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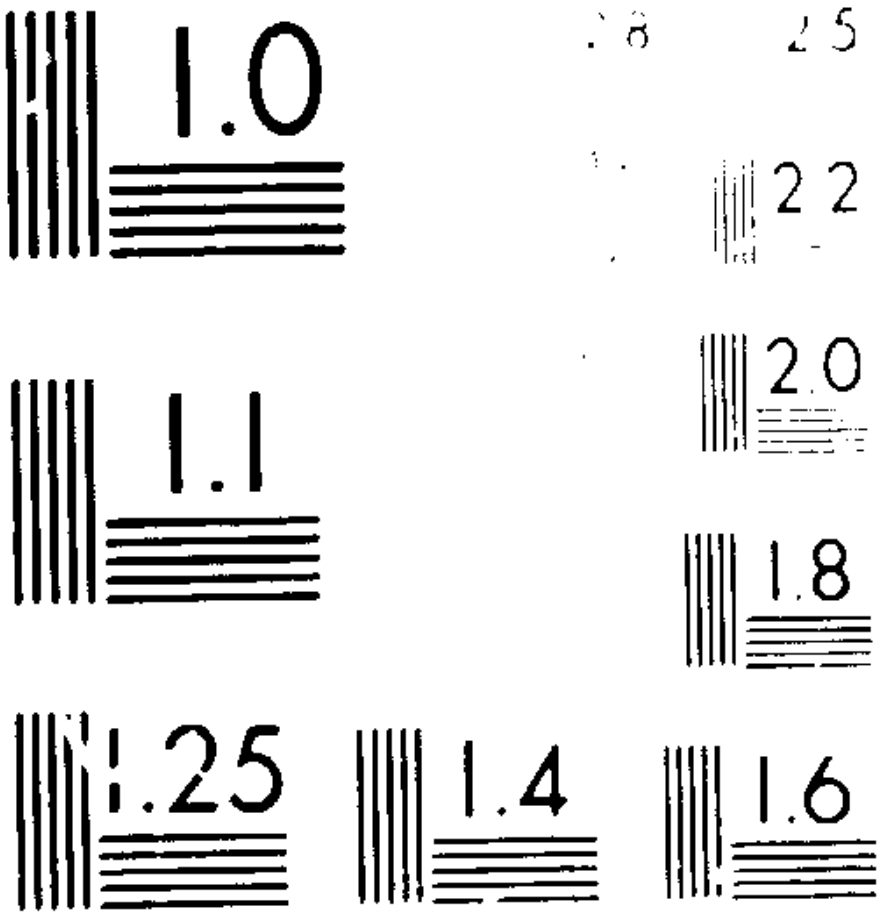
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Distr.
LIMITED

ID/WG.384/1/Rev.1
17 March 1983

ENGLISH

United Nations Industrial Development Organization

Expert Meeting Preparatory to International Forum
on Technological Advances and Development

Moscow, USSR, 29 November - 3 December 1982

IMPLICATIONS OF NEW MATERIALS AND TECHNOLOGY FOR DEVELOPING COUNTRIES*

prepared by

UNIDO Secretariat

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V.83-53553

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INTRODUCTION

1. Materials and materials technology play a key role in the industrial structure and economic development of all countries. There is a strong link between materials technology and the utilization, conservation and productivity of a country's natural resources on the one hand and the nature and pattern of its industrial production on the other.

2. In general,materials can be regarded as the inputs into an industrial process the output being products. There is a chain stretching from raw material extraction through processing and fabrication to production. Changes in materials or materials technology will have repercussions throughout the chain. It will affect the individual firms in the chain of manufacture and may cause changes in the industrial structure and the overall economic development.

3. Much of the current attention on materials stems from the concern about a possible shortage of materials. This aspect was highlighted by the Club of Rome's report "Limit to Growth". As a result many countries re-examined their materials policy especially in relation to the stockpiling of certain materials regarded for one reason or another as strategic. The spectre of an absolute shortage of materials may have receded but there is now greater awareness that non-renewable material resources must be utilized in an efficient manner. In addition, research and development on substitutes for certain key material has been encouraged.

4. The dramatic increase in the price of oil and the subsequent increase in energy costs that occurred during the late 1970s and early 1980s, has led to a reassessment of the energy/material balance. While energy prices were low relative to other factor costs, materials with a high energy input such as aluminium were able to compete successfully with traditional materials. With rising energy costs new materials and technologies with low energy inputs are at an advantage. Table I below shows the relative energy advantage of certain new materials.

5. The conservation of materials has also become an important feature of materials policy. Recycling has become an established practice for a number of materials in many countries. Another important method of materials conservation is the elimination of waste in the processing of materials at all stages of the manufacturing cycle. Like energy conservation materials conservation has benefited greatly from the increase in the price of materials.

Table I

The energy content of selected synthetic and conventional materials (a):

kg of oil equivalent (b)

	Synthetic	Conventional
Energy needed to produce:		
(i) one litre of		
aluminium		15
copper		11
steel		8
synthetics:		
nylon, acetate resins ..	4	
others (c)	1½-2	
(ii) some typical products: (d)		
fertiliser sacks (100)		
paper		39
LD-PE	35	
pressure pipe (100m, 25mm diameter)		
iron		500
copper		96
HD-PE	38	
drain pipe (100m, 100mm diameter)		
cast iron		1,970
clay		275
PVC	154	
one-litre bottles (100)		
glass		23
HD-PE	12	
PVC	8	

(a) The amount of oil equivalent includes energy used in the production of the items listed as well as the energy content of other raw materials.

(b) Rounded.

(c) Copolymers, polystyrene, high and low density polyethylene (HD-PE, LD-PE), polyvinylchloride (PVC) and polypropylene.

(d) Units in brackets.

Taken from G.F. RAY, "The contribution of science and technology to the supply of industrial materials", National Institute Economic Review, May 1980, No. 92, page 49.

I. CURRENT AND ANTICIPATED NEW MATERIALS AND TECHNOLOGY

6. Technological advances are taking place in virtually all groups of materials, such as metals, polymers, ceramics, composites. Improvements are occurring throughout the materials cycle from the extraction of the raw material to the production of the final product. It is possible, however, to categorise advances under two broad headings:

1. Development of new materials

2. Development of new processing techniques for existing or new materials.

7. A number of illustrative examples of advances for several materials are given below. But it is important to note that they are only examples and that it is not possible to provide exhaustive coverage in such a diverse and rapidly developing field.

8. In the metals sector the development of high strength low alloy steels is a case worthy of mention. These steels have been developed by a combination of improvements in the understanding of alloying elements, microstructures of the steel mechanical properties and production processes. 1/ The main advantages of these steels are that they provide superior combinations of strength, ductility, formability and weldability. As a result they have found a ready market in the car industry, ship building, bridges, prefabricated buildings and line pipes.

9. Powder metallurgy is not a new field but new advances are taking place offering savings in costs in certain applications because near net shapes can be obtained. One of the major advances in powder metallurgy is the rapid solidification technique. This has led to improvements in the mechanical properties of many alloys based on aluminium, nickel and steel.

1/ For more detailed information see "Some significant advances in Materials Technology" by Edward Epremian, ID/WG.384/10.

10. Shape memory alloys are being developed although these alloys are currently too expensive for widespread application. The basic feature of these alloys is that they "remember" or recover their shape with a change in temperature. The main features of current development work are: expansion of the transformation range (the temperature at which the original shape is restored); improvements in workability and castability; and reduction in cost.

11. In the field of ceramics a new class has emerged, referred to as fine ceramics. As the name implies a great deal of workmanship goes into fine ceramic materials compared to classic ceramics. The general goal of fine ceramic development is the creation of structural ceramic material to substitute for metal. The materials used for these formed ceramic products of special composition is widening all the time,it includes oxides such as alumina, magnesia, zirconia and lately carbide-silicide and nitride silicide have been used.

12. The development of fine ceramics has opened up a number of new areas of application where light, strong, hard and temperature resistant materials are needed. These new materials have already been used in the production of machine tools, in motor vehicle engines, gas turbines, the aerospace industry, and the electronics industry.

13. Polymer or plastic materials have already established themselves in a wide variety of uses. But a number of new developments are taking place in this field. Generally, these can be regarded as improvements in process technology to reduce costs, save energy and enhance the material performance of the product.

14. A significant new advance in polymers is the technique of mixing plastics with fillers. This process has three main advantages. Firstly, it reduces the amount of petrochemical feedstock needed. Secondly, it can lead to an improvement in the functional properties of the material. Thirdly, it utilises waste products which would otherwise be an environ-

mental problem. A number of substances, both inorganic and organic, can be used as fillers. For the production of inorganic fillers such as slag, perlite and quartz sand can be used unmilled and can provide up to 95 per cent of the feedstock required.[2/] Organic fillers have certain advantages over inorganic. They are usually lighter and therefore do not increase the weight of the material as much. Also they do not give rise to such a brittle product as polymers with inorganic fillers. These organic fillers can be agricultural wastes, or wastes from wood, rubber and plastics. Organic fillers have to be milled before mixing and new improved, lower cost techniques for milling have been developed. These new techniques have applications in many other fields including agricultural flour milling and the production of wood flour from wood waste.

15. Another major development in new materials has been in the field of fibre reinforced composites. Composite materials have a major advantage in that it is possible to select the "right" mix of a particular use. The number and type of fibre reinforced composites is continually growing. In many cases, this proven advantage over traditional materials has been clearly demonstrated. The cost of these new materials has however meant that their application has generally been limited to high value products such as aerospace.

16. Glass fibre reinforced plastic was one of the earliest fibre reinforced composites and has been in use for many years. It has been subject to continuous improvements and cost reduction. As a result, it is used extensively in a wide range of applications such as boat hulls, car bodies, appliances, storage tanks and sports equipment.

17. Aramid (aromatic polyamide) fibre reinforced composites are also in commercial production and are used in aircraft and marine applications. Similarly, boron fibres are used but they produce a material with a relatively narrow range of performance characteristics and are therefore limited to certain specific uses.

2/ "New Material, New Technology" by N.S. Enikolopov and S.A. Volfson, ID/WG.384/11.

18. A recent development has been the production of basalt fibres by drawing from a melt of rock raw material. These fibres are low cost and have a large raw material base. They are used for the reinforcement of concrete, in the production of line pipe and for insulation mats and sheets.

19. Carbon fibres which are produced by the pyrolysis of an organic fibre precursor can be obtained in many combinations of strength and modulus of elasticity by varying process conditions. This material has a much higher strength to weight and modulus to weight ratio than any conventional material. Again because of their relatively early state of development they are a high cost material and this has tended to limit their area of application. At the moment carbon fibres are used in aircraft, automobiles and sports equipment. It is anticipated however that their area of application will multiply over the next few years to include offshore drill pipes, centrifuges for uranium enrichment, television antennas, X-ray tables and robotics.

20. Another new fibre reinforced material which is at the development stage is short-metal fibre. This can be produced from virtually all metals, which are machinable such as carbon steel, stainless steel, copper (and its alloys), and aluminium (and its alloys). It is anticipated that one of the main areas of application for short-metal fibres will be as a shielding material to prevent electromagnetic interference. The problem of electromagnetic interference is likely to intensify with the increased development and use of electronic appliances. Therefore, there could be a large market for this new material for the casing of electronic devices. Composites containing metal fibres can dissipate heat very well and therefore can be used for brake-pads to replace asbestos.

21. The fibre for reinforcement of composites can be natural fibre. In fact, some natural fibres such as sisal and bamboo have already been used for reinforcement of structural materials. With the development of biotechnology and genetic engineering there is the possibility of producing natural fibres with specific properties as reinforcing materials.

II. MAJOR IMPLICATIONS FOR DEVELOPING COUNTRIES

22. The development and use of new materials and the introduction of new process technology for existing materials will have an impact on all countries. The magnitude of the impact will vary among countries depending on the level of production, utilisation and trade in materials.

23. Although many of the advances in new materials generally occur in the industrialised countries which have large research and development programmes in new materials and a ready market for application, the results of the advances will reach the developing countries through changes in the pattern of new material trade and changes in usage of materials in their economies. In addition, developing countries may develop their own new materials and uses, e.g. composites, suitable to their resource endowments. However, the diversity of conditions in developing countries and the endowment of raw materials will require different approaches to be evolved by each country. Such an approach has to be of a techno-economic nature since economics is an important factor in deciding the ultimate pattern of material substitution.

24. Materials and process technology are critical to the process of industrialisation. They largely determine the comparative economic advantage of countries in regard to particular industrial sectors. Once such an industrial structure is established in a country it is often difficult and costly to change. Therefore, before developing countries embark on a major industrial programme it is essential that the effects of possible new materials and process technology be considered.
This is especially true if the industrial development is geared to an export market. But even if the material is destined for the domestic market due account should be taken of technical advances in the field concerned. It is important to note that this is true not only for primary industries but also for the intermediate and final goods sector.

5. Owing to the diversity of materials and developing country conditions a selective approach needs to be adopted. Each country will have to identify specific materials and the criteria on the basis of which policy action should be taken.

26. In regard to criteria, the impact on export possibilities will be an important one, particularly for those countries whose exports or even whole economies are based on one or two materials. Thus developing countries which export raw materials may need to watch the technological trends rather closely in these fields. These trends may be a good indication of change in the export markets of the materials concerned.

27. Another criterion would relate to the impact on imports. Materials substitution possibilities could save imports or substitute import of one material for another. A few developing countries have already made some progress in import substitution through the use of local materials. Many institutions in developing countries also address this problem. Such substitution involves action on the part of producers which incorporate new materials and the acceptance of the product by the users. The optimum use of locally available materials is an area of action with a high pay-off for developing countries.

28. The substitution of local materials by other local materials should not be ignored, particularly from a social, as distinct from a private point of view. A considerable amount of such substitution is possible, particularly for example in construction and building, paper industry, soap, etc.

29. The energy implications of new materials is an important criterion. This is critical, particularly for developing countries which are major oil importers. Given the energy intensity of materials there would be great advantage in changing to materials or technologies which require less energy. It should be remembered that many of the traditional materials technology was developed when energy prices were low relative to other factors of production. This situation no longer exists and therefore there is a strong economic incentive to develop and use less energy intensive materials.

30. The local conditions governing the use of new materials should also be taken into account. In many cases a new type of material or process technology will require different skills, and repair and maintenance facilities, which may not be readily available in certain locations.

31. As regards materials to be selected there are a few which would appear to be especially important to developing countries, (either in terms of potential production or as potential competitors to existing materials).

32. The world iron and steel industry is undergoing major changes and some 65 developing countries are either involved or intend to be involved in the production of steel. The high strength low alloy steels are a new element of the steel market with high growth prospects. Therefore, developing countries producing these quality steels would find a developing market. These new steels are a higher value product than conventional carbon grades and therefore represent better use of the capital investment. This is an important advantage for developing countries which are at an early stage of entry into steel making. The improved quality of high strength low alloy steels could have significant impacts on the metal working industries in developing countries.

33. Powder metallurgy is another area which has relevance to developing countries. It is a highly flexible technology and in certain applications has a lower cost than conventional fusion metallurgy.

34. One such application which may be particularly relevant to developing countries is the rolling of metal powders to produce sheet. Another major advantage of this technology for developing countries with limited capital availability is the fact that the powder metallurgy industry can be introduced on an incremental basis.

35. The field of fine ceramics is high cost and still at the development stage. But it is worthy of close monitoring because of the rapid developments that are taking place and the potential of fine ceramics as a substitute for metals in many different applications.

36. Plastic materials are now well established as substitutes for a wide range of traditional materials such as timber and metal. The oil producing developing countries are planning large scale petrochemical plants with natural gas as a feed-tock. Development work is also under way which would allow the production of petrochemicals and plastics from coal and biomass.[3/] Were this development successful many if not all developing countries would have the possibility of producing plastics independently.

37. The use of fillers in plastic materials is of interest to developing countries because it reduces the cost of the material and also requires less petrochemical feedstock. Developing countries have a wide variety of possible fillers both organic and inorganic which could be used to advantage.

38. Another class of composite materials relevant to developing countries is the fibre reinforced composites. Many of these are specialsit high value materials such as carbon fibres. But a number of inexpensive fibre reinforcements and readily available such as basalt fibres, sisal fibres and bamboo provide a cheap but strong structural material for many applications in developing countries. Another advantage of composite material technology is that it can be fabricated by hand lay up and press moulding which are suitable for small and moderate size markets.

III. POLICY ACTION AT NATIONAL AND INTERNATIONAL LEVEL

39. The central role that materials play in industrial and economic development is such that all countries would benefit from the formulation and adoption of a comprehensive materials policy. The development of such a policy is however a very difficult task. In some developed countries attempts have been made to formulate national materials policies but these have only been partially successful. The position for developing countries is even more difficult for the following reasons: there are a large number of materials and composites in use; the substitution of materials is a techno-economic consideration carried out by different enterprises; different materials may be critical in different countries for import or export purposes; materials

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3/ For more detailed discussion see "Emerging Petrochemicals Technology: Implications for Developing Countries", by V.K.S. Arni, UNIDO/IS.350.

is a dynamic field.

40. Faced with this situation, perhaps the most appropriate course of action for developing countries is to adopt a selective approach to materials. This would mean each country concentrating on the materials and new developments which were most significant in their case. The major exporters of raw materials would be mainly concerned with the development of substitutes and a consequent reduction in demand for their products. Similarly, those countries who were major importers of materials may adopt policies to encourage the development of local materials or seek lower cost substitutes.

41. One area of direct policy action open to all developing countries relates to the specification and purchase of materials by the public sector. Many of the construction programmes being carried out in the developing countries are wholly or partially under the control of national or local government. This could provide an effective instrument for the introduction of at least some elements of a material policy.

42. Another area worthy of strong policy support by developing countries is composite materials. This class of materials maximises, through the use of modern technology, the value of low cost, locally available resources. Composites, in their many different forms, have a very wide range of applications in developing countries in virtually all economic sectors and will reduce the need for imported materials.

43. Many new materials are still in the early stages of development but it is already clear that some will have major impacts on the market for traditional materials. It is therefore essential that developing countries monitor and assess these new developments. This will require as a first step some form of materials information system. The next and most critical stage would be the evaluation and incorporation of this information in government policy making. To carry out such an exercise a multidisciplinary team would be required including material technologists, economists and information specialists. Finally, for the effective implementation of policies on new materials there will be a need for a wide understanding of the subject throughout all economic sectors, which will require specially designed awareness programmes.

44. Materials science is now a recognized discipline and developing countries should examine the need for strengthening their institutions in this field both at the national and the international level. The area of materials is so wide that each country will of necessity tend to be selective in carrying out research and development. Therefore co-operation between material science laboratories in both the developed and developing countries would give access to information on a wide range of new materials. In this connection research and development on new materials and technology should not be restricted to a narrow specialist field of study but should include a wide orientation including techno-economic considerations, and design and manufacturing aspects. This would allow the advances in materials science to be readily translated into new policies and products.

45. At the international level a mechanism could be established on new materials and technology. This need is perhaps greater in the field of materials than others because at the moment there is no international forum for the exchange of ideas on this subject between the scientists and technologists of different countries. One important aspect would be to monitor and disseminate information on new materials and technology. As a starting point UNIDO intends to bring out a quarterly bulletin "Materials and Related Technologies: State of the Art Series". Each issue will review the latest developments and research directions of a subject group of materials. Further action could be in the form of expert meetings on selected topics in the field of materials of particular relevance to developing countries. These meetings would bring together technologists, economists and policy makers from industrialised and developing countries to examine the subject and its implications in suitable detail for decision making and policy action. Guidelines could also be developed for establishing national information systems leading to the formulation of materials policies.