination of ISO materials and preparation of Japanese response plans. The research results of the Research Committee are summarized as follows:

1. In 1954, the 1st collaborative experiment was implemented with the participations of 44 analysis laboratories nationwide, and precision within a laboratory (repeatability) and precision between different laboratories (reproducibility) of the then analysis method (JIS M 8802) were estimated. Because the value of precision between different laboratories reached 10 times the value of precision within a laboratory, the 2nd, the 3rd, and the 4th collaborative experiments were implemented from 1955 to 1957. They selected the factors which were considered to be influential to precision between different laboratories, screened off important factors with experiments

using orthogonal array, estimated optimum conditions, and then obtained the values of precision both within a laboratory and between different laboratories each time. In such experiments, analysis methods were improved, and in 1959, the JIS M8810 – 8814 was finally completed for almost all analysis items. Jiro Nitadori, Takashi Miyazu and Toshimi Fujimori played the central role in these researches, and they were respectively awarded Doctor of Engineering degrees by the University of Tokyo, based on their researches carried out in this Research Committee under the guidance of Prof. Kaoru Ishikawa (See Section7.3). On the other hand, Prof. Ishikawa received the Fuel Society of Japan Award for his promoting the researches mentioned above.

2. The total number of original JIS drafts prepared by the Research Committee was about 20, according to the Bulletin mentioned below.
3. Ever since the results of the Research Committee were issued as the first number of "Bulletin for Sampling Research (BSR)" in February 1952 by the Expert Committee on Iron One, the results have been arranged as materials by respective Expert Committees and published. The bulletin continued to be published even after Prof. Ishikawa's death, and its 238th issue was published in February 1992.
4. As a matter relating to all Research Committees, "General rules on tolerance of analysis and test" were established in 1974. The feature of this standard was that the condition of intermediate precision (reproducibility within a laboratory) was to be recommended rather than the condition of repeatability as a way of repetition of analyses and tests. This came from Prof. Ishikawa's philosophy as follows:
    i. Intermediate precision is essential for the three-shift production sites;
    ii. Priority should be given to the accuracy of average analytical values over analytical precision of each test item.

The standard conformed well to the actual conditions in Japan that had to import most raw materials and fuels and to export products. Though only repeatability and reproducibility (between different laboratories) were stipulated in ISO 5725-1981, intermediate precision (reproducibility within a laboratory) was newly adopted as Part 3 in its 1992 revised edition by the Japanese proposal, which is the proof of Prof. Ishikawa's foresight.

(2) Activities related to the Sampling Research Committee

Based on the research activities of the Sampling Research Committee, the following activities were conducted under the leadership of Prof. Kaoru Ishikawa:

1. From November 15 to 18, 1965, at the Imperial Hotel, Tokyo, a Japan-US Cooperative Science Seminar entitled "Seminar on Sampling Theory in the Characterization of Bulk Materials" was held under the co-sponsorship of the Japan Society for the Promotion of Science (JSPS) and the U.S. National Science Foundation (NSF). This seminar was held because the JUSE Sampling Research Committee and Prof. Ishikawa received a request for cooperation from NSF and JSPS.

   The participants in the Seminar were as follows:

   Japanese side:

   Kaoru Ishikawa, Masumasa Imaizumi, Shiro Joko, Masayo Kanematsu, Toshio Kitagawa, Hitoshi Kume, Saburou Suganami, Umetaro Takahashi, Genichi Taguchi, Takashi Miyazu, Sigeiti Moriguti

   U. S. side:

   R. L. Anderson, Robert E. Bechhofer, Robert M. Becker, Charles A. Bicking, W. Edwards Deming, Louis Tanner, W. A. Thompson, Jr.
2. From October 6 to 9, 1970, at the East-West Center, Honolulu, Hawaii, the Second Japan-US Cooperative Science Seminar entitled "Seminar on Sampling Theory in the Characterization of Bulk Materials" was held under the co-sponsorship of the U.S. National Science Foundation (NSF) and the Japan Society for the Promotion of Science (JSPS). The leader of the Japanese side was Prof. Ishikawa.
3. From October 17 to 19, 1972, at the Keidanren Kaikan, Otemachi, Tokyo, the "International Symposium on Air Pollution Prevention Technology — the Present State of Air Pollution and the Progress of Prevention Technology" was held with Prof. Ishikawa as the organizing committee chairman. The establishment of the Environmental Preservation Sampling Research Committee was inspired by the holding of this symposium.
4. In 1979, the "Basic Research for establishing measurement methods with water quality automatic measuring instruments" ordered by the Environment Agency was conducted under the chairmanship of Prof. Ishikawa.

(3) Writings related to sampling researches

Before the 1950s, there were few publications applying statistical techniques to sampling and measuring methods in industry. Prof. Ishikawa prepared introductory handouts on sampling for the quality control workplace organized by JUSE for the first time in autumn 1950. A book titled *Sampling in Factories* was published by Maruzen in July 1952 after several revisions of the handouts. Moreover, a book titled *Introduction to Sampling Methods* was published by JUSE Press.

Thereafter, many experiments were carried out by the JUSE Sampling Research Committee and JIS committees, etc. As a result, experiment methods and sampling equipment were progressed. Moreover, actual conditions of transactions also changed in various ways. *Introduction to Sampling Methods* was revised to cope with such changes and in July 1967, *Sampling in Factories New Edition* was published by Maruzen.

(Toshimi Fujimori, Toshihiro Arai)

13.3 Establishment of JIS on Tolerance of Analysis and Test

(1) Establishment of JIS Z 8402 “General rules for permissible tolerance of chemical analyses and physical tests” / JUSE Draft Preparation Committee

1. Background of establishment: In the late 1960s, several analysis and test methods prescribed in JIS were numerous, and the number of those related to ores and metal materials alone totaled more than 210 methods. Also in those days, with the rapid increase in import of raw materials and fuels and export of products, these analysis and test methods did not remain domestic issues alone, but also came to attention from overseas. Due to this circumstance, the relation between JIS and ISO, ASTM, BS or other overseas standards also became important issues. At the request of the Agency of Industrial Science and Technology (AIST), the “Ores and Metal Materials Analysis Standards System Survey Committee” (Secretariat: The Union of Japanese Scientists and Engineers (JUSE)) was established and conducted a comparative survey of JIS and overseas analysis standards for about one year from July 1968. One of the conclusions of this survey was related to the issue of tolerance of analysis methods.

"Tolerance is used as one of the means to judge superiority or inferiority of analysis methods themselves objectively. It is required to decide on the number of significant digits of quantification limits and analytical values of analysis methods and also to identify any of the analysis methods and samplings responsible for problems in business transactions. Therefore, tolerance setting is indispensable for the future development and improvement of analysis methods.

However, due to factors such as the relationship with material and product standards, difficulty level of joint experiments, and industry conditions, it is considered difficult to identify tolerances of all analysis methods immediately. So, it is appropriate to establish "General rules on tolerance of analysis methods" as a concrete guide to first give full recognition to the necessity of tolerance and then to determine tolerance in the future."

Based on the above conclusion and the request from all parties concerned, the "Committee of Preparation of JIS Draft for General Rules on Tolerance of Analysis and Test" was established in JUSE by the order from AIST in order to start preparing the draft under the chairmanship of Prof. Ishikawa in June 1969.

Tolerance is defined by JIS Z 8402 established in 1974 as follows:

(a) Permissible limit of variation of judgment values of analyses, tests, etc.

(b) Difference between the prescribed standard value and the prescribed limit value.

2. Process of preparing the JIS draft: The first meeting of the Committee was held in August 1969, and it was decided to expand the scope to cover not only chemical analyses but also physical tests, and to start with the investigation of a large number of documents on tolerance in Japan and overseas. Work was advanced under the policy of preparing a guidebook to determine tolerance by clarifying the errors of measuring methods, etc. when deciding, or after having decided, on analytical or testing methods. Thereafter, by July 23, 1971 when the draft preparation was finally completed, a total of more than 30 committees or manager meetings were held, and the number of submitted or discussed documents totaled 111.

Prof. Ishikawa provided leadership in preparing the draft mentioned above, and in particular emphasized the importance of performing measurements of

reproducibility within a laboratory to determine the tolerance of reproducibility within a laboratory (intermediate precision).

(2) Reflection of JIS Z 8402 in ISO 5725 / Japanese Standards Association (JSA) TC 69/SC 6

ISO 5725 corresponding to JIS Z 8402 was established in 1981, but due to problems with its contents, the work of preparing its draft revision was started immediately after its establishment. Finally in September 1991, the revised edition of ISO 5725, "Accuracy (trueness and precision) of measurement methods and results" was approved. In the revision of the ISO standard, Japan had the charge of preparing the draft on the following points and was able to have the Ishikawa philosophy in JIS Z 8402 reflected in the revised ISO 5725:

1. Introduction of intermediate precision (reproducibility precision within a laboratory as stipulated in JIS Z 8402) in addition to the existing repeatability precision and reproducibility precision in different laboratories,
2. Improvement of checking procedures to judge adoptability of measurement results,
3. Introduction of control procedures within a laboratory.

To promote consistency with the revised ISO 5725, JIS Z 8402 was revised in October 1991. For the 17 years since its establishment in 1974 up to its revision in 1991, the contents of JIS Z 8402 had never been revised although regular confirmation of the contents every five years and correction of some misprints had been made. This is because at the time of the establishment of the JIS standard in 1974, analytical and statistical experts collaborated closely under the leadership of Chairman Kaoru Ishikawa to perform thorough work without any major problem in contents.

(Takashi Miyazu)

Note: In ISO 5725 (1991 Revised Edition), tolerance is defined as follows:

(a) Tolerance is expressed in terms of performance, accuracy, trueness and precision with regard to errors of measurement and test values under the prescribed measurement conditions for the same sample. (permissible tolerance)

(b) The limit with a prescribed probability of the range of measurements and test values of n numbers obtained under the prescribed measurement conditions for the same sample. (critical range, critical difference)

(c) The limit with a prescribed probability of the difference between

measurement/test values and certified values obtained under the prescribed measurement conditions for reference materials and certified reference materials. (critical difference)

Prof. Ishikawa and ISO 5725 (Precision, Trueness of Measurement Method and Measurement Value)

Takashi Miyazu

Life is said to be like a tapestry of chance and necessity... It is rare, however, to come across such a chance or lady luck that may completely change one's subsequent life. In my case, it was good luck to meet Prof. Ishikawa at the Sampling Research Committee of Union of Japanese Scientists and Engineers (JUSE), although I didn't realize it at that time.

When I joined NKK Corporation, I happened to be assigned to the Testing Section. I was in charge of coal analysis and became a member of the Coal Expert Committee of the Sampling Research Committee of JUSE. That was the start of my good luck. In order to revise JIS, joint experiments to find precision within a laboratory (intermediate precision) and precision between different laboratories are implemented, and then experiments to examine causes of analytical error were carried out. In the process, I received guidance from Prof. Ishikawa on statistical data analysis, design of experiments, and so forth. The feeling that "the scales fell from my eyes" at that time is still vivid now.

Until then, I had thought "there should not be analytical errors" and had taken primary, single-factor experiments for granted. However I, a mere analyst in those days, was inspired to reverse my way of thinking by Prof. Ishikawa's words, such as "Data without dispersion are false," "Interaction is important for the research of analysis methods," and "Repeatability has little meaning; what is useful is intermediate precision." These thoughts still continue to resonate as JIS Z 8402-1974 (General rules on tolerance of analysis and test), contributing to the industry immeasurably. This is because the origin of SQC (Statistical Quality Control) is based on data, and all the ideas and techniques for expressing and improving precision and trueness of data are summarized in this standard.

The international standard corresponding to JIS is ISO 5725, of which the current version established in 1981 has, however, no stipulation on intermediate precision

(reproducibility precision within a laboratory). Part 3 (International Measures of the Precision of a Test Method) of the draft revision of ISO 5725 distributed in June 1989 to member countries for voting was prepared by Japan, and it was indeed the intermediate precision in Prof. Ishikawa's style. Prof. Ishikawa's philosophy about analysis some 35 years ago is now finally being recognized internationally as the draft ISO standard*, which can be said to be a formidable foresight.

It took about 9 years to complete the draft of ISO 5725 Part 3, but in the process, I, the present writer, reported the progress status to, and received advice from, Prof. Ishikawa each time I attended the ISO/TC 69/SC 6 meeting every year. Professor Ishikawa was very glad when we completed our final draft in 1988, but it was regrettable that I could not report the result of voting to him. When the revised ISO 5725 is published, I would like to dedicate it to Prof. Ishikawa first of all. To Professor Ishikawa who gave me a turning point in my life, and who supervised my academic dissertation that I was able to write under his guidance, the one and only thing I can do now to repay his favor is to complete ISO 5725.

(Professor, Nishi-Tokyo University;
former NKK Corporation Technical Research Center)

13.4 Standardization of Iron Ore Sampling Methods / The Japan Iron and Steel Federation

With the remarkable growth of the Japanese iron and steel industry and the resultant increase in the import volume of iron ore in the late 1950s, the industry keenly felt the necessity of international standards on rational sampling, analysis and testing methods and appealed it to the Japanese government. In response to this appeal, the Japanese Government gave ISO a proposal to set up a new technical committee (TC) in order to establish international standards in this area in March 1960. The proposal was accepted and a new technical committee TC 102 (Iron ore) and its subcommittee SC 1 (Iron ore sampling) were established in June 1961. Japan became the Secretariat of the TC for the first time. The duties of this TC were to prepare the international standards on iron ore sampling, sample preparation and moisture content measuring methods.

In August of the same year, at the request of the Agency of Industrial Science and Technology (AIST) to improve the domestic system in response to the establishment of

* Re-revision proposals Part 3 was eventually approved at London Meeting in October 1992 and was established as ISO standards.

the new ISO/TC 102, the Japan Iron and Steel Federation (JISF) organized the Japanese internal committee for the ISO/TC 102. Prof. Ishikawa assumed the position of chairman of the sampling technical committee that was established as a subsidiary organization of the Japanese internal committee and started its activities. The first meeting of the sampling technical committee was held on November 13, 1961, and thereafter he had contributed as the committee chairman for about 20 years up to the 204th meeting held in January 1981.

For the last 20 years, he attended a total of 13 SC 1 international meetings, one SC 1/WG meeting and one editorial meeting, of which, he served as the chairman of the 1st and 7th TC 102/SC 1 international meetings held in Tokyo in 1963 and 1972, respectively. Moreover, he represented the Secretariat since the establishment of SC 1, and made an effort to lead the Japanese internal committee to prepare the international standards.

Through Prof. Ishikawa's efforts, the following two JIS standards related to iron ore sampling were established:

JIS M 8105 Iron ore sampling methods, and methods to determine particle size and moisture content (established in 1961 and revised in 1966, 1970 and 1976)

JIS M 8710 Methods of sampling, size determination, moisture determination and physical characteristics determination of iron ore pellets (established in 1970 and revised in 1976)

Note: In 1985, ISO 3081 – 3087 were converted into JIS M 8701 – 8705.

JIS M 8100 which was established on the basis of Prof. Ishikawa's activities in Union of Japanese Scientists and Engineers (JUSE) Sampling Research Committee was a basis for the enactment of these standards.

Furthermore, ISO standards established through Prof. Ishikawa's efforts are as follows:

ISO 3081 Iron ores — Manual sampling method Current JIS M 8701

ISO 3082 Iron ores — Mechanical sampling method and sample preparation method Current JIS M 8702

ISO 3083 Iron ores — Manual method of Preparation of samples Current JIS M 8703

ISO 3084	Experimental methods for evaluation of quality variation	
ISO 3085	Iron ores — Experimental methods for checking the precision of sampling	JIS M 8100
ISO 3086	Experimental methods for checking the bias of sampling	Included in Appendix of JIS M 8100
ISO 3087	Iron ores — Determination of moisture content	Current JIS M 8705

These international standards are all based on Prof. Ishikawa's theories, and also are used in TC (Manganese ore, etc.) which is another kind of mineral product of ISO, so that they may be said to be the basic standards related to sampling in the current ISO.

Prof. Ishikawa was awarded the Asada Medal by the Iron and Steel Institute of Japan (ISIJ) in 1976 for reasons of his contribution to the development of the iron and steel industry by the spread of statistical quality control, etc. The Asada Medal is the prize awarded to the "person who has made outstanding contributions to the progress and development of the iron and steel industry by academic and technological achievements in the peripheral and boundary area of the iron and steel industry."

Note: In finalizing this section, we wish to express our gratitude to all the members of the Standards Office of the Japan Iron and Steel Federation (JISF) for their cooperation in providing us with valuable materials, etc.

13.5 Research of Sampling for the Purpose of Preserving the Environment / Union of Japanese Scientists and Engineers (JUSE), Environmental Preservation Sampling Research Committee

(1) Inauguration of Environmental Preservation Sampling Research Committee

This Research Committee was established in May 1971 as a place of collaborative research for researchers, engineers and statisticians of academic, industry and government research laboratories on the methods of measuring and sampling various materials for the purpose of environmental conservation. The chairman of the management committee was Prof. Ishikawa and its secretariat was established in JUSE.

Environmental problems had already become social issues in those days, and the activities of improving various public environmental regulations and JIS environmental measurement JIS standards had already started. In terms of measurement technology, however, there were problems with the following points:

1. Values of environmental standards and emission standards varied by country and/or prefecture, most of which were caused by the poor level of technology in those days.
2. Most of environmental measurement JIS were established without sufficient experiments and examinations in time, so that specified tolerance on measurement errors was hardly written on it.

In consideration of such circumstances, this Research Committee established the following three subcommittees for the purpose of conducting researches on sampling and measuring methods as a basis for environmental preservation, and collected information and conducted collaborative experiments, etc. The outline of the respective subcommittees is as follows:

	Subcommittee chairman	**Objective substance**
Air Quality Subcommittee	Kaoru Ishikawa	SO_x, NO_x, dust, etc.
Water Quality Subcommittee	Kunisuke Ichikawa	CN, phenol, Cr^{6+}, Hg (inorganic), BOD_5, COD_{Mn}, COD_{Cr}, TOC, TOD, n-hexane extract, etc.
Soil Subcommittee	Tadakazu Okuno	Heavy metals mainly in soil (Cd, Zn, Pb, Cu, As, Hg, etc.)

These subcommittees drew up each research program and conducted collaborative experiments to examine precision within a laboratory (intermediate precision), reproducibility between laboratories and trueness (bias) of relevant JIS standards. Based on their results, they made technical improvements in sampling and measuring methods, and determined tolerance for measurements by the improved methods, contributing to the revision of JIS and yielding some results in this field before finishing their researches in March 1982. (Toshimi Fujimori)

(2) Air quality subcommittee

Prof. Ishikawa formed the Air Quality Subcommittee of the Environmental Preservation Sampling Research Committee of JUSE, and served as chairman of the subcommittee to tackle air pollution problems enthusiastically. He wrote many articles on environmental problems, including “Environmental pollution and sampling and measuring methods” (*Hinshitsu Kanri* (Statistical Quality Control) magazine) and “Air

pollution and the future of its prevention" (*ENGINEERS*). In the Air Quality Subcommittee, he started to make sure of the fact whether environmental (air quality) data was reliable or not and the analysis methods were right or not.

At first, Prof. Kano, as secretary of the subcommittee, called for private-sector research laboratories to form an industry-academic collaborative body to start with the review of analysis methods of JIS and conducted an "examination of SO_x analytical procedures." Thereafter, Prof. Kume and I respectively took over the duties of chairman and secretary of the subcommittee, respectively, and proceeded to an "examination of NO_x analytical procedures," the results of which we reported and/or published in academic meetings, in bulletins, etc.

The results contributed greatly to the revision of JIS and how to handle data on air quality. Prof. Ishikawa left many sayings in his writing *Statistical environmental management*. Some of them are as follows:

1. If you see environmental standards, consider them inaccurate. If you see emission standards, consider them inaccurate. If you see sampling, measurement and analysis under the present emission and environmental standards, consider them doubtful.
2. Grasp the actual state first before thinking about the cause. Grasping the current situation is the first step of quality control. Are you sure you have grasped statistically and epidemiologically the differences between the background and the condition of having problems? If you run toward the cause immediately, you would make a mistakes like a hasty person (type I error).
3. Environmental and emission standards are alternative characteristics. The relationship between alternative characteristics and the real quality characteristics is the same as in quality analysis.
4. Is it possible whether a public officer who has not experienced environmental management is able to perform environmental management? It will be a superficial and uneconomical management. It will be the same as the examination of the JIS mark, bringing about a certain degree of favorable effects, but with adverse effects.
5. Is there any research laboratory or public office related to the environment to run for the Deming Application Prize?
6. Determine the rationalization of emission standards based on data. How do we restrain such a political ignorance of science whereby prefectural governments make their local standards stricter than national standards?

7. Which unit or unit quantity certified by inspection of environmental pollution should be brought into question? Should it be annual, monthly, 24-hour, 8-hour, one-hour or one-minute average? What kind of harmful effect does it have on the health?
8. Unless those engaged in environmental pollution study the theory of statistical errors well, they will be persons leading Japan to unhappiness. What is measurement errors between sampling, analysis and pollution?
9. What is more important is how to interpret errors in view of variations depending on human bodies affected by environmental pollution.

The environmental problems are now showing signs seriously again, and the sayings left by Prof. Ishikawa are still alive and relevant today, don't you think so?

(Nobuo Ikebe)