ORGANISATION FOR ECONOMIC COOPERATION & DEVELOPMENT
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DIRECTORATE FOR SCIENTIFIC AFFAIRS

# THE MEASUREMENT OF SCIENTIFIC AND TECHNICAL ACTIVITIES

## Proposed Standard Practice for Surveys of Research and Experimental Development

"Frascati Manual"

ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

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DIRECTORATE FOR SCIENTIFIC AFFAIRS

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## BACKGROUND OF THE MANUAL

### Brief History and Origins of the Present Manual

1. Encouraged by the rapid growth of the amount of national resources devoted to research and experimental development (R and D), most O.E.C.D. Member countries started the collection of statistical data in this field around 1960. They followed the pioneering efforts of a small number of countries, including the United States, Japan, Canada, the United Kingdom, the Netherlands and France. Differences in scope, methods and concepts, however, made international comparisons difficult and countries encountered theoretical difficulties when starting R and D surveys. An increasing need was thus felt for some attempt at standardization of the kind undertaken for economic statistics.

2. O.E.C.D. interest in this question dates back to O.E.E.C. days. In 1957, the Committee for Applied Research of the European Productivity Agency of the O.E.E.C. began to convene meetings of experts from Member countries to discuss the methodological problems. As an outcome of these meetings an 'Ad Hoc' Group of Experts was set up, under the auspices of the Committee for Applied Research, to study surveys of research and experimental development expenditure. The Technical Secretary of this Group, Dr. J. C. Gerritsen, prepared two detailed studies on the definitions and methods employed in the measurement of R and D in the Government sectors of the United Kingdom and France and later of the United States and Canada. Other members of the Group circulated papers describing the methods and results of surveys in their own countries.

3. When the Directorate for Scientific Affairs took over the work of the European Productivity Agency in 1961, the time was ripe for specific proposals for standardization. At a meeting in February, 1962, the 'Ad Hoc' Group (see paragraph 2) decided to convene a study conference on the technical problems of measuring R and D. In preparation for this Conference, the Directorate for Scientific Affairs appointed a consultant, Mr. C. Freeman, to prepare a draft document which was circulated to Member countries in the Autumn of 1962 and revised in the light of their comments. The Proposed Standard Practice for Surveys of Research and Development was discussed, revised and accepted by experts from the O.E.C.D. Member countries at the conference which was held in Frascati, Italy, in June, 1963.

4. Later in 1963 the O.E.C.D. Directorate for Scientific Affairs invited the United Kingdom National Institute for Economic and Social Research to undertake an experimental comparison of research efforts in five Western European countries (Belgium, France, Germany, the Netherlands and the United Kingdom), the United States and the U.S.S.R. The

Institute study, though based on statistics from surveys undertaken before the international standards had been decided on, also tested the first draft definitions(1). The report concluded that the available statistical information still left a great deal to be desired; the main improvements suggested were:

(a) A more rigorous conceptual separation of research and experimental development and 'related scientific activities'.

(b) Careful surveys in the Higher Education Sector to estimate the proportion of time devoted to research by teaching staff and by (post-) graduate students.

(c) A more detailed breakdown of R and D manpower and expenditure data to permit, inter alia, a more exact calculation of research exchange rates.

(d) A more systematic measurement of expenditure flows between R and D sectors.

(e) More data on the flow of technological payments and of international migration of scientific manpower.

5. In 1964, following the acceptance of the Frascati Manual by the Member countries, O.E.C.D. launched the International Statistical Year (ISY) on Research and Experimental Development. Member countries returned data for the year 1963 or 1964. Seventeen countries took part, many of them conducting special surveys and enquiries for the first time(2).

6. Following the publication of the Statistical Year findings, the O.E.C.D. Committee for Science Policy requested the Secretariat to prepare a revision of the Frascati Manual in the light of the experience gained. An outline of the suggestions was circulated to Member countries in March, 1968. A draft revision, incorporating most of these suggestions, was examined at the meeting of national experts held in Frascati in December, 1968. A revised draft was examined by the meeting of a small group of experts in July, 1969.

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(1) C.Freeman/A. Young "The R and D Effort in Western Europe, North America and the Soviet Union". An experimental international comparison of research expenditure and manpower in 1962, O.E.C.D. 1965.

(2) International Statistical Year for Research and Experimental Development - A study of resources devoted to R and D in O.E.C.D. Member countries in 1963-64. Vol.I. The Overall Level and Structure of R and D efforts in O.E.C.D. Member Countries (1967). Vol. II. Statistical Tables and Notes (1968).

Efforts of Other International Organisations

7. The problems of comparing R and D data, collected in different countries, with varying institutional patterns and traditions in education and research, have been considered by other international organisations as well as by the O.E.C.D. Both the Council for Mutual Economic Assistance (C.M.E.A.) in Eastern Europe and UNESCO have made efforts to improve comparability of R and D data. Special attention was paid to the development of the UNESCO Science Statistics Programme at the thirteenth session of the General Conference (1964) and a Division of Science Statistics was established in 1965. 1967 was the first year covered by a UNESCO survey on R and D in Europe. The definitions used by UNESCO were largely based on the first Frascati Manual. With this survey a first attempt was made to establish standards for data which permit some comparison between R and D activities in C.M.E.A. and O.E.C.D. countries.

Acknowledgements

8. Neither the original version of this manual nor this revised edition could have been completed without the active collaboration of R and D statisticians in all O.E.C.D. Member countries. Particular debts of gratitude are due to the National Science Foundation which pioneered the systematic measurement of R and D, and especially to the late Dr. J. Perlman; to Mr. C. Freeman, author of the draft of the first edition, to the French Délégation Générale à la Recherche Scientifique et Technique, which devoted a great deal of time to the improvement of the first manual; to Mr. H. Stead of the Canadian Dominion Bureau of Statistics, and Mr. P. Slors of the Netherlands Central Bureau of Statistics who assisted at various stages in the preparation of the present edition of the manual, and to Dr. D. Murphy of the Irish National Science Council who prepared the index to this manual.

# CHAPTER I

## The Relevance of R and D Statistics and the Aims and Scope of the Manual

### I.1 The relevance of statistics of research and experimental development

9. R and D statistics are relevant to many aspects of national life. They are important and useful when they cover a large enough range of activities (by country) to make it possible over a period of time to use them in conjunction with other statistics in assessing the benefits of R and D. While they are of greatest use to the science policy makers as a measure of a country's R and D efforts and as an indication of its science potential, they are also, at the same time, of great relevance to its general policy and particularly to its educational and economic policy. They may also, of course, be of interest to individual economists, scientists and to the private citizen.

### I.2 The aim of the Manual

10. This Manual is intended to serve four purposes:

(a) to advise and aid countries in compiling and analysing statistics of R and D;

(b) to stimulate countries which have begun work in this field to continue systematically and on an increased scale to develop the internal analysis of their national science effort;

(c) to act as a framework for international comparisons and for comparisons with other economic data. National practices will, of course, continue to vary but the variations may be further reduced and at least become measurable in terms of international standards;

(d) to provide the definitions from which deviations for special purposes can be explicitly made.

11. The Manual is designed to be useful both at national and at international level and every attempt has been made to reach definitions that are relevant and acceptable to a large number of countries. It is recognised, however, that R and D activities are so varied, dynamic and therefore difficult to define, that definitive standards can never be reached. In surveying resource inputs an element of arbitrariness will necessarily be involved in the decisions on how to classify institutes or activities. The purpose of the Manual is to minimize the arbitrary character of such decisions by making the accepted criteria as clear as possible.

## 1.3 Scope and limitations of the Manual

12. The manual deals, at present, exclusively with resources devoted to research and experimental development in the natural sciences, engineering and technology as well as in the medical and agricultural sciences, but it may also be of use in measuring R and D resources in the fields of systems sciences, policy sciences, ecological sciences and so on. The Manual discusses to some extent, but does not include standards for the measurement of:

(a) other scientific activities related to R and D(1);

(b) research in the social sciences and humanities;

(c) the output of R and D.

However, the Manual is set up in such a way that many guidelines can also be used for the measurement of R and D in the social sciences and humanities, the measurement of which may be of great importance.

13. The structure of the Manual itself is as follows:

(a) Sections II and III form the theoretical basis for measuring resources devoted to R and D and comprise definitions, conventions and the main sectoral and functional classifications which, taken together, delimit the R and D area of the economy.

(b) Sections IV and V contain more detailed classifications within the R and D area and recommendations concerning actual measures of R and D and methods of measuring.

(c) The last section (VI) draws attention to some problems of relating R and D data to other economic variables and of making international comparisons of R and D expenditure.

There are also four appendices:

I. Some comments on the 'Measurement of the Output of R and D and the Balance of Technological Payments'.

II. Pioneering efforts in calculating research exchange rates.

III. The classification by field of science as used by the United States National Science Foundation.

IV. Some recommendations for the lay-out of the national R and D publication.

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(1) See Section II.

## CHAPTER II

## Basic Definitions and Conventions

### II.1 The concept and categories of research and experimental development(1)

14. Research and experimental development may be defined as creative work undertaken on a systematic basis to increase the stock of scientific and technical knowledge and to use this stock of knowledge to devise new applications.

15. For science policy reasons three categories of R and D are normally distinguished:

- basic research
- applied research
- experimental development

(see Graph A).

16. BASIC RESEARCH

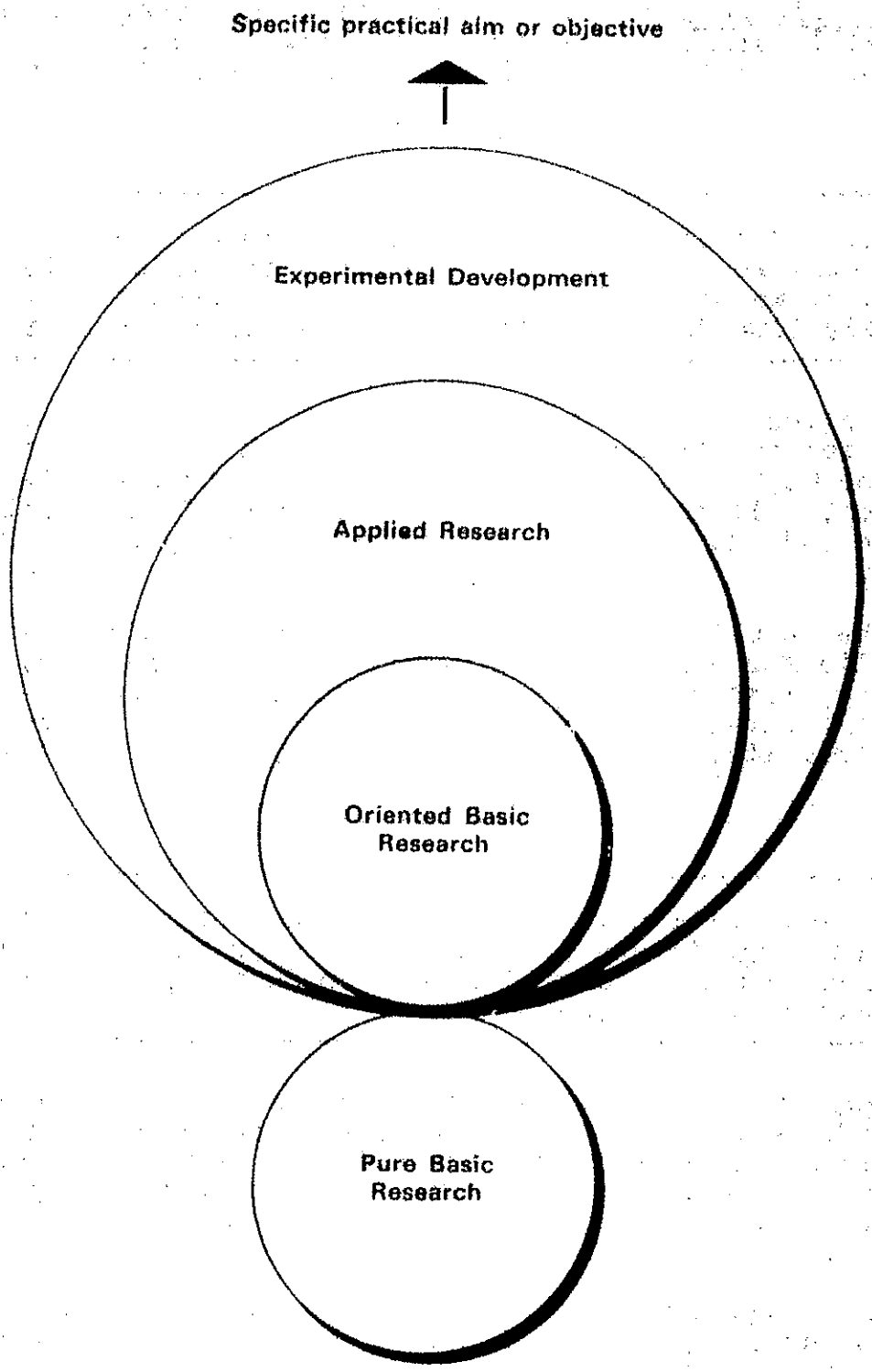
Basic research is original investigation undertaken in order to gain new scientific knowledge and understanding. It is not primarily directed towards any specific practical aim or application.

17. Basic research yields new hypotheses, theories and general laws. It involves the analysis of the properties, structures and inter-relationships of substances and phenomena of all types with a view to organising the findings into general laws using explanatory outlines and interpretative theories. The investigation has no immediate specific practical applications in view but may be oriented towards an area of interest to the performing organisation.

18. The results of basic research are generally non-negotiable and are usually published in scientific journals, or circulated to interested colleagues. Occasionally, basic

(1) The adjective 'experimental' was adopted for the 1968 revision of the Frascati Manual, (a) to avoid a confusion between 'development', a phase of R and D activities, and the same term in economics, and (b) to use the same term as Eastern European countries and UNESCO.

Diagrammatic presentation of the concepts of Basic and Applied Research and Experimental Development Research.

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research may be "classified" for security reasons. Basic research is generally undertaken by scientists who may set their own goals and to a large extent organise their own work. In pure basic research it is generally the scientific interest of the investigator which determines the subject studied. Such research tends to be confined to universities and some non-profit organisations or government laboratories. In oriented basic research the organisation employing the investigator will normally direct his work towards a field of present or potential scientific, economic or social interest.

19. APPLIED RESEARCH

> Applied research is also original investigation undertaken in order to gain new scientific or technical knowledge. It is, however, directed primarily towards a specific practical aim or objective.

20. Applied research is undertaken either to determine possible uses for the findings of basic research or to determine new methods or ways of achieving some specific and pre-determined objectives. It involves the consideration of the available knowledge and its extension in order to solve particular problems.

21. The results of applied research are intended primarily to be valid for a single or limited number of products, operations, methods and systems. Applied research develops ideas into operational forms. The knowledge or information derived from it is often patented but may also be kept secret.

22. EXPERIMENTAL DEVELOPMENT

> Experimental development is the use of scientific knowledge in order to produce new or substantially improved materials, devices, products, processes, systems or services.

23. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products and devices; to installing new processes and systems, and to improving substantially those already produced or installed.

24. Although not all development activity is of an experimental nature, experimentation is a dominant characteristic of this phase of R and D.

25. Examples

1. The study of a given class of polymerization reactions under various conditions, of the yield of products, and of their chemical and physical properties, is basic research. The attempt to optimize one of these reactions with respect to the production of a polymer with given physical or mechanical properties (making it of particular utility) is applied research. Experimental development then consists of the 'scaling up' of the process optimized at the laboratory level and the investigation and evaluation of potential methods of production of the polymer and perhaps of articles to be made from it.

2. The study of the absorption of electro-magnetic radiation by a crystal in order to obtain information on its electron band structure is basic research. The study of the absorption of electro-magnetic radiation by this material under varying conditions (for instance temperature, impurities, concentration, etc.) in order to obtain some given properties of radiation detection (sensitivity, rapidity, etc.) is applied research. The preparation of a device using this material in order to obtain better detectors of radiation then those already existing (in the considered spectral range) is experimental development.

3. The determination of the amino-acid sequence of an antibody molecule would be basic research. The effort to distinguish between the antibodies of various diseases, on the basis of these findings would be applied research. Experimental development would then consist of devising a method for synthesizing the antibody for a particular disease, based on the knowledge of its structure, and clinically testing the effectiveness of the synthetic antibody on patients who have agreed to accept experimental advanced treatment.

26. The three categories of R and D may sometimes be carried out in the same centre by substantially the same staff. In real life, R and D activities do not necessarily fall into the three successive and distinct categories defined above. For survey purposes, artificial divisions may have to be made in what is more or less a continuous process and the appropriate allocation of a given R and D activity to one of the categories may be neither natural nor obvious. For instance, although an R and D project in an institution may be at the applied research/development stage, investigation may reveal that some of the funds are being spent on further basic research that is necessary before progress can be made.

27. During R and D surveys respondents may have great practical difficulties in applying these theoretical distinctions to the wide range of projects in progress in their organisation. As surveying agencies are not always in a position to check the responses they receive and are usually obliged to accept them as such, it is of the utmost importance that they provide the institutions surveyed with the maximum of explanation and guidance to complement the formal definitions and to secure a maximum of uniformity in the basic data of R and D statistics.

28. There are four important tools available to achieve this objective:

(a) explanatory notes

(b) hypothetical examples

(c) guidance to individual respondents

(d) documentation on treatment of difficult cases.

For obvious reasons this Manual deals exclusively with (a) and (b). However, this basis of formal definition and distinction has to be complemented with information of types (c) and (d). In order to secure consistency in the guidance given by the surveying agencies, it is essential to develop a documentation on how difficult border-line cases have been solved. This documentation also can serve as a valuable source of examples for (b) and could help countries to develop more uniform classification practices.

## II.2 The boundaries of research and experimental development activities

29. For survey purposes R and D must be distinguished from a wide range of related activities with a scientific and technological base.

30. These related activities are very closely linked to R and D in terms of operations, institutions and personnel, but they should, as far as possible, be excluded when measuring R and D.

31. The criterion for distinguishing R and D from non-R and D activities is the presence or absence of an appreciable element of novelty.

32. This is shown in the three following examples:

Examples

1. In the field of medicine, routine autopsy on the causes of death is simply the practice of medical care and not research; but special investigation of a particular mortality in order to establish the side effects of certain cancer treatments is research. Similarly, routine tests, carried out for doctors, such as blood and bacteriological tests, are not research but a special programme of blood tests in connection with the introduction of a new drug is applied research.

2. The keeping of daily records of temperatures or of atmospheric pressures is not research but the operation of a weather forecasting service or general data collection. The investigation of new methods of measuring temperature is research as well as the study and development of new systems and techniques for interpreting the data.

3. The construction and operation of a pilot plant should be classed as experimental development as long as it is intended to produce new technical data. If, on the completion of the experimental phase, the pilot plant is used as a unit of production, the activity is no longer part of experimental development even if the title 'pilot plant' is retained and repair work is handled by R and D staff.

### II.3 Activities to be excluded from R and D

33. The activities to be excluded from R and D fall into two major groups:

(a) Activities closely related to R and D and generally referred to in this Manual as "related activities".

(b) Industrial production and distribution of goods and services and the various allied technical services in the business enterprise sector and in the economy at large.

II.3.1 Activities related to R and D

34. We are not concerned here with the problems of measuring R and D related activities but with the conventions to be used to exclude them when measuring R and D activities. (See also Graph B).

The following activities should be excluded from the measurement of R and D.

(a) Scientific education

All education and training of manpower in the fields of science, engineering, medicine and agriculture, in universities, specialised institutions of higher and post-secondary education. However, the research training of (post) graduate students that is an inextricable part of research carried out at universities must be considered, if possible, as a part of research [see also paragraph 99(a)].

(b) Scientific and technical information

The specialised activities of:

- collecting
- coding
- recording
- classifying
- disseminating
- translating

of

- scientific & technical personnel
- bibliographic services
- patent services
- official scientific and technical information services
- at scientific conferences

except where conducted solely or primarily for the purpose of R and D support. This means, for example, that the preparation of the original report of R and D findings should be included in R and D.

(c) General purpose data collection

Undertaken generally by government agencies concerning, for example, the medical situation or the natural environment (routine topographical mapping, geological, hydrological and oceanographic and meteorological surveying as well as routine astronomical observations). The exploration and prospecting activities of oil and mining companies should be considered under this heading. Data collection conducted solely or primarily as part of the R and D process is included in R and D, e.g. data on the paths and characteristics of particles in a nuclear reactor.

(d) **Testing and standardization**

Refers to the establishment of national standards, the calibration of secondary standards and testing and anlysis (physical, biological, bacteriological, chemical, statistical) of materials, components, products, processes, soils, atmospheres, etc.

(e) **Feasibility studies for engineering projects**

Investigation of proposed engineering projects by means of existing techniques in order to provide additional information before deciding on implementation.

(f) **Specialised medical care**

Refers to routine investigation and normal application of specialised medical knowledge. There may be, however, an element of experimental development in what normally is called 'advanced medical care'.

(g) **Patent and licence work**

All administrative and legal work connected with patents and licences.

35. It is sometimes difficult to identify the share of an institute's activities which are 'related activities' and, thus, to be excluded when measuring R and D. In survey practice, this task is facilitated by a certain number of conventions. Four typical cases of the use of these conventions may be cited:

(a) In institutions of higher education, research and teaching are always very closely linked, as most teachers do both. In the absence of complete and accurate information, measurement of the share of R and D is generally based on estimates of the proportion of working time devoted to this activity by university staff.

Where university buildings, equipment or instruments are used exclusively either for research or for teaching, then the expenditure should be allocated accordingly. However, when buildings, equipment or instruments are used for both research and teaching, then the proportion of utilisation should be estimated (see also paragraph 144).

(b) Institutions or units of institutions or of firms whose principal activity is R and D, sometimes also have secondary, non-R and D activities (scientific and technical information, testing, control, analysis, etc.). Insofar as a secondary activity, in such a case, is undertaken predominately in the interest of R and D, it should be included in R and D; if the secondary activity is essentially designed to meet needs other than those of R and D, it should be excluded.

Example

The activities of a scientific and technical information service or of a research laboratory library, maintained predominately for the benefit of the research workers in the laboratory, should be included in R and D. The activities of a firm's documentation centre open to all the firm's staff should be excluded from R and D even if it shares the same premises as the company research unit. Similarly, the activities of central university libraries should be excluded from R and D.

These criteria apply only to cases where it is necessary to exclude the activities of an institution or a department in their entirety. Where more detailed accounting methods are used, it may be possible to impute part of the cost of the excluded activities as R and D overheads. Whereas the preparation of scientific and technical publications is, generally speaking, excluded, the preparation of the original report of research findings should be included in R and D.

(c) Institutions whose main purpose is an R and D related scientific activity (e.g. geological or geophysical surveying) often undertake some research in connection with this activity. Such research should be isolated and included when measuring R and D.

Example

Mining and petroleum prospecting are excluded from R and D but research on new methods or ways of prospecting should be included.

(d) For the present, 'routine' space explorations should be included in R and D.

II.3.2 Boundaries between experimental development and production or technical services

2.1 Introduction

36. Possibly the greatest source of error in measuring R and D lies in the difficulty of locating the cut-off point between experimental development and other technological activities. This problem arises not only in the Business Enterprise sector, where it is necessary to demarcate the boundary between experimental development and production but also concerns some public technology-based services such as inspection and control. Errors at this point are particularly significant because the costs of experimental development are many times higher than the costs of research per se, and the costs of trial production are higher still.

37. No precise definition for the cut-off point between development and production which would be valid for all industrial branches can be given. A series of criteria or conventions by type of industry is needed. However, the basic rule laid down by the N.S.F. provides, for the moment, a practical basis for the exercise of judgement in difficult cases. Slightly expanded, it states:

> If the primary objective is to make further technical improvements on the product or process, then the work comes within the definition of R and D. If, on the other hand, the product or process or approach is substantially set and the primary objective is to develop markets, to do pre-production planning or to get a production or control system going smoothly, then the work is no longer R and D.

2.2 Special borderline cases

38. This section deals with some typical cases of the application of the N.S.F. criterion.

Prototypes

39. A prototype is an original model on which something new is patterned and of which all things of the same type are representations or copies. It is a basic model processing the essential characteristics of the intended product. Applying the N.S.F. criterion, the design, construction and testing of prototypes normally fall within the scope of R and D. This applies whether only one prototype or several are made and whether consecutively or simultaneously. But when any necessary modifications to the prototype(s) have been made and testing has been satisfactorily completed, the boundary of R and D has been reached. In some cases an R and D prototype may subsequently be sold. In principle, such a sale does not affect the issue as long as the original primary purpose in constructing the prototype was to make further technical improvements.

The construction of several copies of a prototype to meet a temporary commercial, military or medical need after successful testing of the original, even if undertaken by R and D staff, is not part of R and D.

Pilot plant

40. The construction and operation of a pilot plant is a part of R and D as long as the principal purposes are to obtain experience and to compile engineering and other data to be used in:

- evaluating hypotheses
- writing new product formulae
- establishing new finished product specifications
- designing special equipment and structures required by a new process
  and
- preparing operating instructions or manuals on the process.

But if, as soon as this experimental phase is over, a pilot plant switches to operating as a normal commercial production unit, the activity can no longer be considered R and D, even though it may still be described as a 'pilot plant'. As long as the primary purpose in operating a pilot plant is non-commercial, it makes no difference in principle if part or all of the output happens to be sold. Receipts from this source should not be deducted from the costs of R and D activity. However, as soon as a pilot plant begins to operate as a normal production unit, the effect is more or less the same as the sale of a pilot plant(1).

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(1) See also paragraph 116.

Trial production, trouble-shooting and engineering follow-through

41. After a prototype, with any necessary modifications, has been satisfactorily tested, the costs of the first trial production runs should not be attributed to R and D since the primary objective is no longer to further improvements of the product but to get the production process going. The first units of a trial production run for a mass production series should not be regarded as R and D prototypes, even if they are loosely described as such. Normally the costs of trial product runs or 'experimental production', including tooling up for a full-scale production (tool making and tool try-out), are not to be included in R and D.

42. After a new product or process has been turned over to production units, there will still be technical problems to be solved, some of which may demand further R and D. Such 'feed-back' R and D should be included.

43. Trouble-shooting occasionally brings out the need for further R and D but more frequently it involves the detection of faults in equipment or processes and results in minor modifications of standard equipment and processes. It, therefore, should not be included in R and D.

Tabulation 1

Chart of Borderline Cases and their Treatment

| Item | Treatment | Remarks |
|---|---|---|
| Prototypes | Include in R and D | As long as the primary objective is to make further improvements |
| Pilot plant | Include in R and D | So long as the primary purpose is R and D. If it is, subsequently, used as a production unit or is sold, deduct the sales price from the capital account of the original year of investment |
| Design and drawing | Divide | Include design required during R and D<br>Exclude design for production process |
| Trial production and tooling up | Exclude | Except 'feed-back' R and D |
| After sales service and 'trouble-shooting' | Exclude | Except 'feed-back' R and D |
| Patent and licence work | Exclude | All administrative and legal work connected with patents and licences |
| Routine tests | Exclude | Even if undertaken by R and D staff |

# CHAPTER III

## Main Sectoral and Functional Classifications of R and D Data

### III.1 Introduction

44. The distinction, already discussed, between basic research, applied research and experimental development is one important breakdown. In addition it is necessary to classify the organisations which perform or finance R and D and to examine both activities and institutions in further detail.

45. In this chapter the following major classifications will be examined:

- Classification, by sector, of the institutional units (institutes, enterprises etc.) which perform or finance R and D.

- Classification of R and D by

  (1) Industry group and product field
  (2) Field of science
  (3) Socio-economic objective.

46. The subclassifications of R and D expenditure by cost-type and of R and D manpower by occupations and/or qualifications are dealt with in Chapter IV on "measuring R and D resources" as are the methods of measuring flows of funds among sectors.

### III.2 Classification by sector

47. In order to facilitate the collection of data, the description of institutional flows of R and D funds and the analysis and interpretation of R and D data, institutional units (institutes, enterprises etc.) should be grouped into sectors of the economy, following as closely as possible existing standard classifications of economic activities.

48. The organisation of R and D surveys on a sector basis offers a number of substantial practical advantages:

(a) Different questionnaires and survey methods can be used for each sector to take into account the different 'mixes' of activities, different accounting systems or different response possibilities of the organisations.

(b) When measuring expenditure, the sectoral approach offers the most reliable way of building up national aggregates.

(c) Sectoring offers a framework for the analysis of flows of funds to (and from) the R and D performing agencies.

(d) Since each sector has its own characteristics and its own blend of R and D, this classification also throws some light on differences between the level and direction of R and D in different countries.

(e) Insofar as the sectors chosen are based on the framework of an existing standard classification, it may be possible to relate R and D to other statistical series, thus facilitating the interpretation of the role of R and D in economic development and the formulation of science policy.

49. The System of National Accounts(1) (S.N.A.) states that "in any national accounting system transactors are necessarily grouped ....but they need not be grouped in the same way in all parts of the system, and, indeed, it is not desirable that they should be". The S.N.A. gives two slightly different systems of sectoring, one based on the productive activity of each establishment and the second on the financial activity at a more aggregate level.

50. The following definitions are based largely on the S.N.A. productive activity approach with the difference that Higher Education has been established as a separate sector and households have been merged with Private Non-Profit. Other slight changes have been made and are noted.

51. In view of the diverse ways in which most contemporary institutions have developed, the definitions of the sectors which follow cannot be logically precise because, like the S.N.A. from which they are partly drawn, they are based on a combination of sometimes conflicting criteria such as function, aim, economic behaviour, sources of funds and legal status.

52. Thus, it will not always be clear in which sector a given institute should be classified and an arbitrary decision may have to be made. Institutions may lie on the borderline between two sectors or the conceptual distinction may be clear but established legal and administrative affiliations or political considerations may prevent strictly logical classifications.

53. When two countries classify institutions with the same or similar functions in different sectors, the survey results will not be internationally comparable. Such divergencies are probably unavoidable as R and D surveys are primarily undertaken to serve national purposes. For international surveys, however, data should be collected and submitted in as much detail as possible in order to leave room for re-arrangement for international comparisons.

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(1) "A System of National Accounts" (United Nations 1968) is both a revision and an extension of A System of National Accounts, first edition, 1953.

54. Four domestic sectors are identified:

1. Business Enterprise
2. General Government
3. Private Non-Profit
4. Higher Education.

A definition is also given of:

5. Abroad.

III.2.1 The Business Enterprise sector

55. This sector includes:

| |
|---|
| 1. All firms, organisations and institutions whose primary activity is the production of goods or services for sale to the general public at a price intended approximately to cover at least the cost of production. |
| 2. The private non-profit institutes mainly serving them. |

56. The core of the sector is made up of private enterprises whether or not they distribute profit. Amongst these enterprises may be found some firms for whom R and D is the main activity (commercial R and D institutes and laboratories).

57. In addition, it includes government departments, establishments and similar units mainly engaged in selling the kinds of goods and services which are often produced by business enterprises though, as a matter of policy, the prices set for these goods may not approximate the full cost of production. In order to qualify as "sales" in this context, the charges should be related to the amount (quality and quantity) of the goods and services furnished and the decision to purchase them should be voluntary. Examples: Nationalised mining and manufacturing units, electricity production and distribution, water supply services, railways, post and telecommunication services, broadcasting etc.

Institutes serving Business Enterprise

58. According to the S.N.A. these bodies should be included in the Business Enterprise sector as long as they are not wholly or mainly both financed and controlled by organs of government. A full description of these institutes will be found in S.N.A.(1).

(1) A System of National Accounts 1968, Chapter V, paragraph 5.13 and 5.14, page 73.

59. There has, in the past, been some controversy about how to classify agricultural (or industrial) research institutes established by government and either administered by government departments or linked to universities and private non-profit institutions. According to the S.N.A., if such institutes serve agriculture (and industry) they should be included in the Business Enterprise sector, except for those which are effectively government controlled, in which case they should go in the latter sector. It can, however, be argued that:

(a) the encouragement and organisation of agriculture is in most countries a typical government function;

(b) the purpose of agricultural institutes is to undertake research in the agricultural sciences for the benefit of the country as a whole, and not to perform R and D intended directly to improve agricultural productivity on the farm.

They are thus not directly serving enterprises and should be classified to government as the sector of effective control. Where the R and D activities in such institutes play an important role in national science policy, they should be considered as a separate sub-sector and reports to international organisations should be as detailed as possible to allow rearrangement of data for the purpose of international comparisons.

III.2.2 The Government sector

60. This sector includes:

> Organisations which furnish but do not normally sell to the community those services which cannot otherwise conveniently or economically be provided and act as the administrative agency for the economic and social policy of the community.

61. All units of government (other than public enterprises and institutes of higher education) which fit the above description, irrespective of their treatment in the government budget or the level at which they operate (national, provincial, state, local) are included in this sector. These units and organisations engage in a wide range of activities, for example administration, defence and regulation of the public order, health, educational, cultural, recreational and other services, and promotion of economic growth and welfare and technological development. Also included are private non-profit institutes and social security arrangements which, by virtue of their relations with the government, are clearly the instruments of government economic and social or scientific policy. The following types of organisations should be included as well:

(a) Non-profit organisations which primarily serve government, that is bodies which are not established with the aim of earning a profit and which are mainly engaged in research and similar activities with regard to publicly administered functions.

(b) Non-profit bodies entirely or mainly both financed and controlled by government.

62. The definition of this sector is based in general on the S.N.A. definition of producers of government services. The main difference is that publicly controlled institutes of higher education are excluded.

III.2.3 The Private Non-Profit sector

63. This sector includes:

> Most private organisations which are not established primarily with the aim of earning a profit. They are maintained by fees, dues and donations from members and sponsors, by grants from government and enterprises, and often also obtain revenue from the direct sale of some of their products and services, as, for example, publications and public lecture programmes.

64. The following types of private non-profit organisations should, however, be excluded from this sector:

(a) Those mainly rendering services to enterprises.

(b) Those which primarily serve government.

(c) Those entirely or mainly financed and controlled by government.

(d) Those offering higher education services or controlled by institutes of higher education.

65. What distinguishes the organisations in this sector from business enterprises is not so much that they are non-profit but the aim of their activity. An independent private research institute selling R and D through R and D contracts, which may be non-profit in the sense that any surplus is dug back into the organisation to be used for research projects of the institute's own selection, is a business enterprise (see also paragraph 81).

66. This sector consists primarily of voluntary associations of individuals who have banded together in order to carry on specific activities. Typical examples of associations belonging to this category are voluntary scientific societies, philanthropic research institutions and voluntary health agencies.

67. This definition is based on the S.N.A. except that it excludes non-profit higher education institutes. In addition, as a convention, all R and D activities of the general public (households) should be included in this sector. Their role in the performance of R and D is extremely small (individual inventors working in their own time and facilities) but they do act as a source of funds for R and D, for example, by making donations to medical foundations.

68. The Private Non-Profit sector is usually small except in those countries where, for juridical reasons, certain special groups of organisations, such as the German Max Planck institutes or part of the Dutch TNO, are included.

III.2.4 The Higher Education sector

69. This sector includes:

> All universities, colleges of technology and other institutes of post-secondary education whatever their source of finance or legal status. It also includes all research institutes, experimental stations and clinics operating under the direct control or administered by or associated with higher education establishments.

70. Higher education, which is not a separate S.N.A. sector, has been separately identified here in view of the important role played by institutions of higher education in the performance of R and D. It is drawn from the S.N.A. government and Private Non-Profit sector.

71. For international comparisons, it would be desirable to have information for universities and colleges separated from that for associated institutes.

III.2.5 Abroad

72. All organisations with R and D activities operating on domestic territory can be divided between the four sectors mentioned above. When examining flows of funds, it is necessary to include a fifth sector - Abroad.

73. Abroad consists of:

> Institutions on all territory outside the political frontiers of a country except that
>
> i. vehicles, ships, aircraft and space satellites operated by domestic organisations and testing grounds leased or acquired by a government in other countries' territory are not to be considered abroad.
>
> ii. the facilities of international organisations situated within the political frontiers of the reporting country are to be considered abroad.

74. Tabulation 2, (see page 29) summarizes the various aspects of a given institution to be considered when deciding in which sector it should be classified.

III.3 Functional Classification of R and D

75. A breakdown of R and D activities by sector gives useful information to the science planner; however, when making detailed analyses, it is necessary to use systems of classification which reveal the orientation of R and D activities. For the purpose of international comparison such functional classifications are far more significant than those based on institutions (except when analysing sources of funds, for which the sectoral approach is necessary).

76. Although it may be possible to define functional classifications which could be applied to R and D activities in all four sectors, for practical purposes it is more useful to discuss classifications in two groups:

(a) for use in the Business Enterprise sector

(b) for use in the Government, Private Non-Profit and Higher Education sectors.

77. The most practical categories for the Business Enterprise sector are:

(a) by industry group and

(b) by product field.

For the Higher Education, Private Non-Profit and Government sectors a classification is generally feasible:

By field of science.

## Tabulation 2

### Useful Indications for Sectoring

| | Function | Economic behaviour | Legal status | Remarks |
|---|---|---|---|---|
| Business Enterprise | To produce goods and services for sale to general public | Market prices intended approximately to cover cost of production (profit or non-profit) or prices which vary according to quantity and quality purchased | Private or public organisations | Includes enterprises organised on a co-operative basis and non-profit institutions mainly serving enterprises |
| Private Non-Profit Institutions | Generally to provide goods and services for their members and special client groups or to raise money for other institutes | Main income: fees from members and clients, grants | Private or quasi-public organisations | Excludes:<br>(1) institutions mainly serving and/or controlled by business enterprises or government<br>(2) universities and associated institutes |
| General Government | To organise for the community those common services which cannot otherwise conveniently or economically be provided | Main income: taxes | Public organisations | Excludes enterprises and institutions for higher education<br>Includes PNP organisations controlled by and/or serving government |
| Higher Education | To provide formal post-secondary education | Main income: fees, government subsidy or allocation, private gifts and grants, income from endowment | Public or private organisations | In S.N.A., institutions of higher education are distributed over the other three sectors above |

78. A further functional approach to the analysis of R and D efforts is the classification by socio-economic objectives, either at national level or in the government sector only.

III.3.1 Classification by industry group and product field

Industry group

79. The basic classification for a breakdown in the Business Enterprise sector is usually a national variant of the International Standard Industrial Classification(1). Here the breakdown is according to the main industrial activity of the unit classified which may be either a whole firm or an establishment. For R and D purposes, however, a classification on an establishment basis is, where possible, strongly recommended.

80. Tabulation 3 (see page 31) shows a re-arrangement of ISIC which is suitable for analysing R and D activity in the Business Enterprise sector (showing revised ISIC numbers). The major one digit classes have been maintained for 'non-manufacturing' industries, as their R and D activities in the natural sciences are at present not particularly noteworthy. In general, three digit classes have been adopted for the "manufacturing" industries. Transport equipment and electrical engineering industries have, however, been subdivided in order to identify separately aeronautics and electronics. Despite the new revision of the ISIC, the nomenclature of which is far more detailed than that of the 1958 version, certain industrial activities with a strong science base cannot be readily allocated to an industry. A particular case is "atomic energy devices" which has been classified in the machinery industry group.

81. Research institutes in the Business Enterprise sector should, as far as possible, be classified according to the industry they serve. When this is not clear they should be included with commercial research institutes in "services".

Product field

82. In the classification by product field, the R and D activity of each enterprise is broken down according to the product field to which it is relevant. In theory, only applied research and experimental development work can be distributed by product field. As, however, the basic research performed in industry may be oriented towards some area of commercial interest to the performing company, it might be possible in some cases to classify a firm's R and D as a whole by product field.

---

(1) Statistical Papers Series M No. 4 Rev. 2, United Nations, 1968.

Tabulation 3

International Standard Industrial Classification (ISIC)
Arranged for Purposes of R and D Statistics

I. Manufacturing industries

| Industry group | ISIC | Component industries |
|---|---|---|
| Aircraft | 3845 | Aircraft and missiles |
| Electrical | 3831/3833/3839<br>3832<br><br>385 | Electrical machinery<br>Electronic components and accessories and telecommunication equipment<br>Instruments |
| Chemicals | 351/352<br>except 3522 and 3523<br><br>3522 and 3523<br>353/354 and 22 | Chemicals<br><br>Drugs<br>Petroleum (inc. petroleum extraction) |
| Chemical related | 311/312/313<br>321<br>355/356 | Food<br>Textiles<br>Rubber |
| Machinery (except electrical) | 382<br>.. | Machinery<br>Atomic energy devices |
| Transport equipment (except aircraft) | 3843<br>3841<br>3842, 3844, 3849 | Motor vehicles<br>Shipbuilding<br>Other transport equipment |
| Basic metals | 371<br>372<br>381 | Ferrous metals<br>Non-ferrous metals<br>Fabricated metal goods |
| Other manufacturing industries | 314<br>322<br>33<br>341<br>342<br>323, 324<br>36 | Tobacco<br>Clothing<br>Wood, cork, furniture<br>Paper<br>Printing<br>Leather<br>Stone, clay, glass |
| Agriculture | 1 | Agriculture, forestry, fishing |
| Mining | 2 | Mining industries except petroleum extractions |
| Services | 4<br>5<br>71<br>72<br>8523/8324<br>93<br>6, 8 NES, 9 NES | Electricity, gas and water<br>Construction<br>Transportation<br>Communications<br>Commercial research institutes<br>Engineering services<br>All other |

83. The main international classification by product, the Standard International Trade Classification(1) is, as its name suggests, trade rather than industry oriented. This, combined with the fact that processes such as mineral extraction, for example, do not fit in this classification, makes it rather inconvenient for R and D purposes. For the moment a reasonable approach seems to be to use the ISIC also for this classification of industry's R and D by product-field. The following example may illustrate the different use of the ISIC in classifying by industry group and product field respectively.

Example

A firm (establishment) belonging to the electrical machinery industry has performed R and D on plastics. When classifying by industry group, i.e. the industry group where this R and D has been performed, the R and D resources will be allocated to the 'electrical machinery industry'. In classifying by product field, i.e. in the actual product field in which R and D has been performed, these resources will be classified as 'chemical'.

Relative advantages of the two approaches

84. Within a country the industry group approach is probably the most practical. Industry group data are collected within the same framework as regular economic statistics which makes for ease of surveying and facilitates comparison between R and D and other economic data.

85. For international comparison, the product field approach has the advantage of avoiding the distortion arising from varying national practices of classifying firms/establishments to industry groups and of ironing out 'blurring' of industrial classifications which occurs when statistics are collected on a company rather than on an establishment basis, as should be done, and large companies operating in several different industries are assigned to a single industry.

86. It is probable that countries will wish to continue to use for their own purpose the industry group for the main subgrouping within business enterprise. For the purpose of international surveys, however, additional information on product fieldsshould be collected insofar as possible.

---

(1) Classification of Commodities by Industrial Origin, Department of Economic and Social Affairs, Statistical Office of the United Nations, Statistical Papers, Series M, No. 43, United Nations, New York, 1966.

III.3.2 Classification by field of science

87. As we stated in paragraph 77 this type of classification is generally most applicable to the Higher Education, the Private Non-Profit and the Government sectors but if, as in the United States and Canada, industry can give some information on the science field of activities, a more complete picture is possible.

88. A classification by field of science can be used to classify three different things:

(a) The object or focus of R and D efforts. Although extremely difficult to obtain, such a classification is of great importance for science policy makers.

(b) The educational background of the scientists and engineers involved in R and D. This classification is a necessary link between science policy and educational policy.

(c) The occupational field in which R and D scientists and engineers actually work. Because of the increased sharing of information and techniques among the different fields, the field of occupation may differ from the field of training.

89. At the present date the standard international classification by discipline is that used by UNESCO for statistics of education. The main features of this classification are shown in tabulation 4 (see page 54),(1). It is, at present, under revision and readers are advised to replace this tabulation by the new one when it appears.

90. Since in UNESCO work in this respect has not yet reached its final stage, it has been thought useful to include information on a more modern classification system as used by the National Science Foundation in the United States of America. (See Appendix III).

91. In practice, the classification of R and D by field of science will sometimes have to be made at the institutional level, which means that university faculties or research institutes as a whole, rather than their individual projects, are classified.

---

(1) For the benefit of countries who wish to survey R and D in humanities and social sciences these fields have also been specified in this tabulation.

Tabulation 4

UNESCO Classification by Scientific Fields

| Principal Fields | Sub-division of principal fields |
|---|---|
| A. Natural sciences | 1. Mathematics<br>2. Physics, mechanics, electronics, astronomy<br>3. Chemistry, physical chemistry<br>4. Biology, botany, zoology, bio-chemistry, bio-physics<br>5. Geology and earth sciences, meteorology, geophysics<br>6. Other |
| B. Engineering | 1. Metallurgy, mining<br>2. Mechanical engineering<br>3. Construction, civil engineering<br>4. Electrical engineering<br>5. Aeronautical engineering<br>6. Chemical engineering, fuel and petroleum technology<br>7. Textile engineering<br>8. Geodesy<br>9. General technology and applied science<br>10. Other |
| C. Medical sciences | 1. Medicine<br>2. Dentistry<br>3. Pharmacy<br>4. Other |
| D. Agriculture | 1. Agronomy, rural science<br>2. Forestry, horticulture<br>3. Dairying, animal husbandry<br>4. Veterinary science<br>5. Other |
| E. Social sciences | 1. Political science, diplomacy<br>2. Economics, commerce, banking<br>3. Sociology, ethnology<br>4. Other |
| F. Humanities and Fine Arts | 1. Humanities<br>2. Fine Arts<br>3. Education<br>4. Other |

### III.3.3 Classification by Socio-Economic Objectives of R and D

92. When attempting to classify R and D by socio-economic objectives at national level, four main categories or motives for undertaking R and D work may be distinguished:

(a) Military reasons: Strengthen the defence potential of a country.

(b) Economic reasons: Increase or maintain the economic strength of a firm, an industry, a country.

(c) Welfare reasons: Improvement of the physical, social and cultural environment of man in order to reduce the restriction on human well-being and advancement.

(d) Mainly scientific reasons: The advancement of science as a desirable cultural manifestation.

93. In addition there are, at present, two broad fields of R and D which are given high priority by science policy-makers in many countries and which, for the time being, should also be separately identified:

(e) Space exploration and space travel

(f) Atomic energy

94. In theory, as in the field of science approach, the breakdown should be made at the project level. In practice, very few Member countries have attempted a systematic continuous analysis of R and D efforts by these objectives, though some estimates have been made on the basis of total government expenditures.

95. The basic institutional classification used in the General Government sector combines an institutional and objective approach for assigning units of government (e.g. ministries, departments) to one of a list of twelve broadly defined objectives as follows:

| Broad objectives of government |
|---|
| A Military |
| B Space exploration and travel |
| C Nuclear energy |
| D Agriculture |
| E Construction |
| F Transportation |
| G Telecommunications |
| H Health |
| I Natural environment |
| J Under-developed regions |
| K Industry |
| L Academic research |

# CHAPTER IV

## Measurement and Classification of Resources and Expenditure Devoted to R and D

### IV.1 Introduction

96. The two principal methods of input measurement are:

(a) Measures of expenditure on R and D

(b) Measures of manpower employed on R and D.

Expenditures and manpower should be surveyed simultaneously and along the same lines so that analyses can cover both and so that it is possible to calculate ratios between R and D expenditures and R and D scientists and engineers for a country as a whole and for each sector surveyed. If different agencies are responsible for the collection of expenditure and manpower data, close co-operation is essential.

### IV. 2 Manpower employed on R and D

97. All manpower directly employed on R and D regardless of level of responsibility, should be included, together with administrators and managers of R and D and those providing direct services, such as clerical staff. Those providing an indirect service, such as canteen staff, janitors, cleaners, etc., should be excluded from the measurement of manpower but their wages should be treated as an overhead in the expenditure data. If possible, calculations should be made in 'full-time equivalence' rather than physical persons. (See "need for estimates and adjustments" paragraph 138).

### IV.2.1 Categories of R and D manpower

98. It is desirable to classify manpower working in R and D both by occupation and by formal qualification. Whereas it is often easier at national level to collect information by formal qualifications, this is not always very meaningful as it does not reveal the actual employment of manpower and, owing to the different patterns of formal education, it does not lend itself to international comparisons.

#### Classification by occupation

99. The standard international classification in this field is the International Standard Classification of Occupations (I.L.O. 1968). This does not have a separate class for R and D workers outside the natural sciences and groups teachers in a separate group. It can, however, be adapted to suit some aspects of an R and D survey. The main definitions of function which follow are specially framed for R and D surveying. A list of suggested ISCO classes to be included in each group is given in tabulation 5 on page 40.

(a) R and D Scientists and engineers

| |
|---|
| Persons actually engaged in the conception and/or creation of new knowledge, products, processes methods and systems. |

Their professional title may very from one country to another and even from one sector to another. Executives and directors responsible for the administration of R and D activities should also be included in this category, as well as (post-)graduate students properly contributing to research [see also paragraph 34(a)].

Identification of the latter may be very difficult for some countries and to facilitate international comparability they should be measured and recorded separately.

(b) Technicians

| |
|---|
| Technicians perform auxiliary technical tasks connected with R and D normally under the direction and supervision of a scientist or engineer. |

Their tasks include:

- assisting with or, under supervision, performing experiments, tests and analyses;
- preparing materials and equipment for experiments, tests and analyses;
- taking records, making calculations and preparing charts and graphs;
- maintaining and operating advanced machinery and equipment.

(c) Workers

| |
|---|
| Craftsmen and unskilled and semi-skilled assistants directly associated with R and D activity. |

(d) Other supporting staff

| |
|---|
| Secretarial and clerical staff directly serving R and D units. |

Manpower providing an indirect service, such as canteen staff, janitors etc., should be excluded. Their wages should be treated as an overhead in the expenditure data.

Classification by qualification

100. The standard international classification in this field will be the International Standard Classification of Education (ISCED), which is available in a preliminary 2 digit version, the definitive version of which is at present being prepared by UNESCO.

101. This system is based on three levels, the first two covering roughly up to the end of secondary education. The third level, which is of interest in the context of R and D surveying, covers post-secondary education divided into three classes:

(a) not leading to an academic degree (or equivalent)

(b) leading to a first university degree (or equivalent)

(c) leading to a post-graduate university degree (or equivalent).

102. This classification does not deal explicitly with the important problem of differentiating between lower and higher technical diplomas and until such time as it is finalized and it becomes clear which of such diplomas Member countries decide to be of university level and which are not, the following classification will probably be more useful:

(a) Holders of university degrees

| |
|---|
| Includes holders of degrees earned at universities proper and also at specialised institutes of university status. |

Examples: Universitäten, Technische Hochschulen (Germany).
Facultés, Grandes Ecoles (France).
Universiteiten, Technische Hogescholen, Landbouw Hogeschool (Netherlands).
4-year colleges granting B.A. or B.Sc. (United States).

Include graduates in all fields including social sciences and humanities. (Post-)Graduate research students should be included in this category but they should be measured and recorded separately.

(b) Holders of higher technical diplomas

Higher technical diplomas are awarded after high level practical studies.

Higher technical diplomas differ from university degrees not so much in level as in kind. Entry requirements may be no lower and length of study no shorter than in some university science or engineering departments but the course taken is more practical in content.

Examples: Graduates of Ingenieurschulen (Germany).
Instituts Universitaires de Technologie Diplômes d'études supérieures techniques (France).
Hogere Technische scholen, Hogere landbouw scholen (Netherlands).
Ecoles Techniques Supérieures (Belgium).
Higher National Certificate and Higher National Diploma (United Kingdom).
Höhere technische Lehranstalten (Austria).

(c) Holders of Lower technical diplomas

Holders of diplomas of all secondary level technical education.

These diplomas are of secondary level though they may be obtained outside the academic secondary school systems.

Examples: Graduates of Technikerschulen and Höhere Fachschulen (Germany).
Middlebare Technische Scholen (Netherlands).
Ecoles Industrielles Supérieures (Belgium).
Ordinary National Diploma and Ordinary National Certificate (United Kingdom).
Diploma from a technical secondary school (United States).

(d) Other qualifications

Includes all those with non-technical secondary school or less, with incomplete post-secondary qualifications or non-university post-secondary education not falling under any of the above categories.

## Tabulation 5

### Suggested Relation Between O.E.C.D. Function and ISCO Classes

This classification should be used within the group "occupied in R and D activities"

| O.E.C.D. Class | ISCO Number | ISCO Classes |
|---|---|---|
| Scientists | 011, 012, 013 | Chemists, physicists, physical scientists NES |
| | 051, 052, 053 | Biologists, medical scientists and related scientists, bacteriologists and related scientists, agronomists and related scientists |
| | 081, 082, 03 | Statisticians, mathematicians and actuaries, systems analysts |
| Engineers | 022-029 inc. | Civil, electrical, mechanical, chemical metallurgical, mining and engineers NES |
| | Part of 1.31 | University and higher education teachers |
| R-D Admin. | Major group 2 | Administrators and managerial workers |
| Technicians | 014 and 054 | Physical and life science technicians |
| | 031-039 inc. | Surveyors, draughtsmen, civil, electrical, mechanical, chemical, metallurgical, mining and other engineering technicians |
| Workers and Other supporting staff | Major groups 7, 8, 9 | Agricultural, service and production and related workers |
| | Major group 3 | Clerical workers and related workers |

Joint occupational and qualification approach

103. The accompanying tabulation 6 (see page 42) shows a matrix of R and D manpower, broken down both by occupation and by formal qualification.

104. While it is probable that most of those occupied as scientists or engineers will have a university degree, they may also include, however, holders of higher technical diplomas, persons with incomplete university training and self-trained persons who have proved their capabilities in a given job.

105. Similarly, many of those occupied as technicians will have higher or lower technical diplomas. In very new fields, however, there may also be some university graduates working at technician tasks which, when the processes are standardized, will be performed by non-graduates (e.g. computer programmers). In countries which did not provide much standard technical training until recently, there will be many technicians with no formal qualification (although they may have had incomplete post-secondary education and/or on-the-job training).

106. The estimation of full-time equivalents is rather impracticable for the cross-classifications. Instead one should always distinguish between scientists and engineers full-time and scientists and engineers part-time in R and D.

IV.2.2 Other characteristics of R and D manpower

107. There are further characteristics of R and D manpower and particularly of scientists, engineers and technicians which may be of interest, notably:

(a) Age

(b) Sex

(c) Fields of qualification (scientific or technical specialization)

(d) Level of university degree

(e) Year of university graduation

(f) Foreign born persons: country where secondary school and where higher education was completed.

108. It is not suggested that these characteristics should be regularly included in R and D questionnaires. They may, perhaps, be better treated in overall surveys of national stocks of scientific and technical personnel; but it should be kept in mind that such cross-classifications may be important for science policy reasons.

## Tabulation 6

## R AND D PERSONNEL

| Occupation | Formal qualification | | | | Total |
|---|---|---|---|---|---|
| | University level degree | Higher technical | Lower technical diploma | Other, incomplete, or no professional qualification | |
| Scientists & engineers | | | | | |
| Technicians | | | | | |
| Workers | | | | | |
| Other supporting staff | | | | | |
| TOTAL | | | | | |

IV.3 R and D expenditure

109. Sums allocated to R and D can be spent either

- inside (intramural expenditure), or

- outside (extramural expenditure)

a firm, ministry or public agency, private non-profit institution or university. Both expenditure categories will be discussed. (See also Graph C).

IV.3.1 Intramural R and D expenditure

110. Intramural expenditure includes all funds used for the performance of R and D within a particular organisation or sector of the economy, whatever the sources of finance.

111. It includes both current and capital expenditure which each consist of a number of various subclasses:

Current expenditure:

Current expenditure is made up of:

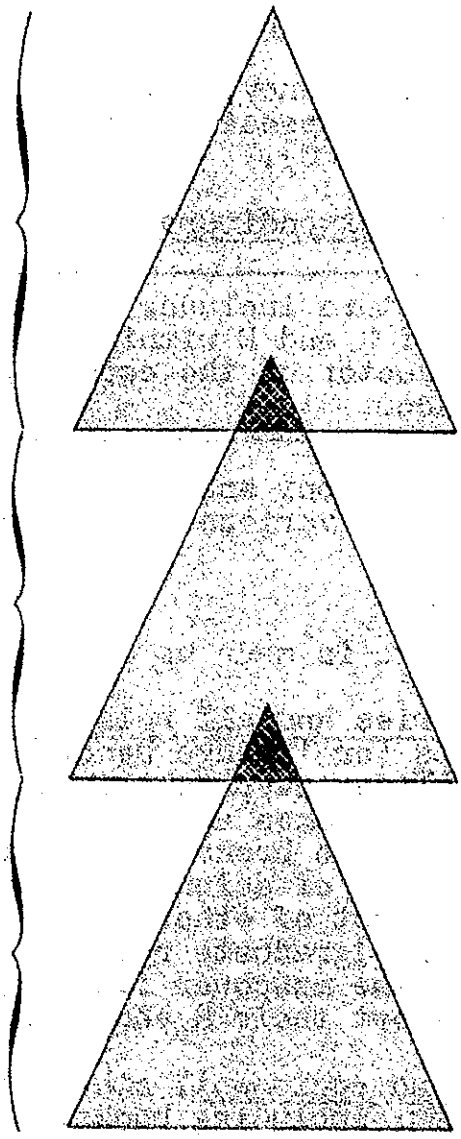
(a) Wages, salaries and all related elements of labour costs (or 'fringe benefits') such as bonuses, holiday pay, contributions to pension funds, payroll taxes and welfare expenditure. This class may be broken down into expenditures made in respect of scientists and engineers and those in respect of other R and D personnel. Even if (post-)graduate research students are not included in the manpower figures, all known funds used to support their R and D should be reported.

(b) Materials and equipment, other than major items of equipment, including books, journals, reference material, subscriptions to libraries, scientific societies, and so forth, whether incurred for individual research workers or for the research organisation as a whole. Including also the replacement of office furniture and fittings, as well as the imputed or actual cost of small prototypes or models made outside the research organisation.

(c) Water and fuel, including gas and electricity.

(d) Maintenance and repair of buildings and equipment. Rent, rates and cleaning.

## Diagrammatic presentation of the conventions underlying the survey concepts of intra-mural and extra-mural R. & D.



Self-performed R. & D.

Case of an Organisation X **without** extra-mural R. & D. expenditure but **with** extra-murally financed intra-mural expenditure on R. & D.

Self-performed R. & D.

Case of an Organisation Y **with both** extra-mural R. & D. expenditure and extra-murally financed intra-mural expenditure.

Self-performed R. & D.

Case of an Organisation Z **with** extra-mural R. & D. expenditure but **without** extra-murally financed intra-mural R. & D. expenditure.

Intra-murally financed R. & D.

Extra-murally financed R. & D.

C

*Each triangle represents the total outlays on R. & D. of any organisation performing and financing this kind of activity. The upper angle represents the extra-mural R. & D. expenditure, the rest of the triangle the intra-mural expenditures. Part of these intra-mural expenditures is extra-murally financed (dark shaded triangle at the basis) or, to put it in another way, represents the extra-mural expenditure on R. & D. of another organisation, etc.*

(e) Administrative expenses and share of overhead costs in the case of research departments or institutes sharing premises or facilities with other parts of a large organisation. Including office supplies, telephone and telegraph, transport, travel, entertainment, printing and duplicating services, canteen facilities, storage expenses, accounting costs, insurance.

(f) Purchase of services (e.g. cost of computer time)

Depreciation

In the scheme of measurement current expenditure on R and D excludes actual or imputed provisions for depreciation.

112. Normally it will not be necessary to ask respondents in each sector to give an annual breakdown of their current expenditure into the above six or more sub-divisions and a combined figure will usually suffice. It may, however, be useful to obtain a detailed breakdown of current expenditure on an occasional basis, first of all in order to provide data for comparison of R and D costs between different sectors, industries and organisations within a country and secondly, to provide the means for constructing indices of R and D costs. Such indices are essential for comparisons and analysis of expenditure over time and between countries (see also Chapter VI).

Capital expenditure

113. It covers

Annual gross capital expenditure actually incurred by performers, irrespective of the method of finance, the period over which this may be written off, or whether the expenditure is for replacement or an addition to assets.

114. Capital expenditure on R and D includes:

(a) the acquisition of land (although this is not a capital expenditure in terms of the S.N.A.);

(b) expenditures on buildings, fixed assets and plant, including major improvements, modifications, repairs and renovations as well as legal fees resulting from the purchase of real estate;

(c) the acquisition of major instruments and equipment.

115. In measuring actual capital expenditure, i.e. as charged on the capital account, small tools and instruments and minor improvements to existing buildings will normally be excluded, as in most accounting systems these items are carried on current expenditure accounts. The boundary between 'minor' and 'major' items varies slightly between countries, according to taxation practice and between different firms and organisations in the same country according to accounting practices. But these differences are rarely significant and it is neither necessary nor practical to insist on any rigid standard for this purpose.

116. A special difficulty arises when a pilot plant switches to operating as a normal commercial production unit or is being sold (see also paragraph 40). In either case, the receipts, (imputed or real) have to be considered as dis-investments in R and D and thus in accordance with the S.N.A.(1) they should be deducted retrospectively from gross investment in R and D in the year of original payment. In practice this is possible only where the construction costs of the pilot plant have been put on the capital account. To avoid inconsistencies in the return, these transactions (dis-investments) should be recorded <u>separately</u>.

117. All depreciation provisions for building, plant and equipment, whether real or imputed, should be <u>excluded</u>.

118. This solution is proposed for three reasons:

(a) The actual sums set aside for depreciation are useless for purposes of international comparison because of differences in tax laws;

(b) In the General Government Sector, no provision is normally made for depreciation of fixed assets. Consequently, even within a country, satisfactory comparisons between sectors cannot be made unless depreciation provisions are excluded, and aggregates for a national series cannot be compiled unless the sector totals are put on a comparable basis.

(c) It is useful to know, whether the pattern of capital expenditure for R and D purposes follows that for business investment in general.

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(1) S.N.A. Ch. VI, paragraph 6.115 page 111: 'Gross fixed capital formation consists of the outlays of industries and the producers of government services and of private non-profit services to households, on addition of commodities to their fixed assets, reduced by their net sales of similar secondhand and scrapped goods. The commodity in question may be purchased or produced on own account.

119. Thus, although for particular surveys, it may be useful to collect figures on actual or imputed provisions for depreciation, it is desirable that these should be separately recorded.

IV.3.2 Extramural flows of funds

120. Essentially the term 'extramural' denotes a flow of R and D funds from one organisation or sector to another.

> Extramural flows can be identified in two ways:
> 1. As 'extramural expenditures' which are payments made for the performance of R and D outside a particular organisation or sector of the economy
> 2. As an 'extramural source of funds' for R and D performed within one organisation or sector using funds received from outside.

Such payments can take the form of contracts, grants or donations and they can be made in cash or kind (e.g. equipment made available to the performer).

121. It is, of course, as important to the science policy maker to know who supports R and D as who performs it and every effort must be made to trace these flows of R and D funds. For various reasons(1) the "source of funds" approach, which involves tracing the funds back from the reporting performer to the original source, is preferable.

122. When making a breakdown by source of funds, only those funds received for the performance of R and D should be considered as coming from outside the unit. Funds received from outside as a payment for other sales or services (e.g. profit on sales of serum, journals etc.) count as the own funds of the institute as do funds received from the sale of patents or licences.

123. However, problems rise when the money passes through several organisations. This can occur when R and D is subcontracted as is often the case in the Business Enterprise sector. The performer should indicate, as far as possible, the original source that provided the funds for R and D.

(1) See Chapter V paragraphs 148, 149.

124. In some countries an important part in the financing of R and D is played by intermediary non-performing organisations which receive grants which are not 'earmarked' for specific projects from several different sources and which distribute these funds among performers. Well known examples are the Stifterverband für die Deutsche Wissenschaft and the Deutsche Forschingsgemeinschaft in Germany. In such cases it is acceptable to regard these intermediary organisations as the source although it is preferable to attempt to retrace the funds to their original source such as a business enterprise.

125. For analytical purposes, however, extramural expenditure data may sometimes provide information which cannot be obtained from performers' reports of sources of funds. All organisations involved in R and D should be asked to report their extramural expenditures to 'abroad' and, where government finances a large share of national R and D, it is useful to draw on data from budgets, legislative appropriations and ministerial programmes since these data offer an advanced view of the likely use of government funds by other sectors and are available long before survey reports on the actual use of these funds are turned in.

IV.3.3 National aggregates and matrices concerning performers and sources of funds

126. If data is collected from respondents in each sector of the economy, on their intramural R and D expenditure during a given period broken down by sources of funds, aggregates can be made for each sector and for the country as a whole without double-counting. The major national R and D aggregate is:

Gross National Expenditure on Research and Experimental Development (GERD)

> GERD is total intramural expenditure for R and D performed on national territory during a given period

It includes R and D performed on the national territory with funds from abroad but it excludes payments to abroad for the performance of R and D (and R and D performance of international organisations within the country).

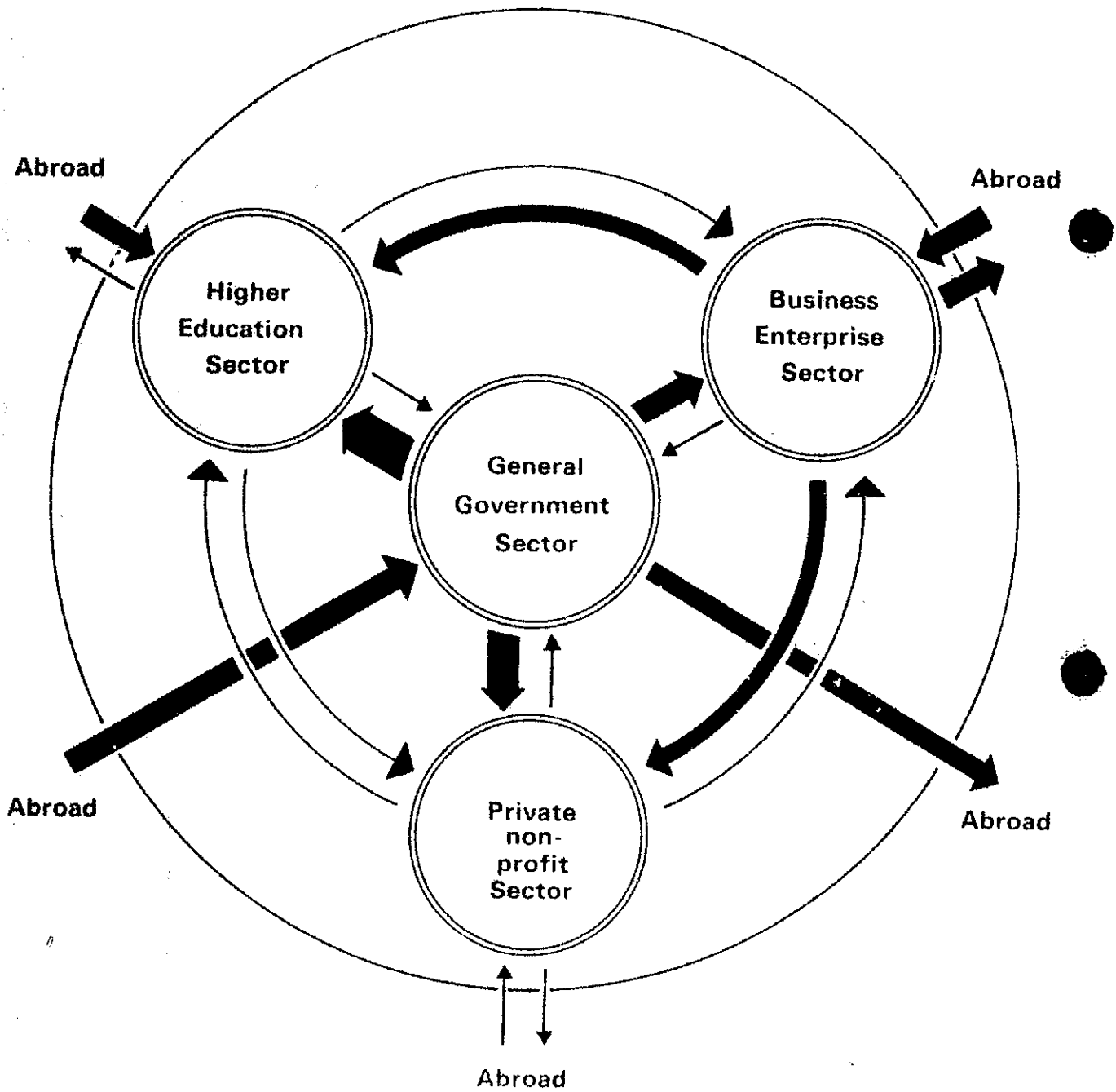
127. On the basis of the data on intramural performance of R and D collected in the different sectors, matrices can be constructed that show the role of each sector in the performance and financing of GERD (see tabulation 7 on page 49). Flows within the sectors do not appear in this table. The sum of R and D financed by and performed within the Business Enterprise sector, for example, includes both performers' own funds and funds received from other business enterprises that were used in the performance of R and D during the survey year. (See also Graph D).

## Tabulation 7

## Gross Expenditure on R and D within a Country

| Source of funds by sector | Sector of Performance | | | | Total |
|---|---|---|---|---|---|
| | Business Enterprise | General Government | Private Non-Profit | Higher Education | |
| Business Enterprise | | | | | Total financed by the Business Enterprise sector |
| General Government | | | | | Total financed by the General Government sector |
| Private Non-Profit | | | | | Total financed by the Private Non-Profit sector |
| Higher Education | | | | | Total financed by the Higher Education sector |
| Abroad | | | | | Total financed by Abroad |
| Total | Total performed in the Business Enterprise sector | Total performed in the General Government sector | Total performed in the Private Non-Profit sector | Total performed in the Higher Education sector | GERD |

Diagrammatic presentation of the possible flows of funds for R. & D. purposes.




D

128. Another interesting aggregate at national level is the sum of expenditure for R and D supported by a country excluding R and D financed from abroad and performed within the country but including payments for R and D performed abroad. The latter has to be based on the relevant extramural expenditures reported by financing organisations.

IV.4 Cross-classifications

129. For various reasons it is not possible to classify current and/or capital expenditure by all the systems described in Chapter II, (type of R and D), Chapter III (sector; industry group; product field; field of science; socio-economic objective). For instance, it is almost impossible to acquire complete data on capital expenditure for basic research since the fixed assets in question may be used for applied research as well. Tabulation 8 (see page 52) summarizes the practical possibilities of classifying R and D at the present state of the art.

IV.5 Classification by size

130. In addition to the systems of classification already considered, the analysis of R and D activities can be significantly improved by giving some structural size data. To facilitate international comparisons, such data should be given in a uniform manner, using the same size classifications. The size categories mentioned hereafter are recommended for the manpower data of the Business Enterprise sector. These manpower data may concern:

(a) the total number of employees;

(b) the number of employees engaged in R and D;

(c) the number of scientists and engineers employed in all activities;

(d) the number of scientists and engineers engaged in R and D.

Whenever possible the elaborated version should be used.

**Tabulation 8**

CHART OF THE PRACTICAL POSSIBILITIES OF CLASSIFYING R and D EXPENDITURE

| Expenditure Categories | Relevant functional classifications | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SECTION II | | | | SECTION III | | | | | | | | | | | | | | | |
| | Type of R and D | | | | Industry Group | | | | Product Field | | | | Field of Science | | | | Socio-economic Objective | | | |
| | Basic Re. | Applied Re. | Exp. Dev. | Total | Basic Re. | Applied Re. | Exp. Dev. | Total | Basic Re. | Applied Re. | Exp. Dev. | Total | Basic Re. | Applied Re. | Exp. Dev. | Total | Basic Re. | Applied Re. | Exp. Dev. | Total |
| Current expenditure | ← Possible → | | | | ← Possible → | | | | Not or rarely possible | ← Sometimes Possible → | | Not or rarely possible | ← Possible → | | ← Less Possible → | | Only possible as one Total | | | |
| Capital expenditure | ← Not or rarely possible → | | | Possible | ← Not or rarely possible → | | | Possible | ← Not or rarely possible → | | | Sometimes possible | ← Not or rarely possible → | | | Sometimes possible | | | | |

Size classification of manpower data (B.E. sector)

(Head Counts)

| Compressed version | | Elaborated version | |
|---|---|---|---|
| I | less than 50 | Ia | less than 25 |
| | | Ib | 25 - 49 |
| II | 50 - 99 | II | 50 - 99 |
| III | 100 - 499 | IIIa | 100 - 249 |
| | | IIIb | 250 - 499 |
| IV | 500 - 999 | IV | 500 - 999 |
| V | 1000 - 4999 | Va | 1000 - 1999 |
| | | Vb | 2000 - 4999 |
| VI | 5000 or more | VIa | 5000 - 9999 |
| | | VIb | 10000 or more |

131. In the case of R and D units in the General Government, Private Non-Profit and Higher Education sectors the following classification of manpower data is recommended for the groups a to d as mentioned in paragraph 130. In practice, there will be some difficulties in classifying university institutes.

Size classification of manpower data

(General Government and PNP sector, Higher Education sector, full-time equivalents)

(Head Counts)

| | | | |
|---|---|---|---|
| I | 0 | - | 9 |
| II | 10 | - | 24 |
| III | 25 | - | 49 |
| IV | 50 | - | 99 |
| V | 100 | - | 199 |
| VI | 200 and above | | |

132. For the analysis of R and D resources in the Business Enterprise sector it is recommended that the data should be classified by size of total employment of the firm or establishment in a manner as is shown in tabulation 9 (see page 55). If possible, classifications should be made at establishment level. When this is not possible the firm will have to indicate explicitly on which level of the unit the classification is based.

133. For the General Government, Private Non-Profit and Higher Education sectors the data should be given in the same way as in tabulation 9. However, in the first column the size classification should be by total R and D manpower and in the second column the number of the appropriate institutional units should be given.

## Tabulation 9

| Enterprise size by total employment | Number of enterprises | R and D expenditure in national currency | | | R and D manpower | |
|---|---|---|---|---|---|---|
| | | Current Exp. | Capital Exp. | Total | Scientists and Engineers | Total |
| (size groups) | | | | | | |
| Total | | | | | | |

# CHAPTER V

## Methods of Measuring R and D and the Need for Estimates and Adjustments

### V.1 Methods of compiling R and D data

134. There is no satisfactory substitute for a special survey. Whilst a certain amount of information about resources devoted to R and D can be obtained from regular publications, such as reports of research councils and government budgets, such data give only a very approximate measure of R and D efforts, firstly because the concept of "R and D" may vary considerably from the Frascati definition or may change over time and secondly, because it is extremely difficult to track down flows of funds from financial statements without incurring double counting.

135. The first question is to decide what institutions are to be surveyed. In most countries it is possible to draw up a list of institutions in the Government, Higher Education and Private Non-Profit sectors which are likely to be performing or financing R and D whilst in the Business Enterprise sector it is normal to survey all large firms and those receiving government contracts plus a specially chosen stratified sample of the remainder. The extent to which sampling is necessary will depend on the size and number of units involved. In the Business Enterprise sector it may be useful to start with a preliminary survey to identify firms performing and/or financing R and D to whom full questionnaires in a total or sample survey can then be sent.

136. A survey stands or falls by its questionnaire which should be clearly and logically laid out, contain the minimum number of questions supplemented by definitions, examples and any special instructions relevant to the sector and the country involved.

137. The extent to which follow-up procedures are used will depend on the level and quality of response, the number of units surveyed and the resources available to the surveying authority. It is rarely possible to make personal contact with all the units surveyed. One possibility is to plan a follow-up programme for a number of enquiries, aiming to visit all the main units over a given period. Another is to limit the follow-up to a sub-sample, checking a few organizations very thoroughly. This does not, of course, preclude making personal contact with respondents who request guidance or who submit incoherent returns.

## V.2 The need for estimates and adjustments

138. The measurement of R and D activities involves a good deal of estimation. It is impossible to make detailed recommendations which would apply in every case. Both the criteria that have been proposed and actual practice leave a good deal to the survey authorities. The latter will be the final judges in deciding if definitions have been properly understood and respondents (performers and financers) have used the same methods for estimating.

### V.2.1 Estimates to be made by the respondent

139. There are many institutional links between R and D and related activities. University departments, besides being units of higher education, are also performers of R and D and may be engaged in a number of other scientific activities as well. Industrial R and D departments often also perform such functions as technical sales service, production control, routine testing while, on the other hand, some development work is carried on in production units. Thus R and D is not just what R and D units do. It is both less and more than this since it is unlikely that all the institutes surveyed have only one activity. R and D cannot be measured by adding up the statistical records of the institutions.

140. Wherever a unit's activity is divided between two or more major functions, the respondent should be asked to exclude non-R and D activity. Activities which are minor in relation to the main body of work of the unit may, for practical reasons, be ignored as long as the resulting distortion is likely to be slight.

141. The measurement of R and D may involve three stages:

(a) Identification and measurement of total activity of all specialised research units;

(b) Subtraction from this total of that portion of their activity which is non-R and D;

(c) Addition to this total of any R and D activity performed outside research units, for instance, in production units, educational departments, hospitals.

#### Expenditure estimates

142. The respondent should report the aggregate full cost of the organisation's R and D projects. To get this figure he will often have to do a substantial amount of estimating and adjusting since

- in most organisations, accounting systems are geared to organisation units rather than to activities;

- even where organisational units are narrowly specialised, the R and D unit may share certain facilities with other units;

- some cost items may be carried on different budgets;

- only the expenditures actually incurred during the reporting period should be reported; often this means dividing the total expenditure on a particular project between two or more years;

- personnel may divide their time between R and D and other activities.

143. As far as current expenditure is concerned, the necessary adjustments will often have to be made on the basis of the distributon of man-hours between the different activities. It should be emphasized in the instructions that the percentages should be applied not only to salaries and wages but to all other items of current cost, including a share of overheads.

144. In the case of capital expenditures, shared facilities present some special problems. When a university building, equipment or instruments are used exclusively either for research or for teaching, then the expenditure can be allocated accordingly, but where equipment, instruments or buildings are used for both research and teaching then the proportion of utilization should be estimated approximately according to manhours (or machine-hours). When this is not practicable, the expenditure should be allocated according to the predominant use. Similar considerations apply in other institutions where capital equipment is shared with non-R and D users. Care should be taken not to overlook capital items carried on a different budget. In some countries, for instance, all building expenditures of government agencies are carried on the budget of the Ministry of Public Works.

Manpower estimates

145. The number of man-hours devoted to each function within an R and D unit should, wherever possible, be converted into "full-time equivalence", when measuring R and D activities in terms of manpower.

Example

An industrial research department employs 80 scientists and engineers who work full-time on R and D plus 15 others who spend a third of their time on technical services and only two-thirds on R and D. The "full-time equivalent" employment of scientists and engineers on R and D is:

$$80 + (15 \times 2/3) = 90$$

V.2.2 Estimates and adjustments by the surveying agency

145. Even if the optimal questionnaire has been used and has been supplemented by efficient follow-up activities, the surveying agency may find gaps and inconsistencies in the data when compiling sectoral and national totals.

147. For instance, whilst it is theoretically necessary for all respondents to give the original source of their funds, many may not be in a position to do so.

148. The reports on one and the same transaction made by the financing organisation and by the performer are likely to differ because of varying referents periods, book-keeping practices, methods of estimation and interpretations of concepts. A government agency may report funding action under legislative appropriations for a fiscal year, whereas a firm under contract may report funds actually spent over a calendar year. The financing organisation may consider the whole of a contract as "development" whereas the performer correctly reports only that portion of work that carries an element of novelty. On the other hand, the performer may have omitted the estimated money value of support received in kind.

149. There are thus sources of errors on both sides but, as a rule, the performer is in a much better position to make the estimates and adjustments. There are other practical reasons for relying primarily on reports by performers of their intramural expenditure rather than on financers' reports of extramural expenditure. Insofar as they finance R and D out of own funds, performers have to be surveyed anyway. Sources of funds located abroad cannot be surveyed. The performer approach keeps the risk of double counting to a minimum because a given sum of money cannot be finally spent on R and D by more than one performer at a time. It has the additional value of yielding intramural expenditure which can be related to figures on intramural employment of scientists and engineers.

150. A special problem is posed when institutions in the Higher Education sector ar unwilling or unable to estimate a breakdown of expenditure between teaching and R and D. In such cases rough estimates should be made, if possible, after consultation with experts in the field, on the basis of the university accounts.

151. Another problem is that university R and D units when giving their sources of funds normally count only research contracts and other 'earmarked' funds as coming from the outside and count all remaining funds as 'own funds'. Actually, using the principle of 'original source', publicly financed

universities may have little or no 'own funds'. Therefore, in most countries, all non-specified funds of such universities will be credited to the state. But in some countries, where the decision to spend part of the general subsidies, including those of the government on R and D is wholly taken at the university level, it may be necessary to credit all non-specified funds of such universities as their 'own funds' (cf. also paragraph 125).

152. Because of these difficulties in measuring R and D activities in the Higher Education sector and the variation in approaches used in different Member countries, it would be useful for purposes of international comparison if data were also collected on total manpower and total expenditure on all activities in the sector.

# CHAPTER VI

## Relation of R and D Data to Other Economic Variables and International Comparison of R and D Expenditure

### VI.1 Comparing R and D data with other economic variables

153. As R and D plays a major role in the scientific and technological advance of a country it also affects its economic growth potential. The science-policy maker needs, therefore, R and D data which can be compared with other types of statistics in order to examine the relationship with certain economic variables. It is for this reason that the standards laid down in this manual have, as far as possible, been based on accepted international classifications and especially on the System of National Accounts.

154. Wherever appropriate in this manual, deviation between O.E.C.D. and S.N.A. definitions have been noted. However the following are the most important and are worth repeating:

(a) The creation in the manual of a separate Higher Education sector, whereas in the S.N.A. institutions of higher education may be included in the other sectors.

(b) The exclusion of depreciation from current expenditure whereas the S.N.A. states that it is included.

(c) The inclusion of acquisition of "land" as capital expenditure whereas it is considered as a tangible non-reproducible asset in the S.N.A.

155. Comparisons with figures on industrial production should be made on the basis of the International Standard Industrial Classification. In comparing R and D expenditure with international trade data, it should be remembered that the latter are based on a classification by product or product group. It is also important to check beforehand that the sets of data to be compared are organised in the same manner.

156. Certain ratios such as

R and D expenditure/Gross National Product or

R and D expenditure/value added,

should be used with circumspection. When making inter-industry group comparisons, the influence of such factors as indirect taxation and depreciation on these two economic variables should not be forgotten. Indeed, indirect taxes,

which differ greatly from industry to industry, tend to increase the value added in each industry. The wage rates in effect in the different branches of economic activity (agriculture, mining, manufacturing) have a similar effect. On the other hand, the subsidies granted to certain branches for economic or social reasons enable producers and manufacturers to lower their sales price and as a consequence, reduce the value added. To cancel out the influence of indirect taxation and subsidies, value at factor cost rather than at market price is generally used. Lastly, depreciation, calculated at various rates in different industries, contributes to the distortion of comparisons.

VI.2 The research exchange rate

157. In order to make international comparisons of expenditure on R and D more useful, it is necessary to convert each country's expenditure into a common currency such as the United States dollar.

158. This raises the problem of what exchange rate should be used. The official exchange rate is based on external trade and money markets and does not necessarily reflect the domestic price level of countries or the real cost of research and development activity. This dichotomy between internal prices and the exchange rate is, in general, most significant when comparing North America and European Member countries and again between Europe and Japan. When making international comparisons it would be preferable to use a special "research exchange rate".

Information required

159. In order to calculate useful 'research exchange rates' it would, for example, be necessary to have information on the prices or quantity for:

(a) labour costs,

(b) other current expenditure,

(c) capital expenditure.

Since this kind of information is almost unavailable it is extremely hard to calculate these exchange rates, as is shown in Appendix II.

Conclusion

160. If meaningful "research exchange rates" are to be calculated by the O.E.C.D., a real effort will be needed on three fronts:

(a) refinement in the collection of the national R and D data;

(b) collection of general price data, for instance on wage levels, fuel and power etc.;

(c) special surveys of prices and at least a sample of quantities of materials and equipment in the various fields of R and D in Member countries.

## APPENDIX I

### Measurement of the Output of R and D and the Balance of Technological Payments

1. The measurement of the output of R and D is not treated in this manual. There is, in fact, no accepted system of measuring the results of research either at national or at international level, nor does it, at the present time, seem possible to frame such a system(1). The most that can be hoped for is that in 10-20 years time some form of statistics on output will be available. There is, however, one measure which, though quite separate from R and D data, may give some indication of the technological situation of a country at international level, that is the balance of technological payments.

2. Payments for patents, licenses and technical know-how are a separate category which should be clearly distinguished from all R and D extramural and intramural expenditure. Although they are a separate category and often neglected, they are extremely important. It is evident that no single country can lead simultaneously in all spheres of R and D. Nor can any business enterprise be permanently ahead of all its competitors. Each country (or enterprise) will wish to 'import' some of the results of R and D already performed elsewhere. This applies with particular force to small countries (or enterprises), where size is itself a limiting factor, and also to underdeveloped countries and technologically backward industries, but it is also true of the largest countries such as the United States and U.S.S.R.

3. Consequently, it is desirable to obtain some measure, however imperfect, of the transfers of research results and technical know-how from one country to another. Some rough indication of the magnitude of the "Balance of Technological Payments" for any individual country can be obtained by collecting information on patent, license and "know-how" expenditure. These statistics have two advantages. Firstly, they are "weighted" by the valuation placed by the world market on a particular patent or licence, even though the market is very imperfect. Only inventions of some economic significance will be the subject of licensing arrangements. Secondly, they include expenditure on inventions and developments which are not patented for a variety of reasons. This expenditure takes the form of payments for "technical know-how" and there is very little doubt that it is increasing rapidly.

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(1) Measurement of the Output of Research and Experimental Development UNESCO 1969.

4. For all these reasons a measure of this flow of funds at international level is desirable. There are, however, serious defects in those statistics relating to the transfers between associated companies. In some cases these are paid for in the normal way as market transactions but in other cases there are probably delayed, fictitious payments or even inflated payments.

5. In some cases statistics on payments and receipts for patents, licences and know-how to and from abroad are obtained quite independently of R and D surveys, for example, as a type of invisible transactions from balance of payments statistics or by patent offices. If these statistics are sufficiently comprehensive, it may not be necessary to include these questions within the framework of an R and D survey. But in most cases it will be necessary, as it is desirable to obtain the figures with the same sector and industrial breakdown as R and D statistics.

## APPENDIX II

### Pioneering Efforts in Calculating Research Exchange Rates

1. The statistical method used in calculating research exchange rates is essentially similar to those involved in international comparison of national products which were developed at the O.E.E.C. in the 1950's(1). The costs of the items in the typical basket of goods of country A is calculated at the prices of country B and their sum compared with the original cost in country A. Similarly, the typical basket of goods of country B is compared at its price in A and its price at home. The two resulting ratios are averaged and the ratio applied to the official exchange rate to give "purchasing power equivalent" for the field in question(2).

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(1) Milton Gilbert and Associates, Comparative National Products and Price Levels O.E.E.C., 1958, see particularly Chapters VIII and XII.

(2) The mathematical formula is the following:

$$\frac{PA}{PB} = \frac{\sum_{i=1}^{n} PiA \; QiA}{\sum_{i=1}^{n} PiB \; QiA} \Bigg/ \frac{\sum_{i=1}^{n} PiA \; QiB}{\sum_{i=1}^{n} PiB \; QiB}$$

Given - 1...,i...n, the indices of the various items etc.

- A and B the specific price indices for the two concerned countries
- Pi the price of one unit of component "i" in country A
- Qi the actual number of "i" units

2. The method has two linked disadvantages. The first is that it yields two results and, therefore, it might be useful to use some method of averaging. It is a matter of discussion whether the arithmetic mean, the geometric, or a combination of the two should be used. Secondly, the method is not transitive. Countries can only properly be compared in pairs. If we calculate a 'purchasing power equivalent' between country A and country B and country A and country C, we cannot, properly speaking, use these results to draw any comparisons between country B + country C. In practice, then, we cannot use the calculations directly to find a ratio between countries B + C but must repeat the operation in each instance.

3. The first efforts to apply this method of comparison of R and D efforts were made by C. Freeman. The first calculation was published in the National Institute of Economic and Social Research review of 1962 and covers a comparison between R and D expenditures in the Business Enterprise sector in the United Kingdom and the United States in 1958/59. In this case the basket of goods was the total R and D expenditure of the Business Enterprise sector and the items: labour costs, materials and equipment and other costs. It was presumed that the price of labour in the United States was three times as high as in the United Kingdom, and that the price of materials and equipment was the same in the two countries and that the prices of other cost components (including depreciation) were 2.½ times as high as in the United Kingdom.

4. The calculation is as follows:

| | USA Exp. of B.E. sector 1958/59 $(P_s \times Q_s)$ | | | | US Exp. at UK Prices $(P_k \times Q_s)$ |
|---|---|---|---|---|---|
| i. Labour cost | 4982 | ÷ | 3 | = | 1,660 |
| ii. Materials and equipment | 1692 | ÷ | 1 | = | 1,692 |
| iii. Other costs | 2726 | ÷ | 2.½ | = | 1,090 |
| | 9400 | | | | 4,442 |

∴ Comparison at US weights = $\frac{9400}{4442}$ = 2.12 or $5.94 to £

| | UK Exp. of B.E. sector 1958/59 ($P_k$ x $Q_k$) | | | | UK Exp. at US Prices ($P_s$ x $Q_k$) |
|---|---|---|---|---|---|
| | £ | | | | £ |
| i. Labour cost | 121 | x | 3 | = | 363 |
| ii. Material and equipment | 60 | x | 1 | = | 60 |
| iii. Other costs | 93 | x | 2.½ | = | 233 |
| | 274 | | | | 656 |

Comparison at UK weights = $\frac{656}{274}$ = 2.39 or $6.70 to £

Arithmetic average : $ to £ = 6.3

5. Freeman again used basically the same method in his international comparison(1) for 1962 of seven countries, United States, Belgium, France, Germany, the Netherlands, United Kingdom and the U.S.S.R. The price/weight (total expenditure) data used were again expenditure in the Business Enterprise sector (except for Germany) and in order to find the final rate, an arithmetic average of the geometric and arithmetic averages of the original results was used.

6. The implications of the use of "research exchange rates" were clear. On an adjusted basis, the amount of financial resources devoted to R and D in European Member countries was higher in comparison with the United States.

7. It had originally been intended that similar "research exchange rates" should be calculated as part of the I.S.Y. 1963/64 exercise. However, as there was an extremely low response to the questions on wages of technicians and supporting staff, included in the questionnaire, and as the source upon which Freeman had drawn was out of date, it was not possible to update the Freeman ratios or to calculate ratios for Member countries not covered. The following paragraphs suggest some further means of obtaining and evaluating data for estimating "research exchange rates".

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(1) The Research and Development Effort in Western Europe, North America and the Soviet Union C. Freeman and A. Young, O.E.C.D., 1965.

Labour costs

8. In surveys where manpower and expenditure data are collected simultaneously and where labour costs are broken down into several classes (e.g. cost of Q.S.E., cost of technicians and supporting staff), one can approach the problem via Q and P x Q (unlike the approach already described where one knows a ratio of P's and P x Q). The material drawn from national surveys is probably not sufficiently detailed or internationally comparable to allow this approach but it is possible where international surveys have been made of similar units, such as the study by Brunner(1), which gives information on the quantity of R and D manpower (Q.S.E., technicians, other workers) and on the actual labour expenditure (on Q.S.E., on technicians, on other workers) per Q.S.E. The expenditure of a research team in country A (= 1 Q.S.E. + supporting staff) can thus be calculated at B's prices and compared with actual cost in A. Similarly, the cost of a B team can be calculated at A prices and compared with actual cost in B and an arithmetic average of the two ratios taken.

9. In the absence of international surveys it is necessary to proceed, as did Freeman, via price ratios. Whilst a certain amount of information is available on wages of scientists and engineers, technicians and workers, the problem remains to decide what is a "typical" member of each group and how to weight the groups. The latter problem is particularly difficult when scientists' salaries are surveyed separately from those of engineers.

Other costs

10. Other costs, which here include all current expenditure except labour costs plus capital expenditure, can be divided into three kinds:

(a) Specific to R and D (materials and equipment)

Materials and equipment vary, not only in price and quantity, but also in kind between fields of science and type of R and D activity.

(b) Dependent on general wage levels (maintenance, repairs, canteen facilities, administration costs)

(c) Dependent on national rates (gas, electricity, water, telephone etc.)

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(1) "The Cost of Basic Scientific Research in Europe", Department of Defence Experience 1956/66, E.D. Brunner, RM 5275 PR, The Rand Corporation, Santa Monica, California, 1967.

11. Whilst it may be possible to obtain information on prices for classes (b) and (c) from international publications or, failing that, from national publications, class (a) 'materials and equipment' raises special problems. Freeman assumed that the cost of materials and equipment was the same in the United States as in Europe. It is not clear how far this could be considered true (1) between Europe and Japan and (2) between European Member countries (if such refinements are to be used).

## APPENDIX III

## Classification by Field of Science as used by the United States' National Science Foundation

| CODE | | |
|---|---|---|
| | **PHYSICAL SCIENCES** | |
| 11 | Astronomy: | Laboratory astrophysics; optical astronomy; radio astronomy; theoretical astrophysics; X-ray, gamma-ray, neutrino astronomy. |
| 12 | Chemistry: | Inorganic; organometallic; organic; physical. |
| 13 | Physics: | Acoustics; atomic and molecular; condensed matter; elementary particles; nuclear structure; optics; plasma. |
| 21 | Mathematics: | Algebra; analysis; applied mathematics; computer science; foundations and logic; geometry; numerical analysis; statistics; topology. |
| | **ENVIRONMENTAL SCIENCES (TERRESTRIAL & EXTRATERRESTRIAL)** | |
| 31 | Atmospheric sciences: | Aeronomy; solar; weather modification; extraterrestrial atmosphere; meteorology. |
| 32 | Geological sciences: | Engineering geophysics; general geology; geodesy and gravity; geomagnetism; hydrology; inorganic geochemistry; isotopic geochemistry; organic geochemistry; laboratory geophysics; paleomagnetism; paleontology; physical geography and cartography; seismology; soil sciences. |
| 33 | Oceanography: | Chemical oceanography; geological oceanography; physical oceanography; marine geophysics. |
| | **ENGINEERING** | |
| 41 | Aeronautical: | Aerodynamics. |
| 42 | Astronautical: | Aerospace; space technology. |
| 43 | Chemical: | Petroleum; petroleum refining process. |

| | | |
|---|---|---|
| 44 | Civil: | Architectural; hydraulic; hydrologic; marine; sanitary and environmental; structural; transportation. |
| 45 | Electrical: | Communication; electronic; power. |
| 46 | Mechanical: | Engineering mechanics. |
| 47 | Metallurgy and materials: | Ceramic; mining; textile; welding. |
| 49 | Engineering NEC: | Agricultural; industrial and management; nuclear; ocean engineering; systems. |

LIFE SCIENCES

Note: The Life Sciences include the following disciplines:

Anatomy; animal sciences; bateriology; biochemistry; biogeography; biological oceanography; biophysics; dentistry; ecology; embryology; entomology; evolutionary biology; genetics; immunology; internal medicine; microbiology; neurology; nutrition and metabolism, opthalmology; parasitology; pathology, pharmacology; pharmacy; physical anthropology; physical medicine and rehabilitation; physiology; plant sciences; podiatry ; preventive medicine and public health; psychiatry; radiobiology; radiology; surgery; systematics; veterinary medicine.

Research in some of these disciplines may be classed as biological, clinical medical or other medical, depending upon the nature of the particular project. Reference should be made to the following definitions in the classification of data on the funding of research in the Life Sciences:

| | | |
|---|---|---|
| 51 | Biological: | Those sciences which, apart from the clinical medical and other medical sciences as defined below, deal with the origin, development, structure, function and interaction of living things. |

| | | |
|---|---|---|
| 52 | Clinical Medical: | Study of the pathogenesis, diagnosis or therapy of a particular disease or abnormal conditions in living human subjects under controlled conditions. |
| 53 | Other Medical: | Studies of the causes, effects, prevention, or control of abnormal conditions in man or in his environment as it relates to health, except for the clinical aspects as defined above.<br><br>(The above three classes exclude the psychological sciences as defined elsewhere). |

PSYCHOLOGY

| | | |
|---|---|---|
| 61 | Biological aspects: | Experimental psychology; animal behaviour; clinical psychology; comparative psychology; ethology. |
| 62 | Social aspects: | Social psychology; educational, personnel, vocational psychology and testing; industrial and engineering psychology; development and personality. |

SOCIAL SCIENCES

| | | |
|---|---|---|
| 71 | Anthropology: | Archaeology; cultural and personality; social and ethnology; applied anthropology. |
| 72 | Economics: | Econometrics and economic statistics; history of economic thought; international economics; industrial, labour and agricultural economics; macroeconomics; microeconomics; public finance and fiscal policy; theory; economic systems and development. |
| 73 | History: | Cultural; political; social; history and philosophy of science. |
| 74 | Linguistics: | Anthropological-archaeological; computational; psycholinguistics; sociolinguistics. |

| | |
|---|---|
| 75 Political science: | Area or regional studies; comparative government; history of political ideas; international relations and law; national political and legal systems; political theory; public administration. |
| 76 Sociology: | Comparative and historical; complex organisations; culture and social structure; demography; group interactions; social problems and social welfare, sociological theory. |
| 77 Social sciences NEC: | Research in law and education NEC; socio-economic geography. |
| 99 OTHER SCIENCES NEC | To be used for multidisciplinary and interdisciplinary projects which cannot be classified within a primary field. |

## APPENDIX IV

## Recommendations for the Lay-Out of the National R and D Publication

1. It is obvious that, when preparing national R and D publications, the primary consideration will be to publish the data of a type and in the layout which will be of most interest to the national reader. However, national publications are often used as a source for international comparisons and, in order to avoid the misuse of data, it is recommended that publications in Member countries should contain the following in one of the official O.E.C.D. languages:

(a) a detailed quality description
(b) a summary text of main results
(c) a glossary of table headings and table text columns
(d) translations of the footnotes to the tables.

Preferably items (c) and (d) should be published in the tables.

### Quality description of the R and D statistics

2. In analysis, it is indispensable to have information on:

(a) coverage and precision of the R and D statistics
(b) deviations (if any) in definitions and concepts from the standards laid down in the manual. When this information is available, misleading comparisons can be avoided and the risk of false conclusions diminished considerably.

3. Quality description data:

A. For each sector, specify as far as possible the following:

A.1 Sector definition

(1) Specify deviations from the manual and indicate their quantitative importance.

(2) Indicate if deviations described in (1) are consistent with national NA practices or not.

(3) Specify important borderline cases and indicate their quantitative importance.

A.2 Sources of information

(1) Survey (specify if by mail and/or by personal interview, add copy of national questionnaire)

(2) Indirect information (specify sources)
Example: Government budget data.

Note: If indirect information is utilised as well as survey, indicate the proportion of the sector covered by each type.

A.3 Coverage

(1) Total survey
(2) Cut-off total survey (specify cut-off point and indicate magnitude of coverage)
(3) Sample survey
(4) Indirect information (indicate magnitude of coverage).

Note: Specify for each of (1) - (3) the relevant data on:

(a) sample design
(b) response data and estimation method(s) including method of imputation for non-response.

B. For each group of variables, specify as far as possible the following:

B.1 Deviation from the definitions in the manual

Example: Classification by industrial branch.

B.2 Data mainly received from:

(1) Accounts of respondents
(2) Budgets of respondents
(3) Other information supplied by respondents
(4) Other external sources (specify).

B.3 Estimates made by collecting agency

(1) Imputation of missing data (specify method)
(2) Transformation of data to proper time (specify method).

C. Editing techniques

It may also be useful to indicate which of the following editing techniques have been used:

(1) Cross-checks of sector classification of units with the NA classification.

(2) Checks on internal consistency of reported data (a) cross-wise, (b) length-wise.

(3) Cross-checks of transfer data between financing and performing units.

(4) Checks of R and D with other information (specify).

Example: Wage rates and wage changes according to R and D statistics compared to general wage statistics.
R and D capital investments compared to total investment by enterprise.

4. Summary and glossary

The usefulness of national publications to foreign consumers of R and D statistics is - as a rule - seriously limited by language difficulties. For this reason a summary and a glossary in one of the official O.E.C.D. languages would be most useful. Furthermore, a summary often is of considerable value to domestic consumers.

# I N D E X

Subjects in the main body of the Manual are indexed by paragraph numbers. Subjects in the Appendices are given the prefix "Appx". Thus, Appx. II.2 refers to paragraph 2 in Appendix II.