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REPORT ON THE WORKSHOP: THERMAL ANALYSIS EDUCATION

9TH ICTA, JERUSALEM, ISRAEL - THURSDAY, AUGUST 25, 1988

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INTRODUCTION

The workshop was organized to discuss the following topics: achievements and future goals of the ICTA Education Committee; improved thermal analyst education; and reports on the status of thermal analysis education in Southern Africa and Japan. After each of the four presentations, there was a question and answer period. It was obvious that the participants appreciated the importance of education in enhancing the professional status of thermal analysts. The four lectures are rewritten from the tape produced during the session, or reprinted from the text submitted by the speaker.

I. ACHIEVEMENTS AND GOALS OF THE ICTA EDUCATION COMMITTEE

E. Turi, Polytechnic University, NY, USA

We learned in 1985 at the Workshop of the 8th ICTA in Bratislava that generally there was very little or no compulsory thermal analysis education at the universities or colleges. Few exceptions to this were mentioned, like Czechoslovakia, Finland, Hungary, Japan and some schools in the USA. Thermal analysis was perhaps a small part of general, physical or analytical chemistry. There were no prerequisites for thermal analysis courses to earn a BS, MS or PhD degree. It was reported that one of the limiting factors was the lack of availability of instruments.

In several countries, there were regular: annual, biennial, and also occasional short courses and summer schools. Some were going on for 12-13 years, (like in the USA and France), others at irregular intervals. Some provided hand-outs, audio tapes or other educational material.

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There were also seminars and society events reported. These were all signs of some initial progress. However, and unfortunately, in many cases scientists working with thermal instruments in research and production had no formal education in thermal analysis. The conclusion was that the thermal analysis education was generally inadequate. There were not enough well-trained specialists on the job, and no new supply of scientists was expected in the years ahead.

The following specific recommendations were made in Bratislava:

(1) Education of new students should include thermal analysis, and their interest in materials characterization should be raised at an early stage of their studies.

(2) Short Courses in thermal analysis should be provided for those who need it because during their school years, the subject was not taught (which was often the case), or they did not take it.

(3) Basic textbooks have to be written.

(4) Last, but not least, it was found very urgent to start to train educators in thermal analysis. Unquestionably, to make this action widespread, world-wide cooperation was necessary.

In order to implement this and other objectives, the 8th ICTA entrusted me to organize and chair an Education Committee on thermal analysis. - First, reputed scientists and educators were asked to evaluate the problems. Members of the Committee were (1985-1988):

E. Turi (USA) (Chair), Hu Ri-Heng (China), L. Mandelkern (USA), T. Ozawa (Japan), M. Richardson (UK), B. Wunderlich (USA). - Incoming members: M. Brown (RSA), T. Hatakeyama (Japan).

Scientists from other countries are going to join the Committee soon. The members of our group are working on short- and long-term goals.

In order to form and activate regional groups around the world, we asked scientists to chair regional committees and initiate educational activities in their area. The Regional Chairmen are: Australia: R. Shanks, Brasil: E. Mano, India: K.Ninan and

I. Varma, Israel: A. Siegmann. Incoming Regional Chairman: Brasil: I. Giolito.

They deserve gratitude for promoting thermal analysis in their countries. I may report here some personal news: two of our Regional Chairmen were given awards for their activities. Prof. Varma in India received the International DuPont Award for promoting thermal analysis of polymers in India. Dr. Ninan received the Netzsch-ITAS Award for his thermal analysis studies and for promoting thermal analysis in his area.

I have reported in the ICTA News, that we set an agenda with short- and long-term projects. The short-term projects represent immediate objectives in promoting the education of thermal analysts. The long-term goals are to achieve systematic training in thermal analysis. I shall not discuss the long-term projects because they will be the subjects of Prof. Wunderlich's presentation (next report), but I will deal with selected items of our short-term program. Among them, the most important projects are the short courses and workshops. Their number grew significantly around the world. In addition to what was discussed in Bratislava, I can report the following progress:

In Japan, the activity and participation increased in short courses, workshops and seminars (See Dr. Ozawa's report).

In the USA, we have now significantly more short courses than in 1985. These are given at several universities and under the sponsorship of local groups. The annual program at the Polytechnic was increased from 3 to 4 days, and includes a day on the viscoelastic properties of polymers. The basic program has been going on now for 13 years and covers most applications of thermal techniques. It was attended by close to 1000 participants. The American Chemical Society introduced a new thermal analysis short course which was given so far 5 times.The Univ. of Illinois, Golden Gate Polymer Forum, The North-East Thermal Analysis Society, the Univ. of Dayton and several others were active in giving short courses. A special program is the audiocourse of Prof. Wunderlich at the Univ. of Tennessee. It had more than 300 participants throughout the years.

Short courses in Malaysia, Brasil and Australia were the first of their kind. They attracted 98 participants on the Phillip Island and 112 in Rio de Janeiro. At both places, after the course, new groups were formed and the activity, especially in Brasil, exceeded all expectations. In Israel, two short courses were held: one in 1986 with more than 130 participants, and another in 1988. In India, the biennial ITAS meetings were preceded by a workshop. The regional Vice-Chairman (Dr. Ninan) gave 12 presentations on application of thermal analysis, mainly in India. In Basel, there was a new program where participants coming from 11 countries created a real international atmosphere. The Tubingen and Stockholm programs enriched further the training of thermal analysts. Certainly, the increased interest in materials characterization generally and in thermal analysis especially, invigorated educational activities at the universities, societies and local groups. The programs, as expected, were very much tailored to the interest of the users, mainly dealing with polymers.

I heard many favorable opinions on the various programs but I do not consider a short course educational enough if it does not provide the participants with adequate study material (at least with copies of the projected slides). The presentation of a good number of applications, and consultations in individual problem-solving usually raises the interest in further studies.

We should mention the role of the instrument companies in helping the promotion of thermal analysis education. Most of them increased their efforts in their hands-on training programs and their exhibitions and demonstrations supported many of our short courses around the world.

Now a few words about the IUPAC, of which ICTA is an affiliate member. In August 1987, in Boston, MA., I had the opportunity to give a short report to the IUPAC on the formation, activities and plans of our Committee. The 23 attending members of the IUPAC "Committee on the Teaching of Chemistry" inquired about details and were very much interested in our progress, particularly in developing and providing low-cost thermal units

for teaching. We call these units "School DTA". They are coming to the market. In some of the developing countries home-made instruments are already used for teaching.

Finally, I wish to make a suggestion. I propose the establishment of a Speakers Bureau. Several attempts were made in NATAS and in other societies to do this. We would like to try it within our Education Committee Program, using different channels for promoting the idea. A good Speaker's Bureau would help around the world to bring together good and willing speakers with an eager audience, without special financial burden.

CONCLUSION

Significant progress was made in the last three years in the education of thermal analysts all over the world. I will give more details in the closing lecture of the 9th ICTA (see Proceedings). The full report will appear at the end of 1989 in the ICTA News. More has to be done to raise a new generation of well-trained thermal analysts, and to update and upgrade the education of those in practice. To achieve these goals, the cooperation of the scientific community and financial support of the governments and industry are needed.

DISCUSSION

Unknown: Is it necessary to have separate thermal analysis education apart from the other instrumental analytical techniques?

E. Turi (USA): While there are undergraduate and graduate courses for several other techniques, there is no curriculum or textbook and only scattered and occasional professional training in thermal analysis.

Unknown: Is the shortage in teaching of thermal analysis caused by the unavailability of instruments?

E. Turi (USA): "School DTA" (very low cost units) are already on the market and more will come. Hopefully, the industry will sponsor academic institutions to purchase these units. In some of the countries, pioneering colleagues construct home-made

units. Developing countries may have a possibility to ask for, and receive help from international organizations such as UNESCO.

D. Dollimore(USA): I suggest the use of Dodd & Tonge's book as a workbook for thermal analysts. It includes hands-on experiments. Also, I recommend M. Brown's recent book. It is significant to mention that the TMG workshop in England provides every second year a special hands-on course for the continuing education of thermal analysts. The TMG program also includes the application of thermal analysis to polymers though it is much less in England than in the USA.

P. Haines(UK): Dodd & Tonge's book should be supplemented by workshops such as the TMG workshop. Quite a lot is going on in England in thermal analysis both in hands-on and classroom education. In some schools they build their own thermal analysis unit for teaching.

S.Yariv(Israel): Do thermal analysis courses cover DTA, DSC and TG?

E. Turi(USA): At the Polytechnic we include all methods, their principles and their applications to a very broad range of materials.

II. TOWARDS THE EDUCATION OF A THERMAL ANALYST

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Thermal analysis is an old technique and the discussion of Professor Turi in this workshop has shown that there are already a series of books on the topic and many short courses on the subject are given. As a professional society we must, however, go beyond promoting the statement "There is a Technique called Thermal Analysis".

Let us compare a thermal analyst, for example, with an X-ray crystallographer. For the latter the subject matter needed in the field is well defined. Crystallography is the theory of the

crystal description and the technique is the diffraction of electromagnetic radiation. In every step of the education, starting in high school science education, going to undergraduate courses, and ending in graduate work, increasingly more sophisticated descriptions are offered to the student permitting this definition of the field and making a choice of career easy. In professional life, no serious laboratory director intending to introduce X-ray diffraction will buy the equipment without hiring an expert in the field to use it. One knows, a long, highly structured training is necessary to get the credentials as a professional X-ray crystallographer. In thermal analysis, in contrast, one may estimate that there are an order of magnitude of 10,000 scanning calorimeters in use. But are there 10,000 professional thermal analysts? I do not think there are as many as 100 thermal analysts that compare in professional training to the example of the X-ray crystallographer. This is the problem to be addressed in this presentation to the workshop. How can we make progress towards the education of a sufficiently qualified professional thermal analysts?

The reasons for the problems in thermal analysis education are rooted in the historic development. We have heard in this meeting by Professor Mackenzie in the opening lecture, thermometry became quantitative in the 17th Century in Florence. The next step occurred in the 18th Century with the development of a series of temperature scales, those in the US are even now not properly sorted out. On the basis of quantitative temperature measurement, the theory of the caloric could be suggested and the first calorimeters were built. The 19th Century brought then development of the basic theory of thermal analysis, the thermodynamics. The nature of heat was recognized as a form of energy. The three basic laws were established. At the turn of the Century the general education still contained a full representative knowledge of thermal analysis. In the early part of the 20th Century, however, things changed. Although the important subjects of kinetic and irreversible theories and differential thermal analysis were developed, much of the education was overshadowed by the new insight into the atomic and molecular description of

matter. Perhaps this was the reason that the teaching of thermodynamics was increasingly idealized and simplified (?) to cover the non-existent equilibrium processes. The new, exciting irreversible thermodynamics did not get integrated into the picture.

Even for the molecular description of matter, a back-integration of the old ideas of phase structures was not made. It is, for example, not widely realized that all matter should be logically subdivided into three groups.

1. Small molecules
(may be solid, liquid or gaseous without losing molecular integrity).

2. Flexible macromolecules
(may be solid or liquid without losing molecular integrity)

3. Rigid macromolecules
(may only be solid without losing molecular integrity)

With this subdivision, a connection between molecular structure and overall phase structure can be made and all types of matter are subdivided into three, about equal sized groups. Teaching can be enormously simplified by such reorganizations of historically developed knowledge into an overall, logical story. Such organization, simplification and combination of proper subject matter is needed for the thermal analyst who is to work with all materials.

The four fields that form the basis of thermal analysis and other analysis methods are:

1. Instrumentation
2. Data Treatment
3. Theory
4. Application

The instrumentation of thermal analysis has increasingly been removed from physical chemistry, analytical chemistry and science teaching as an "old-fashioned" method that had to yield to more modern, usually microscopic methods. Data treatment, although presently much helped by computer, is taught much less than before and one increasingly comes to the conclusion that measurements are not properly analyzed as to their reliability. Students often use computer programs without understanding the basis of the application. The theory, as mentioned above, has become more and more idealized and thus often useless to application. One is

tempted after learning, for example, the phase rule and observing that a linear, flexible macromolecule is semicrystalline, i.e. a one-component system exhibits over a wide temperature range two phases, to discard all thermodynamics for the description of polymers. Without integration to irreversible thermodynamics and kinetics, only very little practical use can be made of thermodynamics. The application of thermal analysis, finally, must cover all materials and a subdivision, as pointed out above, is of use. Teaching of applications must cover all fields of matter, a need rarely satisfied, even (or particularly) at our better universities.

How can these problems then be tackled? I would suggest two basic approaches:

1. Reintroduction of thermal analysis into basic education
2. Development of a professional curriculum

It is not sufficient to concentrate on the development of graduate education only, since at the time of decision for graduate study it is too late for the student to make an intelligent choice to go into the field of thermal analysis. In addition, the non-expert will later not know about the available expertise in thermal analysis. Thermal analysis must thus appear in its modern form already in high school and undergraduate education. The goal of ICTA must thus be to develop from the professional curriculum, modern, exciting teaching material for the earlier education stages to inform and support the teaching staff.

To get started I would like to suggest anyone involved in, or interested in, teaching the subject of thermal analysis to send to me possible curricula for discussion, so that at the next education committee meeting, progress can be made to zero-in on recommending a collection of courses and syllabi. Overall, one should perhaps suggest 3 three-credit semester courses for a MS education, and 8 three-credit semester courses for a PhD education. For a basic thermal analysis course one may want to use a syllabus as developed for our audio course on thermal analysis, presently updated to a textbook to be published in 1989. Advanced courses should cover perhaps Materials Science, Statistical

Thermodynamics, Irreversible Thermodynamics, Kinetics, Structure of Solids and Liquids, Data Treatment, Advanced Thermodynamics, Calorimetry. Please send more, possibly with a short outline of topics and arguments for or against certain topics.

DISCUSSION AND COMMENTS

E. Turi (USA): I would like to suggest that the Education Committee should promote teaching materials such as the available audio courses to make everyone aware of and provide access to the existing information sources.

D. Dollimore (USA): I would like to point out that one or two physical chemistry textbooks introduce thermal analysis in the form of cooling curves as tools to establish phase diagrams. In addition, physical chemistry texts used to be filled with phase diagrams and in the laboratory experiments students used to get practical instruction in this technique. We should devise means to go back to this part of instruction.

B. Wunderlich (USA): I do not think that cooling curves, as such, are what I had in mind as thermal analysis knowledge. Today's scanning calorimetry, thermogravimetry and dialatometry is much more sophisticated. But in particular we should make sure that as the major user we should have an input in how thermodynamics is taught. Since we find it necessary to treat irreversible processes, the treatment of non-equilibrium processes must not be omitted. Since we find that today applications cover also polymers, mesophases, ceramics and metals, they should also not be omitted in the basic physical chemistry or even beginning chemistry courses.

D. Dollimore (USA): This depends on the type of graduate or undergraduate study. One should adopt a course of evolution, not revolution. These new ideas should be introduced little by little.

B. Wunderlich (USA): In my teaching of freshman chemistry at RPI over the last 3 years I found no difficulties revolutionizing the choice of subject matter.

G. Thiel (FRG): Usually in thermal analysis we are not in equilibrium, but it should be remarked that temperature is usually

equilibrated. It is of importance to differentiate between thermal equilibrium and structural equilibrium.

III THERMAL ANALYSIS EDUCATION IN SOUTHERN AFRICA

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Introduction

Southern Africa, in this context, refers to the Republic of South Africa(RSA); the former British dependencies, Swaziland, Botswana and Lesotho and the recently-independent states of Transkei, Ciskei, Venda and Bophuthatswana. Excluded are Zimbabwe, Zambia, Angola, Mozambique and Malawi (although there has been some interest in thermal analysis from Malawi). In the RSA there are 16 universities and 8 technikons and each of the other states has or shares a university.

Most of the problems of promoting education in thermal analysis (TA) are obviously the same as in any other part of the world. I will summarize briefly what has and is being done. The teaching of basic principles and techniques of thermal analysis forms a very small part of degree or diploma courses, but at last seems to be gaining a foothold. At most of the technikons, TA is taught, with a strong practical basis, as part of the Higher Diploma (4th year). Students are usually in employment and are assigned relevant projects. I think that it is true to say that thermal analysis has not been as readily accepted into traditional chemistry courses at universities. One of the reasons for this is its cross-disciplinary nature. At my own university, I offer an option on TA in the Honours (4th) year. Two of the main topics discussed are kinetic information from non-isothermal studies and the determination of purity by DSC, which are both interesting variations on "standard" kinetics and thermodynamics. At one stage we also gave some lectures in TA to students majoring in Chemistry and Geology. More education is provided less-formally through professional societies (e.g. chemistry or polymer science soci-

eties); the thermal analysis society itself or through the representatives of instrument manufacturers. The emphasis has been on introductory courses aimed at the training of operators and users of instruments, but we have also, at times, aimed at providing suitable information to scientists in managerial positions to enable them to assess the potential value of thermal analysis techniques in their specific situations.

Historical

The first "course" on thermal analysis given in the RSA of which I am aware, formed part of a Winter School on "Modern Analytical Techniques presented by the SA Chemical Institute in 1966. Two lectures on TG and DTA were given by Dr. T.L. Webb and J.E. Kruger of the National Building Research Institute (NBRI) who are pioneers in the use of these techniques, especially as applied to clay minerals. Their pioneering contributions are mentioned in the historical articles by Dr. Mackenzie (1).

Interest in the techniques of TA only really began to grow when commercial equipment became available in the early 70's. There was strong competition between the few manufacturers, DuPont,Perkin-Elmer and Mettler, represented in the RSA at that time, with a few of each system being sold.

I was fortunate to be granted funds in 1972 to buy a Perkin-Elmer DSC-2. We also had a Cahn RG electrobalance and various furnaces and temperature controllers. We soon published some papers on DSC studies and, as a result, I was asked to give an introductory course on TA at the Analytical Workshop of the Natal Section of the SA Chemical Institute in Durban in 1979. A similar introductory course was given at another workshop in Durban in 1981, this time with the help of Perkin-Elmer (Mr. John Fursdon) in far-from-ideal accomodation. Later courses (1984 and 1986) were held at the Natal Technikon with considerable help from Mettler (Mr.Richard Stanton) and Perkin-Elmer (Mr. Keith van Loggerenberg) Perkin-Elmer also held several seminars, mainly for their customers, and at one of these (1981) the SA Thermal Analysis Society was established.

Problems

The problems encountered in running a TA course are mainly "non-geographical", but sometimes, as discussed below, geographical factors play a part:

(i) **Participants:** Obviously without people there can be no course! But even with a sufficient number of participants to make a course viable, there are still problems. The varied background of participants - from high - school graduates to PhDs, and from scientists to sales representatives - makes it very difficult to find an acceptable level of presentation. The varied expectations which the attendees have about the course-ranging from helplessness to the prospect of becoming an expert after a few hours of tuition - can also cause problems.

(11) **A suitable venue:** Southern Africa has a very low average population density, the major industrial centres being the Witwatersrand area (mining and general),the Western Cape (agricultural, fisheries, general), the area around Durban (agricultural and petrochemical) and, to a lesser extent, the area around Port Elizabeth (automotive engineering). Most scientific activity takes place in the Witwatersrand area (Johannesburg and Pretoria) so participants from other areas have the added costs of travel and accomodation. A hotel is very good logistically and socially for a course, but the provision of utilities is not usually satisfactory.

(iii) **Lecturers:** Southern Africa is off the "beaten track" and with the perceived political situation we do not get many international visitors. SATAS is a small society (about 60 members) so finding funds to pay for visits is not easy. We have been fortunate in having a recent visit by Professor Slade Warne which was a great boost for SATAS and did much good for the promotion of thermal analysis amongst geologists as well as chemists. It also was a good promotion for ICTA amongst SATAS members to have the Vice-President present at our symposium. Otherwise most of the lecturers for our formal courses have been local people with some very welcome support from lecturers brought out by instrument companies. Several of the course participants from the technikons

have later been involved in their own teaching courses.

(iv) **Equipment:** It is absolutely essential to have an adequate supply of good, but uncomplicated, equipment for "hands-on" practical work. Most institutions do not have a wide range of TA equipment available and the equipment that they do have is often fairly heavily-used. It is also expensive and there is always the danger of damage being caused by inexperienced users. Even the course instructors may not be very familiar with the particular equipment available. To put on a course, then, one usually has to rely on manufacturers to supply equipment. Since they are business and not charitable organisations, there has to be something in it for them, and this is usually the prospect of selling their equipment to the participants. There is thus usually an agreement that exclusively their equipment will be used. There are also problems in that sales of equipment in this part of the world are low in comparison with the USA and Europe and local companies do not, as a rule, keep any instruments in stock for demonstration. Even spares are imported on demand, sometimes with long delays. Equipment may thus have to be specially imported in the hope of being able to sell it later, or the manufacturer may arrange with one of his customers to make their existing equipment available for the course at the manufacturer's risk. The exclusive use of one make of equipment can cause further problems. It is often taken to imply some kind of endorsement of the equipment by the organisation presenting the course and this can lead to loss of support from rival manufacturers. Participants who already have existing equipment in their laboratories, and are being sent to learn to use it, are also not all that happy to find that their "brand" is not available. The manufacturer of the opposition equipment is in turn and rather short-sightedly, not happy that his prospects of a sale are reduced. We have to convince the manufacturers that any effort and investment in thermal analysis education can only be to their advantage in the end - even if it is only that some critical participants (and maybe instructors) point out some of the weaknesses in the manufacturer's system which can lead to improvements.

(v) **Notes or a book:** I have long been an admirer of the book, "Thermal Analysis" by T. Daniels (2) but it was never very readily available and is now a bit dated. The new edition of Professor Wendlandt's book (3) is ideal for the specialist working in the field, as is the book edited by Professor Turi (4) for polymer scientists, but both are too advanced and too expensive for introductory courses. I ended up preparing notes which grew over the years into an introductory textbook (5) which has just been published (June 1988) by Chapman and Hall, London. The recent book by Dodd and Tonge (6) looks as if it could also be useful in elementary courses.

Advanced level courses

Most of my emphasis has been on introductory courses because this is where the only economically-viable demand is at the moment. We did attempt to aim a course specifically at the automotive industry, but could not generate sufficient interest. We have now had three national symposia at which research papers have been presented. Again the problem of small numbers of people interested in any specific application arises. The papers which have been most enthusiastically received have been those where there has been more emphasis on the technique than the application. Workshops, on a smaller scale than the successful ICTA versions, might be worth trying.

What emerges as the greatest need of users of TA seems to be help with the interpretation of results of TA experiments. This something which can only be taught up to a point, the rest only comes with long, hard experience.

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PROVIDERS OF THERMAL ANALYSIS EDUCATION

1. Universities and Technikons
2. Professional Societies
3. Thermal Analysis groups or societies
4. Manufacturers

Basic Requirements for a TA Course

1. Participants
2. A suitable venue
3. Lecturers
4. Equipment
5. Notes or a textbook

DISCUSSION

B. Wunderlich (USA): You pointed out the problem of large distances to collect audiences for lectures on thermal analysis. One solution may be to use telephone or video conferences to bridge the distances? A 2-5 hour conference may be cheaper than the transportation cost.

M. Brown (RSA): I agree that this is a good suggestion. But, perhaps our telephone system may not support 5 hour phone calls.

IV. PROGRESS IN THERMAL ANALYSIS AND THE EDUCATION IN JAPAN

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1. Japan has a long history of thermal analysis, for example Prof. Honda's invention of thermobalance in 1915 and Prof. Akahira's pioneering work of kinetic study in 1925. Even before the Second World War, Honda's thermobalance was commercially

available, and DTA and TG were widely applied to metals, ceramics, minerals, electrical insulating materials, etc. In the middle fifties, fully automated DTA apparatuses became available, and with these instruments research on thermal analysis was further promoted.

Based on this history, the first Japanese Calorimetry Conference (afterwards renamed Japanese Conference on Calorimetry and Thermal Analysis) had been organized in 1965, the same year as the establishment of ICTA. One of the unique points in the Japanese organization is that both calorimetry and thermal analysis were organized from the very beginning. It was done by the leadership of the founder, Prof. Seki, and it has provided bases for collaboration between two fields. In 1969 the Society of Calorimetry and Thermal Analysis, Japan was established. The activities of our society will be described later in relation with education.

In the late sixties, increase in application of thermal analysis, especially DSC, DTA and TG, was accelerated by their application to high polymers in relation to morphology and thermal stability. In this period, Japanese production of the thermal analysis instruments had been increasing by a factor of 200 percent per year. Successful application of thermal analysis was highly appreciated and it also bore fruit in quality control and industrial standardization, as well. This is seen in newly established Japanese Industrial Standards on TG for estimation of thermal stability, DTA and DSC for measurements of temperature and heat of transformations as well as heat capacity measurement, and TMA for high softening temperature determination of engineering plastics instead of the Vicat test. In these establishments, many society members participated in planning, round robin tests and formulation.

There are also similar developments in other fields, such as advanced ceramics, metals and foodstuff. Recently, thermal analysis research in medicine and biological substances shows remarkable advancement.

Thus, the activities of the society cover a wide range of calorimetry and thermal analysis from basic research, such as

ultralow temperature highly accurate calorimetry, through fundamental research and development to quality control and industrial standardization. The number of the society members has been increasing steadily up to more than 700. Besides the members, a great number of non-member scientists are using thermal analysis as a complementary technique in their research work while a large number of technicians are also engaged in thermal analysis for quality control and industrial standards.

2. Multiple Developments in Thermal Analysis

As seen in the history described above, thermal analysis has been developed in multiple directions.

(1) Expansion in applied fields (increase in variety of substances), for example, from minerals and ceramics through polymers and foodstuff to medicines and biological substances.

(2) Transfer of the techniques from fundamental research through development to quality control and industrial standardization.

(3) Advancement from qualitative application to more sophisticated analysis of the data, for instance, from finger print tests to heat capacity measurements, purity determination, kinetic analysis, etc.

(4) Increase in variety of thermal analysis techniques from DTA, DSC and TG through TMA and various simultaneous measurements to EGA with MS and FTIR, etc.

In relation to each direction of development, education has been made in Japan by universities, colleges, our society, a technical newspaper company and instrument producers.

3. Education of Thermal Analysis in Japan

3.1 Universities and colleges

There are 356 universities and colleges which have a faculty of science and/or technology in Japan, so that the total number of departments of chemistry, applied chemistry, industrial, chemical engineering, materials science and mineralogy seems to be more than 400. Because there is not a common curriculum among them, it

is very difficult to investigate education of thermal analysis in these departments. However, differential thermal analysis and heating curve method seems to be taught in undergraduate courses in the majority of them.

3.2 The Society of Calorimetry and Thermal Analysis, Japan

The main activities of the society are (1) annual Japanese Conference on Calorimetry and Thermal Analysis, (2) the quarterly journal named "Netsu Sokutei" (Calorimetry and Thermal Analysis) and other publications, (3) seminar for beginners, which is held once or twice a year and (4) workshop on special topics, which is held precedently or successively to the seminar.

(1) Seminar

Until now, 16 seminars were sponsored by the society, as listed in Table 1, and there are two day courses by several lecturers with instruments demonstration by instrument producers. Because many people begin thermal analysis every year, there is long lasting need for the seminars, and fairly large portion of the newcomers are engaged in quality control and industrial standards, so that some of the lectures cover these fields. To show versatility and wide applicability of thermal analysis, the society edited a text book entitled "Thermal Analysis: Fundamentals and Applications - Various Applications, from Biological Substances to Ceramics," which consists of five parts, and 156 items are described by 104 authors, almost all of whom are society members. Each item is explained in one or two pages with one illustration per page, and there is a comprehensive index. Thus, this text book is also useful as an encyclopedia of thermal analysis.

This text book is used in the seminar together with another text book in which the lecturers write a few pages outline of their lectures.

(2) Workshop

The society also sponsored the workshop to organize informal discussion on a specific topic, usually on sophisticated applications of thermal analysis and calorimetry. It enables the participants to learn advanced utilization of thermal analysis.

Five workshops held until now are listed in Table 2.

(3) Publication

There are two varieties of periodicals published by the society; a quarterly journal named "Netsu Sokutei" (Calorimetry and Thermal Analysis) and an annual publication of "Netsu Sokutei no Shinpo" (Progress in Calorimetry and Thermal Analysis). The quarterly journal was first published in 1974, following the former publication of Newsletter. In this journal, reviews, commentaries and miscellaneous articles are published together with original papers and monographs. Usually, one or two pages are allotted to commentaries on the practical applications, such as process control, quality control and industrial standards. Course on calorimetry and thermal analysis for beginners are often planned and published serially.

The annual publication of Progress in Calorimetry and Thermal Analysis has been made since the first Japanese conference in 1965. In each issue are progress reviews of fundamentals and applications covering calorimetry and thermal analysis.

Thus, these publications offer the members opportunities of self-education.

(4) Conference

Since the first conference in 1965, two to six plenary lectures have been given in each conference, and so-called mini-symposium on specific topics is also organized, in which review papers and monographs are read together with original papers. Usually, about 100 original papers are presented in the conference. To celebrate the 25th anniversary, the special conference will be held in Osaka in the autumn of 1989. The organizing committee will be presided by Prof. Suga of Osaka University and will invite foreign lecturers. Thus, the conference is also an opportunity for education.

3.3 The Technical Newspaper Company and Instrument Producers

A Japanese technical newspaper company, Nikkan Kogyo Shimbunsha, publishing a daily newspaper "Business & Technology", has been making an educational work by correspondence courses on

analytical chemistry, in which thermal analysis is contained as one item among 13. In the course a subscriber receives a text book with a collection of problems and learns it by oneself. Then, the subscriber sends the answers and receives the corrected answers. In the 6 day schooling a 2.5 hour lecture is given on each item. This corresponding course has been made since 1972, and average number of subscribers is 180 per year, roughly 30 of whom are also present at the schooling. Because this course is continued for 17 years, the total number of subscribers who got the certificates seems to amount to a few thousands.

Five producers are now producing instruments in Japan, and they also have sponsored various courses on thermal analysis except for a newly established producer, MAC Science. They are listed in Table 3. Most of them are for beginners, but some are advanced courses on special subjects, such as kinetics and recent oxide superconductors. Several courses have been sponsored by foreign producers.

Some of the Japanese producers publish magazines for publicity, in which magazine reviews and commentaries on thermal analysis are contained with detailed description of their instruments, while others are gathering information on thermal analysis applications and publish technical data sheets on the applications.

Table 1 Seminars by SCTAJ

no.	Date	Place	Attendants	Note*
1	'76.7.8-9	Tokyo	92	
2	77.5.19-20	Osaka	57	life science
3	78.5.18-19	Tokyo	58	bioscience
4	79.7.5-6	Tokyo	70	high temperature
5	80.6.18-19	Tokyo	114	beginners, d
6	81.7.10-11	Osaka	105	beginners, d
7	82.7.1-2	Tokyo	52	beginners
8	83.7.4-5	Tokyo	120	beginners, d
9	84.3.15-16	Osaka	65	beginners, d
10	84.9.5-6	Tokyo	102	d
11	85.5.9-10	Osaka	76	fundamentals and materials, d

Table 1- (continued)

12	85.10.16-17	Tokyo	169	materials, d
13	86.5.7-8	Osaka	62	beginners, d
14	86.12.1-2	Tokyo	63	beginners, d
15	87.6.23-24	Kyoto	101	beginners, d
16	88.7.14-15	Kyoto	94	beginners, d

* The symbol d means demonstration, and the main subject is shown.

Table 2 Workshops by SCTAJ

no.	Date	Place	Participants	Topics
1	'85.10.18	Tokyo	57	Biology
2	86.5.9	Osaka	55	Polymer
3	86.12.3	Tokyo	85	DTA and DSC
4	87.6.25	Kyoto	70	Purity and Heat Capacity
5	88.7.13	Kyoto	56	New Materials

Table 3 Seminars and schools by producers

Company	Type	Times/Period (Frequency)	Attendants	Note
Seiko	Seminar	32/'81 -	100-300(Tokyo)	
Electronics	(1 day lecture)	av 4.5/yr	50-100(Osaka) (initial-recent)	
	Users'	12/'85-	max.15	Operation*
	School (1-2 days)	av 4/yr		
Shimadzu	Seminar	33/'73- av 2/yr	total 613	Operation*
Shinku-	Operating	71/'85-	total 660	Operation*
Riko	School	av 24/year		
	Seminar	16/'85- av 5/year	total 480	High Tech-nologies**
Rigaku	Seminar	every month	max 8-12	Operation*
Denki***	(planned)			

* Attendants operate the apparatus.

** Topics are focused on high technologies.

*** Rigaku Denki Co., Ltd. has not arranged regular and frequent seminars, and it is planning regular seminars.

DISCUSSION

Unknown (UK?): There seem to be many courses offered, but are not all somewhat theoretical? Should one not organize practical courses and give a chance to work with the equipment?

T. Ozawa (Japan): The activities are often directed to industrial application and process control. Demonstration by instrument companies give, in addition, often a chance to work with the equipment during the seminars and workshops.

B. Wunderlich (USA): I find it surprising to call the society Calorimetry and Thermal Analysis Society of Japan. Does not thermal analysis also include calorimetry? Are the reasons historical for this choice?

T. Ozawa (Japan): I am not sure. In 1965 at the first conference only calorimetry was in the title, but first papers of thermal analysis were also presented, so that later the title was changed.

D. Dollimore (USA): This question of nomeclature should be addressed also in other countries.

B. Wunderlich (USA): Yes, I know, and it is very nice to see that in Japan the society at least covers all areas of thermal analysis, irrespective of the name. In the USA, in contrast,there are still separate conferences on calorimetry and thermal analysis.

T. Ozawa (Japan): The contribution of the two fields in Japan was made under the leadership of Professor S. Seki. I would like to add to my presentation that the Japanese Government has also provided funds for developing countries to support thermal analysis. Two examples are that apparatus was given to Pakistan, as written up in a recent issue of the ICTA News, and I am aware of support for thermal analysis research for a guest worker from Indonesia to work with Dr. Hatakejama on DSC.