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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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Consultative Group Meeting on Collaboration
in Testing and Evaluation of New Materials

Daejon, Republic of Korea, 22-24 March 1994

REPORT*

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1. Introduction

The Consultative Group Meeting on Collaboration in Testing and Evaluation of New Materials was organized by UNIDO in cooperation with the Korea Research Institute of Standards and Science (KRISS) and held in Daejon, Republic of Korea, 22-24 March 1994.

The Meeting was attended by 11 participants from 8 countries . The list of participants is attached as Annex I.

The objectives of the Meeting were:

- To exchange experiences among the participating countries in the area of testing and evaluation of new materials.
- To identify the needs, potential and areas of cooperation in this field .
- To discuss a pilot activities phase of an International Centre for Materials Evaluation Technology (ICMET) and sources of its funding.
- To work out recommendations and follow-up activities required for the establishment of the ICMET and promotion of cooperation in the area of testing and evaluation of new materials.

2. Opening of the Meeting

The meeting was opened on Tuesday, 22 March 1994 at 10:00 a.m. at the Korea Research Institute of Standards and Science. In opening of the meeting, UNIDO representative welcomed all the participants and thanked Dr. Park and his staff for their excellent work in preparing the meeting. He pointed out that this meeting covered the issues raised in the Regional Workshop on Testing and Evaluation of New Materials for Asia organized by UNIDO in cooperation with KRISS and held in Daejon, the Republic of Korea, from 25-28 March 1991.

UNIDO representative outlined UNIDO's overall approach on the promotion of new technologies in support of industrialization process in developing countries and increase of competitiveness of their industries. He then introduced UNIDO's work in the area of new and advanced materials, emphasizing the importance of regional and international cooperation and establishment of centres of excellence. In this connection, he reported what results had been achieved by UNIDO and the Republic of Korea in their joint preparatory work for the establishment of an International Centre for Materials Evaluation Technology (ICMET). He also informed the participants about the support expressed by other countries and individual institutions to this initiative during the preparation of the feasibility study on that issue and expressed the hope that further its promotion and establishment would lead to more cooperation in this vital area.

Dr. Park, the President of KRISS, welcomed the participants to the Republic of Korea and KRISS. He highlighted the importance of new and advanced materials for industrialization and economic development of a country and the role UNIDO was playing in promotion of design, manufacturing, testing and evaluation of new materials and in their industrial application in developing countries. Dr Park stressed the fact that new materials with added value and advanced functions required more sophisticated and systematic techniques of testing and evaluation for their practical application. He emphasized that the testing and evaluation technique for new materials should be compatible and standardized at the regional and international level and thus the international cooperation should be strengthened.

Dr. Park noted that strong cooperation in this area took place among the G-7 countries within the frame of the VAMAS project. But there was a lack of concentrated activities among developing countries and between them and industrialized countries. Therefore, KRISS and UNIDO with the support of the Government of the Republic of Korea were working on the preparation for establishing an International Centre for Materials Evaluation Technology. He expressed the hope that ICMET would aim at eliminating of this gap and would lead to even more international cooperation in this important field. Finally, Dr. Park called participants for fruitful discussions and elaboration of concrete plan for the establishment and further promotion of ICMET.

3. Administrative arrangements

Election of Officers

The Meeting unanimously elected Dr. Hahngue Moon as Chairman of the Meeting. The other participants chaired selected working sessions of the meeting.

Adoption of Agenda

After discussion, the Meeting adopted the following agenda:

(i) Opening of the Meeting
(ii) Administrative Arrangements
(ii.i) Election of Officers
(ii.ii) Adoption of Agenda
(iii) Presentation of Issue Paper
(iv) Presentation of expert papers
(v) General Discussion on the subject
(vi) Review session and discussion on the mode and scope of cooperation within the preparatory and pilot activity phase of ICMET
(vii) Discussion on possible sources of funding for the proposed work programme
(viii) Discussion on and adoption of conclusions and recommendations/follow-up activities
(ix) Concluding session and summing up
(x) Closure of the Meeting

4. Conclusions and Recommendations

The Meeting stressed that materials technology is a key enabling technology for a wide range of industrial sectors which have a major influence on the economic and industrial competitiveness and reliable methods of testing and evaluation of new and advanced materials are crucial for their successful development and efficient incorporation into competitive industrial products.

The Meeting fully supported the initiative for the establishment of ICMET as an appropriate institution for international cooperation in the area of materials evaluation.

The Meeting considered it essential to establish a network as a complement to ICMET and participants agreed to undertake initially the role of national focal point.

After reviewing of the background documents for ICMET, the Meeting felt that the Feasibility Study for ICMET was valid and provided the basic steps for its establishment.

The Meeting agreed that the preparatory and pilot activities for the establishment of ICMET be carried out as a UNIDO project to facilitate an international character of the Centre.

The Meeting welcomed with appreciation, the timely offer of the Republic of Korea to host the Centre and provide resources for its establishment.

The participant undertook to explore ways of supporting the centre including in-kind contributions.

The Meeting recognized the efforts and the constructive role that UNIDO has played in promotion of ICMET as well as the resources devoted by UNDP/UNIDO for this purpose.

Based on the Feasibility Report, the Meeting elaborated a detailed programme of activities for the preparatory pilot phase of the Centre. These activities are specified below.

The Meeting thanked KRISS for the hospitality and support provided during organization and holding the Meeting.

5. Activities for the Preparatory Phase of ICMET

A. Introduction Base

(i) To establish national focal points which would be responsible for developing primary contacts within their countries.

(ii) To develop an ICMET roster, initially focusing on the Asian region of a. institutions, b. key facilities for testing and characterization, c. individual experts.

(iii) To collect information on existing data bases relevant to the functions of ICMET.

B. Promotional Works

(i) To prepare a promotional brochure on ICMET including names of contact points at both national and international levels.

(ii) Within the UNIDO monitor on advances in materials technology, to publish a newsletter on activities within the framework of ICMET.

(iii) To promote ICMET through information in national scientific and technical journals.

(iv) To promote ICMET during participation at national/international meetings.

C. Workshops and Seminars

(i) To hold a special session and testing and evaluation during the 8th International Conference on Physics of Semiconductors to be held in India in December 1995.

(ii) To organize a workshop on absorption materials for pollution and environmental control.

(iii) To co-sponsor an international meeting on testing and evaluation of advanced polymer composites planned to be organized in Singapore by SISIR in 1995-1996.

(iv) UNIDO was requested to organize a workshop on problems and trends in materials evaluation and characterization.

D. Training Courses

(i) To consider the organization of two training courses on:

- surface and interface analysis;
- real structure of materials

E. Collaborative Projects

(i) To develop collaborative projects in the following areas:

- characterization and mechanical properties of structural ceramic;
- characterization of materials for microelectronics;
- surface composition analysis by electron/ion spectroscopies;
- degradation of polymer materials;
- tribology of polymers and ceramics; and
- near net shape technology for metal injection moulding.

List of participants

Prof. Min-da Wu
Shanghai Research Institute of Materials
99 Han Dan Road
Shanghai
People's Republic of China
Fax: 008621-5420554
Tel: 021-5420775

Dr. Krishnan Lal
Head
Materials Characterization Division
National Physical Laboratory
Dr. K.S.Krishnan Road
New Delhi 110012
India
Fax: 091-11-5752678
Tel: 581733

Dr. Nilyardi Kahar
Head
R+D Centre for Metallurgy
Indonesian Institute of Services
Kompleks Puspiptek Serpong
Tangerang 15310
Indonesia
Fax: 022-2503050, 021-7560553
Tel: 022-2503052, 021-7560911

Dr. Hahngue Moon
Director
Materials Evaluation Centre
Korea Research Institute of Standards and Science
P.O. Box 3, Taedok Science Town
Daejon 305606
Republic of Korea
Fax: 042-861-1494
Tel: 042-868-5025

Dr. Gun-Woong Bahng
Microstructure Analysis Laboratory
Korea Research Institute of Standards and Science
P.O. Box 3, Taedok Science Town
Daejon 305606
Republic of Korea
Fax: 042-861-1494
Tel: 042-868-5320

Dr. Sunik Hwang
Head
Office of International Cooperation
Korea Research Institute of Standards and Science
P.O. Box 3, Taedok Science Town
Daejon 305606
Republic of Korea
Fax: 042-861-1494
Tel: 042-868-7200/10

Dr. Joo Fai Tung
Standards and Industrial Research Institute of Malaysia
Persiaran Dato Mengeri Section 2
P.O. Box 7035
40911 Shah Alam
Selangor
Malaysia
Fax: 603-5508095
Tel: 603-5592601

Dr. Daniel Yip
Singapore Institute of Standards and Research
1, Science Park Drive
Kent Ridge
P.O. Box 1128
Singapore 0511
Fax: 0065-778-0086
Tel: 0065-778-7777

Dr. Ladawal Chotimongkol
Thailand Institute of Scientific and Technological Research
196 Phahonyothin Road
Chatuchak
Bangkok 10900
Thailand
Fax: 662-579-6538
Tel: 662-579-6538

Dr. Kamal Hossain
Head
Division of Materials Metrology
National Physical Laboratory (NPL)
Teddington
Middlesex
United Kingdom
TW11 OLW
Fax: 081-943-2989
Tel: 081-977-3222

UNIDO

Mr. Anthony Bromley
Chief
New Technologies Promotion
UNIDO
Vienna International Centre
P.O. Box 300
A-1400 Vienna
Austria
Fax: 0043-1-238348
Tel: 0043-1-21131-5158/4822

Mr. Vladimir Kojarnovitch
Industrial Development Officer
New Technologies Promotion
UNIDO
Vienna International Centre
P.O. Box 300
A-1400 Vienna
Austria
Fax: 0043-1-238348
Tel: 0043-1-21131-3720/4822

TESTING AND EVALUATION OF ADVANCED MATERIALS

Kamal Hussain
National Physical Laboratory,
Teddington, Middlesex, UK
TW11 OLW

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TESTING AND EVALUATION OF ADVANCED MATERIALS

by

M K Hossain
National Physical Laboratory, Teddington,
Middlesex, UK, TW11 OLW

INTRODUCTION

Industrial competitiveness, economic growth of nations, and the quality of modern life all rely strongly upon innovations in materials technology and hence it is considered widely to be a critical technology. Without new and improved materials and processes, recent advances in fields such as computers, communications, transport, healthcare and leisure could not have been realised. By the turn of the century markets for advanced materials have been estimated to reach $400 billion globally, and in the USA alone, 1.5 million "high skill" jobs will depend upon new developments in this field[1].

Materials evaluation and testing plays a central role in the successful development, but more importantly, in the applications of new materials into products. In this paper, key issues related to testing and analysis are discussed with particular reference to structural materials ie materials with load bearing properties. The importance of standardisation of testing methods is considered in the light of globalization of markets and of industrial manufacture. Much effort and resources are needed to meet the challenge and there are significant opportunities for co-operation amongst countries in underpinning work to provide the technical base from which widely acceptable standards can be developed. An analysis of the current situation with indications for future developments is presented here.

VALUE OF TESTING AND EVALUATION TO INDUSTRY

Many of the important advantages of advanced materials may be attributed to their superior performance. Market requirements tend to dictate their use in more severe operating conditions, in areas of greater added value and in products emphasising greater design efficiency than traditional materials. All of these require reliable information on materials behaviour and properties based on sound materials evaluation techniques. Thus, reliable testing and evaluation methodologies are required for:

- (a) material development,
- (b) quality control and assurance,
- (c) materials specification,
- (d) engineering design,
- (e) product development and assessment,
- (f) determination of residual life, and
- (g) system maintenance.

Requirements will vary in individual cases, but it follows from above that information or data on a range of material parameters may be called for eg in the case of structural applications of engineering materials this could cover:

Mechanical Properties	Stiffness, strength, creep, toughness, impact, fatigue, wear etc.
Environmental Properties	Resistance to heat, light, humidity, corrosive medium (gaseous or liquid)
Surface Properties	Composition, structure, adhesion etc.
Process-related Properties	Viscosity, surface tension, cure, heat transfer etc.

In addition, measurements of electrical, optical, magnetic or a combination of these properties may be required for certain applications and materials.

In the industrial context, materials evaluation is relevant to all the key stages of manufacture. Based on an identified market need, the designer prepares a design brief using which preliminary ideas about a product (schematics) are developed. At this stage materials selection, selection of manufacturing methods and first order cost estimate for the product are made. These are based on relatively straightforward test data or materials properties and often a family of materials is chosen.

The next phase is concerned with detailed design and developing manufacturing specifications. To undertake this work, the structural engineer must have reliable and high quality materials property data and appropriate design analysis methods. Standards and codes of practice are sometimes available providing guidance on specific types of component design and the codes of practice may specify standardized test methods which must be used to obtain properties data. For detailed design, particularly for critical applications, suitable materials data can often only be obtained by testing materials made by the chosen manufacturing process and in the anticipated environment. Structural testing of the component/product may also be required to fully validate the design and production method. Finally, in the manufacturing phase, tests to comply with quality control and assurance are carried out including non-destructive evaluation (NDE).

Evident from above is the fact that materials property data are required at various stages, but the nature and quality varies according to whether one is dealing with materials selection, design or production.

In Europe, USA and Japan, the importance of testing and evaluation has been clearly recognised. Thus, the Presidential Materials Initiative launched in the US in 1992 contains materials characterisation including assessment of performance, properties and structural relationships as one of the four key components(2). In Japan a large industrial survey has concluded that priority in standardization should be given to testing and evaluation methods(3). Similarly, a 1991 study of the European Commission on Industrial and Materials Technologies: Research and Development Trends and Needs, confirmed that performance testing and standardization should be a priority theme for medium term R&D(4).

ISSUES IN MATERIALS EVALUATION

For high pedigree design data, advanced materials often require different approaches to materials testing based on a sound understanding of their structure and behaviour. In many cases validated measurement methods do not exist with the consequence that there are disagreements about interpretation of results and unwillingness to accept others' results. Accuracy, meaning how close the measured value of a property is to the real value, is a particular problem because real values cannot be calculated or established otherwise. Areas for particular concern are:

- anisotropic nature of many materials and products;
- microstructure and behaviour can be complex relative to conventional materials;
- final properties depend upon processing route and conditions;
- demanding test conditions eg high temperatures, complex environments;
- absence of suitable design methodologies which dictate actual measurement requirements;
- increasing need for extrapolation of data;
- requirement for wider range of data and data of much higher accuracy than previously;
- physical measurement techniques are being used near their current limits.

Testing of Composites Some of the points may be best illustrated by considering, say, testing of composite materials. Components made from composites are often complex and tailored to provide strength and stiffness specifically where these are needed. Such anisotropy and inhomogeneity give rise to immediate complications for materials testing. Even for a relatively simple task as tensile strength measurement, serious problems can arise from non-alignment of test pieces, means of stress transfer and the effects of residual stress and stress concentrations.

For instance, smooth and hard surfaced composites cannot be clamped in the same way as metals because conventional gripping can fracture the matrix and cause failure. End-tabs bonded to the test piece are used, but these can themselves cause failure in some cases. Another method for overcoming the problem is to drill holes in the testpiece and use pegs to transfer the stress but this can lead to a non-uniform stress distribution.

The shape and size of the testpiece also requires careful consideration to ensure that the results are representative of the bulk materials as opposed to the testpiece. In tensile testing of traditional materials, testpieces are waisted so that failure occurs in the thinner more highly stressed part of the sample. Adoption of this procedure, say, for a unidirectionally laid up composite with fibres running along the length of the testpiece, means the testpiece has to be I-shaped. Much of the clamp force on the short fibres terminating at the waist is transferred to the matrix so the testpiece fails by cracking at the shoulders of the I.

Creep Testing of Polymeric Materials and Modelling Measurement of creep in polymeric materials cannot be treated in the same way as metallic materials due to the physical ageing effects in polymers. After processing, continuous increases in density are observed for most solid polymers due to molecular rearrangements associated with the approach to structural equilibrium. This physical ageing process leads to pronounced decreases in properties such as creep rate, impact strength, dielectric constant and loss factor. Hence, for polymers, it is vital to take into account elapsed time after processing (t) for measurement of creep properties.

Figure 1 shows the variation of compliance, D(t), at 23 °C with log(t) for polypropylene samples of different age; D(t) is defined as the time dependent longitudinal strain divided by the constant uniaxial applied stress. At long times, the experimental compliances, (shown as points), are considerably lower than the values obtained by extrapolations (broken lines) of short-term data which have neglected further ageing during the test period. However, if polymer ageing is taken into account using a model developed at NPL[5], the predicted compliances shown as continuous curves, are within 3% of the observed value. This agreement is valid for 2-3 decades beyond the short-term region. Thus, if a polymeric component is subjected to a constant load one month after processing, its deformation may be confidently predicted for times greater than 10 years from tests of about 1 week's duration. A model based on known physical principles associated with accurate traceable measurements can indeed provide a cost effective answer to the measurement problem. In fact, to characterise the creep of a polymer, a minimum of some twenty five sets of measurement is required[6]. For data covering a useful temperature range increases this to several hundred measurements. When one considers that a single basic polymer can exist in the market in many hundreds of different grades the magnitude of the testing task is formidable and models such as above can come to real rescue!

<u>High Temperature Testing</u> There is considerable potential for applications of advanced ceramics in structural applications such as gas turbines where higher operating temperatures are needed to improve fuel efficiency. The materials must be able to withstand stresses at temperatures as high as 1500-1600 °C in hostile environments for extended periods of time whilst maintaining a reasonable tolerance of existing or newly created defects. The high stiffness and damage intolerant behaviour of ceramics, coupled with the requirement for testing at very high temperatures, poses specific problems such as

- measurement of uniaxial properties without introducing bending stresses;
- measurement of small strains at high temperatures;
- establishment of testpiece temperature; and
- development of furnaces with a sufficiently uniform temperature distribution.

<u>Low Cycle Fatigue</u> LCF can be a life limiting factor in critical components such as pressure vessels and turbines, so testing for LCF is carried out extensively in industry to characterise materials performance and to provide design data for components operating under fluctuating loads and temperatures. Although very similar procedures are now being used worldwide, the variability in LCF data from different laboratories is rather large. This can be best illustrated by the results of an intercomparison exercise by twenty six well known laboratories in Europe and Japan[7]. Materials used were Nimonic 101 at 850 °C, and AISI 316L Stainless Steel, 9 Cr - 1 Mo Steel and IN 718 at 550 °C, all materials being sourced and characterised centrally. Guidelines were provided to define the test variables and each laboratory used its own procedure for conducting the tests.

Figure 2 is a typical example of lifetime dataset showing fatigue life for Nimonic 101 as a function of the nominal total strain range. Data from individual laboratories are plotted in separate segments to indicate repeatability (variation within a single laboratory using the same operator) whereas reproducibility (variations between laboratories with different operators) is represented by the overall spread in the "box plot". Good repeatability but poor reproducibility are evident, the worst scatter in reproducibility being a factor of about 50 - which is most unsatisfactory for the designer. Analyses of these results identified the following sources of primary error:

(a) misalignment or bending of the testpieces;

(b) errors in temperature measurement and/or control;

(c) errors in strain measurement and control.

Before the testing problem can be solved satisfactorily, it is necessary to establish the sensitivity of each of the above parameters on the final result. Further work has shown that the effects of variation in strain measurement are quite small. As regards bending, a model has been developed which provides a quantitative relationship between testpiece bending and fatigue life measurement. Prediction made by the model compares well with experimental data[8] as shown in Figure 3 confirming that bending is indeed a major contributory factor. Further work is required to develop a best practice guideline for LCF testing that will be based on harmonised procedures for the measurement of load misalignment and testpiece bending, design of testpieces and fixture, and assessment of the effects of temperature variation.

<u>Engineering Coatings</u> Coatings are applied in many industrial systems where surfaces of bulk materials suffer problems, particularly due to wear or corrosion. Industry often uses simple specifications eg a coating of certain minimum thickness and known porosity, but there is a lack of reliable evaluation methods and adequate standards even for the basic specification. Widely differing methods are sometimes used where results are not easily comparable and cannot be interpreted unambiguously. A recent study of industrial requirements in Europe has identified the need for new or improved test methods for measuring:

adhesion,	corrosion resistance,	porosity,
thickness,	friction/wear resistance,	internal stress,
surface finish,	microhardness,	and fracture toughness.

Fig 4 compares, for each property, its perceived intensity of need against our current level of knowledge. Thus, coatings adhesion to the substrate is considered to be one of the most important parameters to establish whilst accurate determination of adhesion is extremely difficult. For weaker bonds (80-100 MPa), pull tests, lap shear, double cantilever beam, napkin ring and moment methods with adhesives give useful results, but care must be taken to align and establish the failure mode (ie adhesive and not cohesive).

For stronger bonds, it is common practice to use the scratch test, but the analysis of results is by no means straightforward and there is considerable debate about the value and validity of the test method[9]. New techniques, including a four point bend test and nanoindentation, are being developed for measurement of adhesion.

FUTURE TRENDS IN TESTING AND MEASUREMENT

Changes in materials testing and assessment are being dictated strongly by advances in design methodologies and quality initiatives. Traceable data of greater precision and reliability are required by industry, but since good quality data are scarce and expensive, innovative materials models are emerging that enable greater use of the data. Similarly methods for reliable extrapolation of short-term test data to predict long-term service performance and techniques for correlation of simpler test results to performances in complex conditions have increased in demand.

Mechanical testing equipment is becoming more complex - computers are used not only to operate the machines but also to collect, evaluate and process the output data with the minimum of operator intervention. This, however, means the operator must have good knowledge of the test technique and data processing, particularly the limitations, to ensure the pedigree of results. Software validation in this context has become a truly important issue.

More severe test environments and conditions are being required, eg very high test temperatures approaching 1800 °C and above are increasingly needed for testing intermetallics, ceramics and composites. Environments which chemically interact with the material are also being superimposed to predict behaviour in service conditions. In addition, there is a growing drive for more bi-axial and tri-axial testing to simulate complex loading in components.

As discussed earlier, specimen bending can give rise to large errors in mechanical testing such as fatigue life assessment and modulus measurement. Therefore, test machine manufacturers are placing greater emphasis on the design of frames with increased lateral stiffness. Self-aligning grips and sensors for the measurement of bending of testpieces are also available for advanced evaluations.

he demand for servo-hydraulic testing machines in which materials can be tested under high rates of application of load or strain is increasing. Future trends for these machines are towards advanced control strategies with adaptive control using feedback from measurement and sensing devices. Improvements are being sought in the calibration of load cells and extensometers under dynamic conditions.

Currently measurement uncertainties are not regularly quoted which can pose difficulties for the users of test results. The situation is changing with pressure from the standards and accreditation bodies. For instance, it is the declared policy of ISO and the European standardization authority that all new standards concerned with testing techniques shall contain "a statement of uncertainty" or a method of calculating the accuracy of the test method based upon tolerances specified in the relevant standard.

Determination of remanent life of large industrial systems such as power generation and petrochemical plants is now frequently sought in order to decide whether their operational lifetime can be extended beyond the design lifetime which obviously has large financial implications. Generally, fracture or component damage and distortion due to excessive deformation, wear or corrosion leads to loss of function and therefore, for predictive purposes a host of materials properties data such as creep, low cycle fatigue and wear in the presence or absence of corrosive environments are needed. Important to note here is the fact that the data precision level required is much greater than historically demanded for design purposes and so more stringent testing is required.

Improved techniques for quality control and non-destructive testing and evaluation (NDT) are increasing in demand. Thus, industry requires improved methods for the evaluation of mechanical properties (eg bonding of composites), higher-resolution defect detection, improved computer tomography, sensing devices for physical and chemical properties of materials.

<u>Measurements related to materials processing</u> There is a growing recognition that improvements in the processing of advanced materials is of utmost importance. Test techniques that can be used for process design and control are, therefore, in urgent demand. Major customers for engineering components are beginning to insist on process qualification rather than product inspection as a philosophy for quality assurance. Sophisticated mathematical models are being increasingly used as an important tool by industry to improve processes and to "achieve right first time" (see Figure 5) - application of such modelling has advanced enormously due to the availability of computing power and software packages that benefit even quite small producers.

However, these models require reliable data for the physical properties associated with the heat and fluid flow of the processes which are not readily available. This is because appropriate measurement techniques are not available. For example, a recent analysis has shown that for plastics, important problem areas for measurements include:

(a) viscosity, (b) elasticity, and (c) fibre orientation and distribution.

Viscosity is perhaps the most important property with two aspects to be measured - shear viscosity and extensional viscosity - each is a function of temperature and flow rate.
The most common method of measurement of shear viscosity for polymer melts is a capillary rheometer with dies of various lengths and diameters. End corrections are made in analysing the data and generally satisfactory results can be obtained. Difficulties arise in measurement of shear viscosity in relation to high rates and high viscosity. Measurements for extensional viscosity, on the other hand, is not as well developed. When it comes to measuring elasticity there is a great deal of confusion and

much more work is needed before reliable measurements could be made and data incorporated in models.

In the case of metallic materials and processes, new or improved methods are required for measuring:

heat flow	
heat capacities	thermal conductivity
enthalpy	heat transfer properties
melting range	

fluid flow	
density	surface tension
viscosity	thermal diffusivity

Many of the processes operate at high temperatures where interactions between the material and its test container can cause serious problems. It is not surprising that data in the published literature are prone to large uncertainties and frequently there is no information available for commercial materials. At NPL a new programme of work has been initiated to provide the necessary data and methods required for industrial applications of models used in casting, rolling, forging and moulding.

REQUIREMENTS FOR STANDARDIZED TEST METHODS

Testing requirements for an advanced material is dictated by its application. However, because there is a lack of standardized methods, users often develop their own test methods to characterise and qualify the material and establish design allowables. Thus, despite the fact that the need for basic materials properties may be similar for a group of users, they use different methods for pragmatic reasons and expediency. As a result, a major supplier of composite materials is known to undertake up to ten variations of essentially the same test to prove the integrity of its materials to its various customers, many of which are large companies in the Aerospace sector each imposing its own individual specification where a common specification would suffice. Multiple test methods lead to ambiguities and inefficiencies with consequent penalties for materials users, suppliers and test houses alike.

From the market point of view, the principle disadvantages are:

- unnecessary duplication of work by materials suppliers and users;
- customised test facilities are expensive to build and operate;
- test results cannot be compared easily;
- databases for common use are difficult to develop.

Indeed, the lack of widely accepted test methods and data impedes the market use of these materials in new areas. What industry needs is common or international product standards incorporating harmonised materials evaluation/specification methods since this will facilitate trade and reduce the need for multiple testing.

DEVELOPMENTS IN INTERNATIONAL STANDARDIZATION

Materials technology is advancing rapidly making it difficult to set standards for measurements and testing. Although continual progress is being made in relating materials characteristics to properties and performance, the quantitative basis from which widely acceptable standardized methods can be developed are not available in many areas.

International standardization is considered to be a relatively slow process and, traditionally, has been active after the market for new products has been established to allow fair competition. Necessarily this has meant international standardization activities have concentrated on harmonisation of existing national standards.

In 1990 the international standards bodies ISO and IEC initiated a study by a team of top industrialists and businessmen to review standardization needs for rapidly developing technologies such as materials, IT and biotechnology. Their report - A Vision fo. the Future -contains a stimulating analysis of the potential contribution standards can make in the technological innovation process[10].

Different aspects of standardization relate to the different stages of innovation and product development as follows:

State of technological development	Type of standard necessary	Main benefits
Early establishment phase	nomenclature and terminology	improved communication in the market, collection of statistics.
Growth phase	measurement and test methods	design, production and reliability of products; enhance markets.
Well established	product standardization	rationalisation, interface capabilities, market protection etc

For standards which enhance "market entry" of products based on new technologies, it was recognised that international standards bodies needed to take new steps in addition to their traditional consensus activities. These should be

- flexible (ie direction setting agreements or provisional quasi-standards)
- fast (ie very simple procedures)
- open (ie to direct participation from companies and/or national organisations with R&D programmes).

Recommendations of the above report are being implemented with strong support from the ISO/IEC councils. In fact, as a result, three new technical committees in the advanced materials field have been established recently. A list of important ISO committees currently active in the materials field is given in annex I.

STANDARDIZATION IN EUROPE, JAPAN & USA

Europe Dramatic changes are taking place in Europe where measures to develop a Single Market and to open up public procurement amongst the European Community members depend critically on the availability of European standards. These standards are mainly developed by CEN (European

Committee for Standardization), ECISS (European Community Iron and Steel Standards) and CENELEC (European Committee for Electrotechnical standardization). CEN and CENELEC have concluded agreements with ISO and IEC respectively for regular discussion of their work programmes with a view to avoiding overlap and, furthermore, international draft standards are considered for adoption by CEN wherever possible (see Figure 6).

Membership of European Standards Committees is open to EC and EFTA (European Free Trade Agreement) countries, currently 18 altogether. An important feature of European standardization is that while agreement on technical contents is reached by consensus, adoption of the standard is by weighted majority voting. European standards must be adopted as national standards, regardless of the way the national member voted, and any conflicting national standards have to be withdrawn.

In materials CEN's activities are divided into four areas:

(i) iron and steels products,
(ii) non-ferrous metals,
(iii) non-metallic materials, and
(iv) other materials.

A list of the standards committees[11], their scope of activity and standards already developed is given in annex II. ECISS with a long history has the most extensive coverage. In the non-ferrous metallic materials area six committees are active dealing with aluminium, copper, zinc, tin, lead and nickel. Between 1988 and 1991 CEN created all the seven committees working on non-metallic materials covering inter-alia textiles, refractories, plastics and advanced ceramics. In the final area, four committees deal with non-destructive testing, foundry technology, corrosion and powder metallurgy.

Japan Amongst developed countries, Japan has one of the most rigorous standardization programmes on advanced materials with strong industrial involvement and participation. An extensive survey[3] of standardization needs and feasibility of standards development for industrial use covering the fields of metals, polymers and ceramics was undertaken in 1988 by the Japanese Industrial Standards Committee (JISC). They concluded that nearly seven hundred standards should be developed as a matter of urgency within the next 10-12 years. Of particular relevance here is the recommendation of the Committee that terminology, testing and evaluation methods should be given priority.

Following the recommendation of the committee, a five-year plan was launched in 1991 to promote industrial standardization. Highlight of the plan is Japan's new policy for greater co-operation with ISO/IEC activities. In fact, Japan is taking new initiatives to advance international standardization at the expense of national and regional standardization.

USA Most widely known is the work of ASTM, the American Society for Testing of Materials. Individuals from any country can participate in ASTM committees which rely primarily on voluntary effort by professionals in industry, academia and government. ASTM currently have 120 technical committees covering the following main areas:

A Ferrous metals	B Non-ferrous metals
C Cementitious, ceramic, concrete and masonry materials	D Miscellaneous materials
E Miscellaneous subjects	F Materials for specific applications
G Corrosion, Deterioration and Degradation of Materials	

SOME IMPORTANT STANDARDIZATION ACTIVITIES

<u>Advanced Ceramics</u> Applications of advanced ceramics in high technology products require the availability of test and measurement methods for powder properties as well as the properties critical to the design and manufacture of ceramic components. These materials have very different properties and applications compared with traditional ceramics, so the scope for adoption of existing test and evaluation methods developed for, say, porcelain and refractories is rather limited. Since the majority of potential users of advanced ceramics have little experience of how to apply them in products effectively, it is widely acknowledged that reliable evaluation techniques would pave the way for increased application and market penetration.

As early as 1981 saw the first publication of a standard for these new materials by the Japanese who continue to provide a major thrust in this area. The first standard was on "Testing method for flexural strength (modulus of rupture) of high performance ceramics". Since then the Japanese have published ten more standards in English concerned with the measurement of various mechanical, thermal and corrosion properties. The Japanese Industrial Standards Committee has identified[3] some 47 items on test methods for priority action (annex III).

In the USA, standardization work in this area commenced in 1985. ASTM and its committee C-28 on advanced ceramics has a comprehensive work programme in the following key areas:

- Properties and performance
- Design and evaluation
- Processing and characterisation
- Ceramic matrix composites, and
- Nomenclature.

In Europe, 4/5 years ago, the European Commission made a mandated request to both CEN and CENELEC for the establishment of a comprehensive programme for setting up voluntary Eurostandards (ENV) and European Standards (EN) in the field of advanced industrial ceramics. Accordingly, in 1989 CEN established a Committee, CEN/TC 184, with specific tasks to develop up to forty standards on classification, terminology, sampling and methods of test. The methods of test include physical, chemical, mechanical, thermal and textural properties for ceramic powders, monolithic ceramics, ceramic composites and ceramic coatings. The standards developed by CEN TC 184 and its work programme are shown in annex IV[12].

Internationally, research related to standardization is being carried out under VAMAS (described later) and also under the International Energy Agency Programme by the USA, Sweden and Germany. Based on the VAMAS programme standards have already been developed for wear test methods of ceramics and further standardization can be expected for testing dynamic fatigue, hardness, fracture toughness at room and high temperature, fatigue and grain-size measurements.

A very important development has come recently from ISO when a Japanese proposal to set up a committee on technical ceramics was endorsed by five ISO member countries. The new committee, TC 206, is being launched with participation from Australia, Indonesia, Jamaica, Japan (Secretariat), Republic of Korea, Malaysia, Russian Federation and USA. A wide ranging programme has been proposed, but the final scope has not been agreed, partly because of lack of participation from Europe and the need to develop a programme that will build upon existing work in Europe and USA. The first meeting of the TC is expected to be held in 1994.

Polymers and Polymer-Composites Internationally the drive for harmonisation of test methods for polymers and polymer-composites has grown steadily over the past 6/7 years and a number of new initiatives has been launched. A very important development relates to standards for the presentation of comparable data for plastics in ISO. Manufacturers of polymeric materials supply property data but, historically, different manufacturers have used different test procedures to obtain their data. As a result, users of plastics are faced with the problem that the data available for nominally similar materials from different suppliers are not readily comparable, making materials selection rather difficult. Furthermore, properties of plastic materials depend not only on the molecular structure, and orientation and concentration of any fibres or reinforcements, but they also vary with the test conditions chosen for the measurement, such as time, temperature, loading rate and the stress level. Hence, an adequate characterisation of materials and behaviour can be expensive.

In recognition of these problems a series of international standards is being developed that specify test methods, specimen geometries and test conditions to enable comparable data or plastics to be measured. These standards deal with single and multipoint data; the first group relates to a limited range of common properties, each property being described by a single measurement value. These single point data are used for the initial stage of materials selection and are shown on the next page.

Properties included in the single-point data presentation standard ISO 10350	
<u>Mechanical</u>	<u>Thermal</u>
Tensile modulus	Melting temperature
Yield stress	Glass transition temperature
Stress at break	Temperature of deflection under load
Yield strain	Vicat softening temperature
Elongation at break	Linear thermal expansion
Tensile creep modulus	Flammability
Flexural modulus	Ignitability
Flexural strength	
Charpy impact strength	
Tensile impact strength	<u>Rheological</u>
	Melt mass-flow rate
<u>Electrical</u>	Melt volume-flow rate
	Moulding shrinkage
Permittivity and dissipation factor	
Electric strength	
Volume and surface resistivity	<u>Other</u>
Comparative tracking index	
	Density
	Water absorption

Properties included in the multipoint data presentation standards ISO 11403-1, 2 and 3				
Part	Property	Status	Standard	Variables
1	**Mechanical properties**	Draft international standard		
	Dynamic modulus		6721-2,4	T
	Ultimate values of stress and strain		527-2	T
	Tensile stress/strain curves		527-2	ε,T
	Tensile creep strain		899-1	σ,t,T
	Charpy impact strength		179	T
2	**Thermal and processing properties**	Draft international standard		
	Enthalpy			T
	Linear expansion			T
	Melt viscosity		11443	γ,T
3	**Environmental influences**	Committee draft		
	Liquid chemicals		175	L,t,T,I
	Prolonged action of heat		2578	t,T,I
	Artificial weathering		4892-2	H,t,I
	Environmentally assisted stress cracking		6252	L,t,T

T - temperature σ - stress
H - radiant exposure t - time
γ - shear strain rate I - indicative property
ε - strain L - liquid chemical

The multipoint data standard ISO 11403, as described in the preceding table, has three parts. It deals with more extensive data sets on property values as a function of variables such as time, temperature and the environment, and the data, therefore, can be used for later stages of materials selection. In fact, some of these data will be suitable for use in design calculations for predicting performance in service and for selecting optimum process conditions.

The ISO plastics committee (TC 61) has a broad range of activities on unreinforced and reinforced materials, although many of the current test methods in composites are related glass-fibre reinforced materials. Standardization of materials reinforced with carbon and aramid fibres has been slow, but this is changing. Recently, methods for the determination of density and size, and definitions and vocabulary for carbon fibres have been standardized. Furthermore, as existing standards are updated, advanced composites are being included as is the case with ISO 527: Plastics: Determination of Tensile Properties. Also, for example, the revised ISO 1268 - Test Panel Manufacture covers a variety of fabrication routes such as autoclaving, filament winding, spray-up moulding, contact moulding and compression moulding.

Further topics include linear density and twist of fibres, strength of glass fibre yarns and mats, tensile properties of carbon fibre impregnated yarns and single filaments, curing behaviour of pre-pegs or compounds, and tensile strength of laminates. ISO/TC 61 has ten sub-committees with nearly 65 Working Groups:

ISO TC-61 (Plastics) Sub-committees	
Sub-committee number	Area of activity
SC1	Terminology
SC2	Mechanical Properties
SC4	Burning Behaviour
SC5	Physical-chemical properties
SC6	Ageing, chemical and environmental resistance
SC9	Thermoplastic materials
SC10	Cellular materials
SC11	Products
SC12	Thermosetting materials
SC13	Composites and Reinforcements

Standardization for polymer composites has gathered momentum in CEN during the last 3 years. Since the pressure to produce standards is high, consideration is given to adopting ISO standards wherever appropriate. Otherwise adoption or re-drafting of European Aerospace standards or national standards is favoured as the next step. The CEN Committee on Plastics (TC 249) has five sub-committees as follows

SC1 Plastics materials and test methods
SC2 Composite reinforcements and pre-pegs
SC3 Semi-finished plastic products
SC4 Cellular materials
SC5 Plastics for packaging

Each sub-committee is served by Working Groups; SC2, for example, have five working groups: WG1 is responsible for all small diameter fibres (carbon, glass and aramid), WG2-4 are responsible, respectively, for aligned reinforced thermosets, random reinforced thermosets and all reinforced thermoplastics, except short fibre systems (covered by SC 1). Test methods applicable only to specific materials are covered by WG2-4, but WG5 is responsible for test methods which are applicable generally.

That standardization is needed badly in this area is demonstrated by annex V which contains a list of differing standards currently used by various trade and industrial organisations.

Standards on Corrosion An adequate knowledge of the degradation behaviour of a material due to its interaction with the operating medium is vital for the efficient utilisation of materials. Such degradation can take different forms; the most well known in this category is corrosion of metallic materials, the cost of which can be very high, 2-4% of GDP, with large impacts on industrial competitiveness, environment and health and safety. Greater awareness and understanding of the processes and effects of corrosion have led to significant improvements in design and building of corrosion-resistant products and systems as well as protective techniques. It is evident that reliable test and evaluation methods to measure corrosion resistance and the effectiveness of corrosion protection techniques play a very important part in this development.

Not surprisingly there is now quite an intensive activity in developing international standards in this field. In ISO, the most relevant activity is being undertaken by TC 107: Metallic and other inorganic coatings, and TC 156: Corrosion of metals and alloys.

Eight sub-committees operate under TC 107, three of which are concerned with terminology, electrodeposited coatings, hot dip coatings, thermal spraying, vitreous and porcelain enamels and chemical conversion coatings. Altogether nearly 70 standards have been prepared so far, the majority covering defined preferred properties of applied coatings. Methods for determination of their properties, thickness and corrosion resistance are included. Sub-committee 7 has the responsibility for developing standards mostly on test methods and procedures.

TC 156 "Corrosion of Metals and Alloys" is primarily concerned with test methods and has 19 participating countries and 27 observer countries[13]. There are nine working groups working in the following areas:

Activities of ISO TC 156 (Corrosion of Metals and Alloys)		
Working Group No	**Subject area**	**Comments**
WG1	Terminology	ISO 8044 - defines terms relating to corrosion of metals and alloys
WG2	Stress-corrosion cracking	• ISO 6509: determination of dezincification resistance of brass. • ISO 7539: 8-part standard on stress corrosion testing (a standard for Stress corrosion Cracking of alloys in preparation) • a standard on corrosion fatigue to be published
WG3	Atmospheric corrosion	ISO 7441 - bimetallic corrosion in outdoor corrosion tests ISO 8565 - general requirements for field tests
WG4	Classification of corrosivity of atmospheres	Four ISO standards nearly completed (ISO 9223-6) including one on Methods of determination of corrosion rates of standard specimens for the evaluation of corrosivity
WG5	Intergranular corrosion	• ISO 9400 - Determination of intergranular corrosion of nickel alloys • a standard on intergranular corrosion of aluminium alloys to follow
WG6	General Principles for conducting corrosion tests and criteria for evaluation and treatment of results	• ISO 8407 - Methods for the removal of corrosion products from corrosion test specimens
WG7	Accelerated corrosion tests	ISO 9227 - Salt spray tests
WG8	Co-ordination	
WG9	Corrosion testing of materials for nuclear power generation	• A standard on aqueous corrosion of zirconium alloys under discussion • Work in progress on Electrochemical Potentiokinetic Reactivation (EPR) test for measuring susceptibility to intergranular attack in stainless steels

New work programmes on electrochemical test methods and cathodic protection of underground structures and marine corrosion test methods are under development.

In the USA, ASTM committee G-1 is principally responsible for standards related to corrosion testing and evaluation. It has twelve sub-committees which have produced over sixty standards covering a wide range of tests and corrosion conditions[14].

Over the last 2-3 years European activities on standardization in the corrosion area have intensified considerably through the establishment of a committee, CEN TC262 entitled Corrosion Protection: metallic materials. However, collaboration between CEN and ISO is close and indeed in certain areas the work proceeds jointly with ISO.

INTERNATIONAL CO-OPERATION IN PRE-STANDARDS RESEARCH

The world's most industrialised countries recognised nearly a decade ago the importance of co-operation in advanced technologies for the creation of employment and economic growth. Accordingly, a new initiative known as the Versailles Project on Advanced Materials and Standards, VAMAS, was launched in 1987 with the underlying aim of removing barriers to trade by encouraging the development of standards from a commonly agreed technical base. VAMAS operates on a cost-sharing principle without any central funds whereby project work is carried out by participants with support from their own countries under existing programmes and schemes. In addition to the G7 countries, the CEC is a member of VAMAS, but many organisations from non-member countries have also participated in specific activities by special agreement.

Over sixty technical projects have been initiated so far covering all the key materials classes; activities include the development and validation of test methods, guidelines, codes of practice, terminology schemes and data handling. Primarily VAMAS is active in pre-standards research necessary for the drafting of standards for advanced materials. Close liaison is maintained with national and international standards organisations to focus the pre-standards activities and also to assist in the transfer of results to standards. As a follow-up to the recommendations made in the ISO/IEC report "A Vision for the Future", ISO has recently signed a Memorandum of Understanding with VAMAS to publish suitable VAMAS outputs as "Technology Trend Assessment" documents to accelerate standards development and to disseminate rapidly methods and guidelines which industry can use in the absence of a standard.

Currently, VAMAS has seventeen Technical Working Areas (TWAs) under five main themes as shown below. A full list of the TWAs are given in annex VI.

VAMAS THEMES

Theme 1	Metals and Metal-matrix composites
Theme 2	Polymers and Polymer-matrix composites
Theme 3	Ceramics and Ceramics-matric composites
Theme 4	Test Techniques
Theme 5	Materials classification and Data

<u>Surface Chemical Analysis</u> Technical Working Area 2 in VAMAS is dealing with surface chemical analysis techniques: Auger Electron Spectroscopy (AES), X-ray Photoelectron Spectroscopy (XPS) and Secondary Ion Mass Spectroscopy (SIMS), all extensively used in many industrial sectors for the development of high technology products and materials. VAMAS became active because of a need to produce widely acceptable reference procedures, reference data and reference materials as a basis for standards for surface chemical analysis. In fact VAMAS took the lead in bridging on-going activities in the USA, Japan and Europe all aimed to overcome similar problems.

In this area of VAMAS, nearly 100 laboratories have been participating from about ten countries. Accuracy of measurements of chemical compositions and concentrations are two key issues in AES and XPS. Figure 7 shows that for XPS, the intensity/energy response function of even one instrument cannot be defined uniquely and are different for two operating conditions[15]. Complications arise because spectra from commercial instruments are distorted from the true spectrum by the instrument transmission function which depends on the electron energy and the instrument settings. To calibrate these functions NPL has established a reference spectrometer with traceability to primary Measurement Standards so that true spectra and hence true chemical compositions and concentrations can be found[16].

As a result of this pioneering work, one can now obtain consistent and mutually recognisable analysis of the same specimen in different instruments throughout the world. Furthermore, it is now possible to produce reference databanks for international use. To this end the VAMAS group has already developed a standard data transfer format to aid the process of transferring data from one laboratory to another[17].

Success of the VAMAS programme has led to wider international interest and, in fact, recently ISO have set up a new Technical Committee, TC 201 on Surface Chemical Analysis, with Japan providing the Secretariat and the USA the Chairman. That there is wide interest in this area is demonstrated by the fact that ten national standards bodies have become participating members (P-members) and fifteen others have become observer members (O-members). VAMAS has liaison category A with ISO/TC 201 that will ensure full communication between the two activities and the results of VAMAS work will have rapid access to ISO. The sub-committees of TC 201 and their proposed areas of work are given in the annexes VII and VIII.

It is of interest to note here that ISO at the same time has set up a new Committee on Microbeam analysis (TC 202), in which China has taken on the important role of the Secretariat.

Testing of Advanced Ceramics In this area VAMAS has been active on a number of fronts. Under TWA1, co-operative work involving nearly 40 laboratories examined wear testing of alumina and silicon nitride which showed the importance of controlling machine dynamics and humidity of the testing environment; the latter was found to have a particularly large influence as a humid atmosphere encourages the formation of lubricating films of hydrated debris thereby reducing wear rates. DIN and ASTM have developed two new standards (DIN 50234 and ASTM G-99) based on the VAMAS work; in addition an Austrian draft standard (ÖNORM M 8125) and a UK guideline have been produced recently. Currently, the TWA is working on the development of (i) a uniform format for presentation of wear data, (ii) quantitative methods of assessment of wear volumes to obtain more accurate wear rates, (iii) a directory of standard wear test methods and (iv) harmonised wear testing method for inorganic coatings.

Other important areas in ceramics are covered in TWA3 and TWA14. TWA3 has been concerned with mechanical properties and microstructural characterisation, and examined (i) dynamic fatigue testing, (ii) hardness measurement, (iii) fracture toughness testing, and (iv) measurement of average grain size in alumina. For the last activity VAMAS initiated a round-robin exercise at the request of the CEN Committee TC184 and within a year produced robust information on the use of line and circle methods for grain size and porosity measurements on the basis of work by twenty five laboratories in USA, Europe and Japan. The results have directly led to a European standard[18].

Hardness is often considered to be a useful materials property by industry. Although there are a number of well established techniques for hardness measurement of conventional metallurgical materials, it is not clear whether these techniques are suitable for advanced ceramics. Indentation sizes can be very small and the material around the indentation can crack and spall leading to serious measurement difficulties. Indeed a VAMAS exercise[19] on two high-alumina ceramics using Brinell HR 45N, Vickers HV 1.0 and 0.2, and Knoop HK 0.2 tests showed that when indentation sizes are as small as 15 μm and the position of the corners on the indentation cannot be specified to lower than 1 μm, the mean hardness value can vary by as much as 20% between observers. Therefore VAMAS recommended that hardness values, especially microhardness, should not be used for materials specification purposes. A guideline for hardness measurement of advanced ceramics has been produced and is being considered for standardization by CEN and other international standards organisations. Similarly, VAMAS work on fracture toughness has led to advancement of the technical knowledge necessary for standardization and further work is in progress.

<u>A classification scheme for advanced ceramics</u> As a relatively new category of materials, advanced ceramics has no formal classification scheme with the exception of IEC 672 covering electrical insulators. Conflicting schemes can impede efficient functioning of international trade and markets in advanced ceramic materials and products. Accordingly VAMAS initiated an activity in TWA14 with the aim of developing the technical basis for a unified classification scheme which will enable

- unambiguous materials specification;
- unique specification for entries in databases;
- a link between materials and application;
- unambiguous collection of statistical information on trade and markets.

Based on the findings of an extensive international survey of producers and users of advanced ceramics, a matrix coding system with the following four key elements has been developed[20]:

- Application (A)
- Chemical character and product form (C)
- Processing (P)
- Property data (D)

Such a system is very flexible and can meet simple to fairly complex requirements. For example, if only chemical composition is of interest only one element of the matrix is required. If a breakdown of markets by materials composition and application is needed, then two elements are used whereas all the elements may be necessary for materials specification. Such a system can be used by industry in the design of databases, product promotion, inventory purposes and analysis of market trends. Governments can use the scheme to gather economic statistics or to handle trade matters. ASTM and CEN are using the results of VAMAS as a basis for new classification standards, and it is expected that ISO will also adopt the scheme in the future.

LABORATORY ACCREDITATION

Industry increasingly recognises that in today's demanding and competitive markets, good product design and efficient manufacturing must be underpinned by properly authenticated measurement and testing to ensure quality, performance and reliability of products. Laboratory accreditation plays an important part in this context because it signifies recognition by a third party of a Laboratory's competence to perform test and evaluation in specific fields. It provides confidence in the overall quality of operation and competence of a laboratory (although it does not guarantee that an individual test result or data is correct or valid). Accordingly many countries have set up in recent years national accreditation schemes which avoids multiple assessment of testing laboratories and provides uniformity in accreditation criteria and rules. On the international scene an increasing number of agreements are being reached for mutual recognition of test results across national boundaries. Industrialising countries are also examining accreditation schemes because of the realisation that it has an important role in developing industrial capability and international trade.

To perform tests consistently from one day to the next, accredited laboratories should use standardized methods whenever available. From a user's point of view, the same test carried out in different accredited laboratories, even across national boundaries, to a standard specification should produce similar results.

Certified Reference Materials (CRM) serve a very useful purpose for interlaboratory comparisons and proficiency checks and are regularly used by accredited laboratories. A CRM has been defined by ISO as a material or a substance, one or more physical or chemical properties of which are sufficiently well established to be used for the calibration of an apparatus or for the verification of a measurement method. The material is accompanied by, or traceable to, a certificate stating the property value of concern and is issued by a nationally or internationally recognised and competent organisation. Although there are various sources of supply for CRMs, both in the developed and the developing countries, CRMs for advanced structural materials have limited availability.

STRATEGY FOR THE FUTURE

Standards are of strategic importance for stimulating new applications necessary to realise the market potential of advanced materials with consequent economic benefits as well as improvements in health, safety and the environment. In this respect the traditional view that standards are only needed to establish the basis for fair trading after a market has been established must be discarded.

In the early stages of market development in a rapidly advancing technological area as materials, there is a strong demand for standardized terminology for effective technical communication and technology transfer. To support innovation and indeed technological progress, reliable information about the behaviour, properties and performance is required to give users the necessary confidence for incorporating new materials into their products thereby providing competitive advantages. With standardized test methods both producers and users of materials can have a common basis for materials evaluation and increased confidence in the properties data.

Throughout the world much R&D is being carried out in the field of advanced materials and significant benefits can be derived if the standardization and R&D activities are well integrated. This may be achieved by establishing proper co-ordination and channels between R&D and standardization for which both government and industry need to act in a cohesive fashion.

Appropriate capability in materials evaluation technology has to be built with partnership between the public and the private sectors. Generally, government can be expected to take the lead in the development of an infrastructure that will adequately support a wide range of industrial test and measurement activities. Understandably, industry is reluctant to invest in the underpinning work on developments of techniques and methods which are generic and have wide applicability. On the other hand, testing and generation of data on specific materials or for specific applications have more immediate commercial value such that industry can be expected to bear the costs. However, even in the infrastructural area, very close consultation and collaboration with industry is essential to ensure that the results are directly relevant and applicable in industry.

Quite commonly, in the standards area, the materials supply industries tend to dominate whilst users are not adequately involved. This is perhaps inevitable as user industries concentrate more on short-term problems facing the business rather than long-term issues. However, it is essential that user industries become involved from an early stage in the standardization process so that the most appropriate and useful standards are developed to maximise benefits to industry.

Trade in materials and their products is international in character and so it is vital that specification, codes of practice and standards are developed on an international basis whenever possible. This is now widely accepted. As a result we have seen Europe, USA and Japan are all putting greater emphasis on international standards to facilitate the removal of technical barriers to trade and to increase industrial efficiency.

In the developing countries consumers accept lower quality goods due to economic pressures. This necessarily means that the standards do not have to be as rigorous. However, as economic ambitions of these countries increase and markets are globalized, their industries will need to employ higher standards in order to become more competitive on an international scale. Hence, standards work cannot be merely left to others. To have an effective voice in the international standardization forum, developing countries need to participate with a good technical base. It is interesting to note here that in the recently set up ISO committee TC 202 on Microbeam Analysis, China has the Secretariat; also in TC 206 on advanced ceramics, several less developed countries are participating members. Only from a position of strength industrialising nations will be able to command respect and influence standards in the international arena.

It will be evident from earlier discussions that testing and evaluation of advanced materials can be highly complex, so a sound technical base is required before effective standards can be developed. Often this means much pre-standards research, validation of methods and intercomparisons amongst laboratories are needed. International collaboration in this type of pre-standards and pre-competitive research can be beneficial on two grounds:

(i) cost of this type of work, which is quite significant, can be shared between countries;

(ii) any standard developed as a result is likely to be readily accepted by all partners because of the common technical base.

Not surprisingly the G7 nations use VAMAS as a mechanism for cost-shared action in pre-standards research on advanced materials. There is certainly scope for developing countries/regions to use similar models.

Good co-operation amongst developed countries could ensure that the leading laboratories including the facilities and expertise could be used to tackle priority problems in testing and evaluation in a way that brings considerable synergistic benefits. Co-operation could also be effective in developing certified reference materials.

Industrial design and manufacturing require increasingly sophisticated and high pedigree data in a form that can be integrated readily with advanced IT systems. Although many databases of materials properties are available throughout the world, their scope and quality vary widely and, not surprisingly, there is a strong demand for good quality data for advanced materials. The cost of producing and evaluating data can be very high, so data have commercial value. Nevertheless, there is scope for international co-operation in developing standards and accreditation procedures for databases which should enhance data utilisation. Developing countries could benefit significantly from cost-sharing and co-operation in building databases of common interest.

Many of the developing countries have significant skills and expertise in materials characterisation and testing. UNIDO have carried out consultations with several countries about their perception of the current situation and future needs in this important area. Generally, the effort and resources are dispersed in these countries and it was commonly acknowledged that improved co-ordination and co-operation across national boundaries would be highly beneficial. UNIDO are exploring mechanisms for establishing a suitable framework that would enable improvements in technological capabilities of individual countries through co-operative work and at the same time enhance links with the activities of industrialised nations. Training, sharing of facilities, awareness of developments in testing and evaluation as well as establishment of information networks for standards, could be an integral part of the overall plan in this context.

REFERENCES

1 "Emerging Technologies: A Survey of Technical and Economic Opportunities", Technology Administration, US Department of Commerce, (1990).

2 "Advanced Materials and Processing: The Federal Programme in Materials Science and Technology", A Report by FCCSET Committee on Industry and Technology to Supplement the President's FY93 Budget, (1992).

3 Japanese Industrial Standards Committee Report, "Standardization of Advanced Materials - Summary Report of the Special Committee on Standardization of Advanced Materials. JISC, Agency of Science & Technology, Japan, (1988).

4 H Czichos, R Helms and J Lexow: Industrial and Materials Technologies: Research and Development, Trends and Needs, ISBN 3-894, 29-105-2, (1991).

5 B E Read, G D Dean and P E Tomlins, "Effects of Physical Ageing of Creep in Polypropylene, Polymer, Vol 29, 2152, (1988).

6 ISO-DIS 11403/1, "Plastics - Acquisition and Presentation of Comparable Multipoint Data - Part 1, Mechanical Properties, (1992).

7 G B Thomas & R K Varma, EUR 14105EN (European Commission Report), "Evaluation of low cycle fatigue test data in the BCR/VAMAS intercomparison programme", Commission of the European Communities, Brussels, (1993).

8 F A Kandil and B F Dyson, "The influence of load misalignment during uniaxial low-cycle fatigue testing", I Modelling: "Fatigue Fract Eng Mat Struct, Vol 16, No 5, p 509-27, (1993). II Applications: ibid, pp 529-37

9 S J Bull, "Surface and Coatings Technology", 50, p 25-32, (1991).

10 ISO, "A Vision for the Future", ISBN 92-67-10154-4, (1990).

11 CEN, "Standards for Access to the European Market": The Technical Programme, ISBN 92-9097-192-4, (1993).

12 J J Kübler, R Morrell, "European Standardization Activities for Technical Ceramics", ASME publication 93-GT-158, (1993).

13 A D Mercer, "ISO and Corrosion Standards" in "Corrosion Standards", pp 14-22, published by the Institute of Materials, UK, ISBN O-901716-09X, (1991).

14 D E Landlot, ibid pp 28-41, (1991).

15 G C Smith & M P Seah, "Surface and Interface Analysis", 16, 144-148, (1990).

16 M P Seah & G C Smith, "Surface Interface Analysis", 15, 751, (1990).

17 W A Dench, L B Hazell, M P Seah, "Surface & Interface Analysis", 13, p 63-122, (1988).

18 VAMAS Bulletin No 16, Published by NPL, ISSN 1016-2178, (1993).

19 R Morrell, D M Butterfield & D J Clinton, Euroceramics, 3, 3.339-3.345, (1990).

20 VAMAS Report No 15 - "Classification of Advanced Ceramics", ISSN 1016-2186, (1993).

CAPTIONS FOR FIGURES

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Figure 2	Results of an intercomparison exercise on the measurement of low cycle fatigue.
Figure 3	Comparison of a model predicting testpiece bending in LCF and experimental results.
Figure 4	Current status and importance of various property measurements for engineering coatings.
Figure 5	Use of Material data in process models and production.
Figure 6	Key stages of standards development in CEN.
Figure 7	MG XPS spectra of Silver taken for two different analytical areas and pass energies

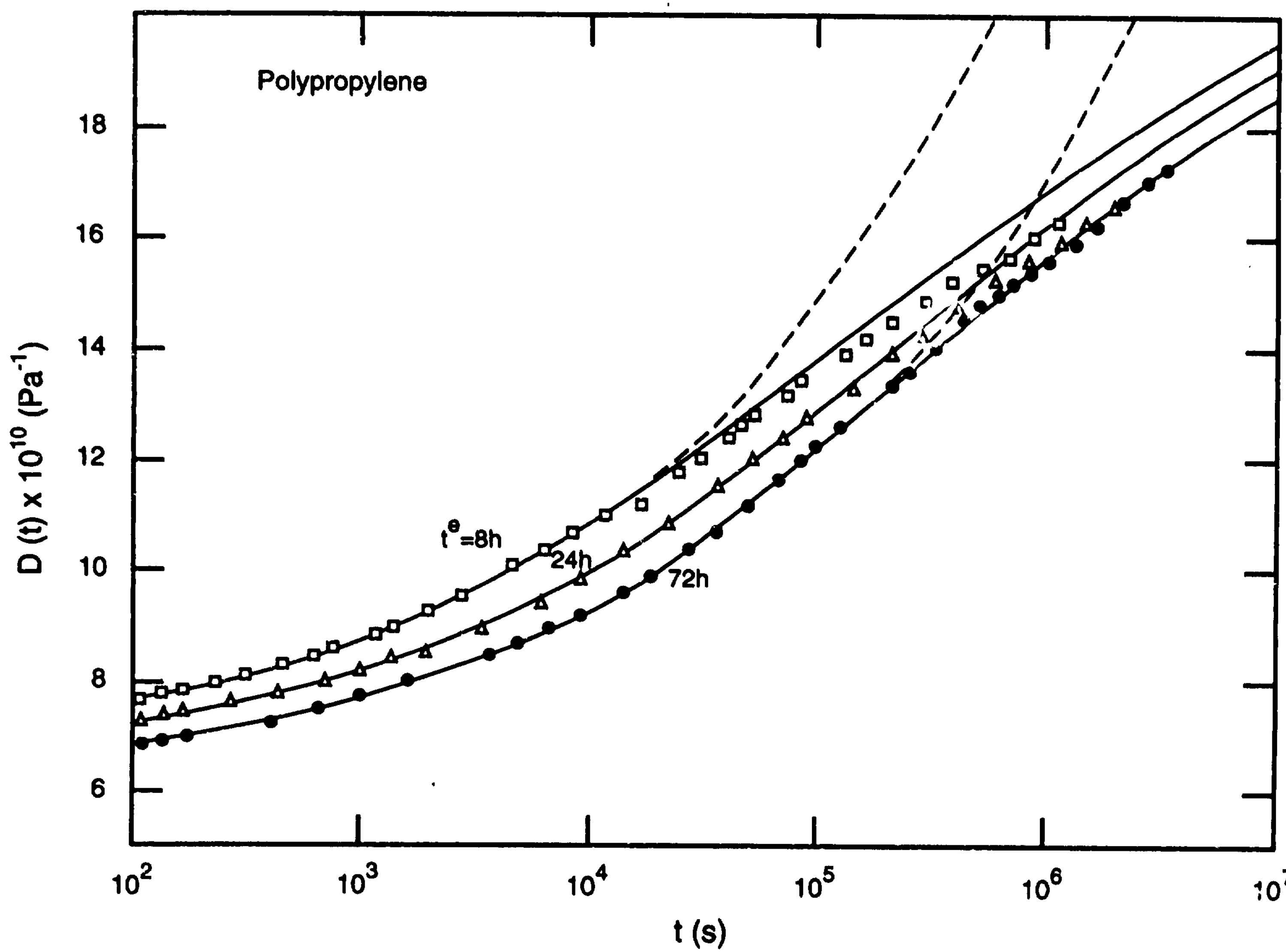
Polypropylene
D (t) x 10^10 (Pa^-1)
t (s)
t^e=8h
24h
72h
18
16
14
12
10
8
6
10^2
10^3
10^4
10^5
10^6
10^7

Fig. 1

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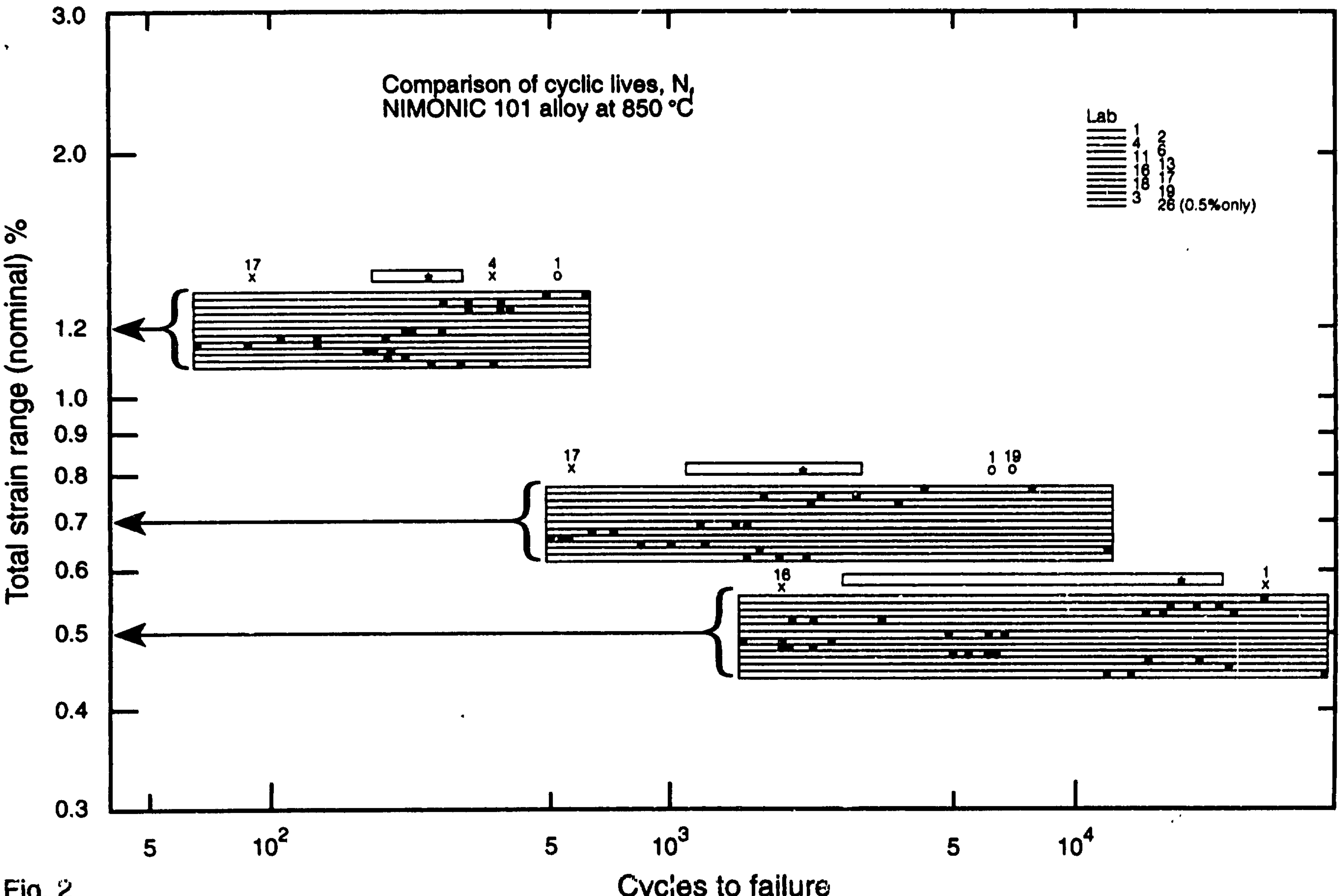
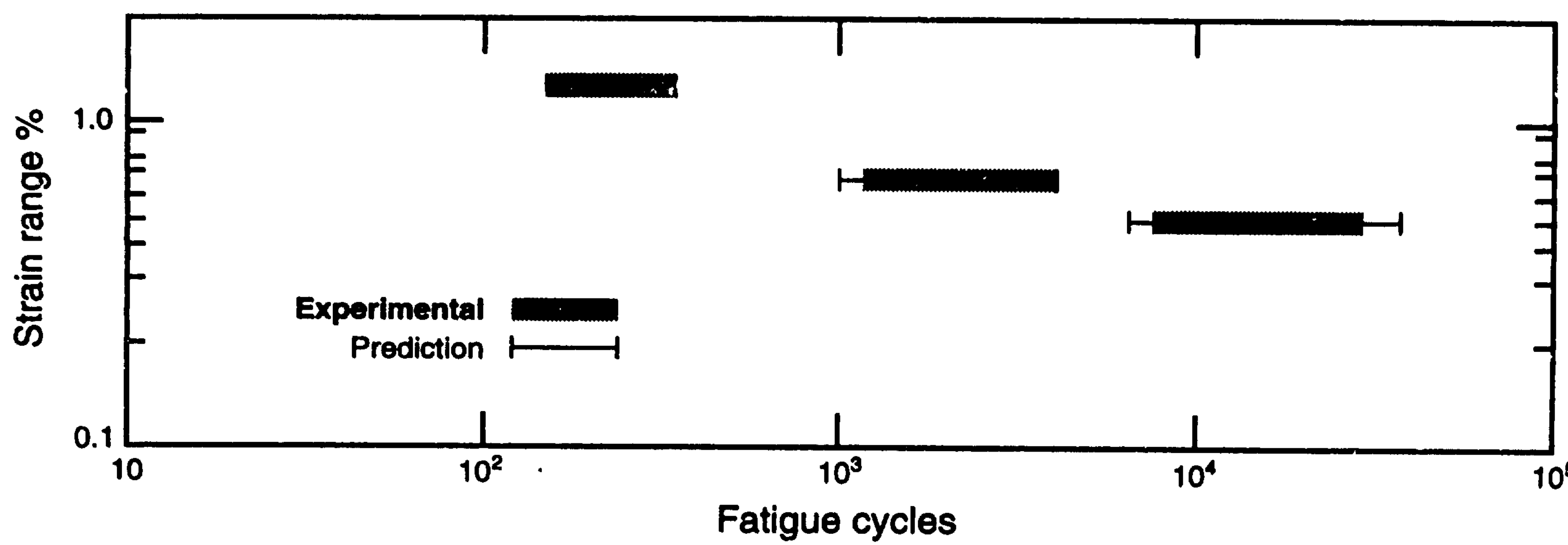

Comparison of cyclic lives, N,
NIMONIC 101 alloy at 850 °C
Lab
1 2
4 6
11 13
16 17
18 19
3 26 (0.5%only)
Total strain range (nominal) %
3.0
2.0
1.2
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
5
10^2
5
10^3
5
10^4
17
4
1
17
1 19
16
1
Cycles to failure

Fig. 2

01554/8



Strain range %
1.0
0.1
10
10^2
10^3
10^4
10^5
Fatigue cycles
Experimental
Prediction

Fig. 3

01554/C

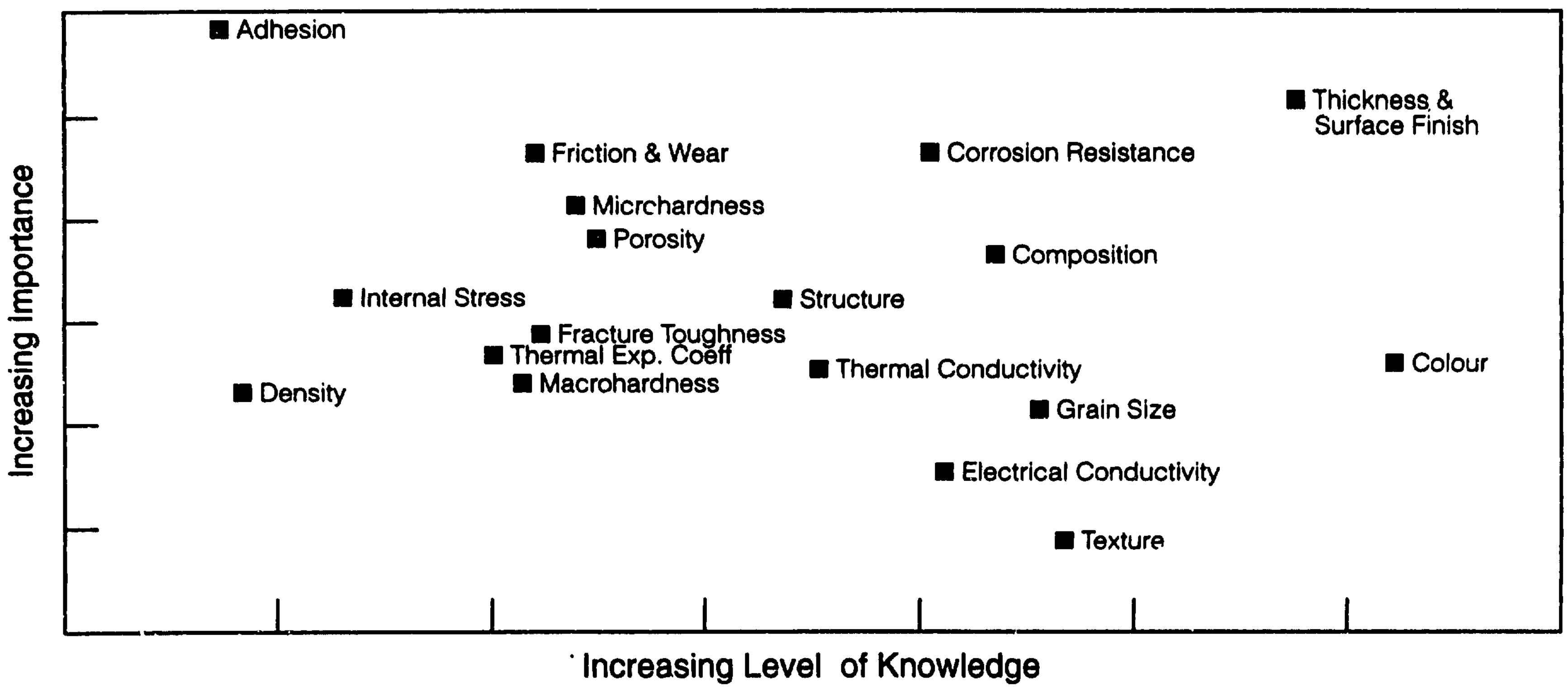

Adhesion
Thickness & Surface Finish
Friction & Wear
Corrosion Resistance
Micrchardness
Porosity
Composition
Internal Stress
Structure
Fracture Toughness
Thermal Exp. Coeff
Thermal Conductivity
Colour
Density
Macrohardness
Grain Size
Electrical Conductivity
Texture
Increasing Importance
Increasing Level of Knowledge

Fig. 4

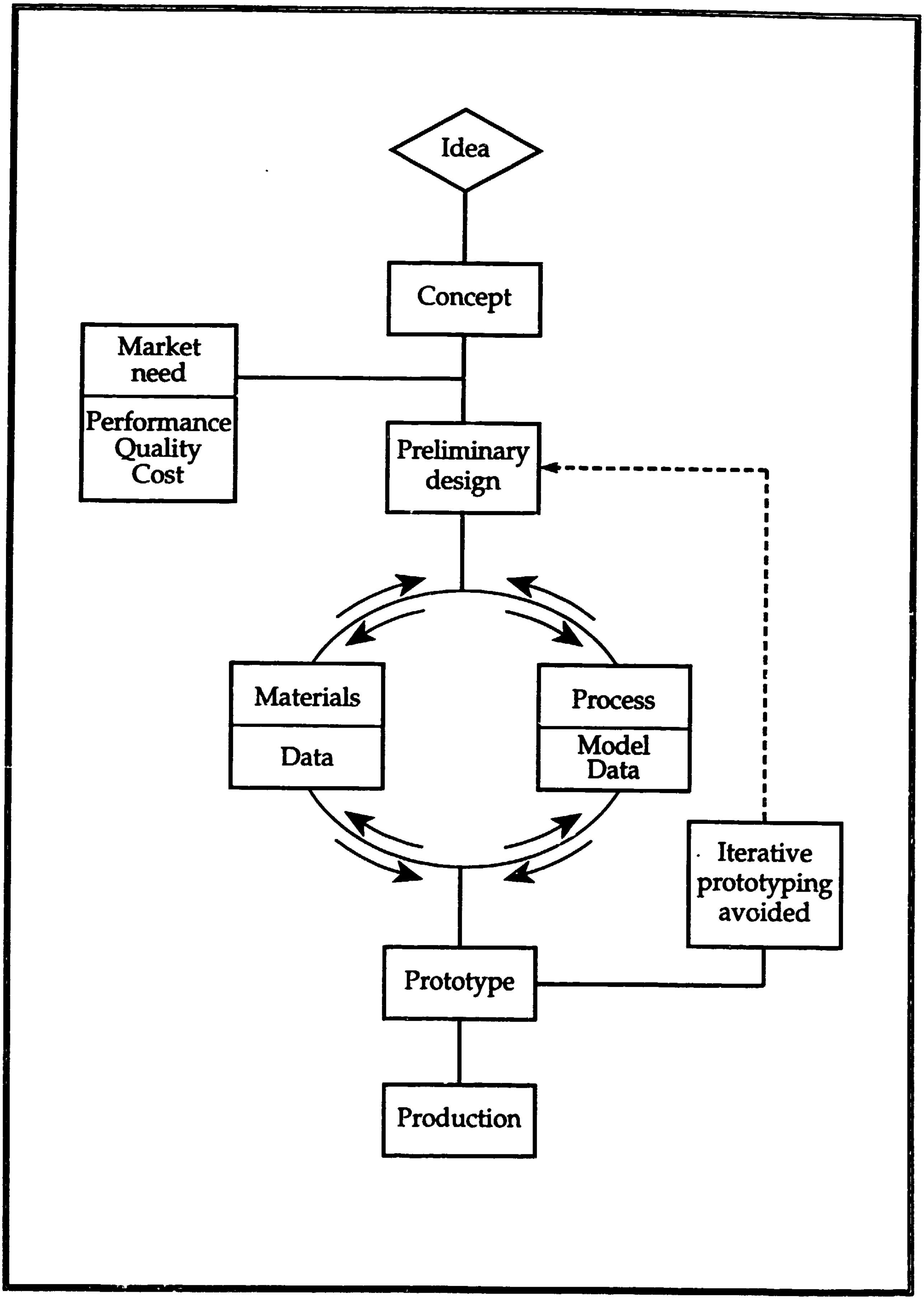
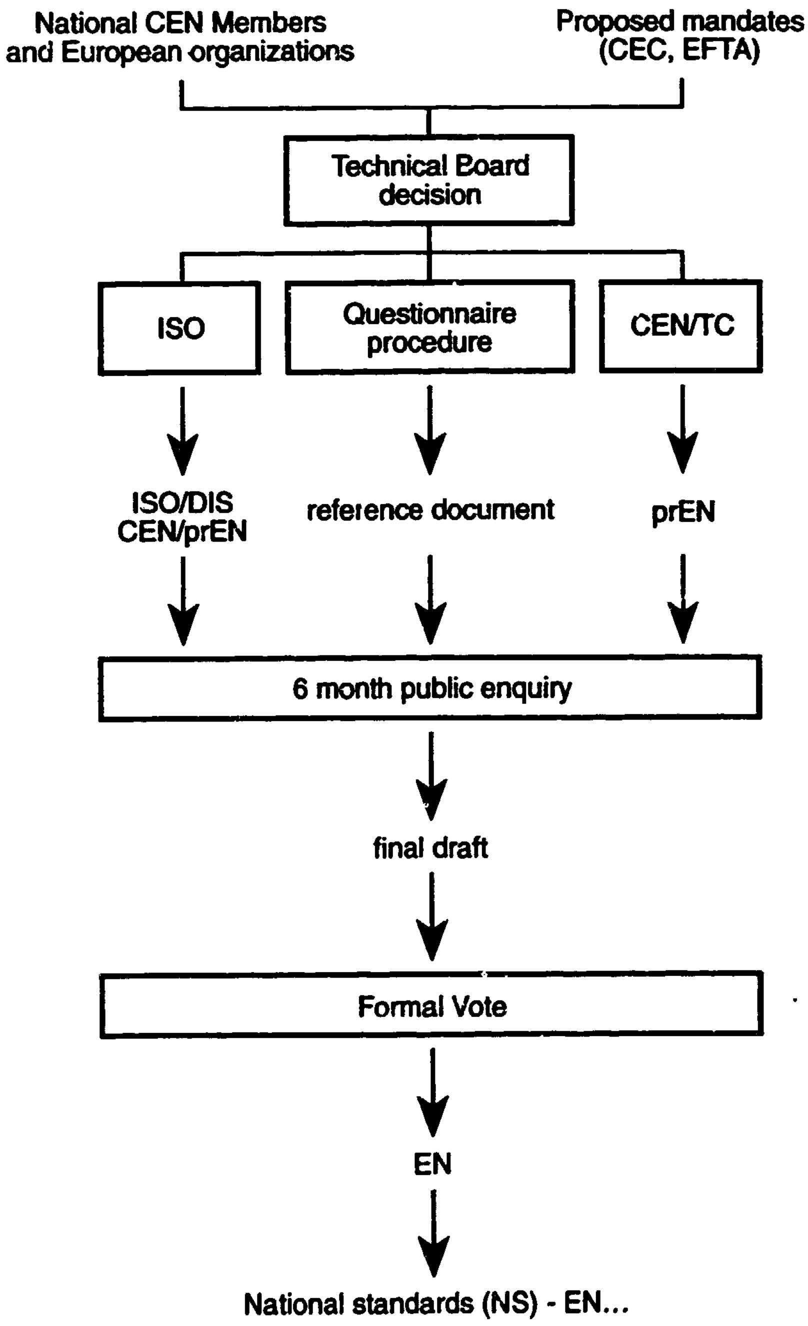

Idea
Concept
Market need
Performance
Quality
Cost
Preliminary design
Materials
Data
Process
Model
Data
Iterative prototyping avoided
Prototype
Production

Fig. 5



Development of CEN standards

Fig. 6

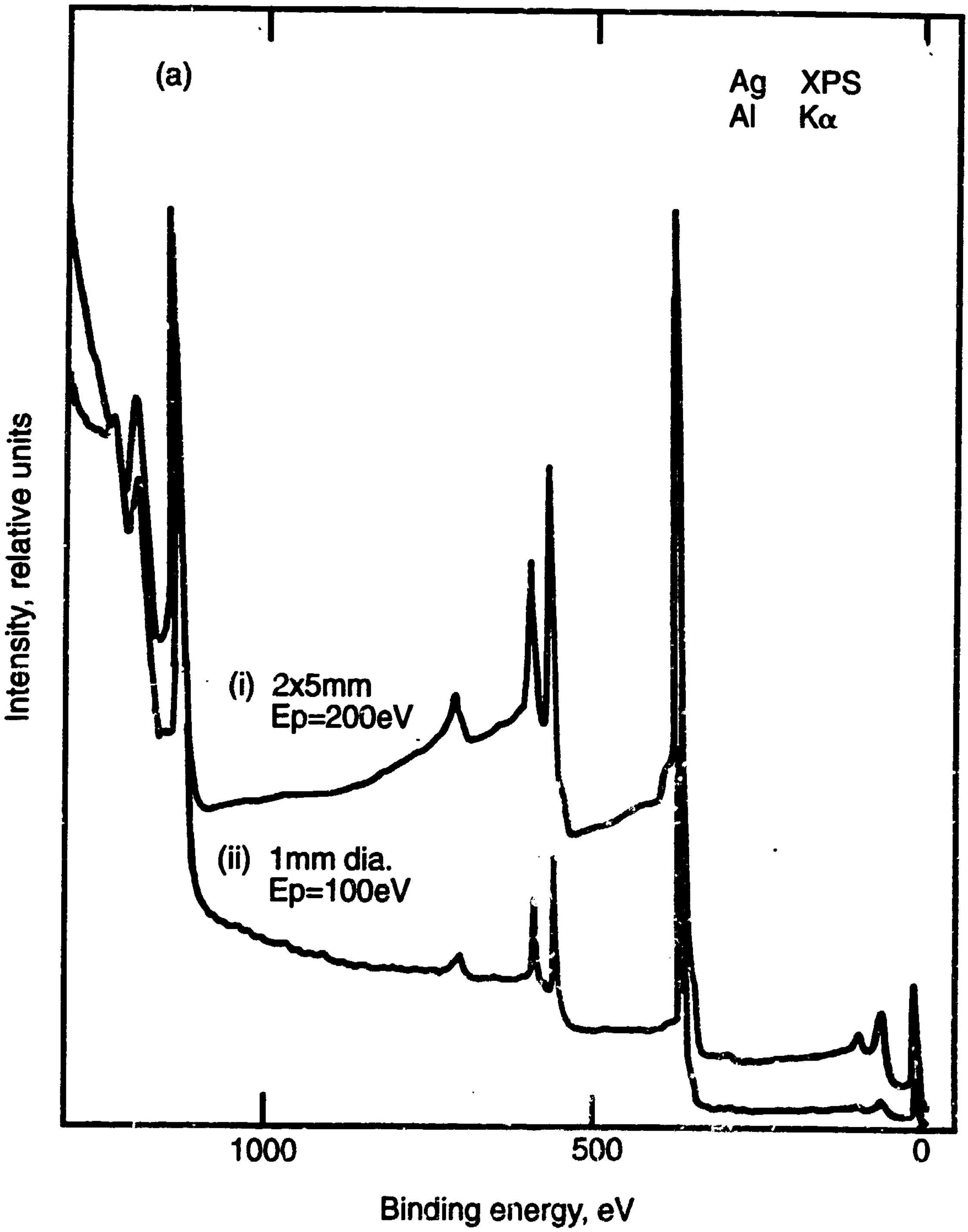

(a)
Ag XPS
Al Kα
Intensity, relative units
(i) 2x5mm
Ep=200eV
(ii) 1mm dia.
Ep=100eV
1000
500
0
Binding energy, eV

Fig. 7

01564/G

ANNEXES

Annex I	ISO Technical Committees in the Materials Field
Annex II	CEN Committees in the Materials Field
Annex III	Standardization Needs on Advanced Ceramics in Japan
Annex IV	Standards and Programme of CEN TC 184
Annex V	Review of potential for test method harmonisation
Annex VI	VAMAS Technical Working Areas
Annex VII	Proposed subcommittees of ISO/TC 201 on Surface Chemical Analysis
Annex VIII	Proposed areas of work to be considered by the subcommittees (shown in parentheses) of ISO/TC 201 on Surface Chemical Analysis

Annex I

ISO Technical Committees in the Materials Field

TC 33 Refractories
TC 35 Paints and Varnishes
TC 38 Cinematography
TC 45 Rubber and Rubber Products
TC 47 Chemistry
TC 61 Plastics
TC 76 Transfusion, Infusion and Injection Equipment for Medical Use
TC 79 Light Metals and their Alloys
TC 84 Syringes for Medical Use and Needles for Injections
TC 106 Dentistry
TC 119 Powder Metallurgy
TC 150 Implants for Surgery
TC 156 Corrosion of Metals and Alloys
TC 164 Mechanical Testing of Materials
TC 173 Technical Systems and Aids for Disabled or Handicapped Persons
TC 189 Ceramic Tile
TC 194 Biological Evaluation of Medical and Dental Materials and Devices
TC 201 Surface Chemical Analysis
TC 202 Microbeam Analysis
TC 206 Advanced Technical Ceramics

Annex II CEN Committees in the Materials Field

CEN/TC (or other)	Title	EN,ENV,HD,CR	Comments
Metallic - ferrous, general			
ECISS/TC 1A	Mechanical and physical tests	EN 10002-1, EN 10002-2, EN 10002-5, EN 10045-1, EN 10045-2	Testing methods for metallic materials
ECISS/TC 5		EN 10001	Definition, classification, conventional designation of pig iron and ferro alloys
ECISS/TC 6A		EN 10020	Terminology
ECISS/TC 6B		EN 10079	Terminology
ECISS/TC 7	Conventional designation of steel	EN 10027-1, EN 10027-2	Definition of steel names and steel numbers
ECISS/TC 9	Technical conditions of delivery and quality control	EN 10204	General technical delivery conditions for steel products - Inspection documents for metallic materials - Conformity assessment for steel products
ECISS/TC 20	Methods of chemical analysis	EN 10036, EN 10071, EN 10136 EN 10177, EN 10178, EN 10179, EN 10181, EN 10184, EN 10188, EN 10200, EN 24159, EN 24829-1, EN 24829-2, EN 24934, EN 24935, EN 24937, EN 24938, EN 24943, EN 24946, EN 24947, EN 29658	Defining methods of chemical analysis for iron and steel
ECISS/TC 21	Vocabulary of heat treatment terms		Terminology
Metallic - ferrous, products			
ECISS/TC 11	Sections - dimensions and tolerances		Definition of dimensions and toleerances for structural steel sections and bars
ECISS/TC 12		EN 10029, EN 10051	Definition of dimensions and tolerances for steel flat products for structural and pressure applications
ECISS/TC 13	Flat products for cold working - Qualities, dimensions, tolerances and specific tests	EN 10130, EN 10131	Definitions of qualities, dimensions, tolerances and specific tests for steel flat products for cold working

CEN/TC (or other)	Title	EN,ENV,HD,CR	Comments
ECISS/TC 15	Wire-rod - Qualities, dimensions, tolerances and specific tests		Definition of qualities, dimensions, tolerances and specific tests for steel rods for drawing or cold rolling
ECISS/TC 27	Surface coated flat products - Qualities, dimensions, tolerances and specific tests	EN 10142, EN 10143, EN 10147	Definition of qualities, dimensions, tolerances and specific tests for coated flat products
ECISS/TC 28	Steel forgings		Technical delivery requirements for all types of steel forgings
ECISS/TC 29	Steel tubes and fittings for steel tubes		Technical delivery requirements for steel tubes and fittings for steel tubes for all applications
ECISS/TC 30	Steel wires		Technical delivery requirements for steel wire and wire products
TCISS/TC 31	Steel castings		Technical delivery requirements for all types of steel castings
Steels - other uses			
ECISS/TC 10	Structural steels - Qualities	EN 10025, EN 10163-1, EN 101632-2 EN 10163-3	Definition of qualities of steels for structural applications
ECISS/TC 19	Concrete reinforcing steel - Qualities, dimensions and tolerances		Definition of qualities, dimensions, tolerances and specific tests for concrete reinforcing and prestressing steels
ECISS/TC 22	Steels for pressure purposes - Qualities	EN 10028-1, EN 10028-2, EN 10028-3, EN 10207, ENV 22605-1, ENV 22605-2, ENV 22605-3	Technical delivery requirements for steel bars and flat products
ECISS/TC 23	Steels for heat treatment, alloy steels and free-cutting steels - Qualities	EN 10083-1, EN 10083-2	Technical delivery requirements
ECISS/TC 24	Electrical steel and strip qualities - Qualities, dimensions, tolerances and specific tests		Definition of qualities, dimensions, tolerances and specific tests for electrical steels
ECISS/TC 26	Tinplate and blackplate - Qualities, dimensions, tolerances and specific tests	EN 10202, EN 10203, EN 10205	Definition of qualities, dimensions, tolerances and specific tests for steel products (<0.5 mm thick) intended for packaging
Metallic - non ferrous			

CEN/TC (or other)	Title	EN,ENV,HD,CR	Comments
CEN/TC 132	Aluminium and aluminium alloys	EN 23134-1, EN 23134-2, EN 23134-3, EN 23134-4	Product standards - Wrought and unwrought products
CEN/TC 133	Copper and copper alloys		Copper and copper alloys for general, electronic machining, building, electrical purposes; for heat exchangers, refrigeration etc
CEN/TC 209	Zinc and zinc alloys		Primary zinc and zinc alloys - Flat rolled products - Testing methods
CEN/TC 220	Tin and tin alloys		Pewter, pewterware and ingot tin - Methods of analysis
CEN/TC 306	Lead and lead alloys and oxides (provisional title)		Lead, alloys and oxides in unwrought or finished products and oxides. Committee created in 1992
CEN/CS M14		EN 26352, EN 26501, EN 27520, EN 27526, EN 27527, EN 28049, EN 29050, EN 28343	Chemical analysis
Non-metallic			
CEN/TC 66		EN 59, EN 60, EN 61, EN 62, EN 63	Tests for glass reinforced plastics. Committee disbanded in 1987
CEN/TC 172	Pulp, paper and board	EN 20216	Work mainly based on ISO work
CEN/TC 184	Advanced technical ceramics	ENV 820-2, ENV 658-3, ENV 658-4, ENV 658-5, ENV 658-6, ENV 820-2	Classification, terminology, sampling, test methods
CEN/TC 187	Refractory products and materials		Analysis and test methods
CEN/TC 248	Textiles and textile products	EN 20104-A01, EN 20105-A02 EN 20105-A03, EN 20105-B02 EN 20105-C01, EN 20105-C02 EN 20105-C03, EN20105-C04, EN 20105-C05, EN 20105-C06 EN 20139, EN 20811, EN 22313 EN 2490, EN 29073-1, EN 29073-2, EN 29073-3, EN 29073-4, EN 29092	Mainly based on ISO work
CEN/TC 249	Plastics		Specifications and test methods
CEN/TC 289	Test methods for leather (provisional title)		Committee created in 1991

CEN/TC (or other)	Title	EN,ENV,HD,CR	Comments
Others			
CEN/TC 138	Non-destructive testing	EN 473, EN 25580, EN 27963	Terminology, equipments, principles, methods, acoustics, ionization, liquid penetrant, magnetic, optical, leakage - Testing, qualification of NDT personnel. Part of the programme of work linked to the directive for simple pressure vessels
CEN/TC 190	Foundry technology		Technical delivery conditions, material specifications and testing methods for casting
CEN/TC 262	Protection of metallic materials against corrosion		Terminology, methods of test and evaluation of corrosion probability - Performance standards for corrosion protection by coatings, electro chemical protection, inhibitors. Partly based on ISO work
CEN/CS M11			Methods of test, chemical analysis. Based on ISO work

EN = European standard ENV = European prestandard HD = Harmonised Document CR = CEN Report

Annex III Standardization Needs on Advanced Ceramics in Japan

	Standardization Achievable in a Short Period of Time	Standardization Requiring a Somewhat Longer Period of Time	Standardization Requiring a Long Period of Time	Totals
Standardization Especially Necessary	Coefficient of Thermal Expansion Tensile Strength (Room Temperature) Fracture Toughness (Room Temperature) Thermal Shock Resistance Hardness Sampling and Sample Preparation Methods Oxidation Resistance (Room Temperature) Particle Size Distribution (0.1 μm or greater) Particle Absolute Specific Gravity Particle Tap Density Filling Characteristics Creep Strength Sintering Coefficient of Contraction Electromechanice Binding Coefficient Piezoelectric Stress Coefficient Transmission Factor Chemical Component Analysis Cutting Characteristics Thermal Conductivity Total 47	Thermal Conductivity Tensile Strength (High Temp) Fracture Toughness (High Temp) Static Fatigue (Creep) Mechanical Shock Resistance Friction Resistance Non-Destructive Inspections Non-Metallic Impurities Analytical Methods Corrosion Resistance (acid, alkali, salt solution) Maximum Particle Diameter Particle Shape (Aspect Ratio) Fluid Properties (Angle of Repose) Particle Diameter (Powder, Organizer Structure) Granular Body Properties Adhesion and Bonding Properties Components Shock Resistance Critical Temperature (Tc) Critical Current Density (Jc) Critical Magnetic Field (Hc) Meissner Effect Absorption Coefficient Existing State Analysis Crystal Phase and Crystalline Characteristics Fluidity Modulus of Elasticity Poisson's Ratio Total 39	Design Standards Assurance Testing Particle Size Distribution (0.1 μm or less) Secondary Particle and Aggregation Properties Powder Forming Characteristics Extrusion and Forming Properties Surface Phase Evaluation Grinding Characteristics Grindability Cutting Characteristics Friction Resistance Fatigue Crystal Volume Determination Form Determination Shapeability (Forming Characteristics) Granular Body Particle Size Granular Body Density Granular Body Strength Sintering Characteristics Bending Strength Tensile Strength Compressive Strength Torsional Strength Shearing Strength Multiaxis Strength Thermal Shock Fatigue Erosion Resistance Bonding Strength Total 38	124
Other needs	22	62	11	95
Totals	69	101	49	219

Standards completed by TC 184	EN(V) No	Future standards programme (1993-95)
GENERAL		**GENERAL**
1 Classification	-	1 Terminology
POWDERS		**POWDERS**
2 Impurities in Al_2O_3	EN 725-1	2 Impurities in zirconia
3 Impurities in $BuTiO_3$	725-2	3 Crystalline phases in zirconia
4 O_2 in non-oxides (thermal ext)	725-3	4 Impurities in silicon nitride
83 O_2 in non-oxides (XRF)	725-4	5 Flowability of powders
5 Particle size distribution	EN 725-5	
6 Specific area	EN 725-6	
7 Absolute density	EN 725-7	
84 Tap density	EN 725-8	
85 Untamped density	EN 725-9	
8 Compaction	EN 725-10	
9 Sintering curve	725-11	
MONOLITHIC CERAMICS		**MONOLITHIC CERAMICS**
10 Sampling and testing	-	6 Statistical evaluation of fracture testing
11 Cracks by dye penetration	EN 623-1	7 Microstructural analysis
12 Density and porosity	EN 623-2	8 Oxidation testing, method
13 Grain size	623-3	9 Flexural creep
14 Surface roughness	623-4	10 Fractography, standard practice
15 Flexural strength	EN 843-1	11 Elastic moduli, high temp
16 Elastic moduli	843-2	12 Fracture toughness (preliminary)
17 Sub-critical crack growth	843-3	13 Chem corrosion testing, laboratory procedures
18 Hardness	843-4	
19 Flexural strength, high temp	820-1	
20 Deformation	820-2	
21 Thermal shock	820-3	
22 Thermal expansion	EN 821-1	
23 Thermal diffusivity	EN 821-2	
24 Specific heat	821-3	
LONG-FIBRE COMPOSITES		**LONG-FIBRE COMPOSITES**
25 Tensile strength	658-1	14 Notations and symbols (under discussion)
26 Compressive strength	658-2	15 Tensile properties (inert atmosphere, 2000 °C)
27 Flexural strength	658-3	16 Tensile properties (air 1700 °C)
28 Shear strength (Compression)	658-4	17 Sheat strength, in-plane
86 Shear strength (3-point)	658-5	18 Interlaminar shear strength, high temp (inert atmosphere, 3-point)
87 Shear strength (double punch)	658-6	19 Tensile properties of a dry fibre tow
29 Thermal expansion	...-1	20 Tensile strength, single filament at high temp
30 Thermal diffusivity	...-2	21 Flexural strength (inert atmosphere, 2000 °C)
31 (Deleted)		22 Flexural strength (air, 1700 °C)
32 Specific heat	...-3	23 Thermal conductivity
33 Density	...	24 Compression properties (neutral atmosphere, 2000 °C)
		25 Compression properties, high temp (air)
		26 Resistance to crack propagation
		27 Elastic properties of NDT
		28 Resistance to creep
FIBRE PROPERTIES		
34 Size content	...-1	
35 Linear mass	...-2	
36 Filament diameter	...-3	
37 Filament strength	...-4	
COATINGS		**COATINGS**
69 Chemical comp (EPMA)	...-4	29 Chemical comp (GDOS)
70 Thickness (step and cap grinding)	...-1	30 Chemical comp (XRF)
88 Thickness (grinding)	...-2	31 Chemical comp (AAS)
71 Topography (SEM)	...-6	32 Chemical comp (ESCA)
72 Porosity (metallography)	...-5	33 Coating hardness
73 Adhesion (scratch)	...-3	34 Residual stress distribution

Annex V

Review of potential for test method harmonisation
[C = carbon fibre, G = glass fibre, A = all fibres, P = plastics, * = drafts,
SRM = SACMA, AITM = Airbus Industries, ACO = ACOTEG,
CRAG = Composites Research Advisory Group (for Aerospace), UK

Test	Methods	Assessment
1 Longitudinal Tension (0°)	ISO 527(P), ISO 3268(G), EN 2561(C)*, EN 2747(G)*, ASTM D3039(F), JIS 7073(C), CRAG 300(F)	Normally straight tabbed specimen. Tab design and material different. 1 or 2 mm thick and between 10 and 20 mm wide. Different moduli measurement methods. Harmonisation started. ISO draft
2 Transverse Tension (90°)	EN 2597(C)*, ASTM D3039(F), JIS 7073(C), CRAG 301(F)	As above but 2 mm thick and 10-25 mm wide. Harmonisation started. ISO draft
3 Multidirectional Tension	ASTM D3039(F), CRAG 302(F), ACO/TP/14	Similar methods except that CRAG includes any $\pm\theta$. ISO 527 Part 4 may cover
4 Longitudinal Compression (0°)	ISO 8515(G), ISO 604(P), EN 2850(C)*, ASTM D3410(F), ASTM D695(M), CRAG 400(F)	Similar philosophy (except D695) but differences in gauge area and support jig. 6.35-12.5 mm wide and 2-4 mm wide. More difficult area to harmonise because of many support jigs. CEN new draft
5 Transverse Compression (90°)	ASTM D3410(F), ACO/TP/8	Both compression options as for Test (4). CEN new draft
6 Multidirectional Compression	CRAG 401(F), ACO/TP/14	Similar specimen geometries as Test (3)
7 Flexure	ISO 178(P), EN 63(G), EN 2562(C)*, EN 2746(G)*, ASTM D790(P), CRAG 200(F)	ASTM and JIS include 4 pt. Older standards (eg ASTM) have a range of thicknesses, later 2 mm but EN(G) is 3 mm. CEN new draft
8 Interlaminar Shear	ISO 4585(G), EN 2563(C)*, EN 2377(G)*, ASTM D2344(F), CRAG 100(F)	Normally 5/1 span/depth. ASTM range of thicknesses, EN(C) is 2 mm but EN(G) is 3 mm thick. CEN new draft. CRAG 2 mm
9 In-plane Shear	ASTM D3518(F), CRAG 101(F), ACO/TP/9, AITM 10002	Normally 2 mm thick. ASTM and CRAG 25 mm wide and ACO is 16 mm. AITM 25 mm x 1 mm. CEN preparing new draft
10 Open Hole Tension	CRAG 303(F), ACO/TP/12, SACMA SRM5(F), AITM 10007, DIN 65559	Same specimen width/hole diameter (6/1) for metric and non-metric versions except AITM 5/1. Hole diameter 6 or 6.35 mm CRAG has a range for both values
11 Holed Compression	CRAG 402(F), ACO/TP/11, SACMA SRM3(F), AITM 10008, DIN 65560	As above for tension

12 Compression After Impact	CRAG 403(F), DIN 65561 AITM 10010, SACMA(ASTM)(F)	Boeing test method (ASTM R-R) gaining acceptance, in DIN draft

Annex VI VAMAS Technical Working Areas

Area No	Title	Materials under study	Chair
TWA1	Wear Test Methods	Alumina, Silicon nitride, AISI 52100 steel	USA, Germany
TWA2	Surface Chemical Analysis	Wide ranging reference materials, metallic and non-metallic	UK
TWA3	Ceramics	Alumina, zirconia-alumina	USA
TWA4	Polymer Blends	Polycarbonate/ Polyethylene blend, Orgalloy R-6000 commercial blend	Canada
TWA5	Polymer Composites	Glass and carbon fibre reinforced resins	France
TWA6	Superconducting and Cryogenic Structural Materials	Niobium-tin and niobium-titanium filaments, cryogenic steels	Japan
TWA7	Bioengineering Materials	Hydroxyapatite, alumina, zirconia	Japan
TWA8	Hot-Salt Corrosion Resistance	Rene 80 and IN738, Nickel-base superalloys, protective coatings	UK
TWA9 (completed)	Weld Characteristics	304 and 316 stainless steels	UK
TWA10	Material Databanks	Creep and fatigue data from low and high alloy steels	EC,USA
TWA11	Creep Crack Growth	Chromium/molybdenum/ vanadium ferritic steels	UK
TWA12	Efficient Test Procedures for Polymer Properties	Wide range of polymers	UK
TWA13	Low-cycle Fatigue	IN718 and Nimonic 101 nickel-base alloys, 316L and 9Cr/1Mo steel	EC
TWA14	The Technical Basis for a Unified Classification System	Engineering Ceramics	USA
TWA15	Metal-Matrix Composites	Discontinuous SiC reinforced aluminium	USA

Annex VII Proposed subcommittees of ISO/TC 201 on Surface Chemical Analysis

1	Terminology
2	General Procedures
3	Data Management and Treatment
4	Depth Profiling
5	Auger Electron Spectroscopy (AES)
6	Secondary Ion Mass Spectrometry (SIMS) (includes Sputtered Neutral Mass Spectrometry and Fast Atom Bombardment Mass Spectrometry)
7	X-Ray Photoelectron Spectroscopy (XPS)

Annex VIII Proposed areas of work to be considered by the subcommittees (shown in parentheses) of ISO/TC 201 on Surface Chemical Analysis

A	Instrument Specifications (AES, GDOS, SIMS, TXRF and XPS)
B	Instrument Operations (AES, GDOS, SIMS, TXRF, XPS, Depth Profiling, and General Procedures)
C	Specimen Preparation (General Procedures)
D	Data Acquisition (AES, GDOS, SIMS, TXRF and Depth Profiling)
	Data Processing for Qualitative Analysis (AES, GDOS, SIMS, TXRF, XPS, and Data Management and Treatment)
F	Data Processing for Quantitative Analysis (AES, GDOS, SIMS, TXRF, XPS, and Data Management and Treatment)
G	Reporting Results (AES, GDOS, SIMS, TXRF, XPS, Depth Profiling, General Procedures, and Data Management and Treatment)
H	Terminology (Terminology)
I	Reference Materials (General Procedures)

GDOS Glow discharge optical spectroscopy
TXRF Total reflection x-ray fluorescence spectroscopy

SUMMARY OF PRESENTATION

Testing and Evaluation of New Materials: Thailand

L. Chotimongkol
Director of Metal and Material Technology Department, TISTR

N. Pankurdee
Director of Material Properties Analysis and Development Centre, TISTR

New and advanced materials may be defined as materials which are composed of new composition, new or improved processes for new applications. The terminology of advanced or new materials in this paper refers to advanced ceramics than other materials. The main requirement of these materials is that they should withstand higher properties in mechanical, thermal, chemical resistant, etc. Furthermore, new materials will perform their functional properties better or newer than classical or traditional materials, such as Engineering Ceramics, Electronic Ceramics, Composite Products. Since the private sector is responsible for most of the present economic growth, many companies are changing their attitude from traditional reliability in cheaper labour to more utilization of automation technology. This leads some major companies to start to put more investment in their own R+D units. In Thailand, the development of new materials has only recently started. Testing of their properties and its performances are difficult to characterize and evaluate. Due to a lack of expertise on testing methods in both public and private sectors, the need of expertise and standard method of testing of evaluation service of new material is critical for the success factor of new material development.

Testing and Evaluation of New and Advanced Materials in China

Prof. Wu Min-da
Shanghai Research Institute of Materials

Reliable methods for testing and evaluation of new and advanced materials play a very important role in the rapid industrial development of China.

Projects of R+D in this respect are provided through three approaches in China. Those of basic research of new methodologies and techniques are categorized as national projects and funded by National Natural Science Foundation. Those of applied research are brought into the projects of relevant industrial ministries or regional (provincial or municipal) economy committees and funded by their respective foundations. Contracts of those projects for specific purposes are made between the demander enterprise or factory and certain materials research or testing laboratory. There are many institutes in a ministry, as for instance, the Ministry of Machinery Industry involves many institutes, such as Institute of Automobile, Bearing Research Institute, Institute of Electric Power Plant Equipments, etc. In each institute, a materials research and testing division or group is in charge of investigating the materials for its respective product services.

As the characterization method for new and advanced materials would be much more complicated than for the routine engineering materials, testing machines and apparatus would be more expensive than what developing countries could afford. Therefore, it is a very good idea to establish an International Centre for Materials Evaluation Technology (ICMET), in order to organize the collaboration in testing and evaluation of new materials in Asia. and it will surely be with synergistic benefits for developing countries.

We are glad to do our best to support this meaningful task. All the activities of this Centre would be on a voluntary basis. It seems worthwhile to initiate even a bilateral programme at its first stage. The possible areas of cooperative R+D will be very wide. It would seem highly recommended firstly to edit a newsletter (probably in English), for exchange of ideas, information and experience. The editorial board should consist of representatives of all member countries. Round Rob in Test of some CRM (Certified Reference materials) among member countries would seem also recommendable. For the time being their funding, however is a problem to be settled.

Testing and Evaluation of Materials: Indian Experience

Krishnan Lal
National Physical Laboratory

Research and development in the area of materials science is being pursued in a variety of institutions all over the country. These R+D groups are part of national laboratories of Indian Institutes of Technology and Universities. Premier institutions like Indian Institute of Science, Bangalore and Tata Institute for Fundamental Research, Bombay are also active in this area. In industrial sector also there is activity on a limited number of materials. Both for understanding of the behaviour of materials on fundamental level as well as for control of properties so that these can be employed in different devices, a strict control is required over basic materials' characteristics and properties. There is considerable infrastructure in the country for characterization of materials regarding all aspects, namely: composition, purity, crystallographic structure and lattice imperfections. Also a number of properties can be measured at a level of accuracy. Advanced techniques for elemental analysis include atomic absorption spectrometry (with graphite furnace and background suppressing facility); ICP emission spectrometry; ICP mass spectrometry and a variety of usual spectrochemical techniques. X-ray fluorescence spectrometry is also widely utilized. For specialized situations, magnetic resonance techniques are employed. For characterization of surfaces, the following analytical techniques are being used: (i) Auger electron spectrometry; secondary ion mass spectrometry (SIMS) and electron spectroscopy for chemical analysis (ESCA).

This infrastructure is being used to prepare Indian Reference Materials to ensure quality of measurement in testing laboratories all over the country. Some of these reference materials have been exported. Also, we are participating in a few international activities in this area.

Testing and Evaluation of New Materials in Indonesia

Nuryardi Kahar
Head
Research and Development Centre for Applied Physics

Industrialization has been growing very fast in the last 25 years of Indonesia national development effort. The contribution of manufacturing industry to the national GDP was consistently increasing. Demand for new material to sustain the operation of the industries is also increasing.

Testing and evaluation of materials are becoming one of the important issues in conjunction with the issue of sustainable growth and development of Indonesian manufacturing industry. The needs of testing cover the area of metals, ceramics, polymers, composites and functional materials.

The availability of facilities is still in the early stage of development and they are scattered in various institutions and industrial establishment

Recognizing the complicated issues of testing and evaluation of materials as well as the high cost investment to develop reliable facilities, there is an urgent need for evolving policies, procedure and mechanisms to enhance the materials evaluation technology capacity in Indonesia. The existing groups and facilities will be the valuable assets to develop such an important technological infrastructure. The initiative undertaken by UNIDO and the Republic of Korea to establish an International Centre for Materials Evaluation Technology (ICMET) will be relevant and could help developing countries, such as Indonesia, in strengthening their technological based development endeavour.

R+D Activities of New and Advanced Materials in Malaysia

Dr. Joo Fai Tung
Standard and Industrial Research Institute of Malaysia

Vision 2020 is the road for Malaysia to become a fully industrialized nation by the year 2020. To achieve this goal, Malaysia must aspired to be a highly competitive manufacturing nation trading in the world markets and with full understanding of issues such as market knowledge, industrial and engineering design, as well as leading technological edge in both materials and manufacturing technologies.

The Malaysian Government Technology Action Plan recognized these important aspects of technological development and accordingly focuses on building up a body of competence in new and emerging technologies. These technologies, with careful guidance and appropriate selectivity, will point to niche areas and can possibly provide opportunities in an increasingly competitive global trading environment.

Towards this objective, the National Plan of Action has designated six priority areas, namely: Automated Manufacturing Technology, Advanced Materials Technology, Electronics Technology, Energy, Biotechnology and Information Technology for R+D initiatives. When considering these five areas of technology, it is obvious that a high degree of interdependence may be noted, but possibly not so great as the role of advanced materials.

"Advanced Materials" is a collective term that is convenient to use, and that has a wide range of meanings depending on the topic under discussion. For this purpose, the term refers to the following materials categories:

- Ceramics
- Metals
- Polymers
- Composites

The opportunities and potential for materials falling under these classification will always depend on the products into which they are embedded and the world market for these products. The sale of a "high tech" raw material, or the technology associated to produce it, may bring revenue to the country, but the real benefits are to be generated by using the qualities of those materials to promote Malaysian "high value added" products in the world arena.

New mechanisms will certainly be needed for coordinated planning and implementation of multi-agency programmes in Malaysia for the development of new and advanced materials. This multi-linkage synergism will certainly increase the effectiveness of this technical agenda. The long range goal is to allow government agencies and the private sector to develop coordinated R+D programmes that will be both technology-driven and goal-oriented. This is more important in view of the fact that Malaysia is committed to developing business and technological capacity in advanced materials and composite products manufacturing for both the aerospace and non-aerospace applications.

Testing and Evaluation of New Materials at Singapore Institute of Standards and Industrial Research (SISIR)

Dr. Daniel Yip
Materials Technology Division
SISIR

The Singapore Institute of Standards and Industrial Research (SISIR) is a Singapore government statutory board and a national testing laboratory. Our mission is "to excel as the national standards authority and to lead Singapore industry towards greater international competitiveness through quality and industrial technology".

SISIR currently has a staff strength of some 600, of which 25 per cent are graduate professionals. In addition to product and materials testing activities, SISIR offers a highly integrated package of multidisciplinary services which include contract R+D, product design and development, failure analysis and consultancy, calibration, ISO 9000 and other technical services.

Organizationally, SISIR has seven divisions, each headed by a Director. it is guided by a Board comprising members from industry, the Ministry of Trade and Industry of which SISIR reporting to and other government members. The Board is directed by a non-executive Chairman. The day to day operation is managed by the Chief Executive, and assisted by the Assistant Chief Executive of SISIr.

Materials Technology Division is one of the three divisions classified as the "Hard Technology" division. Within the same category are the Product and Process Technology Division and the Electronics and Computer Applications Division. In contrast, our Standards and Quality and Technology Transfer division are classified as the "Soft Technology" division. The hard technology divisions are mainly responsible for the implementation of testing activities and applied R+D contracts whereas supporting services such as laboratory accreditation, ISO 9000 certification as well as technology market programme are done by the soft technology division.

Current Activities of Materials Evaluation Centre

Dr. Hahngue Moon
Materials Evaluation Centre
Korea Research Institute of Standards and Science

The National Research Project funded through Ministry of Science and Technology is to develop or improve materials evaluation techniques required in industries. The long term development plan covers the following areas:

- evaluation of forming process and durability of structural fine ceramics
- nanostructure analysis of ultra thin films
- surface/interface composition analysis
- evaluation of materials used in extreme environment, and
- real-time/in-process evaluation

This project starts this year and US$810.000 was allocated for 1994.

There are so many kinds of materials. properties. and many kinds of evaluation methods that institutes or even one country cannot cover all of them. That is why we need international collaborations, especially among developing countries. KRISS is willing to share its manpower. facilities, and experiences with any organization in the region for collaboration in testing and evaluation of new materials.

UNIDO and Korea Research Institute of Standards and Science (KRISS), following the conclusions of Regional Workshop on Testing and Evaluation of New Materials for Asia held on 25-28 March 1991 at KRISS, have been preparing for the establishment of International Centre for Materials Evaluation Technology (ICMET). Although ICMET was not established yet, the possibility is increasing now. If ICMET is located here at KRISS, Materials Evaluation Centre (MEC) of KRISS will play an important role in various activities of ICMET.

Feasibility Study on

The Establishment of an International Centre for Materials Evaluation Technology

EXECUTIVE SUMMARY

Materials Technology is a key enabling technology for a wide range of industrial sectors. It is commonly acknowledged that reliable methods of testing and evaluation of new and advanced materials are crucial for their successful development and efficient incorporation into competitive industrial products. However, activities associated with the development of widely recognized evaluation methods are slow and dispersed in the developing countries and there is a genuine need to develop a concerted activity. Therefore, it is proposed that an International Centre for Materials Evaluation Technology (ICMET) is set up to provide a framework under which developing countries can co-operate with synergistic benefits.

A mission of experts organized by UNIDO, has consulted leading institutes and experts in nine countries in Asia and America, and found considerable interest in the concept. Based on the findings of the mission, it is recommended that a pilot phase activity over two years should start as soon as possible to lay the basis for the establishment of ICMET and the development of a longer term plan. Since the work of the Centre is novel and complex in nature, some pump-priming funds are required before it can be expected to become stable. For the pilot phase it is estimated that US$674,750 over 3 years will be required.

The present document contains proposals for the pilot phase activities which cover training, information exchange, advisory services and co-operative R&D. Countries consulted warmly supported the idea that the Centre should be based at the Korean Research Institute for Standards and Science (KRISS) and operated as a UNIDO project to benefit from UNIDO's wide experience in promoting international co-operation in new technologies.

I. INTRODUCTION

During the past five years, a number of meetings on advanced materials for developing countries have identified the common need for regional and international co-operations in the field of evaluation, testing and standards on new materials[1-4]. To facilitate an effective co-operation amongst the developing countries, it has been proposed that an International Centre for Materials Evaluation Technology (ICMET) be established in the Republic of Korea at the Korean Research Institute for Standards and Science (KRISS). Accordingly, in March 1992, UNIDO sent an expert mission to consult leading institutes and experts in nine countries in order to determine the strength of international interest in such a Centre and to develop a proposal covering its scope, functions and the operational framework.

The mission was co-ordinated by Dr M K Hossain of the National Physical Laboratory, UK and included Drs H Moon and G Bahng from KRISS and UNIDO staff member. Drs Hossain and Bahng visited People's Republic of China, Thailand, Malaysia, Singapore and India, whilst Dr Moon and UNIDO staff member visited North America, Brazil, Mexico and Argentina. Very valuable inputs to the analysis have been made by UNIDO's delegation, through wider consultations, both in the developing and the developed countries, and also by Dr Park, President of KRISS.

The mission met top government officials, senior scientists and technologists in key research institutes as well as standards and industrial organizations in the nine countries. Altogether it is estimated that face-to-face consultations with over 100 persons have been carried out. A meeting was then held in London between Dr Hossain and UNIDO staff member to discuss the overall findings and conclusions based upon which the following proposal for ICMET has been prepared.

II. BACKGROUND

Innovation in engineering materials has been responsible for major technological advances in recent years and the trend is set to continue into the next century. As we enter 1990s, the world economy will increasingly be driven and shaped by the development and application of three major technology families, namely: new, improved and advanced materials, microelectronics and biotechnology.

Worldwide demand for advanced materials production has been increasing rapidly within the last decade and it tends to rise by 2000 and beyond that period. Only between 1985 and 1988, the number of companies involved with advanced materials grew more than 1800, from 302, worldwide. It expects the global market to reach US$72 billion to US$95 billion by 2000, almost an order of magnitude growth from 1987. Inorganics, such as semiconductors, powder metals, amorphous alloys, and magnetic materials, will comprise between 36% and 52% of the total market by 2000; composites, a US$12 billion market in 2000, up from US$4 billion in 1987. Polymers are projected to approach US$17 billion, from US$ 6,5 billion in 1987. The demand for advanced ceramics will increase 8.5% a year worldwide between 1990 and 2000 to reach US$25 billion market in 2000, up from US$11 billion in 1990.

It is the materials sector, emerging as a new high technology sector in itself, upon which technological change across industry is increasingly coming to depend. Further, new and advanced materials technologies are becoming more and more linked in the diffusion process across high-technology and traditional branches of industry. Economics in possession of a critical mass of materials scientific and technological capabilities, associated infrastructure will be able to gain global competitive advantage in the 1990s and beyond that period. Given the pressures of the world market and the user industries for higher quality, durability and reliability, no economy or industry can afford to ignore this in the years to come, at any stage of the materials cycle.

With the realization that materials technology is a prime enabling technology which will have a major influence on the economic and industrial competitiveness, the industrialized countries have made substantial investments in R&D. Efforts are being directed towards developing new and improved materials along with their processing technologies. Major improvements in the industrial production cycle - from the processing of raw materials to the manufacture of finished products - are envisaged affecting many industrial sectors (eg electronics, mechatronics, energy, aerospace, automobile and biomedical). The variety of advanced materials stretches from existing modern materials which are being improved to extend their performance and applications, to those that are being developed with unique properties.

Quite significantly, various developing countries have also recognized now the crucial importance of advanced materials and are embarking on new programmes to build and strengthen national activities with the aim of increasing industrial competitiveness. In this context, it is most important to appreciate that the greatest benefit of advanced materials will arise from the wider diffusion of the technology into industrial products. Indeed, the impact of the technology on user industries will be a relatively more important consideration than simply the market size of the materials themselves.

III. JUSTIFICATION FOR ICMET

To transform advanced materials into competitive industrial products successfully, it is widely acknowledged that the evaluation technology is important. Materials evaluation technology is known as the methods of measurement, testing or analysis used to determine the physical, mechanical or chemical characteristics and properties of materials. Reliable and appropriate methods of materials evaluation and specification are, in fact, vital for the development of new materials, materials selection, product design, process selection, quality control and assurance, and the prediction and assessment of in-service performance. However, advanced materials often require a new approach and more sophisticated and systematized techniques for characterization, testing and evaluation which are not generally available. This acts as a serious barrier to the wider diffusion of the technology and poses significant problems for the developing countries. For example, testing needs for advanced composites are driven by user requirements - each user tries to develop its own set of test methods to characterize and qualify a material, and to establish design allowables. Thus, while the need to know basic materials properties is essentially the same for all users, methods used to determine these properties are different. Thus, to assess composites performance under compression, one can find 15-20 different test configurations. Multiple test methods is clearly inefficient, not just for the materials suppliers but also for the materials users and test houses. Key factors are:

- it is costly to purchase and maintain different test facilities;
- training to develop expertise for each method can be expensive;
- it is difficult or even impossible to combine test results into a database.

In fact, what industry requires is a set of consistent and widely recognized evaluation techniques for common use by both the producers and users of new and advanced materials. Ideally, these techniques should be standardized, but the technical bases from which reliable standards can be developed are lacking in many areas with the consequence that often there are large disagreements on evaluation techniques and even on results obtained from the same technique. Much underpinning work is required to resolve basic but complex issues.

Trade in advanced materials and products made from them is global in character and therefore there is a genuine requirement for international co-operation in the development of characterization and evaluation techniques which can be accepted across national boundaries. The seven most industrialized countries of the world had already recognized this and initiated a multilateral programme in the 1980's on Advanced Materials known as VAMAS[5]. This programme provides a focus for co-operation amongst the industrialized nations in developing common technical bases from which harmonized standards can be produced with considerable benefits.

In the developing countries, progress on materials measurement and evaluation technology is slow because of the heterogeneity of the activities concerned, the amount of necessary work compared with the available resources, and the diverse bodies involved (industrial federations, users, test laboratories, government authorities, individual firms, international organizations etc). Often in the developing countries there is no focus for materials evaluation work and some lack a critical mass at present making it difficult for them to undertake this work efficiently. The materials base, and the technological capabilities and needs of developing countries, are somewhat different from those of the developed countries so that the case for co-operation amongst developing countries is vital if their needs are to be met properly.

It must be stressed that now the acquisition and development of high-tech competence in measurement and materials performance evaluation to facilitate both large scale production and trade of materials has become an absolute necessity for the development of economics of these countries in the 1990. Hence, the concept of an International Centre for Materials Evaluation Technology is both timely and necessary in order to meet the pressing needs for a new approach to promoting international co-operation in the fields of materials testing and evaluation. Such a Centre should assist co-operation amongst the developing countries and between them and developed countries through the use of bi- and preferably multilateral R&D programmes, training, and the exchange of information, ideas and experiences. The Centre should enable the limited resources available for this type of work to be utilized more effectively.

Three options were considered for this International Centre:

(i) establish an international Centre which would physically house a set of key measurement and testing facilities and be staffed internationally;

(ii) establish a simple network of laboratories involved in evaluation work in the developing countries; and

(iii) set up an International Centre which would provide the basic organizational support to develop and maintain multilateral co-operation on a cost-shared basis. Necessarily, this will include an element of networking of laboratories with overlapping interests.

For the first option, funding from participating countries has to be sought and this was considered difficult to secure at least in the short term. It might be possible to obtain some funding from the developed countries, but this requires further investigations and a long-term plan. Only selected developing countries can afford to establish and maintain such type of a sophisticated centre. Also, quite importantly, each country requires its own local capability and an infrastructure in testing and evaluation to support its industry. In some countries like India and People's Republic of China, national institutes are well equipped so that it is important that national centres are utilized in a complementary way to develop ICMET and its activities.

The second option is considered to be effective for utilizing all resources involved optimally. But simple networking assumes that there are strong nodal points which are in a position to cooperate without additional support and assistance and this is not the case of developing countries.

There is a need to go beyond the networking of existing institutions and centres of excellence, and to set up an international nodal point which can assist developing economics in both frontier scientific and engineering research and in information gathering monitoring and dissemination, the generation of materials properties data bases which would provide the basis for national industrial and economic development and strategic planning. The speed of change, the enormous complexity and multidisciplinary, transectoral aspects of materials issues mean that all opportunities for technical, economic and industrial cooperation between developing countries be grasped, and that collective approaches may be necessary, including the setting up of appropriate international nodal point. The nodal point would also have an advantage of providing access to instrumentation to those research institutions in developing countries that can not afford such instrumentation. This brings us to the third option which was widely accepted as the most attractive route for initiating an effective international co-operation which can be steadily built over the next few years. During this time some pump priming funds are essential. However, in the longer term, much of the research work on test and measurement methods, validation, etc. leading to the development of guidelines, codes of practice and standards, could be carried out under a cost-sharing basis when each participating member agrees to carry out a specific complementary component of a larger Programme and in return gain access to the total research output.

The suggestion that KRISS should provide the focus and host the proposed International Centre was almost universally welcomed. The mission found that KRISS enjoys a high reputation amongst scientists and technologists in the developing world and is seen as a credible organization to lead the initiative. The people appreciate that the Republic of Korea has made a big progress in economic development and it would be very useful for other countries to learn its experience gained. Its resources and growing capabilities were seen as vital for the success of the International Centre, particularly in the formative stages when a strong driving force and momentum is needed.

Several of the developing countries visited by the mission are preparing plans for increasing their efforts including the creation of national centres on materials R&D which will include testing and evaluation work. However, resources are limited and there is a shortage, with the exception perhaps of India, People's Republic of China and one or two Latin American countries, of trained materials scientists and technologists. The countries are keen and consider it essential to have avenues for international exchange and co-operation to combat part of this deficiency. Although some countries have bilateral arrangements with one or two developed countries these are far from adequate. Co-operation amongst developing countries who share common problems and whose perspectives are similar, are believed to be of significant importance. Indeed, similar technological capabilities and requirements can provide an excellent basis for fruitful and effective partnership amongst developing countries.

Development, processing and applications of materials are near-market activities which means considerations of commercial confidentiality can impede free exchanges and collaboration. However, work on materials evaluation and testing methods is pre-competitive in nature making it relatively easy to collaborate bringing common benefits to all participants. Thus the concept of ICMET found immediate support from all countries alike.

The mission found that the initiative of UNIDO to establish ICMET was overwhelmingly supported. Undoubtedly UNIDO will have a key part to play by acting as the catalyst and enhancing international collaboration. Over many years UNIDO has built up expertise to promote the establishment of international centres of excellence in new technology areas. Of special note is the International Centre for Genetic Engineering and Biotechnology (ICGEB), and the more recent International Centre for Science and High Technology (ICS) both in Trieste, Italy. Within the ICS there is a specific programme on new materials and it is foreseen that ICMET will have strong linkages and be complementary to it. UNIDO is also promoting regional co-operation in the area of new materials in general and has links with groups working on new materials in developed countries such as ASM International.

In the view of the mission, the establishment of an International Centre on Materials Evaluation Technology for the developing countries will have a number of important wider benefits:

(a) It will provide a basis for developing countries' gaining access to engineering and processing of new materials and their characterization. That would assist the development and strengthening of general technological capabilities in the materials evaluation technology area vital for future competitiveness of industry. It would also raise the level of understanding throughout the materials related industry of the importance of specifics in test methods

(b) Co-operative international programmes will enable the developing countries to address materials evaluation issues within their own national institutions in a more co-ordinated and effective manner.

(c) Collaborative work on materials evaluation should provide a strong platform for the materials research communities in the developing countries to build closer contacts on wider topics.

(d) The Centre should have better scope for interactions and linking up with established centres and other related initiatives of the developed countries than individual institutes or even countries of the developing world would on their own.

(e) International standards are of crucial importance to industry and business, and through ICMET's work, the developing countries will be in a good position to contribute and influence the standard development in a positive manner.

(f) ICMET will assist accredited laboratories to perform to a higher standard and would ease the laboratory accreditation process as a whole in the developing countries.

In fact, it might be said that without ICMET, there would be a lack of co-ordination, co-operation and exchange of information amongst the developing countries and they would lose an opportunity to reduce the gap between them and developed countries in a technological area of major industrial significance and continue to have to follow these countries.

IV. INDICATIONS OF INTERNATIONAL INTEREST AND SUPPORT

The vast majority of government representatives in developing countries responded most positively to the concept of ICMET and considered that the multilateral action is very timely and should assist vital strengthening of national and regional activities. At the same time, some expressed the view that effective links with the activities in the developed world are essential to ensure that work is not done in isolation and that developing countries should contribute to the development of global standards wherever appropriate. There was very enthusiastic support for ICMET from scientists and technologists. Annex I contains a list of the organizations and people visited by the mission.

Most countries are keen and willing to provide support for their own establishments wishing to participate in co-operative R&D work on materials evaluation. Some offered to host workshops, training events etc. in their country with some financial support to meet local costs of delegates. Commonly it was acknowledged that there has to be a two-way process for participating countries in which they both give and take although the exact levels will vary and not always match.

For advanced materials, the mission noted a spectrum of capabilities in the different countries dependent upon the strengths of specific industries, the portfolio of current activities and the availability of manpower and financial resources. However, it was evident that most countries are developing policies and plans to strengthen their technological capabilities in advanced materials so that significant growth in R&D activities and funding can be expected during the coming years. Detailed interests varied although some common areas such as engineering ceramics (functional and structural), composites (polymer- and metal-based), surface chemical analysis, corrosion, and construction materials were identified as possible areas from which some initial activities in the pilot phase can be developed.

Certain countries stressed the need to ensure that ICMET's activities do not simply try to follow the same pattern as in developed nations; proper account must be taken of the industrial potential of specific classes of materials and also the availability of raw materials. For example, People's Republic of China is developing technical ceramics (SiN, SiC) from rice husks which is an abundant resource in many developing countries and such an area can provide good scope for transnational collaboration.

However, it was felt that any delay in launching the Centre would be damaging and that contribution prospects would be much higher if there were a pilot phase during which some successful demonstration activities could be developed; funding options could be explored more fully during such a pilot phase. In this respect, suggestions were made that industry, industry associations as well as funding organizations in the developed countries could be approached.

A substantial measure of support was shown for the organization of training courses to improve manpower skills of developing countries in the materials field. Various centres of excellence exist in the different countries and would be prepared to host courses.

An important point which came up frequently in the discussions is the role of industry and the desirability of its involvement in the ICMET programme. Even in the developed countries, with one or two exceptions, industry is reluctant to become involved in pre-standards or underpinning work on measurement and evaluation technology. There is no simple recipe for success, but it is essential that identification of work programmes for ICMET are carried out in close consultation with industry and that continuous effort is made in all countries to attract industrial laboratories and test houses to co-operate in intercomparison exercises on test methods and data. Other forms of in-kind support, such as contribution of materials, should also be sought.

Overall, the conclusion of the mission was that leading experts of the developing and developed countries are very keen to co-operate on ICMET and took the view that the initiative is very timely. They all recognized the need to secure some core funding to launch pilot phase activities through which the feasibility and value of such a co-operative programme can be demonstrated. The immediate objective of the pilot phase is to lay the basis for the establishment and effective operation of ICMET through the development of an appropriate organizational and operational structure which will enable the formulation of an initial work programme based upon which a detailed longer term plan can be developed.

The aim should then be to develop the work steadily through an operational phase over a period of years during which the Centre could be expected to forge good relations with industry and Government on the strength of its record and future programme. However, because of the nature of the work and the international dimension, it would be vital to have funding from a central source which will help the nucleus to grow to a stable size. Once this is achieved, the Centre should be expected to raise sufficiently additional amounts from other sources for carrying out its activities.

V. FUNCTIONS OF THE CENTRE

Objective

The overall objective of the International Centre for Materials Evaluation Technology is to establish and strengthen the capabilities of developing countries in materials evaluation and act as the focus for promoting international co-operation in this field.

Functions

As regards the functions of the Centre, the mission has established support for the following activities to meet current needs; however, it must be stressed that these should be reviewed and tuned regularly to take account of changing requirements of the participating countries:

(a) **Awareness**

The Centre should gather, monitor and disseminate information from both developing and developed countries in the field of testing and evaluation of advanced materials, including on-going work of important standards committees and standards issues. Given the large scale of activity, the Centre has to adopt a selective approach.

(b) **Co-operative R&D**

The Centre should identify industrially important areas for developing or improving new materials evaluation and characterization techniques through co-operative R&D programmes. The aim should be to generate validated and widely acceptable techniques which can form the basis for the development of regional and international standards. It is envisaged that laboratory intercomparisons and the development of key reference materials will also be included in the programme.

(c) **Advisory Services**

The services should be organized by the Centre in co-operation with national centres to help industry and R&D institutions in the developing countries. Delivery of the service should be provided by a network of organizations and locally wherever possible. However, the Centre must be able to direct enquirers to appropriate sources of advice.

Part of the remit of the Centre should be to encourage the development of leading edge services in a co-ordinated manner and reducing unnecessary duplication. Advice could also be provided to assist in the establishment of new facilities and laboratories drawing upon knowledge and experience from existing facilities.

(d) **Training**

Shortage of skilled manpower is a serious problem for developing countries and in this area the Centre can make a valuable and sought-after contribution by organizing training programmes which offer practical experience to participants in key and developing fields of materials characterization and evaluation. Training courses should provide the scientists and technologists access to state-of-the-art instrumentation and testing facilities which are relevant and important to industry. Emphasis should be placed in seeking industrial views in the design of the courses and making them attractive to participants from industry in the developing countries.

Intensive training courses should be held at centres of excellence bringing international experts, not exclusively from the developing countries but also from the developed countries, to ensure that up-to-date training is provided to meet the skills gap. At the same time, it is crucial to design courses which fully take into account the special needs of developing countries. Training could also be arranged through guest worker and visiting scientist schemes which can be developed and promoted by the Centre.

VI. IMPLEMENTATION AND WORK PROGRAMME

Establishment of ICMET should be executed as a UNIDO project under a Trust Fund Agreement with the Government of the Republic of Korea to secure the international character without complicated procedures. To provide stability to the Centre there is a need for core funding over a period of years.

Taking into consideration the novel nature of the Centre and the complexities of arrangements for international collaboration, it is recommended that the task should be tackled in two phases.

(a) **Pilot Activity Phase**: It is proposed that this should start from 1995. Prior to this a Project Co-ordinator, as a national expert, should be appointed with the agreement of the Korean Authorities. A Technical Advisory Group of high level international experts should be formed to provide guidance in the detailed development of the Centre and the formulation of a work programme. It is envisaged that, in addition to the Co-ordinator and some local secretarial support, national and international experts will be appointed to undertake the activities of the pilot phase with UNIDO playing a supervisory role.

The Project Co-ordinator will have the following functions:

- to serve as the focal point for co-ordination of all activities in the country leading to the establishment of the Centre;
- to ensure the necessary co-ordination with relevant national institutions and international organizations;
- to develop a long-term plan in liaison with the Technical Advisory Group.

During the pilot phase, the following key activities and targets are proposed:

(i) **Form a Technical Advisory Group - end 1995**

It is proposed that the Advisory Group will contain 8-10 leading experts from the developing and developed countries.

(ii) **Hold two meetings of the Technical Advisory Group - Spring 1996, Spring 1997**

The Advisory Group will provide guidance for the establishment of ICMET, advise on the selection of work programmes and assist in formulating a long-term plan for the major second phase of the project.

(iii) **Establish a list of contact points and identify key institutions in the developing countries who will be actively involved in the work of ICMET - Jan. - March 1995**

Information about the area of interest and key capabilities of institutes should be obtained through a questionnaire if necessary. Surveys will also be done on materials usage in the developing countries in key sectors of industry and also their future requirements.

(iv) **Promote the concept and work of ICMET - continuous**

- o publish a newsletter - 2 per year
- o visits to developing countries
- o attendance at key regional/international conferences relevant to testing and evaluation of materials.

(v) **Design of appropriate data base facilities and networking activities in relation to the provision of the databases and information system - June 1995**

The Technical Advisory Group will appoint a consultant and two specialists who will design the information systems of ICMET including the selection of computer hardware, specification of software capabilities and database. Desirability and requirements of networking of existing databases in the field of testing and evaluation and global accessing should also be reviewed. This activity will be undertaken in close collaboration with institutions such as ASM International in order to minimize waste and duplication of efforts, ensure the complementarity, comprehensiveness of coverage, compatibility and standardization of data between the institutions from an early stage, and increase the efficiency and usefulness of the information services offered by ICMET during its operation.

(vi) **To organize 2-3 Workshops, on "Problems and Trends in New Materials Evaluation"**

Meetings held regionally are likely to be more successful in attracting wider participation and therefore at least one in Asia and another in Latin America are proposed. Three experts from developed and developing countries should be invited at each meeting to give authoritative papers critically reviewing the current status and future directions. Topics should be selected carefully and the aim should be to attract about 25 selected participants who can contribute to the discussion and help to identify areas for future work of ICMET. Some assistance towards travel costs will be needed to ensure adequate participation, whereas local costs may be met by the Government of the country.

(vii) **To organize two training courses on materials characterization and evaluation - Mid 1996, Mid 1997**

About 10-15 participants should be aimed for each course. Two experts from developing and developed countries should be invited with support from the Centre hosting the events.

(viii) **Formulate and launch at least three collaborative projects involving intercomparison and validation exercises - from Spring 1996**

This will be an important part of the pilot phase since it will demonstrate the basis on which future R&D programmes can be developed and supported. Success in this area will help to demonstrate the value of such an initiative to developing countries, and attract further support for the next phase.

(b) **Operational Phase (1998-2002)**: Based on the experience of the pilot activity phase, a fully fledged work-programme for the Centre will be put into operation. This is expected to cover all the important categories of materials and an extensive range of activities described earlier. The long-term structure and administrative arrangements for ICMET will be completed and it is expected that ICMET will require core funding over this period after which the Centre should be self-supporting. These proposals are based on current thinking and would be subject to revision during the pilot activity phase according to experience.

VII. FUNDING REQUIREMENTS

On the basis of the tentative work programme for the pilot activities phase as outlined above, a three-year budget is presented in Annex II. It is estimated at about US$674,750 and the first installment will be US$100,000.

In the nature of things, estimates of this type cannot be completely precise but the figures above represent the order of resources that are needed. The mission emphasizes that the figures mentioned in the budget represent the minimum requirement if the pilot activities should make an impact and lead to the establishment of the Centre on a regular basis.

Annex II
COST ESTIMATES

for the duration of three years

for the pilot activities phase of an
International Centre for Materials
Evaluation Technology (ICMET)

Operational Activities	**1994 Prices US Dollars**
Short-term consultants (fee, travel, DSA) (30 m/m)	270,000
Secretarial and technical support (18 m/m)	38[illegible]00
UNIDO staff mission (travel, DSA) (2-3 missions)	40,000
National Project Coordinator (18 m/m)	75,000
Group Training (20 m/m)	137,000
National consultants (5 man/month)	30,000
Non-expandable equipment	20,000
Sundries	17,124
Project Total	**597,124**
Project Total, incl. 13% Programme Support Cost	**674,750**

First Installment of US$100,000

Short-term consultants	**80,000**
UNIDO staff mission (travel + DSA)	**12,000**
Sundries	**8,000**
Project Total	**100,000**