INTERNATIONAL LABOUR OFFICE

MEETING OF EXPERTS ON RESPIRATORY FUNCTION TESTS IN PNEUMOCONIOSES
(Geneva, 20-28 September 1965)

REPORT

Corrigendum

Document RFTP/1965/8(rev.) last page: the Russian terminology should be replaced by the following text:

Остаточный объем
Функциональная остаточная емкость
Общая емкость легких
Резервный объем вдоха
Дыхательный объем
Резервный объем выдоха
Жизненная емкость легких
Объем форсированного выдоха за первую секунду
Максимальная вентиляция легких.
Sixth Item on the Agenda

REPORT OF THE MEETING OF EXPERTS ON RESPIRATORY FUNCTION TESTS IN PNEUMOCONIOSES
(Geneva, 20-28 September 1965)

1. The Meeting of Experts on Respiratory Function Tests in Pneumoconioses convened in accordance with decisions taken by the Governing Body was held in Geneva from 20 to 28 September 1965.

2. The report of the Meeting is being distributed now in order to enable members of the Governing Body to study its contents as soon as possible.

3. In view of the relatively short interval between the end of the Meeting of Experts and the beginning of the present Governing Body session, it is suggested that the Governing Body should take no action on the attached paper at its present session but that it should consider it at its next session, scheduled for February-March 1966.

Sixth Item on the Agenda

REPORT OF THE MEETING OF EXPERTS ON RESPIRATORY FUNCTION TESTS IN PNEUMOCONIOSES

(Geneva, 20-28 September 1965)

1. In accordance with the decision taken by the Governing Body at its 160th Session (Geneva, November 1964) a Meeting of Experts on Respiratory Function Tests in Pneumoconioses was held in Geneva from 20 to 28 September 1965. As decided by the Governing Body, the Meeting was attended by nine experts, one of whom was chosen after consultation with the Employers' group and one after consultation with the Workers' group. The W.H.O. and the High Authority of the European Coal and Steel Community were represented at the Meeting.

2. The agenda of the Meeting, as approved by the Governing Body, was as follows:

1. Pneumoconioses and the respiratory function:
   
   (a) disorders which may be evaluated by respiratory function tests;

   (b) classification of pneumoconioses according to the type of respiratory disorder which is prevalent.

2. Review of the respiratory function tests used in the examination of persons suffering from pneumoconiosis.

3. Tests to be recommended internationally for the assessment of the respiratory function in pneumoconioses and the techniques for carrying out such tests.
4. Criteria to be adopted for the interpretation of the results of these tests with a view to their international comparability.

3. In the course of the general discussion, the experts stressed the role of respiratory function tests in detecting anomalies in the respiratory function caused by dust inhalation, in following their course and in assessing disability. The experts noted that inhalation of dust also had marked effects on pulmonary circulation, on the nerve centres controlling respiration, on the respiratory muscles, and on other systems and organs. However, they decided to confine their attention mainly to changes in the function of the lungs and to discuss the effects of inhalation of mineral and vegetable dusts. They further agreed to consider the possibility of using tests either at the workplace or in centres specially equipped for medical investigation.

Pneumoconioses and Respiratory Function

4. In certain circumstances, the inhalation into the lungs of mineral or vegetable dust of industrial origin may give rise to pneumoconiosis. The presenting features of the condition will vary with the type of dust, the length and severity of exposure, and the susceptibility of the individual, and may also be influenced by other factors. In some pneumoconioses the function of the lungs is quite unaffected by the presence of dust foci visible on the chest radiograph, for example in stannosis. In other forms, the function of the lungs is normal to start with and then progressively deteriorates as the quantity of dust and/or pathological lesion increase, for example in kaolinosis, simple pneumoconiosis of coal workers and moderately advanced silicosis. In other mineral pneumoconioses and in some vegetable pneumoconioses the changes are not necessarily related to the severity of the changes on the chest radiograph.

5. The disturbance of lung function in the early stages of pneumoconiosis usually takes one of two forms - either a reduction in breathing ability, that is to say ventilatory capacity, or an impairment of the processes of gas exchange. Either condition may progress to include the other at a later stage. Impaired ventilatory capacity may be due primarily to obstruction or narrowing of the airways (obstructive syndrome) or to diminished lung expansion (restrictive syndrome). Impairment of the process of gas exchange, when it occurs, may be the result of abnormal distribution of pulmonary ventilation and perfusion, or due to loss of alveolar surface and pulmonary vessels for the transfer of gases in the lung. These conditions are usually associated with characteristic changes in lung function, including the occurrence of increased ventilation and arterial blood gas abnormalities on standard exercise.
Review of Respiratory Function Tests

6. For convenience of assessment the function of the lungs may be divided into the ventilatory function, the gas-exchange function and lung perfusion. These in turn may be subdivided into a number of components. The components which influence the ventilatory function include the size of the lungs (lung volumes), their distensibility (compliance) and the calibre of the airways (airway resistance); these components, together with the properties of the chest wall, largely determine the ventilatory capacity.

7. Under the heading of gas exchange the major components of function include the distribution of gas and blood to the different parts of the lungs (mixing indices and ventilation perfusion relationships) and the capacity to transfer gas across the alveolar capillary membrane (transfer factor or diffusing capacity). These components contribute to the gaseous composition of the arterial blood (blood gases) and hence to the drive to respiration from the respiratory centres in the brain.

8. Among the criteria to be taken into account in selecting lung function tests, the experts mentioned the following:

Acceptability: the test should be safe and simple for the subject.

Objectivity: so far as possible the information which is obtained should be independent of the instruments used to make the measurement, the motivation of the subject and the personality of the operator.

Reproducibility: the measurement should have, on the same subject, a variability which is small in relation to its absolute magnitude.

 Discrimination: the test should describe an attribute of function which may become impaired during the course of a particular disease.

9. The experts stressed the importance of exercise tests in revealing inadequacies of lung function not readily detectable at rest; such tests also provide a means of simulating conditions of breathlessness such as the subject may experience during physical work. The experts discussed how these tests should be carried out; while specifying that it was not at present desirable to state precisely the procedure to be followed in making the tests, they recommended that a number of indices should be obtained regarding ventilation and expired gas, blood gases and their distribution, and the accompanying effects on circulation and the heart.
Disorders which may be Evaluated by Respiratory Function Tests

Syndromes of Lung Function

10. The function of the lungs in pneumoconioses reflects both the underlying pathology and the changes associated with other conditions, including chronic bronchitis, emphysema and cardiac failure.

11. The experts noted that these syndromes of abnormal lung function could be identified by application of lung function tests, and that the early detection of signs of respiratory impairment of any type was of the greatest importance, but often difficult in practice.

Pneumoconioses

12. The experts discussed the criteria to be applied in making a study of workers exposed to dust inhalation. They considered in detail the changes in lung function which occur in silicosis, pneumoconiosis of coal workers, siderosis, asbestosis, byssinosis, berylliosis and farmer's lung, and indicated, for each of these diseases, which features of lung function were most generally affected.

Applications in Occupational Health

13. Tests of lung function may be of use in the prevention, clinical management and certification of pneumoconioses. These different applications make use of essentially the same tests, but the emphasis is different.

14. Prevention. In so far as suppression of dust is incomplete, there is a place for pre-placement and periodic examinations with a view to safeguarding those who may be unusually susceptible and protecting those who show early effects of exposure. Tests of lung function have a place in these examinations. In addition, where it is intended to establish or define safe conditions, it is necessary to conduct a biological calibration of the environment by assessing its effect on the lungs of those who are exposed to risk.

15. Clinical Management. Lung function tests are particularly useful in the diagnosis of cases where there are characteristic changes. They also make it possible to assess the severity of the disease in all cases. Moreover, such tests are indispensable for the application of certain types of treatment, and they are of great value in the assessment of prognosis in patients with pneumoconiosis and its complications.
16. **Assessment of Disability.** Procedures for assessment are usually based on a number of features, including the industrial history, chest radiograph, clinical symptoms and findings on clinical examination, assessment of lung function and clinical pathology, as well as evaluation of capacity for exercise. In this context the experts noted that the tests provide a means of describing the lungs in terms of functional syndromes: the existence of an appropriate functional syndrome in a subject with a positive industrial history will permit a presumptive diagnosis of pneumoconiosis.

**Screening Tests**

17. The experts recommended that the preliminary screening tests which can be made at the workplace should always include the measurement of forced expiratory volume \( (F.E.V._1) \) and, where possible, the vital capacity \( (or \text{forced vital capacity}) \) and possibly the peak flow. The measurement of respiratory frequency and measurements derived from inspiratory and expiratory chest radiographs may also provide useful information. At the second stage, in addition to the preliminary screening tests listed above, a number of other tests may be applied in the vicinity of the workplace. These include measurement of lung volumes, distribution of ventilation, perfusion and exercise tests. In the latter context, the experts noted that a simple exercise test may provide valuable information and be of use in the absence of facilities for more complete assessment.

**Further Tests**

18. The experts recommended that specialised laboratories should be set up in all countries to make more detailed examinations of lung function, as specified in their report.

**Criteria for Interpretation of Results**

19. As regards the criteria for interpretation of results, the experts stressed the importance of the following points: standardisation of techniques, as indicated in their report; calibration of equipment; standardisation of conditions of measurement; biological calibration of equipment; reporting results. They also stressed the importance of the definition of "normal" values and indicated the factors which should be taken into account in order to determine the exact significance of these values.
Conclusions

20. The experts recommended that data concerning normal values should be obtained by standard methods from all parts of the world and expressed the hope that the I.L.O. would be able to undertake this task, in co-operation with the W.H.O. and the International Biological Programme.

21. They considered that, for certain pneumoconioses, the time had come to make a synthesis of the accumulated experience of scientists in different countries and expressed the hope that this synthesis would be made under I.L.O. auspices.

22. The experts considered that, for certain trades, lung function tests should form part of the pre-employment and periodic examinations.

23. They also recommended that such tests should be used in assessing disablement due to pneumoconiosis and that the practice of the various countries in this respect should be studied. They further pointed out that it would be useful to collect information concerning the assignment of workers with respiratory impairment to certain types of work. These questions should be studied by the I.L.O.

24. The experts recognised that some tests of lung function were not yet practicable for countries with limited technical resources. They suggested that the I.L.O. should consider how this difficulty could be overcome by the provision of additional help, including medical and technical advice and training in the proper use and maintenance of equipment.

25. Finally, the experts recommended that the report of the Meeting, which is appended, should be distributed widely to all persons concerned.

26. The Governing Body is invited -

(a) to take note of the report of the Meeting of Experts on Respiratory Function Tests in Pneumoconioses and to authorise its widest possible distribution;

(b) to authorise the Director-General to communicate the report to governments with the request that they transmit it to the bodies and services concerned;
(c) to request the Director-General to take account of the recommendations made by the Meeting of Experts, as reproduced in paragraphs 20 to 25 above, when drawing up the work programme of the Office for future years.


POINT FOR DECISION:

Paragraph 26.
INTERNATIONAL LABOUR OFFICE

MEETING OF EXPERTS ON RESPIRATORY FUNCTION TESTS IN PNEUMOCONIOSES

(Geneva, 20-28 September 1965)

REPORT
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Paragraph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1-7</td>
</tr>
<tr>
<td>SECTION I. General Considerations: Pneumoconioses and Respiratory Function</td>
<td>8-12</td>
</tr>
<tr>
<td>SECTION II. Review of Respiratory Function Tests</td>
<td></td>
</tr>
<tr>
<td>Brief Description of Lung Function</td>
<td>13-15</td>
</tr>
<tr>
<td>Criteria for the Choice of Tests including acceptability, objectivity, reproducibility, discrimination and technical considerations</td>
<td>16-21</td>
</tr>
<tr>
<td>Lung Volumes including total lung capacity, residual volume, functional residual capacity and vital capacity</td>
<td>22-23</td>
</tr>
<tr>
<td>Ventilatory capacity including forced expiratory volume and peak expiratory flow</td>
<td>24-28</td>
</tr>
<tr>
<td>Airway Resistance</td>
<td>29</td>
</tr>
<tr>
<td>Compliance</td>
<td>30</td>
</tr>
<tr>
<td>Distribution of Inspired Gas</td>
<td>31-34</td>
</tr>
<tr>
<td>Gas Exchange: Distribution of Ventilation and Perfusion</td>
<td>35-38</td>
</tr>
<tr>
<td>Transfer Factor</td>
<td>39-41</td>
</tr>
<tr>
<td>Physiological Response to Exercise</td>
<td>42-47</td>
</tr>
<tr>
<td>SECTION III. Disorders which may be Evaluated by Respiratory Function Tests</td>
<td></td>
</tr>
<tr>
<td>Syndromes of Lung Function, including obstructive syndrome, restrictive syndrome, syndrome of abnormal function of the lung parenchyma (transfer defect), large lung syndrome, hypoventilation syndrome, respiratory impairment and respiratory failure</td>
<td>48-55</td>
</tr>
<tr>
<td>The Pneumoconioses, including problems of definition, silicosis, pulmonary cancer of coal workers, siderosis, asbestosis, byssinosis, beryllium disease (berylliosis), farmer's lung, other pneumoconioses</td>
<td>56-77</td>
</tr>
<tr>
<td>SECTION IV. Applications in Occupational Health</td>
<td></td>
</tr>
<tr>
<td>Prophylaxis</td>
<td>79</td>
</tr>
<tr>
<td>Clinical Management, including diagnosis, therapeutic measures, assessment of prognosis</td>
<td>80-82</td>
</tr>
<tr>
<td>Assessment of Disability</td>
<td>83-84</td>
</tr>
<tr>
<td>Screening Tests including preliminary and second stage screening tests</td>
<td>85-87</td>
</tr>
<tr>
<td>Lung Function Laboratory</td>
<td>88</td>
</tr>
</tbody>
</table>
SECTON V. **Criteria for Interpretation of Results**

- Standardisation of Techniques ........................................ 89
- Physical Calibration of Equipment ..................................... 90
- Standardisation of Conditions of Measurement .................... 91-92
- Biological Calibration of Equipment ................................. 93
- Reporting Results ...................................................... 94
- Definition of "Normal" Values ........................................ 95-97

**Conclusions** .......................................................... 98-106

APPENDIX. **Procedure for Measurement of the Forced Expiratory Volume and Vital Capacity**
REPORT

Introduction

1. In accordance with the decision taken by the Governing Body of the International Labour Office at its 160th Session (Geneva, November 1964) a Meeting of Experts on Respiratory Function Tests in Pneumoconioses was held in Geneva from 20 to 28 September 1965.

2. The agenda of the Meeting, as approved by the Governing Body, was as follows:

1. Pneumoconioses and the respiratory function:
   (a) disorders which may be evaluated by respiratory function tests;
   (b) classification of pneumoconioses according to the type of respiratory disorder which is prevalent.

2. Review of the respiratory function tests used in the examination of persons suffering from pneumoconiosis.

3. Tests to be recommended internationally for the assessment of the respiratory function in pneumoconioses and the technique for carrying out such tests.

4. Criteria to be adopted for the interpretation of the results of these tests with a view to their international comparability.

3. The following attended the Meeting:

Members

Dr. Erick BOUNDER,
Medical Adviser to the General Federation
of Swedish Trade Unions,
Landsorganisationen i Sverige,
Barnhusgatan 18,
STOCKHOLM (Sweden)

Dr. J.E. COTES,
Member of the Scientific Staff,
Pneumoconioses Research Unit of the
Medical Research Council,
Llandough Hospital,
PENARTH, Glamorgan (United Kingdom)

Dr. Mostafa A. EL BATAWI,
Associate Professor of Occupational Health,
Head of the Department of Occupational Health,
University of Alexandria,
165 Horria Avenue,
ALEXANDRIA (United Arab Republic)

Dr. M.N. GUPTA,
Director of Research,
Office of the Chief Adviser of Factories,
Ministry of Labour and Employment,
2 A/3 Asaf Ali Road,
NEW DELHI (India)

Dr. Lia OHNIANSKAIA,
Head of the Department of Clinical Physiology,
Institute of Hygiene and Safety in Industrial Medicine,
MOSCOW (U.S.S.R.)
Mr. H.A. Majid, Assistant Director-General of the International Labour Office, declared the Meeting open. He recalled that the I.L.O. had already done important work in promoting the study of occupational diseases due to inhalation of dusts and encouraging preventive measures, both at the technical and medical levels. The subject of the Meeting was of special interest to the I.L.O. Respiratory function tests were used in prevention, diagnosis, clinical management...
and assessment of disability for purposes of compensation. The time had come for an appraisal of experience to date. It would be valuable if the Meeting could agree on the place of tests of lung function in the detection and the assessment of respiratory disorders due to inhalation of dust.

5. Professor P. Sadoul was elected Chairman of the Meeting. Dr. J.E. Cotes was appointed Rapporteur.

6. In the course of general discussion, the experts stressed the role of specialised tests in describing normal and impaired lung function. The test provided useful data for detecting anomalies caused by dust inhalation, for following their course and for assessing disability. The tests were also useful for the supervision of workers and for epidemiological purposes. However, the diagnosis of a pneumoconiosis should be broadly based on occupational history, clinical and radiological examination and often clinical pathology and lung function.

7. The experts noted that inhalation of dust caused widespread disturbance of function including that of the pulmonary and systemic circulations, the nervous control mechanism, the respiratory muscles, the lungs and other organs. In view of the agenda the experts agreed to confine their attention mainly to the lungs. They also agreed to include the effects of both mineral and vegetable dusts and to consider the requirements of those concerned with occupational health at the workplace and in applied lung function laboratories devoted to this subject.

SECTION I

General Considerations: Pneumoconioses and Respiratory Function

8. In certain circumstances, the inhalation into the lungs of mineral or vegetable dust of industrial origin may give rise to pneumoconiosis. The presenting features of the condition will vary with the type of dust, the length and severity of exposure and the susceptibility of the individual and may also be influenced by other factors. In a subject who gives a history of occupational exposure the presenting feature may be an abnormal chest radiograph, a characteristic symptomatology which usually includes a history of breathlessness, the onset of respiratory or cardiac failure or positive findings on assessment of lung function or application of clinical pathological tests. The experts also noted that pneumoconiosis may arise as a result of proximity to a source of industrial dust in subjects who have not themselves worked in the industry.

9. In some pneumoconioses the function of the lungs is quite unaffected by the presence of dust foci visible on the chest radiograph, for example in stannosis. In other forms, the function of the lungs is normal to start with and then slowly deteriorates as the quantity of dust and/or pathological lesion increase, for example in kaolinosis, simple pneumoconiosis of coal workers and moderately advanced silicosis. In other mineral pneumoconioses and in some vegetable pneumoconioses the diagnosis may be made on the basis of breathlessness which, when it occurs, is due to demonstrable impairment of the lung function; in these conditions the changes are not necessarily related to the severity of the changes on the chest radiograph.

10. On removal from further dust exposure the impairment of function may regress, for example in early byssinosis, farmer's lung and beryllium disease; it may remain the same, as in simple pneumoconiosis of coal workers or it may progress as in the majority of cases of progressive fibrosis of silicosis and coal workers' pneumoconiosis, also diffuse fibrosis of asbestosis and the later stages of farmer's lung and beryllium disease.

11. The disturbance of lung function in the early stages of a pneumoconiosis usually takes one of two forms, either reduction in breathing ability, that is to say ventilatory capacity, or impairment of the processes of gas exchange. In either case the condition may progress to include the other at a later stage or it may become complicated by the changes in function which are associated with bronchitis or emphysema. The impaired ventilatory capacity may be due primarily to obstruction or narrowing of the airways (obstructive syndrome) or to diminished
lungs expansion (restrictive syndrome). The latter change may be due to the presence of a space occupying lesion, for example progressive fibrosis or a diffuse infiltrative lesion or diffuse fibrosis.

12. Impairment of the process of gas exchange when it occurs may be the result of abnormal distribution of pulmonary ventilation and perfusion or to loss of alveolar surface and pulmonary vessels for the transfer of gases in the lung. These changes may be the result of diffuse tissue destruction in emphysema, diffuse infiltration in pulmonary fibrosis or a space occupying lesion. The conditions are usually associated with characteristic changes in lung function including the occurrence of increased ventilation and arterial blood gas abnormalities on standard exercise.

SECTION II

Review of Respiratory Function Tests

Brief Description of Lung Function

13. The lungs are the organs of gas exchange where the body absorbs oxygen from the air and gives off excess carbon dioxide. Through the latter function, the lungs contribute to the maintenance of the acid base balance of the body; they also supply air for phonation and other purposes. The function of the lungs depends on their structure, on the integrity of the chest wall and on the mechanisms which regulate movement of the respiratory muscles and distribution of blood and gas at the level of the alveoli and alveolar capillaries.

14. For convenience of assessment the function of the lungs may be divided into the ventilatory function, the gas exchange function and lung perfusion. These in turn may be subdivided into a number of components. The components which influence the ventilatory function include the size of the lungs (lung volumes), their distensibility (compliance) and the calibre of the airways (airway resistance); these components together with the properties of the chest wall largely determine the ventilatory capacity.

15. Under the heading of gas exchange the major components of function include the distribution of gas and blood to the different parts of the lungs (mixing indices and ventilation perfusion relationships) and the capacity to transfer gas across the alveolar capillary membrane (transfer factor or diffusing capacity). These components contribute to the gaseous composition of the arterial blood (blood gases) and hence to the drive to respiration from the respiratory centres in the brain. Disturbances of any aspect of lung function may give rise to breathlessness on exertion through an effect on the ventilatory capacity or the processes of gas exchange or the regulation of respiration. The ways in which these factors are inter-related are illustrated schematically in fig. 1. Lung function tests may be used to assess the integrity of any of the components or of the over-all function.

Criteria for the Choice of Tests of Lung Function

16. The following considerations need to be borne in mind:

17. Acceptability. The test should be safe and simple for the subject; the latter criterion may require extensive instrumentation. Where the procedure is to some extent unpleasant the operator should be satisfied that it is really necessary and explain this in detail to the subject.

18. Objectivity. So far as possible the information which is obtained should be Independent of the instruments used to make the measurement, the motivation of the subject and the personality of the operator.

19. Reproducibility. The measurement should have, on the same subject, a variability within and between days which is small in relation to its absolute magnitude (the coefficient of variation in normal subjects preferably below 10 per cent.).

20. Discrimination. The test should provide useful information. To this end the test should describe an attribute of function which may become impaired.
during the course of a particular disease. The variability of the test should not be so large as to interfere with the interpretation of the result. For this to be possible the index should be reproducible and its variability from one normal subject to another should be small in relation to the differences between normal and grossly abnormal subjects.

Fig. 1
Lung Functions
21. **Technical Considerations**

**Reliability** - the equipment should preferably be rugged, portable and easy to maintain and operate.

**Ease of calibration** - this should be based on some physical or chemical property which is described in absolute units and is not influenced by interaction with the subject. The procedure should be simple and preferably use materials which are available in most laboratories.

**Output of data** - this should preferably be in the form in which the data are to be used. For some applications an instrument providing a chart record is to be recommended and for others a direct reading instrument. In either case the operator should introduce appropriate correction factors before reporting the results.

---

**Lung Volumes**

22. The volume of gas in the lungs at different stages of lung expansion may be described in terms of a number of indices of which the following are recommended for routine use (see fig. 2 and, in Appendix, the nomenclatures used in various countries).

- **Total lung capacity (T.L.C.)**: the volume of gas contained in the lungs at the end of a full inspiration.

- **Residual volume (R.V.)**: the volume of gas remaining in the lungs at the end of a sustained maximal expiration.

---

Fig. 2

Spirogram Labelled to Show the Subdivisions of the Total Capacity
(a) total lung capacity;
(b) inspiratory reserve volume;
(c) tidal volume;
(d) expiratory reserve volume;
(e) residual volume;
(f) vital capacity;
(g) functional residual capacity.

Functional residual capacity (F.R.C.): the volume of gas in the lungs at the end of expiration when the subject is breathing normally.

Vital capacity (V.C.): the volume of gas expired during a complete but gentle expiration after the deepest inspiration (expiration starts from total lung capacity and ends at residual volume). A similar volume is recorded by full inspiration from residual volume. Vital capacity can also be recorded in two parts, first from residual volume to functional residual capacity, and second, from functional residual capacity to total lung capacity; the total volume so obtained is called the two-stage vital capacity.

23. The experts recommend that the functional residual capacity and residual volume normally be assessed by closed circuit spirometry using helium as an indicator gas. This method is described in the Appendix. The open circuit nitrogen washout method is also satisfactory in skilled hands. Alternatively, the measurement may be made using a body plethysmograph: the procedure is appropriate for those centres where this equipment is used for measurement of airway resistance (see below). The area of the lung fields on a chest radiograph taken at a distance of five feet from the subject after full inspiration and expiration and the total diaphragm movement may be used as guides to the lung volumes where no more accurate means of assessment are available.

Ventilatory Capacity

24. This is the ability to move gas rapidly in and out of the lungs and may be measured directly in terms of maximum breathing capacity (M.B.C.). This index, measured as the maximum voluntary ventilation (M.V.V.), is fundamental to a proper understanding of the ventilatory function of the lungs; however, for many purposes in practice it has largely been replaced by single breath tests. These are less fatiguing and less dependent on both the exertion of the subject and the resistance and inertial characteristics of the recording equipment. The experts recommend that ventilatory capacity should normally be assessed in terms of the one-second forced expiratory volume (F.E.V.1.0). This index is the volume of gas which can be expired from the lungs in one second by forced expiratory effort starting from full inspiration (i.e., total lung capacity).

25. In some countries the forced expiration is continued until the subject can breathe out no further. The total volume expired in these circumstances is called the forced vital capacity (F.V.C.). It should be noted that in subjects with obstructive syndrome (see paragraph 49), the F.V.C. is less than the vital capacity as defined in paragraph 22. The ratio of the forced expiratory volume to the vital capacity (or to the forced vital capacity) which is called the F.E.V.% i.e., \( \frac{F.E.V.}{V.C.} \times 100\% \) (formerly the timed vital capacity or Tiffeneau Index), should also be reported. It should be noted that the F.E.V.% measured using the forced vital capacity will differ from that using the vital capacity so that the method of deriving the index should be stated clearly.

26. Additional information will be obtained by repeating the measurement after the administration of a bronchodilator drug; the use of bronchoconstrictor substances may also be informative.

27. The measurement of forced expiratory volume including criteria for choice of equipment, is described in the Appendix.
In some circumstances, it may be convenient to measure the peak expiratory flow rate (P.F.R.). This is the maximum flow that can be sustained for a period of ten milliseconds by forced expiratory effort starting from full inspiration. The procedure is similar to that for the F.E.V. The test has the disadvantages that the true peak flow is only recorded accurately by equipment having a very low resistance and inertia; its calibration may present difficulties. In addition the result is very dependent on the effort exerted by the subject.

**Airway Resistance**

The airway resistance is expressed as pressure difference which must be applied between the alveoli and the mouth in order to produce a flow rate at the lips of 1 l/sec. In practice it is normally measured at an air flow rate of 0.5 l/sec. and at a thoracic gas volume near to functional residual capacity, which should also be reported. The experts suggest that airway resistance be assessed by the plethysmograph method which also provides a rapid means for estimating lung volumes. However, it should be borne in mind that the measuring and recording equipment should be of good quality and, therefore, expensive and setting up the test at the present time is a skilled job requiring trained personnel. Other methods are also of use in some circumstances as is the measurement of respiratory work.

**Compliance**

The compliance is an index of the distensibility of the lung and is expressed as the change in lung volume when the pressure gradient between the pleura and the alveoli is changed by 1 cmH₂O. It may be measured during breath holding (static compliance) or during regular breathing (dynamic compliance). The experts regard this test as probably unsuitable for routine use at the present time but the measurement of static compliance may be included amongst tests to be used for special purposes.

**Distribution of Inspired Gas**

This may be assessed with respect to the several parts of the lung (spatial inequality), to the times of filling or emptying the differently ventilated groups of alveoli (temporal inequality) and to the perfusion of the lungs (ventilation perfusion relationships). The latter is considered in paragraphs 37 to 40.

The distribution of gas with respect to time during inspiration and expiration may be assessed by a single breath technique, for example the single breath nitrogen index of Fowler. In this test the subject inhales a vital capacity breath of oxygen and then immediately exhales. The result is expressed as the change in concentration of nitrogen at the lips between 750 ml. and 1,250 ml. after the start of expiration.

Distribution with respect to lung volume may be assessed in terms of mixing of gas in the lungs following a change in composition of the inspired gas. This is commonly carried out during a period of breathing oxygen when lung mixing may be described in terms of either the concentration of nitrogen in alveolar gas after seven minutes, or of the lung clearance index. The lung clearance index is that volume of oxygen expressed as a multiple of the functional residual capacity, which when breathed under quiet resting conditions will lower the concentration of nitrogen in the end tidal gas to 2 per cent.

The uniformity of distribution of inspired gas may also be deduced by closed circuit spirometry from the rate of change of concentration of helium in the apparatus during the course of measurement of the functional residual capacity. The index is easy to obtain but is not particularly precise because it is very dependent on the characteristics of the closed circuit apparatus. Other indices of distribution are also available and may be employed in some circumstances.

**Gas Exchange: Distribution of Ventilation and Perfusion**

Gas exchange takes place in those parts of the lung which are both ventilated with inspired gas and perfused with blood from the pulmonary artery. It depends on a proper balance between ventilation and perfusion. Insufficient ventilation to a part of the lung which is perfused leads to passage into the
pulmonary vein of poorly oxygenated blood which then reduces the saturation of oxygen in the systematic arterial blood. This may be described as the venous admixture effect. Insufficient perfusion to a part of the lung which is ventilated has a different effect. Gas which leaves poorly perfused alveoli mixes with that from alveoli where gas exchange is taking place normally and has the effect of reducing the tension of carbon dioxide and increasing the tension of oxygen in the mixed alveolar gas: this may be described as the dead space effect.

36. The consequences of uneven distribution of ventilation and perfusion can be assessed in a number of ways. Of these, some techniques which show great promise require special items of equipment and are still in the course of development. Other techniques can be applied using equipment which is available in most lung function laboratories. Of these the most widely applied is the measurement of saturation of oxygen in the arterial blood. At sea level, in the absence of congenital heart disease or extra-pulmonary vascular shunt, a saturation when breathing air which is below that to be expected is usually evidence for either uneven distribution of pulmonary ventilation and perfusion or of other interference with the exchange of gas (transfer defect). In the former case the low saturation is usually associated with a normal or increased tension of carbon dioxide in the arterial blood, whereas in the latter the tension of carbon dioxide is often reduced. This change, when it occurs, is accompanied by an increase in the ventilation minute volume and often by a rise in the pH of the arterial blood.

37. Thus, analysis of the arterial blood for oxygen, carbon dioxide and pH may provide invaluable information on disturbances of gas exchange especially if the measurements are also made on exercise (see paragraphs 44 to 49). Additional information may be obtained if these measurements are combined with analysis of the expired gas. Measurement of the expired minute volume together with the concentration of carbon dioxide in expired gas permits calculation of the physiological dead space and alveolar ventilation.

38. Where equipment for analysis of alveolar gas is also available, this may be used in conjunction with measurements of blood CO\textsubscript{2} tensions to calculate the tension difference for carbon dioxide between arterial blood and end tidal gas. This is normally of the order of 1 mm.Hg but is increased when distribution of ventilation and perfusion is uneven.

Transfer Factor (diffusing capacity, T\textsubscript{L} or D\textsubscript{L})

39. The transfer factor or diffusing capacity of the lung is the rate of uptake of a test gas (oxygen or carbon monoxide) per minute for a mean tension difference across the alveolar capillary membrane of 1 mm.Hg. The index reflects both the diffusion characteristic of the alveolar capillary surface available for the exchange of gas, including its area and thickness and the rate of reaction of the test gas with whatever volume of haemoglobin is present in the alveolar capillaries. The diffusing capacity of the alveolar capillary membrane (D\textsubscript{L}) and the volume of blood in the alveolar capillaries (V\textsubscript{c}) can be calculated from the data for carbon monoxide, but not for oxygen.

40. For oxygen the method is not recommended for routine use. For carbon monoxide two methods, steady state and single breath methods are available and widely used. The steady state method should be carried out on exercise, at least in normal subjects for whom the procedure yields variable results at rest; a low result is evidence for impairment of gas exchange, but cannot be used to differentiate clearly between uneven distribution (V\textsubscript{A}/Q inequality) and factors affecting the alveolar surface (transfer or diffusion defect).

41. The single breath method is more suitable for use at rest than on exercise when the subject sometimes has difficulty in performing the breath holding manoeuvre correctly. It has the advantage of being suitable for subjects with normal lung function as well as those who are moderately disabled, and can be used in conjunction with measurement of the lung volumes to provide an index of uneven distribution of inspired gas. The test is recommended for use in those centres where the necessary skills and equipment are available.

Physiological Response to Exercise

42. Exercise increases the functional demand on the respiratory and circulatory system and may therefore reveal inadequacies of lung function not
readily detectable at rest; in addition, it provides a means of simulating conditions of breathlessness such as the subject may experience during physical work. For these reasons assessment of the physiological response to exercise has an important place in the over-all study of lung function in suspected cases of industrial pulmonary disease. The procedures are safe in those who live active lives but, as a precaution against the possible development of myocardial ischemia, the tests should be preceded by clinical assessment preferably including electrocardiography in individuals with any cardiac symptoms.

43. Exercise tests may be subdivided into maximal and submaximal tests. The former provide information on maximum exercise ability and the factors limiting exercise. In the present context maximal exercise may be subdivided into that limited by inadequate lung function and by the capacity of the cardio-vascular system. In the former at the breaking point the ventilation often approaches the maximum breathing capacity whilst the heart rate is usually submaximal. In the latter the heart rate is at a maximal level whilst the ventilation may not be more than about 60 per cent. of the maximum breathing capacity. (For the purpose of this assessment, the maximum breathing capacity is best determined directly but in the opinion of some authors may also be estimated indirectly from the forced expiratory volume.)

44. When exercise is limited by breathlessness due to inadequate lung function, maximum exercise is usually well tolerated by highly motivated subjects. However, the results are often unreliable when obtained as part of an assessment for disablement. In such circumstances the necessary information should be obtained from the study of lung function at rest and during submaximal exercise. Maximal exercise which is limited by the capacity of the cardio-vascular system is fatiguing and should not be undertaken lightly.

45. Submaximal exercise provides information on aspects of lung function including gas exchange, the control of respiration and the capacity of the pulmonary circulation. For these purposes, measurements are best made after the initial period of adjustment to exercise, i.e. after five or sometimes ten minutes. Exercise is best performed under standard conditions on a treadmill or bicycle ergometer, but a standardised exercise step test may also be used. In such cases the experts recommend that the level of energy expenditure as judged by the consumption of oxygen should be approximately 1.5 litres per minute. Other work levels may also be appropriate, depending on the capacity for exercise and customary activity of the subject.

46. Circumstances and facilities for the study of exercise vary and it is not appropriate to recommend a detailed procedure. However, the experts recommend that the following indices should be obtained when possible:

(a) ventilation and expired gas
   (either inspired or expired)
   - ventilation minute volume
   - respiratory rate
   - tidal volume
   - concentration of oxygen and carbon dioxide in expired gas
   - oxygen consumption

(b) blood gases
   - saturation and tension of oxygen
   - tension of carbon dioxide
   - hydrogen ion concentration or pH

---

1 An oxygen consumption of 1.5 l/min. corresponds approximately to the following work levels for different types of exercise: for bicycling a work level of 600 kgm/min., for stepping exercise a work rate of 350 kgm/min. and for treadmill walking up an incline of 10 per cent. a walking speed of 60-90 m/min. or 2 1/4 - 3 1/2 m.p.h.
physiological dead space
alveolar ventilation
(c) circulation - heart rate (preferably from electrocardiogram).

47. In the assessment of respiratory function other indices may also be of use including the blood lactic acid concentration and the transfer factor (diffusing capacity of the lung). In the assessment of function of the heart and circulation further procedures will also be required.

SECTION III
Disorders Which May be Evaluated by Respiratory Function Tests

Syndromes of Lung Function

48. The function of the lungs in the pneumoconioses reflects both the underlying pathology and changes associated with other conditions including chronic bronchitis, emphysema and cardiac failure. The changes in general fall into one or other of a number of syndromes. In their most typical form these may be described as follows.

49. Obstructive syndrome. This is present when the ventilatory capacity is reduced as a result of narrowing of the lung airways. The condition is characterised by a low value for the forced expiratory volume expressed as a percentage of the vital capacity (or of the forced vital capacity), i.e. F.E.V.%. In addition the airway resistance is increased, the distribution of inspired gas is uneven and usually the residual volume occupies a larger proportion than normal of the total lung capacity (R.V.% increased). The changes may be more or less reversible by bronchodilator therapy.

50. Restrictive syndrome. This is present when the ventilatory capacity is reduced as a result of reduction in vital capacity. The condition is characterised by a normal (or increased) value for the F.E.V.%. In addition, when the condition is due to pulmonary disease, it is usually accompanied by a decrease in the static lung compliance.

51. Syndrome of abnormal function of the lung parenchyma (transfer defect). This is characterised by increased ventilation (hyperventilation) and diminished amount of oxygen in arterial blood (hypoxaemia) on exercise and a reduction in the transfer factor or diffusing capacity of the lung at rest and on exercise. Indices of uneven ventilation perfusion relationships (V/Q ratios) also show evidence of abnormality. In addition, when the syndrome is due to a diffuse infiltrative condition uncomplicated by disease of the airways, it is usually accompanied by the features of the restrictive syndrome.

52. Large lung syndrome. This syndrome, which is not recognised by all authorities, is usually characterised by an increased total lung capacity and R.V.. In addition, the ventilatory capacity is usually reduced, the distribution of inspired gas uneven and the transfer factor or diffusing capacity of the lung diminished. The airway resistance may be within normal limits.

53. Hypoventilation syndrome. This is characterised by a rise in the tension of carbon dioxide in arterial blood (hypercapnia) which in conjunction with other changes may lead to acute episodes of hypoventilation. The condition may be due to depression of the respiratory centre, a marked increase in respiratory work and gross inequality of ventilation and perfusion either separately or in combination. The syndrome is often accompanied by congestive cardiac failure.

54. These syndromes of abnormal lung function may be identified by application of lung function tests. However they do not fully reflect the complex pattern of changes (both primary and compensatory) which may arise as a result of stimulation of receptors in the lungs by the inhaled dust. Some of these may be detected by studying the activity of the respiratory centre using a pneumotachograph, an electromyograph and tests of lung function. The syndromes may vary in
their severity between minor deviation from normal and total incapacity. However, it should be noted that they occur not only in a pure form but in combination, when some of their characteristic features may be lost. The severity can conveniently be categorised as follows:

**Respiratory impairment** - when the lung function is inferior to that of normal subjects of the same age, sex, race, etc. The degree of impairment may not be sufficient to give rise to symptoms.

**Respiratory failure** - when respiratory impairment is accompanied by abnormal arterial blood gas tensions, for example, a marked fall in the tension of oxygen outside the normal range, with or without a rise in the tension of carbon dioxide.

55. Diagnosis of early respiratory impairment of whatever type is of the greatest importance in industrial medicine but it is often difficult in practice. Diagnosis in the intermediate stage when the syndrome is well developed is usually relatively easy. Diagnosis of respiratory failure is also straightforward; however, the characteristic features of the underlying syndrome may become blurred due to the presence of complicating features. On this account, in the advanced stages of respiratory failure all aspects of lung function show evidence of abnormality.

**The Pneumoconioses**

56. Problems of definition. The changes in lung function which occur in association with the pneumoconioses may fall into one or more of the above syndromes. However, in addition to variations attributable to the course of the disease, there may be changes due to superimposition of other diseases or as a result of mixed dust exposure. The relative importance of these factors is likely to be affected by living conditions, atmospheric pollution, smoking habits and other variables including altitude, which may vary from one place to another.

57. These sources of variation need to be taken into account in considering the lung function changes in any pneumoconiosis. Another cause of variation is in the selection of subjects. In particular, care should be taken before drawing conclusions from subjects applying for compensation since such a group inevitably includes an unduly large proportion of those with respiratory impairment. A working population may also be misleading in some circumstances since it will not include those subjects who have left on account of illness. However, some allowance can often be made for this factor by including in the analysis an estimate of severity of exposure of the subjects to the dust in question.

58. A more representative picture is obtained by a study of all those who have been exposed to the dust by including those who have left as well as those who are still at work and the experts recommend that this approach should be adopted where possible. The findings in groups within such a population or a suitable sample of it should be compared with those in a control group which should ideally be similar in all respects except for the absence of either the pneumoconiosis in question or of exposure to dust. This aspect is considered further in Sections IV and V.

59. The following account of the changes in lung function in the pneumoconioses is based on the combined experience of the experts. It is intended as a general guide. However, deviations may be expected on account of the great number of factors which contribute to lung function of which some are described above. The occurrence of certain features in one place shall not be taken to imply that they will also occur in another where the circumstances are different.

60. Silicosis. This may occur as a result of exposure to quartz or free silica, for example in tunnelling, quarrying and mining, including gold-mining, sandblasting, pottery and refractories industries, sandstone quarrying and dressing, the granite industry; sand moulding and fettling, ripping and driving a hard head in coal mines, etc. The different forms vary with the intensity and duration of dust exposure and the effectiveness of preventive measures.

61. The primary lesion is the silicotic nodule which is found particularly along the lymphatics and in the interstitial tissue of the lung. Silicosis may occur in acute, sub-acute, progressive and chronic forms and may progress to massive fibrosis. It may give rise to respiratory and/or cardiac failure and be
accompanied by bronchitis, emphysema and tuberculosis, including silico-
tuberculosis: the latter may occur in diverse forms.

62. In minimal nodular silicosis, lung function may be within normal limits and remain so over a period of years. In other and more advanced forms of disseminated silicosis the lung function will vary with the stage of the disease. It will typically be of the form associated with the restrictive syndrome including reductions in the F.E.V.1 and V.C.; the F.E.V.1% may remain within normal limits whilst the distribution of inspired gas is usually uneven. In acute silicosis and in chronic forms accompanied by diffuse fibrosis there is usually hyperventilation and hypoxaemia on exercise and the transfer factor (diffusion capacity of the lung) may be reduced. When the condition is accompanied by bronchitis, features of the obstructive syndrome are (paragraph 49) also present.

63. Pneumoconiosis of coal workers. This may occur amongst those who handle coal in large quantities including coal workers, firemen, coal trimmers working in ships and others. The condition may be combined with silicosis (anthraco-silicosis). The primary lesion in pneumoconiosis is the dust focus; this occurs in proximity to the respiratory bronchioles which may become dilated. It may lead on to progressive massive fibrosis or be associated with other changes. The radiological features of pneumoconiosis are classified under the headings small opacities (p,m,n.) and large opacities (A,B,C.) in the International Classification of Radiography of the Pneumoconioses.1

64. In simple pneumoconiosis (small opacities) lung function may be within normal limits and remain so over a period of years. However, in some subjects the pneumoconiosis is accompanied by respiratory insufficiency which may be of the restrictive or of the obstructive types (paragraphs 49 and 50). These changes in function may progress to respiratory or cardiac failure.

65. In a progressive massive fibrosis (large opacities), the findings on assessment of lung function include reductions in the total lung capacity and ventilatory capacity and an increase in the residual volume and in the residual volume as a percentage of total lung capacity. The transfer factor (diffusing capacity of the lung) is often reduced and there is usually some degree of hypoxaemia particularly on exercise. These changes may be accompanied by features of the obstructive syndrome including a fall in the F.E.V.1%, rise in airway resistance and impaired distribution of pulmonary ventilation and perfusion.

66. Siderosis. This condition occurs in foundry workers, haematite iron ore miners, ocre workers and others exposed to dust containing Fe2O3. In some circumstances, the condition is combined with silicosis (sidero-silicosis). Siderosis gives rise to the radiological changes of small opacities pneumoconiosis (p and m). Lung function in this condition may be within normal limits and may remain so over a period of years. However, some subjects may, after years of exposure develop respiratory insufficiency of the obstructive type. This may lead on to respiratory and sometimes to cardiac failure.

67. In addition to the inhalation of Fe2O3 dust, the inhalation of fumes may give rise to a fine nodulation on the chest radiograph. This condition, which may occur in arc welders, is due to deposition of iron in perivascular lymphatics; the lung function is usually within normal limits.

68. Asbestosis. This condition may occur in workers with asbestos, including mattress makers, cardroom workers, weavers and other textile workers, laggers and insulators, miners, sprayers and those concerned with dismantling installations containing asbestos. The primary lesion is diffuse destruction of alveoli, particularly those lining the respiratory bronchioles and their replacement by fibrous tissue. There is also thickening of inter-alveolar septa, bronchiolectasia of respiratory bronchioles and pleural fibrosis. The chest radiograph may show a diffuse reticular pattern of varying intensity, pleural thickening and other changes.

69. In subjects with respiratory impairment the typical changes in lung function are those of disease of the lung parenchyma (transfer defect) which is usually accompanied by features of the restrictive syndrome. However, the obstructive syndrome is also observed particularly in subjects working in a heavily polluted atmosphere.

70. The typical features include reductions in F.E.V., V.C., transfer factor (diffusing capacity of the lung) and static lung compliance without much change in the residual volume and F.E.V.%_. On exercise, the ventilation is usually increased and this change is accompanied by hypoxaemia.

71. Byssinosis. This disease may result from inhalation of certain vegetable dusts, including cotton and flax, during the course of ginning, pressing, blowing, carding and other processes. The composition of the dust, particularly the content of plant debris, influences the response. The subject typically experiences chest tightness and difficulty in breathing on exposure to dust after being away from it, or during continuous exposure when the concentration of dust is increased. Prolonged exposure may lead to permanent respiratory impairment. The changes in lung function are of the obstructive type. There are no specific changes on the chest radiograph.

72. Characteristic features during exposure to dust follow a similar pattern as the symptoms; they include a reduction in ventilatory capacity, a rise in airway resistance and probably uneven distribution of inspired gas with subsequent recovery. On exposure to dust similar but less marked alterations occur in subjects without byssinosis. Some changes during the course of the condition are summarised in the following table.

**TABLE 1**

<table>
<thead>
<tr>
<th>Function Test</th>
<th>Early</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilatory Capacity (F.E.V.₁)</td>
<td>Transient drop with exposure episodes</td>
<td>Transient drop and permanent reduction</td>
<td>Transient drop and permanent marked reduction</td>
</tr>
<tr>
<td>Vital Capacity</td>
<td>Normal</td>
<td>May be reduced</td>
<td>Reduced</td>
</tr>
<tr>
<td>Residual Vol.</td>
<td>&quot;n&quot;</td>
<td>May be increased</td>
<td>Increased</td>
</tr>
<tr>
<td>Airway Resistance</td>
<td>Transient increase with exposure episodes</td>
<td>Transient increase, i.e. exposure episodes and some permanent increase</td>
<td>Transient and permanent increase</td>
</tr>
</tbody>
</table>

Other changes in lung function are those associated with the obstructive and large lung syndromes.

73. Beryllium disease (berylliosis). This condition may result from inhalation of various compounds of beryllium as dust or fumes. The disease is characterised by generalised granulomatous formation in many organs but especially the lungs. It may be of acute, sub-acute or chronic type. The acute reaction to beryllium includes a pneumonitis or pulmonary oedema and is liable to occur only as a result of heavy exposure. The sub-acute stage may present chills and fever and is often effectively controlled by corticosteroids. Cases not recognised at this stage may develop dyspnea on exertion and clinical evidence of cyanosis; this stage is often accompanied by interstitial fibrosis. Other cases
may develop symptoms years after their last exposure whilst the majority never show symptoms. It is suggested that exacerbations of the condition coincide with periods of lowered corticosteroid levels in the blood which trigger the onset of respiratory symptoms.

74. The changes in lung function are typically those of disease of the lung parenchyma of the restrictive type, with hyperventilation and hypoxaemia on exercise and reductions in the transfer factor (diffusing capacity of the lung) and usually in the static lung compliance. The condition may be complicated by cardiac failure.

75. Farmer's lung. This may occur in workers handling hay and other material contaminated by moulds, for example Actinomyces thermo-polyspora polyspora. In its acute form the condition presents malaise and fever which typically comes on a few hours after exposure. In sub-acute and chronic forms breathlessness is a prominent symptom. The histological features include a granulomatous reaction which may progress to interstitial fibrosis and there usually is a rise in the titre of precipitating antibodies to Actinomyces in the blood plasma. The chest radiograph may be within normal limits, but frequently shows diffuse changes at some stage in the disease.

76. The pattern of lung function is that of disease of the lung parenchyma (transfer defect) of the restrictive type. It is reversible in the early stages but, as a result of repeated exposure may progress to permanent impairment and to respiratory failure. The changes include reductions in the vital capacity, the transfer factor (diffusing capacity of the lung) and the static lung compliance. The ventilation during submaximal exercise is increased.

77. Other pneumoconioses. There are a number of other mineral and vegetable pneumoconioses on which less information is available; these appear to share features of lung function in common with one or other of those that have been described. Some are cited below.

TABLE 2

Functional Features of Some Pneumoconioses

<table>
<thead>
<tr>
<th>Pneumoconiosis</th>
<th>Occupations and Hazards</th>
<th>Conditions sharing some functional features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagassosis</td>
<td>Sugar cane crushing</td>
<td>Farmer's lung</td>
</tr>
<tr>
<td>Diatomite Pneumoconiosis</td>
<td>Exposure to dusts of these materials</td>
<td>Silicosis and Pneumoconiosis of coal workers</td>
</tr>
<tr>
<td>Fuller's Earth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mica</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaolin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suberosis</td>
<td>Cork processing</td>
<td></td>
</tr>
<tr>
<td>Talc Pneumoconiosis</td>
<td>Talc mining and milling</td>
<td>Asbestosis</td>
</tr>
</tbody>
</table>

SECTION IV

Applications in Occupational Health

78. Tests of lung function may be of use in the prophylaxis, clinical management and certification of the pneumoconioses. These different applications make use of essentially the same tests, but the emphasis is different.
Prophylaxis

79. The prevention of pneumoconiosis depends primarily on measures for dust suppression and on prevention of pollution of the working environment. However, in so far as suppression is incomplete, there is a place for pre-placement and periodic examinations with a view to both safeguarding those who may be unusually susceptible and protecting those who show early effects of exposure: tests of lung function have a place in these examinations. In addition, where it is intended to establish or define safe conditions, it is necessary to conduct a biological calibration of the environment by assessing its effect on the lungs of those who are at risk. For both these applications, tests of lung function may be of use as part of an over-all assessment, which may also include inquiry into respiratory symptoms, the taking of a clinical history and examination, chest radiography and clinical pathology. The tests should be of use in detecting early changes of respiratory impairment and of application to large numbers of subjects at the place of work. They are described below under the heading "Screening Tests".

Clinical Management

80. Diagnosis. For clinical purposes a diagnosis of pneumoconiosis is usually made on the basis of dust exposure together with other features including the findings on assessment of lung function.(see para. 83). Lung function tests are of particular value for those conditions where the findings on chest radiography are not specific (for example, byssinosis and farmer's lung). In this context the experts note that the tests provide a means of describing the lungs in terms of functional syndromes; however, except in a few conditions the occurrence of these syndromes is not confined to pneumoconiosis. On this account the existence of an appropriate functional syndrome in a subject with a positive industrial history will permit a presumptive diagnosis of pneumoconiosis. The likelihood of this diagnosis being correct should be established in other ways. Lung function tests are also of use for assessing the severity of respiratory impairment and may be of diagnostic value when other lesions co-exist.

81. Therapeutic measures. Treatment of pneumoconiosis may take a number of forms, including application of specific remedies, for example bronchodilator drugs to relieve obstructive symptoms, or of corticosteroids to promote resolution of hypertrophic granulomatous lesions. Lung function tests are indispensable for the application of these forms of treatment as well as being of use in assessing the need for, and control of, other remedies.

82. Assessment of prognosis. Tests of lung function may be of use for the assessment of prognosis in patients with pneumoconiosis and its complications. The control of therapeutic measures may be carried out by measurement of the forced expiratory volume and vital capacity (or forced vital capacity) but it is often of use to supplement these with additional tests. The other applications described in this section require the resources of a "lung function laboratory"; the facilities which should be available are discussed under this heading below.

Assessment of Disability

83. The requirements for compensation vary from one country to another and are outside the present terms of reference. Procedures for assessment are usually based on a number of features including the industrial history, chest radiograph, clinical symptoms and findings on clinical examination, assessment of lung function and clinical pathology, as well as evaluation of capacity for exercise. It is recommended that lung function tests be included in these procedures.

84. Lung function tests are sometimes used to assess impairment of function relative to an earlier (for example, pre-placement) examination or to average normal value. The former is likely to be a valid procedure where the tests have been properly standardised and allowance is made for subsequent ageing. The latter is sometimes misleading on account of the wide range of normal variation, which both diminishes the sensitivity of the tests and introduces a bias depending on whether the initial function is above or below the mean. (For example, in a group of subjects in whom function is deteriorating at a constant rate, those whose initial values are above the mean will take a longer time than others to
deteriorate to a level at which they experience symptoms.) Factors which may influence the levels of normal values and the ways in which they shall be reported are described in Section V. Lung function tests are also used for assessments in relation to job requirements. However, experience of interpreting lung function tests in this way is confined to a few countries and there is not yet general agreement on the criteria which should be adopted.

Screening Tests

85. Preliminary screening tests should be simple and usually confined to tests of ventilatory capacity; however, for certain pneumoconioses, including berylliosis, asbestosis and farmer's lung, a test of distribution or gas exchange may also be appropriate. The tests should form part of a wider examination including for example clinical and radiological assessment. Subjects in whom abnormalities are detected should be referred for treatment to a centre where more specialised investigations can be carried out. Concerning tests of ventilatory capacity, the experts recommend that the screening procedure should always include the measurement of forced expiratory volume (F.E.V.) but other measurements should be made where possible, for example the vital capacity (or forced vital capacity) and possibly the peak flow (but see para. 30). Other measurements including respiratory frequency and those derived from inspiratory and expiratory chest radiographs may also provide useful information.

86. Concerning tests of gas exchange for preliminary screening purposes the methods are still in course of development and trained technicians are scarce so the experts are unable to make detailed proposals; however, they note that certain procedures, including measurement of the transfer factor (diffusing capacity of the lung) are applied in this way in some countries.

87. Second stage screening tests. In addition to the preliminary screening tests listed above, a number of other tests may be applied in the vicinity of the workplace. These include measurement of lung volumes, distribution of ventilation and perfusion and exercise tests. In the latter context, the experts note that a simple exercise test may provide valuable information and be of use in the absence of facilities for more complete assessment (see para. 46).

Lung Function Laboratory

88. It is envisaged that a well-equipped laboratory will have facilities for most of the procedures outlined in Section II. However, many laboratories, for example those attached to general hospitals, whilst competent to carry out most assessments, will not undertake detailed studies: these will be conducted at lung function laboratories which should be available in all countries for the purpose of routine assessment. Further facilities may also be needed at specialised research laboratories but these are outside the scope of the present report.

SECTION V

Criteria for Interpretation of Results

Standardisation of Techniques

89. The procedure for measurement should, as far as possible, be standardised along the lines of Section II.

Physical Calibration of Equipment

90. This is to ensure that the apparatus is working properly. The initial calibration should include all the items in the performance specification of the equipment. Subsequently, the variable components should be calibrated daily. These include: the timer on a direct reading spirometer, the kymograph on a recording spirometer, the linearity and sensitivity of physical gas analysers, gas meters, pressure recorders and other equipment. As an additional check against failure of components, the operator should make serial measurements at regular intervals on himself or a colleague.
Standardisation of Conditions of Measurement

91. The results of all tests of lung function are to some extent affected by physiological and other factors which influence the lungs. Items of particular importance in this respect include the altitude above sea level, the posture of the subject, the blood concentration of catecholamines (e.g. adrenalin), the recent use of bronchodilator aerosols, the recent consumption of tobacco or inhalation of other dust or fumes and, for some tests, the body temperature and the proximity to meals or previous exercise. The time of day and the season of the year may also exert an effect.

92. As a general rule the temperature of the laboratory should be maintained constant at a level appropriate for the country and the equipment should be arranged in an inconspicuous manner; tests of lung volume, ventilatory capacity and gas exchange should be made with the subject seated in a comfortable, upright posture, and in all cases what is required should be explained to the subject in detail. Ventilatory tests and measurement of airway resistance should not be carried out until at least an hour has elapsed after smoking a cigarette and the time since the last inhalation of bronchodilator aerosol should be recorded. For measurement of the transfer factor and study of the physiological responses to exercise, meals before the test should be avoided (at least one hour being allowed after a light snack and at least two hours, but not more than 12 hours, after a main meal). A short rest period should also be allowed after the subject has reached the laboratory before the start of the test. For exercise tests, a period of practice exercise (preferably on the day preceding the test) is also recommended.

Biological Calibration of Equipment

93. This is to ensure that the results are comparable with those of other workers. The calibration should ideally comprise a study of normal subjects along the lines recommended for the definition of normal values below. However, for indices where extensive normal data are already available a more limited calibration is acceptable. This should take the form of duplicate measurements on a group of at least ten subjects of the same sex, age and ethnic group. The test procedure may be regarded as satisfactory when the mean results agree closely with the best available normal values for similar subjects.

Reporting Results

94. These should be reported in fundamental units together with occupational, medical and other data about the subjects, including ethnic group, sex, age, height and smoking habits. The method used for assessment should also be reported. Where the results are compared with predicted values, the source of these should be given. The practice of expressing results as percentage of predicted normal may be misleading and has little to recommend it.

Definition of "Normal" Values

95. The experts recognise that after taking account of sex, age and body size, the lung function of groups of subjects sometimes show differences which may be related to one of a number of factors, including ethnic group, nutrition, altitude, climatic conditions and customary level of exercise. For this reason, the normal values obtained for one group of subjects will not necessarily be applicable to another where the circumstances differ.

96. To obtain normal values, the criteria set out in earlier sections should so far as possible be adopted. A comment should also be made on the practical experience of those making the measurement and, if more than one, on how their performance was standardised. The subjects should be described as precisely as possible with a view to making comparisons with other data. For this purpose, the way in which they were obtained, whether a random sample, working population or other group, should be described; also the basis for any exclusions, for example an abnormal X-ray or history of recent chest illness. Additional items which should where possible be collected and included in the analysis of results are, inter alia, sex, age, standing height, body weight, smoking habits, level of atmospheric pollution, climatic condition, altitude above sea level and ethnic group.
97. The smoking data should indicate if the subject is a non-smoker (for example, has never smoked as much as one cigarette or one gram of tobacco per day for one year), a smoker or an ex-smoker. The duration in years and the amount smoked in cigarettes or grams of tobacco per day should be recorded separately for cigarettes, pipes and cigars.

Conclusions

98. The pneumoconioses may be prevented by suppressing dust. Measures to achieve this should be applied vigorously wherever there is a known dust hazard.

99. Tests of lung function have an important place in prophylaxis, diagnosis, assessment and clinical management of respiratory impairment due to the pneumoconioses. The tests should be standardised and applied by trained personnel. Recommended tests are included in this report; some technical details about the measurements should be examined further.

100. More data are needed on the prevalence of respiratory impairment in relation to dust exposure and lung pathology. Studies should embrace persons with pneumoconiosis at different stages in their illness, other dust-exposed persons and persons of similar age, race, etc., not exposed to dust. Data on dust exposure and post-mortem material should be obtained where possible.

101. Normal values for tests of lung function are available for some populations but, on account of selection and use of non-standard methods, are not always appropriate. Values which are technically satisfactory are needed for all parts of the world and I.L.O. should collaborate with the World Health Organization, the International Biological Programme and others to promote their collection.

102. For some pneumoconioses the time is right for a review of experience in different countries: this can best be undertaken under the auspices of I.L.O.

103. The use which is made of tests of lung function varies for different industries and from one country to another. In the opinion of the experts the tests should be used in the assessment of functional disability. They should also form part of pre-employment, and periodic examination in certain occupations.

104. Information is needed on the employment of subjects with respiratory impairment including the relationships to job requirements and life expectation; also the use of lung function tests in assessment of disablement due to pneumoconiosis. These questions should be examined by I.L.O.

105. The complete assessment of lung function is at present beyond the resources of some countries. I.L.O. should consider providing additional help including technical advice, also training in proper use and maintenance of equipment. Grants towards apparatus and establishment of survey teams will be appropriate in many instances.

106. Finally, to permit comparative studies of respiratory impairment on a world scale the proposals for standardisation contained in this report should be brought to the notice of those to whom they may be of use. A wide distribution in an attractive format is therefore recommended.
APPENDIX

Procedure for Measurement of the Forced Expiratory Volume and Vital Capacity

Principle of Measurement

The subject first fills the lungs by inhaling to a maximal extent then exhales into a spirometer which is either equipped with an automatic timing and volume measuring device, or arranged to record on a kymograph or chart recorder. The volumes expired during one second and after complete expiration are recorded.

Apparatus

Equipment for making the measurement is available in most countries but may have undesirable features; the following are minimal requirements for satisfactory results. They should be checked before the equipment is accepted for use.

The spirometer should be linear and record volume accurately to within 50 ml. over its whole range of movement which for the single breath procedures should be at least 6.5 l, or for closed circuit spirometry 10 l. The linearity of calibration may be checked by addition of known volumes of air from a calibrated tonometer (usually 500 ml.) by displacement with water. The corresponding deflections on the kymograph should not differ by more than 1 per cent. The factor for converting from the indicated reading to the volume displacement is obtained from these data.

The apparatus should have a low inertia and offer a low resistance to gas flow. For this purpose the diameter of the tubing should be not less than 3 cm. and of the mouthpiece not less than 2.5 cm. The combined effects of inertia and resistance may be assessed by measuring the back pressure in the tubing during the performance of the test. For a subject having an F.E.V. 1.0 of at least 3.5 l the back pressure should not exceed 5 cm. H₂O for longer than 30 milliseconds, and after that should not be more than 1.5 cms. H₂O.

Apparatus incorporating a timing unit. This should be self-contained, accurate to ±1 per cent. and capable of calibration under the conditions of use. During expiration the timing mechanism should be actuated after the exhalation of 100 ml. (range 75-150 ml.) of gas.

Closed current apparatus incorporating a kymograph. The minimum paper speed for measurement of F.E.V. should be 4 cm./sec. and for vital capacity 5 cm./min. The convention which should be adopted when measuring the one second timed period from the record on the kymograph (forced expiratory spirogram) is illustrated in fig. (i).

Forced expiratory spirogram showing the derivation of F.E.V. 1.0 and F.V.C. The volume axis has been adjusted to BTPS.
To test for leaks in the apparatus the mouthpiece should be occluded and a 2 kg. weight placed in the bell. The kymograph should be left running for 20 min. during which time the change in volume should not exceed 15 ml.

When reading the scale on the apparatus or measuring the tracing on the kymograph the data should be recorded to the nearest 0.1 l; if the reading is exactly half-way between 0.1 l divisions the higher of these should be recorded.

Training of Personnel

The results of the test are influenced by the personality and exact procedure adopted by the operator. The latter can be standardised by learning from one who is experienced with the method. To this end two operators each measure the forced expiratory volume and vital capacity of a group of subjects who are presented to them in random order; the observers should be in separate rooms which are some distance apart so that the sounds of their voices do not travel between them. If a systematic difference of more than 3 per cent, emerges from this preliminary study the new operator should receive further instruction and the trial be repeated.

Technique for Measurement

(a) Forced Expiratory Volume

The procedure should be explained in simple terms to the subject who should then remove his overcoat and loosen any tight clothing. He should sit upright but comfortably in front of the apparatus.

The height of the tube between the apparatus and the mouthpiece should be adjusted to the height of the subject.

The subject is asked to take as full a breath as possible, then to insert the mouthpiece, close the lips around it and blow out as hard as possible. It is often helpful for the operator to give a demonstration using a detached mouthpiece.

During an initial practice attempt the subject is observed for any faults (see below), then after explanation a second practice blow is made. Three further blows are then made, making at least five in all, with an interval of at least 15 seconds between them. This interval should be increased if the subject appears in any way distressed.

If, during any attempt, it can be seen that the performance is incorrect the measurement should be rejected and repeated. The following in particular should be borne in mind.

The mouthpiece height may be incorrect, giving an uncomfortable posture.

The subject may not take a full inspiration. Often the reason is that he does not realise that there is no hurry to begin expiration.

There may be hesitation at the beginning of expiration. It should be emphasised that, once started, the breath must continue rapidly without any pause. A demonstration usually corrects this difficulty.

The mouthpiece may be incorrectly inserted and the lips not closed around it. A common fault is to purse the lips in front of the mouthpiece as if playing a trumpet. The usual reason is a loose upper denture.

(b) Vital Capacity (V.C.) and Forced Vital Capacity (F.V.C.)

(i) Single breath procedures. The procedure for vital capacity may follow on after that for the F.E.V., the subject being asked to make three further expirations which should be gentle and not forced and continued until no more air can be exhaled. Alternatively, where it is desired to measure the forced vital capacity (F.V.C.), the subject can be instructed to perform this manoeuvre instead (see fig. (i)).

(ii) Closed circuit procedure. The mouthpiece is placed in the subject's mouth and the kymograph operated at low speed. A baseline of quiet breathing is obtained and the subject then is instructed to inhale to a maximum extent.
Additional encouragement is provided by the operator until the maximum inspiratory position is indicated on the kymograph by the appearance of the record (see fig. (ii)). For measurement of vital capacity the subject is next instructed to breathe out smoothly and completely without force or haste. During the manoeuvre the operator again provides encouragement until exhalation is complete as judged by a short horizontal trace on the kymograph. The subject then continues with normal breathing. The manoeuvres should be repeated at least three times and the volumes derived from the kymogram in the manner illustrated in Fig. 2 of the Report (see para. 22). Common errors: The faults encountered in measuring the F.E.V. may arise. In addition, expiration may be incomplete either because of cough or because insufficient time has been allowed for complete recovery from the previous test. Some patients try to limit their inspiration or expiration to reduce coughing.

Figure (ii)
Spirograms illustrating technical aspects of the measurement of vital capacity. The records are from left to right. (1) spikey record indicating incomplete inspiration and expiration; (2) and (3) inspiration satisfactory but expiration incomplete; (4) expiration satisfactory but inspiration incomplete.

Recording Results
Two different procedures for recording results are widely used. Some experts on the basis of statistical considerations, record the forced expiratory volume and vital capacity or forced vital capacity are each the mean of three technically satisfactory results following two practice attempts at the F.E.V. Other experts use the maximum value of between 5 and 12 attempts. The method which is chosen should be indicated. In either event the volumes should be reported at body temperature (table A). A form which may be used for recording the results is illustrated in table B.

Table A
Factors for conversion of gas volumes from ambient temperature and pressure (ATP) to standard temperature and pressure dry (STPD) and to body temperature (37°C) saturated with water vapour (BTPS). These are derived from the following relationships:

\[ V_{BTPS} = V_{ATP} \times \frac{210}{273 + t} \times \frac{P_B - P_{H2O}}{P_B - 47} \]

\[ V_{STPD} = V_{ATP} \times \frac{273}{273 + t} \times \frac{P_B - P_{H2O}}{760} \]

Where \( V \) is the gas volume under the conditions specified, \( t \) is the ambient temperature in °C and \( P_{H2O} \) is the aqueous vapour pressure in mmHg at this temperature. The conversion factors for expired gas which is saturated with water vapour at ambient temperature (ATPS) and a barometric pressure of 760 mmHg are listed below. These factors may be used over the pressure range 780-740 mmHg. Outside this range the actual barometric pressure should be substituted in the relationships.
<table>
<thead>
<tr>
<th>Ambient temperature (°C)</th>
<th>Aqueous vapour pressure (mmHg)</th>
<th>Factor to convert to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>STPD</td>
</tr>
<tr>
<td>14</td>
<td>12.0</td>
<td>0.936</td>
</tr>
<tr>
<td>15</td>
<td>12.8</td>
<td>0.932</td>
</tr>
<tr>
<td>16</td>
<td>13.6</td>
<td>0.928</td>
</tr>
<tr>
<td>17</td>
<td>14.5</td>
<td>0.924</td>
</tr>
<tr>
<td>18</td>
<td>15.5</td>
<td>0.920</td>
</tr>
<tr>
<td>19</td>
<td>16.5</td>
<td>0.916</td>
</tr>
<tr>
<td>20</td>
<td>17.5</td>
<td>0.911</td>
</tr>
<tr>
<td>21</td>
<td>18.7</td>
<td>0.906</td>
</tr>
<tr>
<td>22</td>
<td>19.8</td>
<td>0.902</td>
</tr>
<tr>
<td>23</td>
<td>21.1</td>
<td>0.897</td>
</tr>
<tr>
<td>24</td>
<td>22.4</td>
<td>0.893</td>
</tr>
<tr>
<td>25</td>
<td>23.8</td>
<td>0.888</td>
</tr>
<tr>
<td>26</td>
<td>25.2</td>
<td>0.883</td>
</tr>
<tr>
<td>27</td>
<td>26.7</td>
<td>0.878</td>
</tr>
<tr>
<td>28</td>
<td>28.3</td>
<td>0.874</td>
</tr>
<tr>
<td>29</td>
<td>30.0</td>
<td>0.869</td>
</tr>
<tr>
<td>30</td>
<td>31.8</td>
<td>0.864</td>
</tr>
<tr>
<td>31</td>
<td>33.7</td>
<td>0.859</td>
</tr>
<tr>
<td>32</td>
<td>35.7</td>
<td>0.853</td>
</tr>
<tr>
<td>33</td>
<td>37.7</td>
<td>0.848</td>
</tr>
<tr>
<td>34</td>
<td>39.9</td>
<td>0.843</td>
</tr>
<tr>
<td>35</td>
<td>42.2</td>
<td>0.838</td>
</tr>
<tr>
<td>36</td>
<td>44.6</td>
<td>0.832</td>
</tr>
<tr>
<td>37</td>
<td>47.1</td>
<td>0.826</td>
</tr>
<tr>
<td>38</td>
<td>49.7</td>
<td>0.821</td>
</tr>
<tr>
<td>39</td>
<td>52.4</td>
<td>0.816</td>
</tr>
<tr>
<td>40</td>
<td>55.3</td>
<td>0.810</td>
</tr>
</tbody>
</table>

**Table B**

Form for Recording Results

Forced Expiratory Volume (F.E.V₁₀) and Vital Capacity (V.C.) or Forced Vital Capacity (F.V.C.)

<table>
<thead>
<tr>
<th>Subject:</th>
<th>Serial No.</th>
<th>Race</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Sex</th>
<th>Date</th>
<th>Height (m.)</th>
<th>Date of Birth</th>
<th>Circumstances of test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Non-smoker/Smoker: light/heavy cigarettes/pipe/cigar/other
(Table B cont'd.)

**Apparatus:**
- Recording spirometer. Serial No. ........................................
- factor converting mm. to 1 ............................................... (a)
- Spirometer with timing device. Serial No. ....................
- calibration reading expected ..............................................
- observed .................................................................

**Readings:**
- Time (24 hr. clock) ...........................................................
- Barometric pressure (mmHg) ................................................
- Apparatus temperature (°C) ..............................................
- Conversion factor to BTPS (table A) .................................. (b)
- Over-all correction factor (i.e. (a) x (b)) .........................

**Comment:**
- Coughing during test Yes/No
- Co-operation satisfactory Yes/No
- Performance of test Good/Fair/Poor
- Hours since antispasmodic ...........................................
- Hours since last smoked ..............................................
- Other .................................................................

<table>
<thead>
<tr>
<th>Practice attempts</th>
<th>F.E.V.₁₀(l or mm.)</th>
<th>V.C. or F.V.C.(l or mm.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sum of three satisfactory attempts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean or maximum Result *</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Corrected to B.T.P.S.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F.E.V.₁₀%</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Indicate which
### Nomenclatures concerning Lung Volumes according to French, English, Spanish, Russian and German Terminologies

<table>
<thead>
<tr>
<th>Français</th>
<th>English</th>
<th>Español</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume résiduel</td>
<td>Residual volume</td>
<td>Volumen residual</td>
</tr>
<tr>
<td>Capacité résiduelle</td>
<td>Functional residual capacity</td>
<td>Capacidad residual funcional</td>
</tr>
<tr>
<td>fonctionnelle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacité totale</td>
<td>Total lung capacity</td>
<td>Capacidad total</td>
</tr>
<tr>
<td>Volume de réserve inspir-</td>
<td>Inspiratory reserve volume</td>
<td>Volumen de reserva inspira-</td>
</tr>
<tr>
<td>ratoire</td>
<td></td>
<td>ratoria</td>
</tr>
<tr>
<td>Volume courant</td>
<td>Tidal volume</td>
<td>Volumen corriente</td>
</tr>
<tr>
<td>Volume de réserve expi-</td>
<td>Expiratory reserve volume</td>
<td>Volumen de reserva expira-</td>
</tr>
<tr>
<td>ratoire</td>
<td></td>
<td>ratoria</td>
</tr>
<tr>
<td>Capacité vitale</td>
<td>Vital capacity</td>
<td>Capacidad vital</td>
</tr>
<tr>
<td>Volume expiratoire</td>
<td>Maximum breathing capacity</td>
<td>Volumen espiratorio máximo</td>
</tr>
<tr>
<td>maximum seconde</td>
<td></td>
<td>por segundo</td>
</tr>
<tr>
<td>Ventilation maximale</td>
<td></td>
<td>Ventilación máxima</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Русский</th>
<th>Deutsch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Резидуальный объем</td>
<td>Residualvolumen</td>
</tr>
<tr>
<td>Функциональная резидуальная</td>
<td>Funktionelle</td>
</tr>
<tr>
<td>емкость</td>
<td>Residualkapazität</td>
</tr>
<tr>
<td>Общая емкость легких</td>
<td>Totalkapazität</td>
</tr>
<tr>
<td>Объем резервного вдоха</td>
<td>Inspiratorisches Reservevolumen</td>
</tr>
<tr>
<td>Вентиляционный объем</td>
<td>Atemvolumen</td>
</tr>
<tr>
<td>Объем резервного выдоха</td>
<td>Expiratorisches Reservevolumen</td>
</tr>
<tr>
<td>Жизненная емкость легких</td>
<td>Vitalkapazität</td>
</tr>
<tr>
<td>Объем воздуха при максималь-</td>
<td>Atemstoß/Sekunde</td>
</tr>
<tr>
<td>ном выдохе в сек.</td>
<td></td>
</tr>
<tr>
<td>Максимальная вентиляционная</td>
<td>Atemgrenzwert</td>
</tr>
<tr>
<td>емкость</td>
<td></td>
</tr>
</tbody>
</table>