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ABSTRACT

The objectives of this study were to submit all the information necessary for making a decision on the establishment of a comprehensive materials data bank for West Germany. The problems investigated were: determination of the present state of the art, examination of a number of systems and other resources existing in the subject, site visits to similar centers in the U.S., determination of needs and requirements, evaluation of storage and retrieval requirements, development of an overall concept for the data bank, a cost analysis, and development of initiation and implementation plans. The study showed a demand for information on material and their properties that the basic requirements for a data bank can be satisfied. The advantages of the data bank are better and easier selection of material, better and a more complete survey of the materials supply, and better fundamentals for obtaining information on trends of development, for research and development planning and for standardization in the field of materials. (AE)

Results of a Feasibility Study for a National Materials Data Bank of the Federal Republic of Germany

Paper presented at the
Second International Codata Conference on Generation, Collection, Evaluation and Dissemination of Numerical Data for Science and Technology
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Ladies and Gentlemen,

It is a great honour for me to report before this audience on some results obtained in the «**Feasibility Study for a National Materials Data Bank of the Federal Republic of Germany**». This study, which was supported by the **German Federal Ministry for Education and Science,** was conducted by Battelle on behalf of the **Institute for Documentation,** Frankfurt/Main, and the Space Research Association, Bad Godesberg, and completed in May 1970. *The objective of this study was to submit to the competent authorities all the information necessary for taking a decision on the establishment of a comprehensive materials data bank (MDB).*

The study was carried out by a Battelle research group, which included staff members from the Materials Sciences, Electronics and Computer Sciences, and Economics Research Departments. In addition, scientists of all disciplines represented at Battelle were available for discussing special problems.

The research group worked in close *co-operation with an advisory committee* established by the Institute for Documentation *and with experts from research institutes, universities and industry.* Fig. 1 shows the problems investigated under the study.

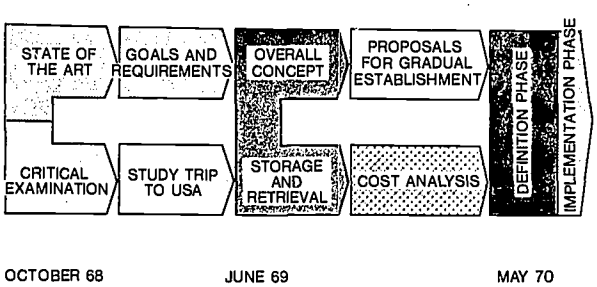

Fig. 1: Flow sheet of the study

1. **State of the art**

   Finding out the present state of the art with regard to existing materials data centres.

2. **Critical examination**

   of a number of systems and other resources already used in selecting materials and in solving materials problems.

3. **Study trip**

   to the USA in order to visit 23 important materials data and information centres.

4. **Goals and requirements**

   Finding out the needs for information and the functions of a materials data bank as expected by materials experts in industry and research.

5. **Storage and retrieval**

   Evaluation of storage and retrieval requirements.

6. **Overall concept for a materials data bank**

   Development of an overall concept for a comprehensive materials data bank.

7. **Cost analysis**

   Elaboration of a cost analysis.

8. **Gradual establishment of a materials data bank**

   Proposals for the gradual establishment of a comprehensive materials data bank.

9. **Definition phase**

10. **Implementation of a comprehensive materials data bank**

One of the *basic results* of the study is the *definition of the functions and the scope* of a comprehensive materials data bank. As shown in Fig. 2, its main functions are

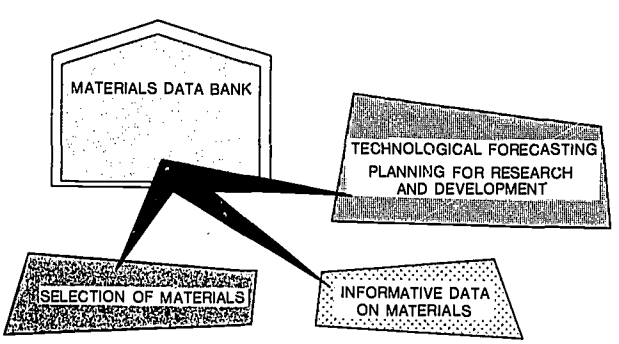

Fig. 2: Functions of a MDB

- selection of materials,
- providing of informative data on materials,
- information basis for technological forecasting and research and development planning.

These functions have been *formulated on the basis of the ascertained information needs of potential users in industry, research and Government agencies;* they are described in more detail as follows:

- Selection or preselection of materials on the basis of requirement profiles. These have to be derived by the user of the materials data bank by defining the requirements the object has to meet and by deriving the properties required of materials*.
- The materials data bank provides all necessary information on
  - characteristics of materials,
  - materials offered and suppliers,
  - experience in the application of materials,
  - literature references,
  - institutions and specialists experienced in different fields of application.

  This information should be objective, comprehensive, up to date, and available rapidly and at reasonable cost.
- In addition, the materials data bank will be used as an information basis for recognising trends of development, for technological forecasts, for research and development planning and for the establishment of standards and specifications.

Thus we know what we are talking about when speaking of a comprehensive materials data bank.

Before giving an account of the potential users' information interest profiles in some detail, I should like to report very briefly on some results of points 1 through 3 of the research programme.

As to the state of the art we know that *in West Germany a number of institutions exist* which are engaged in the *collection, documentation and dissemination of materials data and information* for different limited areas by various methods.

* Materials as used in this context refer primarily to structural materials. In addition, attempts will be made to consider also auxiliary materials, such as lubricants and adhesives.

These institutions supply their information upon request mainly free of charge. By well-organised *co-operation* of the existing information centres *with the materials data bank* to be established, the *efficiency* of the advisory services rendered by the centres *could be increased. Co-ordination* in the collection and storage of materials data and information by a materials data bank *would reduce multiple work,* for instance in literature screening, as is frequently observed today. *Most of the institutions* which have been contacted for establishing the present state of the art (for example: VDEh, DNA, BAM and others) *are in principle prepared to co-operate* with a materials data bank.

Critical examination of a number of systems and aids already used in selecting materials and in solving materials problems *showed that* in some respects *the development of a materials data bank can be based on systems that have proved adequate in limited areas.* These systems include, for example,

- **Zentrale Werkstoffkartei für Luft- und Raumfahrt** (central materials file for air and space flight)
- **Dechema Werkstofftabelle** (Korrosion) (Dechema materials table [corrosion])
- **Stahl-Eisen-Liste** (steel and iron list) and others.

The central materials file for air and space flight was developed in the 1960s by the firm Dornier System GmbH on behalf of the space research association. In this system data of about 1000 aircraft materials are stored, for each material up to 100 properties.

By means of a «computer programme», suitable materials can be selected on the basis of a requirement profile. Although the system has not yet been subjected to comprehensive practical trials for a sufficiently long period of time, it was possible to show that electronic selection of materials is feasible in principle. As one of the first steps in the establishment of a comprehensive materials data bank, the central materials file should be tested by a circle of industrial companies for an extended period of time. This would yield valuable experience and information for the establishment of the materials data bank.

During the study trip to the USA, *23 information centres were visited, which are* in one way or the other *concerned with the collection, documen-*

tation and dissemination of materials literature. In addition, *they handle individual requests for materials data and information.* The majority of these information centres is supported essentially by Government. Consequently, most of the centres supply the information free of charge. Only two of the information centres visited by the Battelle staff members are similar in structure and operation to the concept of a comprehensive materials data bank as proposed by Battelle. These are the **Mechanical Properties Data Center** (MPDC), Traverse City (Mich.) and the **Air Force Machinability Data Center** (AFMDC), Cincinnati (Ohio). They are operated by private research institutes and supported by the Air Force Materials Laboratory, Dayton (Ohio). To our knowledge, the MPDC is at present the only information centre in the field of materials in the USA which actually sells its information services.

The study trip to the USA has provided many valuable data and suggestions which will have to be considered in the development of a comprehensive materials data bank.

I shall now revert to the point **«goals and requirements»** and present to you several results of the identification of the potential user needs for information. These *results are based on interviews* which were held *with representatives of 74 industrial companies* in West Germany. Measured by their sales volume, these 74 enterprises represent about 30 percent of the total number of firms which may be regarded as potential users of the materials data bank.

The following figures show *summarised information interest profiles* with respect to materials, materials properties and related information.

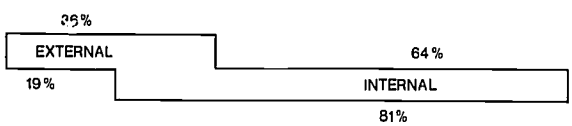

Fig. 3: Sources of materials data

As can be seen from Fig. 3,

- 19 percent of the companies interviewed use external sources of information,
- 17 percent use both external and internal sources, and
- 64 percent use mainly their own sources, in order to obtain the materials data and information necessary for taking decisions on materials. By use of «external sources» we understand only those cases where information on materials is actually obtained from external information centres (e.g. aluminium centre). The result shows that external sources are used only to a comparatively small extent.

The following diagrams indicate for each «item» the percentage of companies interviewed which expect information about this «item» from the materials data bank.

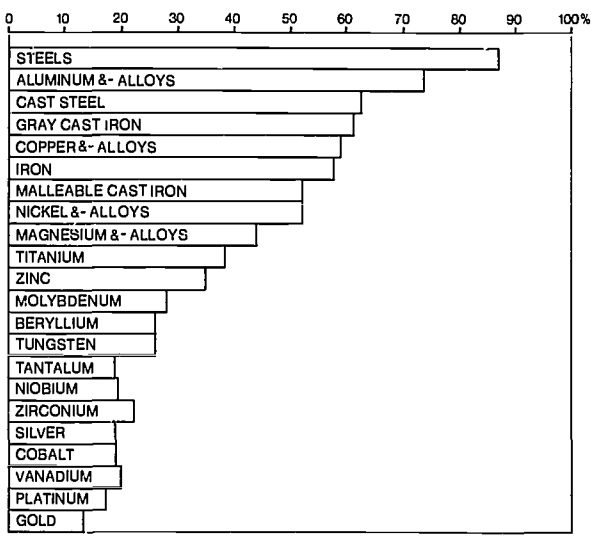

Fig. 4: Metallic materials

Fig. 4 shows the interest profile for metals. The main interest is directed to steel, followed by aluminium, copper, nickel and their alloys as well as to cast iron materials.

The level of interest expected for the other materials is below 50 percent. Some of the companies interviewed indicated in addition lead and its alloys, less frequently uranium, thorium and in one case sodium.

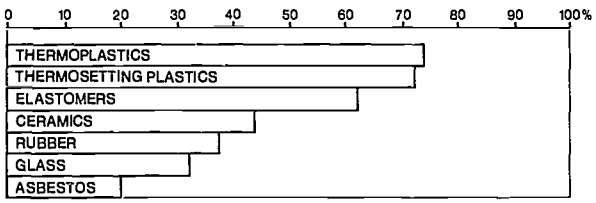

Fig. 5: Non-metallic materials

Fig. 5 refers to the nonmetallic materials. The inquiries for these materials will concern in particular the three types of plastics (thermosetting resins, thermoplastics and elastomers). The values expected for the «classical» nonmetallic materials, such as ceramics, rubber, glass and asbestos, are about 50 percent lower. In some cases data on wood, leather, felt, paper (for example, as sealing material) as well as on adhesives and other auxiliary materials (for example lubricants) were required in addition.

Fig. 6: Specific groups of materials

The groups of materials shown in Fig. 6 are of interest to 30 to 64 percent of the companies interviewed. As the designations of these groups of materials are of a very general nature, possible overlapping cannot be excluded.

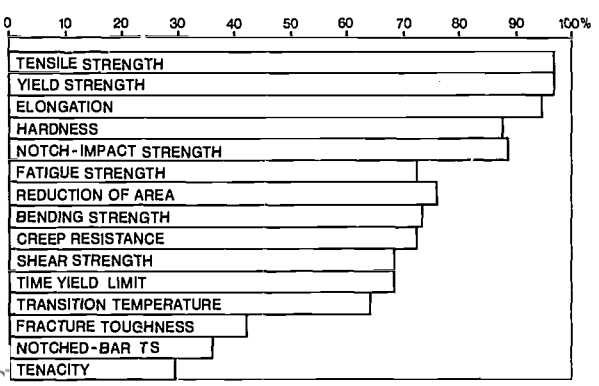

Fig. 7: Mechanicals properties

Fig. 7 shows that 65 to 100 percent of the companies interviewed require almost all the technical materials data and 30 to 45 percent are also interested in data on fracture toughness, notched-bar tensile strength and tenacity.

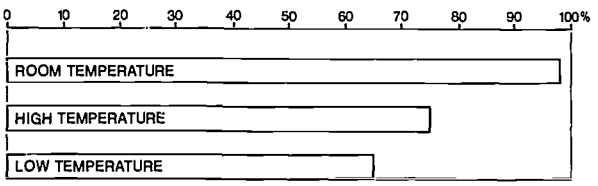

Fig. 8: Interest for data in different ranges of temperature

Fig. 8 shows the interest of the firms interviewed in data for the different temperature ranges:

- 64 percent require data on all three temperature ranges
- 12 percent require only the data for the high-temperature and room-temperature ranges
- 21.5 percent require only the data applicable to room temperature

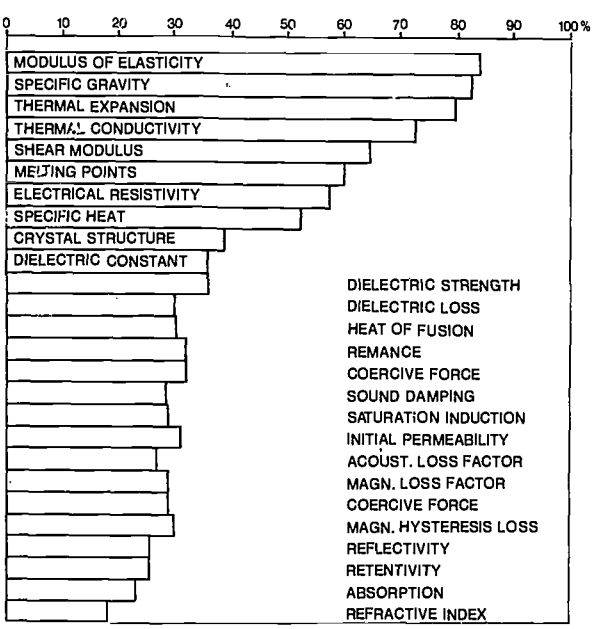

Fig. 9: Physical properties

The interest in physical data is more differentiated than that in technical materials data; as can be seen from Fig. 9, only a small percentage of the firms interviewed needs data in the fields of magnetism, optics and acoustics.

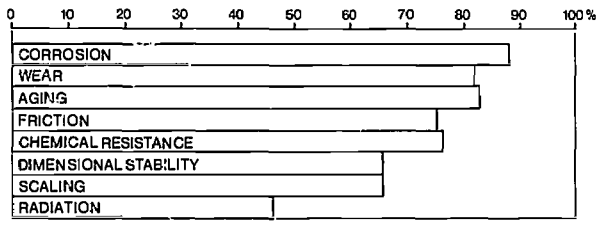

Fig. 10: Behavior of materials under complex conditions

The by far highest level of expectation have data on the behaviour of materials under complex conditions. Half of the data shown in Fig. 10 is considered very important by 70 to 90 percent of the interviewed firms. With the exception of the behaviour under irradiation, all data indicated in this figure are considered necessary by at least 65 percent of the interviewed firms. The situation is similar for the group of technological properties shown in Fig. 11. In combination with the *great interest in information on experience in the use of materials, these two findings may be regarded as the most important partial results of the survey.*

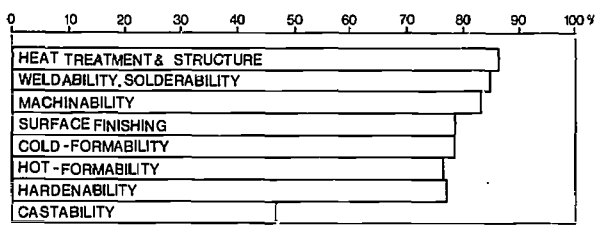

Fig. 11: Technological data

According to Fig. 12, the expectations concerning information on terms of delivery and trade names are also very high.

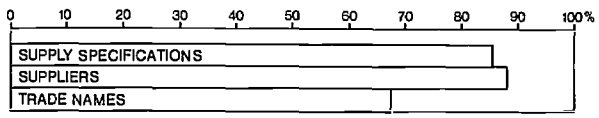

Fig. 12: Supply data

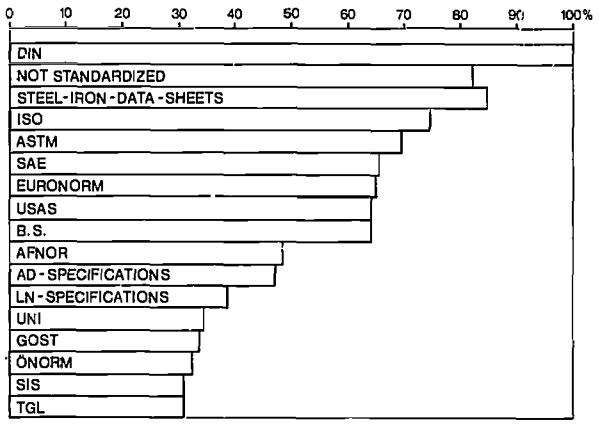

Fig. 13: Materials identification data

From Fig. 13 we note that 80 to 90 percent of the firms interviewed recommend considering also materials which are not standardised; also a *high percentage of the firms* interviewed *desires information on foreign materials designations in addition to the material designations according to DIN.*

These results of the survey can of course be regarded only as approximate findings. The complete spectrum of materials, materials data and information which have to be considered by a comprehensive materials data bank *should be determined pragmatically* during its development. This means that an optimal ratio of effort to profit must be achieved with regard to scope and quantity of data. This ratio can only be found on the basis of practical experience gained during the establishment of the materials data bank. Simply for this reason, a sufficiently flexible and adaptable concept of storage and retrieval programmes will be necessary.

To be able to *meet this information interest profile, the materials data bank must be given a suitable storage capacity.* We have made some estimates of the storage requirement, which are represented in Fig. 14.

Terms	Number of Term Values	Number of Materials	Storage Requirement in Words
Material identifications and trade names	30	5500	165000
Composition	40	2500	100000
Structure (Plastics)	20	3000	60000
Fabrication	50	5500	275000
Mechanical properties	200	5500	1100000
Physical properties	200	5500	1100000
Technological properties:			
Cold-formability	720	2750	1980000
Hot-formability	20	3700	74000
Hardenability	20	1000	20000
Heat treatment & structure	240	2500	600000
Castability	80	3700	296000
Joining methods (welding, etc)	(100)	(3700)	(370000)
Machinability	(3000)	(2750)	(8525000)
Surface finishing	60	3700	222000
Behavior under complex conditions:			
Scaling	300	2000	600000
Aging	100	3700	370000
Dimensional stability	5	3700	18500
Radiation	(300)	(3700)	(1110000)
Corrosion	(50000)	(3000)	(150000000)
Wear	(100000)	(2500)	(250000000)
Supply data	360	5500	1980000
Sources of reference	200	5500	1100000
Application data	.	5500	4000000
Total:	2645 (15340C)		14060500 (400005000)

Fig. 14: Estimated values for storage requirement

Notes:

The terms necessary for parameter indication and internal coding (for example, temperature or accession number of the source document) and for combinations have been included.
Data on a number of terms or categories need not be indicated for all materials; therefore, the number of materials for which the individual data are required have been estimated.
For one «word» eight alphameric characters have been assumed.
For some categories the estimates are very unreliable; therefore, the numerical values have been put in parentheses.

The large number of terms for machinability, corrosion and wear is due to the fact that two or more parameters have to be assigned to each individual term.

Fortunately, exact knowledge of the storage requirement is not of decisive importance for the following reasons:

- Because of the requirement of random access, the only suitable active storage elements are magnetic discs or magnetic cards with a great storage capacity (40 to 350 million characters).
- The capacity of the external storage devices can be pragmatically adapted without major difficulties to the demand determined by experience.

In our opinion, a storage capacity of 15 million words is sufficient for the establishing phase of the materials data bank; this estimate does, however, not include the storage requirement for the categories of complex terms. Solutions for these categories remain to be found; thus the materials data bank should handle only the most important data in a very concise form, while specific inquiries should be referred to other institutions.

The storage organisation must be flexible so that it is possible to adapt it at any time to changed requirements. The *requirements* for the storage organisation *result* mainly *from* the *two basic types of inquiries* to be handled:

- The question for information on specific data for given materials
- The question for materials which fulfill given values of specific data

Of course, it must also be possible to handle combinations of these two types of inquiries.

While the first type of inquiry requires an organisation of storage by identifying material designations (designation by standard, material number, trade name), the second type of inquiry calls for an arrangement of the data to be stored by values or by value intervals of specific properties (for example, tensile strength, yield point, specific gravity). For each of these terms only a number identifying the material needs to be stored. This means that the data and information have to be stored in a master file and in an inverted file. The scope of the terms to be considered in the inverted

file and the depth of value differentiation will largely depend on the types of potential inquiries. Therefore, the inquiries received must be statistically recorded and evaluated, in order to be able to adapt the storage organisation to changed requirements.

Now I should like to make some *remarks on the number of inquiries to be expected from the industry*. This has been *an important point* in the interviews with experts of industry.

Concerning the question for the frequency of inquiries, *three categories have been distinguished* with respect to their scope:

- Inquiries for specific data
- Inquiries for all data available for a specific material
- Inquiries for surveys, tables, etc. on specific groups of materials and materials data

It is obvious that the results of the interviews with regard to the expected number of inquiries have to be viewed critically, because they relate to future potential information services whose quality and scope has not yet been clearly defined.

Nevertheless, the results furnish some important information. Thus, it was found that the major part of the inquiries, i.e. about 75 *percent*, are *inquiries for specific data*, while the remaining 25 percent relate to inquiries for all data available for a specific material and to inquiries for surveys, tables, etc. on specific groups of materials and property data.

The total number of inquiries per year was calculated on the basis of the share of the interviewed firms in the total sales volume of the sector of industry concerned (extrapolation factor); the results were as follows (it should be mentioned that these results are due to the structure and technological and economic conditions of German industry):

The *largest number of inquiries* is to be expected *from* the sectors of industry belonging to the **capital goods industries:** in this group mechanical engineering ranges first with 12,200 inquires per year. The iron, sheet and metal products industry and the electrical industry follow with 8,900 and 6,000 inquiries per year, respectively. The demand expected from the other sectors of industry (steel construction, motor vehicle construction, aircraft construction) is by several orders of magnitude lower; it ranges between 250 and 500 inquiries per year. These figures are due to the relatively small number of firms concerned in these sectors of German industry. The *total number of inquiries from* the firms of *the capital goods sector may be expected to be about 28,000 inquiries per year.*

The *demand from the primary transformation industries,* which *is expected to total about 2,800 inquiries per year, is only about 10 percent of the demand from the capital goods industry*. The major part, about 2,200 inquires per year, falls to the metal industry, the number of inquires expected from each the chemical industry and the non-metallic minerals industry will be as low as 300 per year.

All in all *the number of inquiries expected* from the industry *is about 30,000 per year.* It is to be assumed, however, that *the materials data bank will be used not only by the industry, but also by others including*

- Government authorities and research centres,
- research laboratories,
- technical, scientific and economic associations, and
- public institutions.

The number of inquiries to be expected from these sectors has not been determined under this project. *Informative talks* with representatives of such institutions, however, *clearly showed that they would also be highly interested in a materials data bank;* this interest is directed mainly towards its utilisation as a comprehensive source of *information for technological forecasting and research and development planning.*

Therefore, *it appears reasonable to expect a total of about 30,000 inquiries per year for the phase of full operation of the materials data bank.* If we assume that an amount between DM 100.00 and DM 150.00 will be paid for answering one inquiry, the annual receipts of the materials data bank may be expected to range between DM 3 and 4.5 million.

It is obvious that this frequency of inquiries can only be achieved if the quality of the information

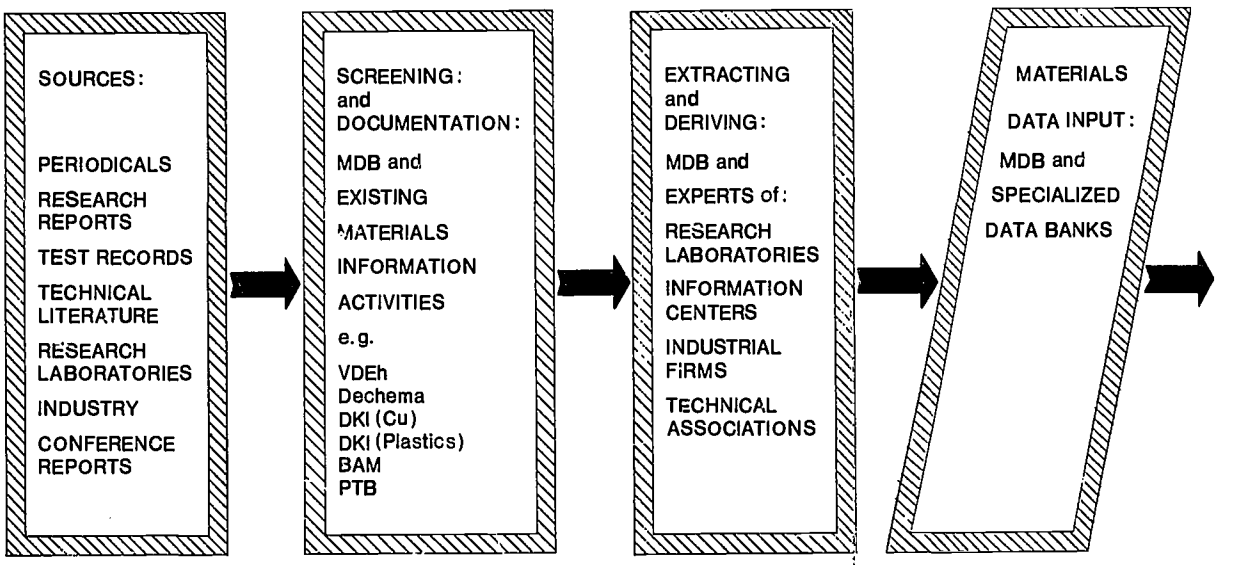

Fig. 15: Materials data and information flow; input

services offered by the materials data bank *meet the expectations and requirements of the potential users.*

The next figures show the problems to be handled by the materials data bank and proposals for their solution under the input/output aspect.

The sources for the materials data and information input are:

- Periodicals
- Research reports
- Test records
- Technical literature (handbooks, etc.)
- Research laboratories
- Industrial firms
- Conference reports, and others

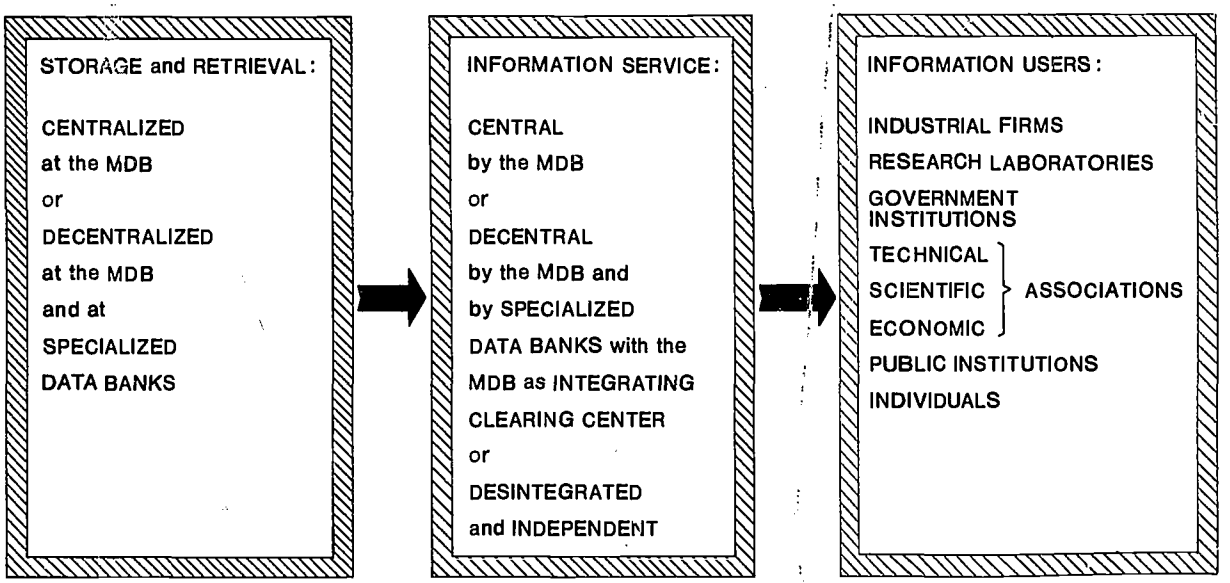

Fig. 16: Materials data and information flow; output

Screening and documentation of these sources should be done by the materials data bank in *collaboration with* existing materials information activities, for example

VDEh - Association of German Steelmakers,
Dechema - German Association for Chemicals Engineering,
DKI - German Copper Institute,
DKI - German Plastics Institute,
BAM - Federal Institute for Materials Testing,
PTB - Physikalisch-Technische Bundesanstalt,
and many others.

The staff members of the materials data bank and experts of research laboratories, information centres, industrial firms and technical associations could in well coordinated co-operation extract and derive the data from the screened and documented sources. This means that 15 to 25 staff members of the materials data bank and 100 to 200 external experts would contribute to the extracting and deriving of data. The data input could be effected by the materials data bank and by specialised data banks.

The data could be stored and retrieved centralised at the materials data bank or decentralised at the materials data bank and at specialised data banks.

The inquiries by the users can also be handled either centralised by the materials data bank or decentralised by specialised data banks with the materials data bank acting as integrating clearing centre, or disintegrated and independent.

The ascertainment of information needs showed a great demand for information on experience in the application of materials, on the behaviour of materials under complex conditions (e.g. corrosion, wear, machinability) and on the working and processing of materials.

This information is difficult to provide by numerical data but rather requires textual descriptions. *Valuable textual information*, however, can be obtained *only by the joint effort of qualified experts.*

For these reasons and with a view to cost effectiveness *it appears reasonable to establish an integrated materials data bank network* instead of a *central materials data bank.* An integrated materials data bank network could be operated, with regard to its data input, in the manner shown in Fig. 17.

Screening, documentation and evaluation of technological and scientific literature (periodicals, reports, etc.) are already carried out by a number of institutions (e.g. Dechema, VDEh, Infos, BAM, DNA, VDMA, GfKF) for various fields of activity. It would be no difficulty for these institutions to make their information output available to the integrated data bank network.

A number of these institutions could also derive the required materials data and information and prepare them for electronic data processing.

Some of these institutions have conducted valuable preliminary investigations for establishing specialised data banks or are engaged in development work in this direction. Thus, the conditions for the establishment of an integrated materials data bank network are fairly well satisfied.

I now *invert this diagram* with respect to the data output in order *to illustrate the comprehensive and integrating character* of the integrated data bank network.

The sources of materials data and information are now in the centre, which is surrounded by four rings:

1. Screening and documentation of literature.
2. Evaluating and deriving of materials data and information.
3. Storage of these data in the specialised data banks.
4. Integrating ring of the data bank network which ensures that the activities of the specialised data banks are automatically registered by the integrated data bank network. On the other hand, it will be possible for the specialised data banks to establish a direct contact with their users.

The basis of all these functions *and a prerequisite* of smooth co-*operation* of all participants in this data bank network *will be the MDB thesaurus* which has to be developed. *Its elaboration* and continuous improvement *will be one of the most important tasks* in the establishment and operation of a materials data bank which co-operates as the integrating centre with a number of specialised

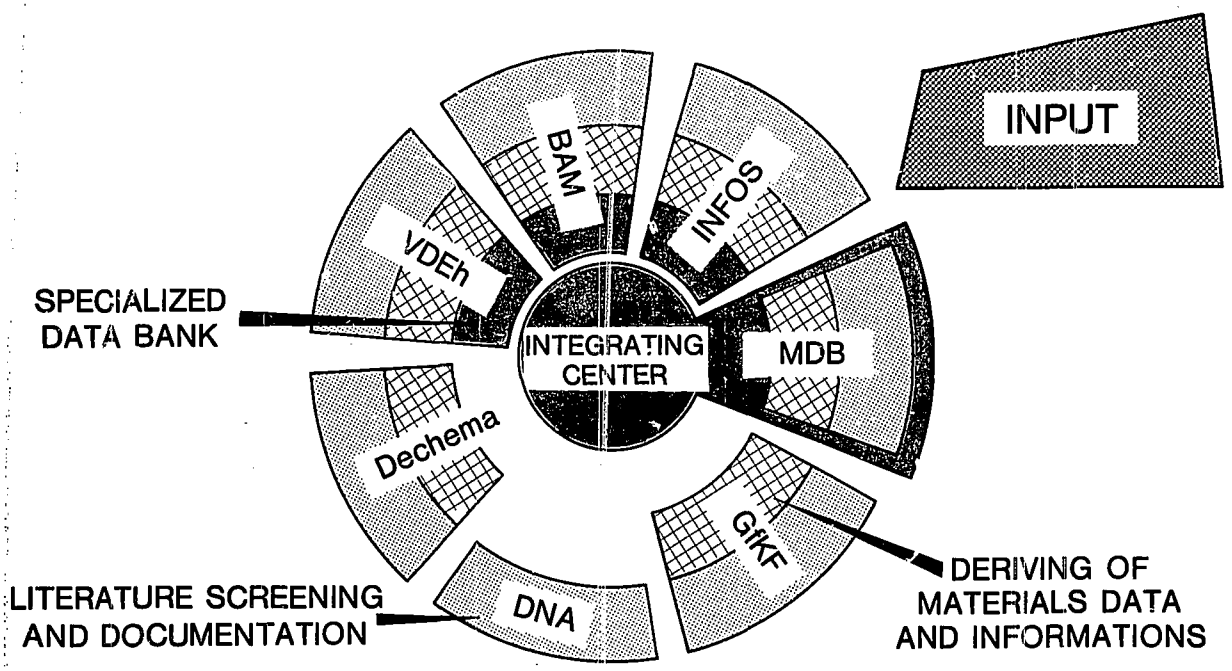

Fig. 17: Integrated materials data bank network

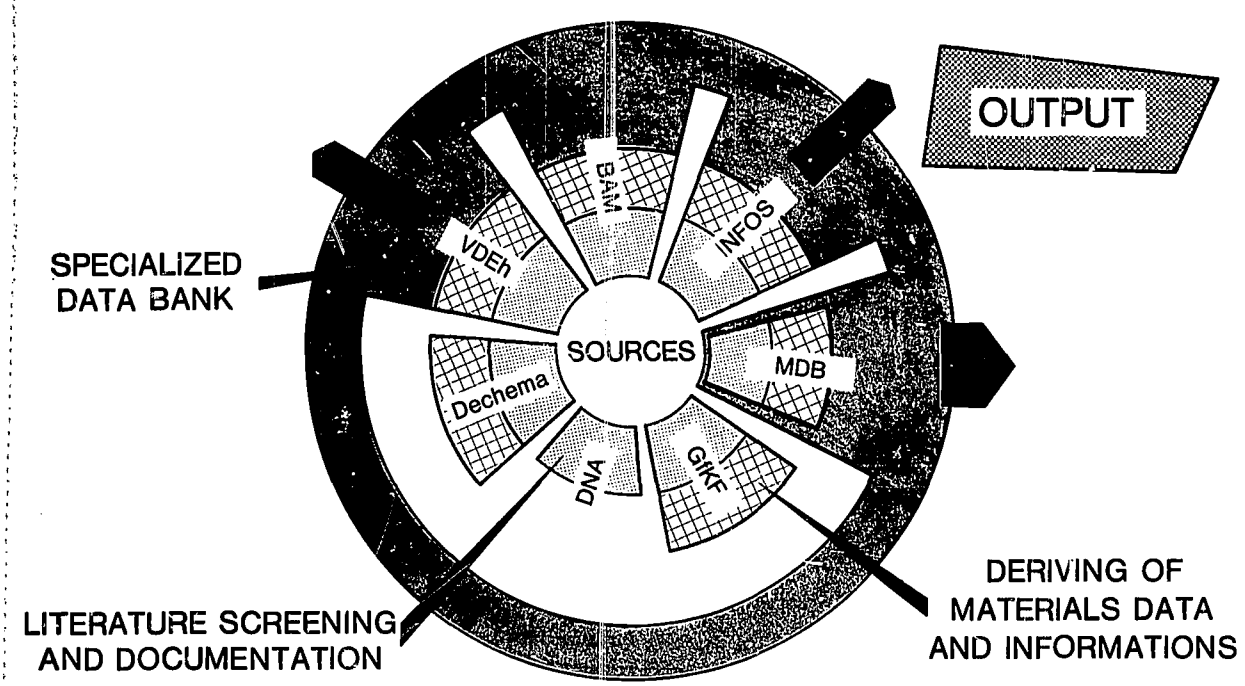

Fig. 18: Integrated materials data bank network

data banks. This thesaurus will have to include the following terms:

- Material designations
- Definitions of materials data
- Definitions for the behaviour of materials
- Definitions for the working and processing of materials
- Definitions concerning the material supply

The thesaurus will form an open system of interconnected definitions, which are used for describing facts in materials science, technology and economy. It goes without saying that the thesaurus should be based mainly on the terms defined by the DIN standards and similar specifications and on the designations fixed in these standards. The utilisation of internationally accept thesauri like the **Thesaurus of Engineering and Scientific Terms** should also be considered.

The operation of the described comprehensive materials data bank has been estimated to involve an expenditure of DM 5 to 7 million per year. Of this amount, about 37 percent is attributed to rent for the computer and the storage devices, about 48 percent falls to staff expenses for 30 to 50 staff members of the materials data bank and 100 to 200 external experts, while the balance of 15 percent will be required for rental of rooms, the procurement of documentations, for publicity and miscellaneous activities. If we compare these figures with the potential receipts of the materials data bank which are expected to amount to DM 3 to 4.5 million per year, we see that a *materials data bank will probably require substantial subsidies even in the phase of full operation.*

The establishment of a comprehensive materials data bank in the form of *an integrated data bank network is a complex long-term project.* The different phases of its implementation are depicted in Fig. 19.

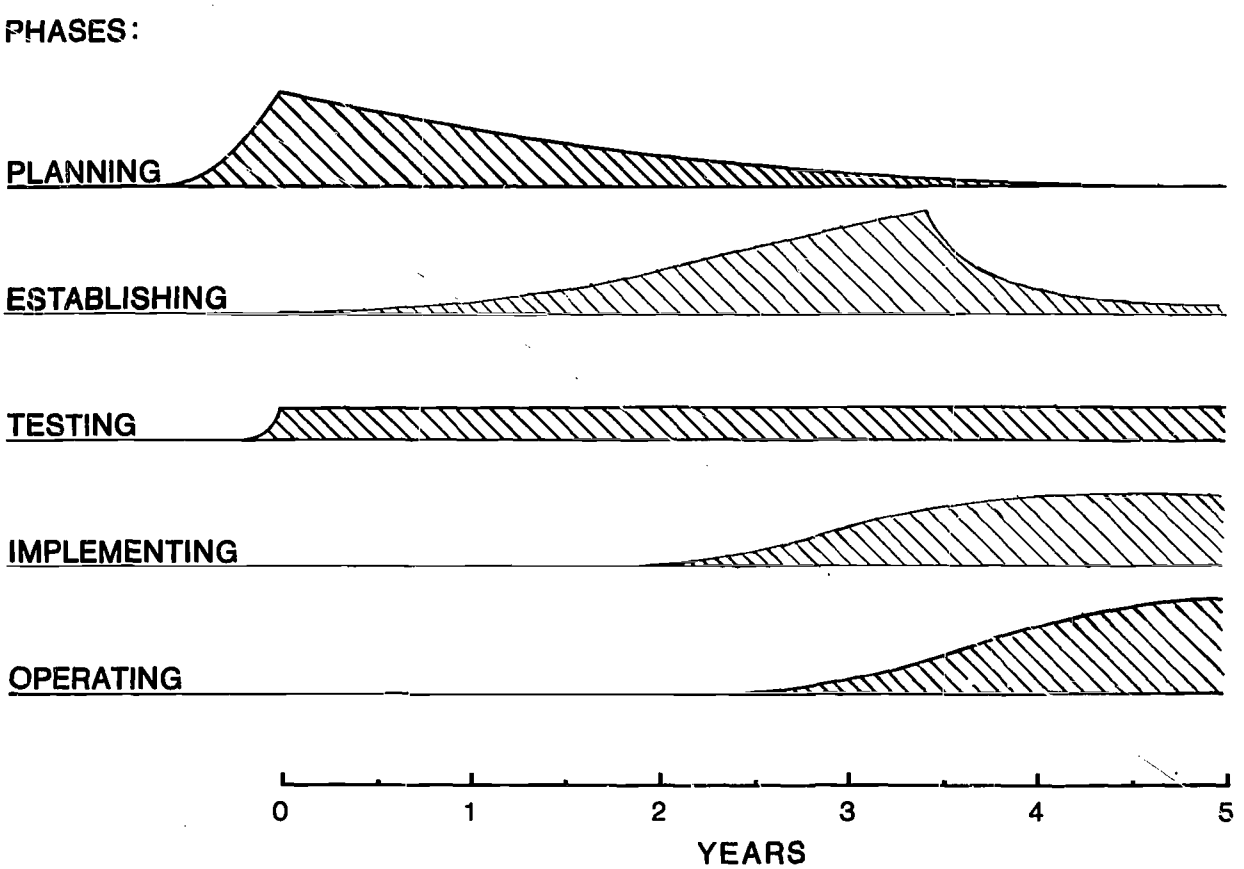

Fig. 19: Proposals for gradual establishment

The coloured areas are to show qualitatively the assignment of time and effort to the individual phases.

On the whole the *planning phase* should be completed after *1.5 to 2 years. After one year the establishing phase* of the materials data bank *can be started,* for example, with the collection of the first data. *After 3.5 to 4 years the establishment should be completed. Trials* could be carried out *from the start with the central file for aerospace materials* mentioned before. Trials using new methods of information technique and the information capacity of the materials data bank should be continued over an extended period of time or even permanently. *After 2.5 to 3 years the implementing phase* should be started, for example, with trial operations for the users free of charge. The *phase of full operation* of the comprehensive materials data bank *could finally be reached after* four or five years.

The successful realisation of the materials data bank in these five phases will *require an efficient organisational basis and adequate support of the project by stimulating ideas and financial means.*

National and international co-operation *will have to be particularly activated from the beginning.*

Let me finally summarise the results of the study:

The study has shown that in industry and research there is a great demand for information on materials and their properties. The establishment of a materials data bank meets with general approval. The basic requirements for its establishment are or can be satisfied.

The usefulness of a materials data bank for the scientific and industrial community is beyond question. It will offer the following advantages:

- **Better and easier selection of materials**
- **Better and more complete survey of the materials supply**
- **Better fundamentals for obtaining information on trends of development, for research and development planning and for standardization in the field of materials**

Let us hope that the materials data bank can be used by the scientific and industrial community within five or six years.

Thank you.