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SURVEY OF CURRENT CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS IN MEDICAL SELECTION AND CONTROL OF AIRCREW

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15. Abstract

This volume consists of 13 Chapters containing the description of cardiovascular and respiratory examination methods, currently applied in medical selection and control of the aircrews in most NATO Countries, with special emphasis on functional tests.

The topic was intended to provide a comprehensive review of the techniques and evaluation procedures concerning the aforesaid methods, in order to improve the effectiveness of the medical examination and the reliability of selective judgements.

This AGARDograph was sponsored by the Committee on Special Clinical and Physiological Problems in Military Aviation of the Aerospace Medical Panel of AGARD.

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SURVEY OF CURRENT CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS IN MEDICAL SELECTION AND CONTROL OF AIRCREW

by

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PREFACE

In Aerospace Medicine, the questions of aircrew selection and aeromedical maintenance of aircrew are constantly recurring themes.

In an attempt to proceed in its tasks and responsibilities and as a logical consequence of its past activities, the AGARD-ASMP Committee on Special Clinical and Physiological Problems in Military Aviation had recommended to prepare and publish a general survey of current cardiovascular and respiratory examination methods in medical selection and control of aircrew used in the NATO component countries.

This topic was accepted because

1. the NATO air forces' flying population has increased in mean age: currently about 50% of all aircrew are 35 years of age or older. But with this age increase there is an associated increase in the incidence of degenerative and other chronic disease, frequently not meeting the – historical – aeromedical standards.

2. there is still a great variety of functional tests in use as well as significant differences in the interpretation and application of the results;

3. in spite of many common efforts of several years, however, there are still varying standards and rules to determine whether an applicant for flying duties is to be accepted and when, during his career, an aircrew can or cannot control aircraft.

Some physiological or pathophysiological symptoms and conditions need to be interpreted with respect to flying, correlated on age, flying experience, training status, and also on the different requirements and stresses of flying as posed by the individual's operational task, aircraft types, and operational missions. Continuing advances in clinical knowledge have modified older criteria for fitness for aircrew duties with the result that certain findings, conditions, medical abnormalities which were formerly considered causes for rejection and/or grounding are now accepted as compatible with flying duties.

We can hope for advanced diagnostic and investigative techniques and procedures to improve our detection and analyses of many challenging, unresolved medical problems, too.

This compilation identified the particular cardiovascular and respiratory diagnostic methods and techniques used in NATO's various national aeromedical centers and compared the results with regard to the clinical evaluation. Thay may well result in a reexamination of current philosophies and policies, regulations and practices, in order to enhance flight safety and operational effectiveness.

Dr Heinz S.Fuchs
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Chairman,
AGARD-ASMP
Committee on Special Clinical and
Physiological Problems in Military Aviation

CONTENTS

CHAPTER 1

SHORT INTRODUCTION ON THE AIMS, EVOLUTION AND VALIDITY OF CURRENT CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS IN THE AEROMEDICAL FIELD WITH PARTICULAR REGARD TO FUNCTIONAL TESTS

by

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1. INTRODUCTORY REMARKS

Aircraft construction technique and operational philosophy are in continual, rapid evolution. The principles for the choice of pilots, specialists and flying personnel must therefore be adapted to the new requirements immediately and in some cases they must even look ahead of them. In the last twenty years we have witnessed the almost complete replacement of conventional aircraft by jets and helicopters in the military field and in civil aviation. An even deeper transformation, perhaps, will be brought about by the use in the near future of aircraft that take off and land vertically or semi-vertically and of the so called trisonic aircraft as well as of new operative techniques (high speed and low altitude flight). Far-sighted researchers are already studying not only the physiopathological and ergonomic problems of these new flying methods but also the best characteristics for the pilot of the planned aircraft. The necessity of continually adapting selection to the characteristics of the aircraft and of operative techniques has been officially sanctioned for various years in the regulations of the French Air Force Medical Service, which establish, under art, 5 that "owing to the incessant evolution of aviation technique, the methods and principles of evaluation of flying personnel cannot remain unchanged: on the contrary, they must often be modified, whenever circumstances make it necessary".

A practical aspect, which must also be taken into account, is represented by the necessity of engaging a sufficient number of flying personnel even when candidates are few. This makes selection more difficult, for while it is easy to apply strict standards and reject all candidates with the slightest deficiency, obtaining a few exceptionally fit subjects from a large number of competitors, it is hard to choose from a small group a sufficient number of persons with the necessary psycophysical characteristics to make good military pilots and specialists.

There is an equally rapid development of instrumental and laboratory diagnostic techniques which make it possible to reveal or ascertain, at an early stage and often with certainty, diseases, metabolic disorders, imperfections and physiological deficiencies which up to a few years ago could hardly have been detected in the brief span of a selective examination. The introduction of new techniques entails, however, the necessity of discovering promptly possible deception and errors depending on the apparatus used, there is a need to define and unify the objective data which must serve as the basis for assessing the findings normal or otherwise, as well as for their diagnostic and prognostic value. Let it suffice to mention here the numerous and still debated interpretations of electro-cardiographic, electroencephalographic, nystagmographic recordings, laboratory data (cholesterolemia, differential blood count, liver function test) and functional evaluation to understand that this field is continually subject to change and requires periodical updating.

Also it should be added that some characteristics of the population which presents for examination, change with time so that part of the statistical values to compare the results of certain tests lose their validity after a few years and must be re-evaluated. Examples of this transformation are afforded by various anthropometric, respiratory, and laboratory values. Consequently selective methods and policies must be partly modified.

As is well known, a selection of aircrew applications based on the mere elimination of candidates unfit because of illnesses and imperfections, is no longer acceptable today. It must be integrated with the results of functional, physiological and psychological tests which make it possible to place the candidates who are physically fit into different levels according to the degree to which they possess the aptitudes necessary for flying activity. This involves, among other things, the awarding, in the phase of partial and total judgment, of an adequate bias factor to the results of the various tests, according to a "selective doctrine" adaptable to the various circumstances and requirements.

This motive has also brought about the need to revise the norms of selection in various Air Forces, which has led to the introduction of the concept of various independent levels of fitness in decreasing order for each apparatus or function, adaptable to new and hitherto unforeseeable requirements. These are distinct from those regarding the personnel in service, for whom numerous factors can modify the judgement of total or partial fitness. In fact the requirements in the case of an ordinary check-up must necessarily differ in accordance with the anatomo-functional modifications caused by age flying activity, and the different significance they assume in persons with professional experience, adaptation and skill.

2. AN OUTLINE OF PHYSIOLOGICAL SELECTION IN THE AIR FORCES OF NATO COUNTRIES

In our opinion a preliminary panoramic survey of the methods and policies followed by the Medical Services of most of the Air Forces of NATO Countries for the physiological selection of flying personnel, may be of a certain interest. The regulations on this matter are obviously very similar, on the whole, but the presentation of the norms differs considerably. In some regulations it is synthetic and does not go into detail, leaving the expert considerable autonomy of method and judgement; in others it is analytical and makes provision for nearly every case, thus limiting disparity of evaluation of findings and difference of judgement, at the same time narrowing the possibility of special consideration in some instances.

We shall try to summarize current regulations, with special stress on functional evaluation.

The Belgian regulations condense in some short but comprehensive chapters the norms regarding the medical examination for aircrew and pilot candidates; one for flying personnel in service and the other for personnel with limited fitness for flying. A considerable number of Articles (see Chapter 2) are dedicated to respiratory and cardio-circulatory organs and functions. Many useful details are given concerning functional respiratory and cardiovascular tests. These regulations introduce or stress interesting concepts, such as the limit of maximum height, the necessity of accompanying the clinical examination with functional tests, the acceptance of slight deficiencies in the case of personnel with a great deal of flying experience.

The present norms of the Canadian Armed Forces (see Chapter 3) do not prescribe real functional tests, but their use is implied: for example, art. 712 (h) (1) speaks of cardiomegaly (which presupposes a radiograph at the distance of 2 m) and of shortness of breath on exertion (which presupposes some physical exercise test with objective measurement of ventilation); numerous recommendations are given to ensure correct recordings of the ECG and maximum and minimum blood pressure limits are laid down.

The regulations of the French Air Force Medical Service are detailed and provide, among other things, for a low pressure test, and a physical exercise test, which become optional examinations. Minima and maxima are laid down for height and weight and systolic and diastolic blood pressure. Electrocardiographic, telecardiographic, electroencephalographic examinations are prescribed. These regulations always distinguish clearly between the first examination for selection and medical periodical examinations. For the latter the diseases compatible with complete and limited fitness are specified.

As can be seen from the careful and complete study which constitutes Chapter 4 of the present publication, techniques of a certain complexity are used in both fields explored, in order to assess quantitatively, with the greatest accuracy, functional reserves in the various situations of emergency in which a pilot may find himself. Thus experienced and able pilots can be retained.

The functional evaluation of pilots in the Federal Republic of Germany finds concrete expressions in the methods used at the GAF Institute of Aviation Medicine, Furstenfeldbruck. Tests of physical exercise in various conditions, when breathing air or hypoxic mixtures, with measurement of the classical respiratory, metabolic and circulatory parameters, are carried out regularly. Particular importance is given to the behaviour of the respiratory ratio, the O_2 respiratory equivalent (which is the opposite of the cal/liters ratio) and the "oxygen pulse": that is the ratio between O_2 intake and heart rate. Orthostatic tolerance tests (tilt table), decompression chamber and – when necessary – more sophisticated cardiovascular examinations are performed (see summary table in Chapter 5).

The results of these tests are always considered together with the results of the general medical examinations, the electrocardiogram, Master's test, and cardiac volume determined radiographically. Pulmonary function is also thoroughly examined.

Kirchhoff (1965) stressed the usefulness of the comparative study of the values and findings obtained in the various tests, since only this can give – in his opinion – the range and the limits of a man's physiological performance. He concludes: "such a functional study is complex and time-consuming, but its results justify our medical efforts".

The first references to a functional exploration of Italian Air Force pilots are found in a booklet by A.Casarini entitled "La scelta dei piloti per la navigazione aerea" (The choice of pilots for aerial navigation) published in 1925. The official regulations for selection in 1929 include a low pressure tolerance test.

At present, on the basis of experimental work carried out since the early fifties and the experience of many thousands of examinations, functional tests are used as a matter of routine in the selection and periodical control of aircrews and also for particular diagnostic purposes (see Chapter 6) which may concern other Air Force personnel.

The Royal Netherland Air Force prescribes the performance of functional tests for pilots and other flying personnel in the selection phase and during periodical examinations (which are not annual). The physical exercise is carried out with a constant load of average intensity and the evaluation of the energy consumed is calculated indirectly.

The Portuguese Air Force is in progress of organizing the performance of functional tests with a standardized method. Already, however, it is able to conduct exercise and hypoxia tests and Schneider's index whenever this is seen to be necessary from the clinical and instrumental examination (X-ray, ECG, blood pressure) carried out for all the candidates and aircrews.

Aptitude selection in the United Kingdom is carried out in a special Centre and consists of three phases: aptitude tests of various type (visual-motor co-ordination, arithmetic and technical questionnaires and problems) clinical and instrumental tests and so-called "aptitude exercises", which consist of discussions on various cultural issues, a peculiar "crosscountry run", a very short lecture, overcoming obstacles in the way of the execution of tasks, etc.

The RAF Manual AP 1269A "Assessment of Medical Fitness" gathers all the regulations for the medical selection and periodical control of RAF personnel and civil pilots in the United Kingdom. The examinations listed are numerous and strict – though mainly of the clinical type – and are accompanied by a careful description of the method of measurement, particularly of instrumental data.

Though with some criticisms, simple exercise tests are advised, like Schneider or other step tests and examination of postural variations of the heart rate. Radiography of the thorax, urine analysis (specific weight, albumin, reducing substances) are compulsory; other examinations included are the determination of glycemia with a check test in doubtful cases, and an electrocardiogram for candidate pilots.

A special code makes it possible to group easily the prerequisites for the various categories of military and civil flying personnel. The final evaluation is an overall one, taking into account the results of all the examinations. Each one is given a rate which is weighted according to the value attributed to it.

The regulations regarding the functional evaluation carried out at the US Army Aeromedical Service are reported in Chapter 10 and are contained both in the sections that establish the typical standards for flying fitness and in those that prescribe the semeiological and instrumental techniques to be used. The functional tests laid down are fairly numerous and include the timed vital capacity and the maximum breathing capacity, the perviousness of the nasal cavaties, examination in the low pressure chamber of the subject when recumbent, seated and standing (orthostatic regulation) and possibly carotid sinus reflex, posteroanterior X-ray, the ECG with the subject recumbent and at rest, standing up and immediately after exercise (which, however, is not standardized).

In the case of the USAF, at the Clinical Sciences Division of the School of Aerospace Medicine, strenous exercise tests are carried out by means of the treadmill with ECG recording and vectorcardiography, particularly in cases that require further study. Master's two step test is a routine procedure (always preceding other exercise tests).

Pulmonary function is also carefully explored, especially from the age of 39: vital capacity, timed vital capacity, maximum voluntary ventilation (if necessary, these tests are repeated after giving a bronchodilator) and determination of blood gases in a low pressure chamber at the height of 3600 metres are measured (Chapter 11).

At US Naval Aerospace Medical Institute (NAMRL, Pensacola) routine ECG recordings and muscular exercise tests with simultaneous ECG are used. In some instances, special examinations are performed (Chapter 12).

We think it useful to add here some information concerning ICAO policy about our theme. Annex 1 of the International Civil Avition Organization is of particular interest both because it governs the whole field concerning medical fitness for civil flying activities and because it expresses an international compromise different tendencies and needs.

For the latter reason and owing to the fact that various countries do not have special Aeromedical Institutes with specialized staff, the ICAO norms consist in many cases of formulations of a general character. They do not envisage the routine use of important means of investigation such as the electro-encephalograph. They often refer to "normal limits", without specifying which. They solve the cases most difficult to define with the formula "provided it does not compromise flight safety", which can be interpreted with great elasticity. There are also considerable gaps in the psychiatri-psychological field: the family anamestic precedents, in fact, are not considered, nor the attempt to trace through reliable sources any personal pathological precedents. No psychological examination is contemplated.

The numerous "recommendations" limit considerably the disparites of judgement that might arise owing to the very wide formulations of Annex 1. There still exist, however, the defects in its approach which, as has been mentioned, consist mainly in having a harmonize diverse requirements and trends in a common body of regulations and in having to adapt the latter to the concept that the examination to determine fitness can be carried out even by a single medical examiner with modest equipment.

However, in the Institutes for the selection and medical control of flying personnel of many nations, far stricter standards of selection than the ones contemplated in the present ICAO norms are applied. In the case of airline pilots they are achieved by means of multiple and careful examinations and tests. In this way the gaps and liberality of the present regulations and, if necessary, future ones, are counteracted. This is particularly the case regarding subsequent check-ups for the renewal of licences, when the deficiencies tolerated at the moment of selection might be transformed into real impairments, such as to cause situations harmful to flight safety and delicate from a human point of view.

3. FUNCTIONAL TESTS IN AEROSPACE MEDICINE

As is known, the purpose of functional exploration is mainly diagnostic since it aids clinical and instrumental research by showing with greater precision and quantitatively the degree of normality and specific performance of an organ or of one or more systems. Thus it facilitates the classification of subjects clinically defined as "healthy" or "normal", arranging them according to a progression of values which essentially express their functional reserves.

It is clear that aerospace medicine must be deeply interested in this field of research by means of which it can perfect the selection and physiopsychological control of flying personnel, and adapt them to the new performances required by the progress of technique. In various Laboratories, therefore, attempts are being made to extend and deepen researches, especially for the purpose of reducing or revealing causes of error in methods and interpretations and validating principles of judgement.

At present the term "functional test" is mainly used if a man is subjected to a condition that requires performances superior to, or different from, the usual activity levels of the organ or system explored when at rest. In the cardiovascular and respiratory field, the functional tests generally consist of mild or maximum muscular exercise, with the recording of various physiological parameters before, during and after the exercise. Many laboratores, in fact, base their judgement on a single test – certainly of fundamental value – which gives the subject's maximum capacity of aerobic work (V_{02} max). To carry it out, all that is needed is a step 40–50 cm high and a spirometric system for the continuous measurement of the O_2 consumed (or suitable analyzers). Various authors have tried to simplify it by calculating the O_2 intake from from variations in the pulse rate. The latter method has not always yielded the results desired. However tests of maximum O_2 uptake, with the continuous recording of this parameter, of pulmonary ventilation, the ECG and possibly the CO_2 output, is universally used, especially in the field of sport medicine. The W.H.O. has dedicated to this important subject a recent monograph (1971), the result of the collaboration of eminent specialists.

The wide use of this test has pushed into the background another method which we consider very useful: we are referring to the hypoxia test, which is carried out in many military and civilian aviation medicine institutes. The Aviation Medicine Institute of the DFVLR (Bonn – Bad Godesberg) can be cited as an example. It carries out the ECG, measurement of the blood pressure and phychomotor tests during a routine climb in a low pressure chamber.

An interesting technique for the functional exploration of the systems considered here, is the pharmacological one. For various reasons, it is limited at present to the use of bronchodilating substances in cases in which other examinations point to a possible bronchoconstriction. However vasoactive substances especially will be a useful tool of investigation.

Another very promising method (as the recent space experiences have shown) is that of passive orthostatism, which is carried out by means of the tilt table. In practice this method is little used, probably because subjects find it unpleasant.

The tests of maximum exercise (or better max V_{02}) are carried out for the most part by means of steps, bicycle-ergo-meter or treadmill. The last mentioned apparatus is considered preferable today because it meets the physiological principles better and is suitable also for persons without any physical training. This notwithstanding, we have already pointed out that work on the treadmill is influenced by whether the subject supports himself on hand rails or not. Having eliminated this cause of error (and consequently applied a safety system to prevent the subject from being thrown backwards in the case of indisposition), we decided to examine the influence of the length of step on the mechanical work carried out when the belt of the treadmill has a constant slope.

As is known the work of walking upwards depends on raising of the body mass and on forward acceleration to bring about its translation (the resistance of the air is very slight at walking speed and can be neglected). In the case of the treadmill, for this to happen the subject must walk with steps of the adequate length The shorter and more frequent they are, the more the displacement of the mass centre upwards and forwards is reduced, for every single step, so that, in the extreme case, the subject could carry out walking movements while remaining always in the same place. Cinematographic recordings carried out by Rossanigo (1954) have shown that a subject of average bodily dimensions tends, at the lower speeds of the belt, to take steps of a length such as to determine the execution of a muscular work corresponding to the one calculated. At the higher speeds, when the steps become shorter, the displacement of the bodily mass centre becomes less, with a consequent decrease of the work carried out. These results confirm the necessity of a strict unification of the technique, even in the details usually left to the collaboration of the subject.

Many laboratories use the bicycle-ergometer for carrying out of precisely measured muscular work of prefixed quantity. This apparatus has the disadvantage of creating difficulties for those who cannot ride a bicycle. On the other hand it makes it possible to avoid causes of error dependant on the method in which the subject carries out the prescribed work. It is very important to establish whether the test is carried out sitting or recumbent as the cardiovascular responses are different in the two cases.

Another important aspect consists in the difficulty of accounting in a quantitative and uniform way for all the variables that influence the physiological responses to exercise and which are correlated with the latter in various ways. For example, evaluation of the behaviour of heart rate, during muscular work, presents no small difficulties. In the same individual the values obtained at the end of the work for the parameters usually assessed may be very different owing to the fact that the subject may have interrupted the test after slightly different periods of time and therefore may or may not have reached the bradycardic phase that immediately precedes failure.

The final value is also influenced by sport training, the neurovegetative tone and particularly the degree of determination of the subject to reach the limits of his own physical performance. For these reasons we have recently renounced the evaluation of the absolute value of heart rate which does not take these numerous variables into account. In its place we utilize the ratio between the O_2 intake per minute and heart rate (V_{O2}/HR), studied by other authors (Hollman, Valentin and coll., 1961), which seems to us to express better the cardio-circulatory performance in relation to the energy requirements of the body and to be less influenced by the variables quoted above, especially if its rate is considered.

For instance, the results on 500 subjects studied by Janigro (1964) show a close correlation of this ratio, in various conditions, with the amount of work carried out ($r = 0.96$) and with the behaviour of the ratio Cal/litres ($r = 0.88$) which, as already seen, is an appreciable indication of the respiratory performance.

It is interesting to note the finding that emerged from this research that there is a difference (appreciable in the group, not in the single individual) between the values of VO_2/HR presented at rest or during recovery by subjects who carried out a short and smaller amount of work over a shorter period in comparison with those who were capable of a greater amount of work over a longer period. It will be necessary, however, to undertake further research to be sure of the validity of the above mentioned relationship.

In this connection we wish to stress the difficulties characteristic of our environment in the method of ascertaining, the prognostic capacity of the "functional" judgements some time after the event. Unlike the field of sport medicine, in which respiratory and cardio-circulatory efficiency has a close and preponderant relationship with athletic performance, in the field of aviation medicine this efficiency is only one of the requirements necessary to make a good pilot. Consequently, a high number of pilot cadets are actually as passively eliminated from flying owing to deficiencies in the field of culture, aptitudes, discipline or for primate reasons for illnesses, to list but a few.

It is therefore very difficult to follow up a large enough group to be able to draw significant conclusions regarding the accuracy of the classification made in the selection phase. It will be possible to do so only after a number of years and represents one of our programmes of work.

Another important result, in our opinion, derived from experience, concerns the limited validity of some parameters on which judgement is based both from geographical and chronological considerations.

A convincing example seems to us to be Vital Capacity, for the evaluation of which we have used different formulas successively, finding them not completely satisfactory for our population. Also an assessment carried out by Rossanigo and Janigro in 1963 has proved to be unsuitable in some degree for a group of airline pilot candidates, whose average values were approximately 10% higher (ml 5477 ± 575 as against the foreseen value of 5018).

The average values of other data fundamental to the purposes of evaluation (O_2 intake, ratio Cal/L and VO_2/HR) were also seen to be higher, so that it would seem more accurate (even if more troublesome from the practical point of view) to evaluate the members of each group at the end of the tests on all the subjects after working out the statistical averages for the data obtained on that group. When such high precision is not necessary, the values obtained on sufficiently numerous groups of population of corresponding age will be sufficient.

In a word, therefore, tests of respiratory and cardiovascular functional evaluation still need some experimental, technical and critical work as well as continual adaptation to the characteristics of the population operated on, if reliable data and true judgements are to be obtained from them.

We think the recommended policy for physiological requirements, though subject to various technical revisions and updatings consequent upon the progress of research, can be summed up as follows:

(1) The modern pilot must possess, together with other important psycho-physiological qualifications, an adequate respiratory and cardiovascular functionality. These personnel though not usually exposed to hypoxia (which, as is known, makes great demands on the two systems), may meet with it in emergency situations. Furthermore pilots are subjected in various ways to the effects of barometric depression, accelerations, vibrations and protracted neuro-psychologic strain and to the use of pressurized equipment, for example, all conditions which, to varying extents, load the circulatory and respiratory systems. The greater the functional reserves of the body, the better it will respond to these demands.

(2) The objective evaluation of these reserves cannot be made with the classic semeiotic methods, indispensable though they are in the vaster framework of personnel selection. However, it must be based on "functional tests", which represent a test of standard characteristics to which the organism is subjected in order to study its responses quantitatively and qualitatively. Since the personnel in question are required to fly it is also advisable to carry out tests which simulate one or more conditions of flying.

(3) For this reason, and because of the necessity of having at one's disposal several data which can confirm one another thus reducing possibilities of error and narrowing by mutual integration, the range of natural

variability of the individual results, it seems better to use groups of functional tests and to base the judgement on the weighted evaluation of the data that are most significant on the physiological plane. The choice and unification of method of the individual tests could be based on some essential physiological premises and on the critical examination of the common experience. The selected tests should be calibrated for each population.

(4) The richness of the statistical data collected, the possibility of repeating on some of the subjects all or part of the tests some time afterwards and the observation of the results obtained at other aeromedical laboratories or at University laboratories using these methods, have proved to us that their substantial validity can be weakened by errors of technique (of uniformity or measurement), which are all the more frequent the more complex the apparatus is. This validity can be weakened also by the considerable individual variability in different applications of the test for contingent reasons (state of well-being of the subject, his commitment and ability in carrying out the test) and by the continual, though slight, transformation of some characteristics and therefore of the average values of the successive groups of candidates to be evaluated.

(5) The results can be improved by increasing the weight of the tests that can least be influenced by the behaviour of the subject and by replacing the absolute values of some data, such as heart rate, pulmonary ventilation etcetera, with the values of the ratio between these data and another value correlated physiologically (e.g. O_2 intake per minute).

For the purpose of obtaining simple applicative orientations, the attempt has been made in our laboratory for some time to correlate height, weight, Vital Capacity on the one hand and pulmonary ventilation, O_2 intake, maximum capacity of muscular work on the other hand. However the results have been equivocal. Studies have been made of the ratios between Vital Capacity, volume expired in the first second, maximum voluntary ventilation and height, weight, body surface and among the latter variables. Interesting correlations have been found particularly as regards timed vital capacity.

The discrepancy that can be observed in various cases between the results of the anthropometric examination and the results of functional tests (orthostatism, physical exercise of various types), has been the object of comparative researches on height, weight, height of the trunk, length of the lower limbs, thoracic perimeter, sagittal thoracic diameter, transverse thoracic diameter, Vital Capacity, heart rate in clinostatic position, results of Crampton's test and results of Schneider's test. Practically no correlation was found between the various series of values.

The fact that little or no correlation was found by various researchers is not surprising, if we take into account some statistical and biological considerations.

From the statistical point of view it should be pointed out that both the dimensional morphological parameters of the body and the dimensional physiological ones commonly measured do not represent the result of single factors. They can be considered as resulting from the more or less interrelated action of many factors. Each of these acts to a different extent and all the various actions together lead to a complex which necessarily masks the influence of the single factor.

From the biological point of view it should be kept in mind that every individual represents a section in time of dynamic processes which find their determining and conditioning causes in the large and variable number of genetic and environmental factors, the latter more or less past or present, and also in the degree of physical training Furthermore, some physiological elements that have a considerable influence on respiratory and cardiovascular performance, have no morphological equivalents or, if they exist, they cannot be measured easily and directly. Let us mention, among the main ones, the speed at which gases are diffused through the alveolar wall, the haemoglobin flow and the adaptation of the vascular bed.

An evident though modest correlation between the parameters that are usually considered can be expected only in the extreme cases of each phenotypical combination, both morphological and functional. In all the other cases, which represent the majority of the collectivities, the variations are so gradual and subtle as to call for a very large number of subjects among whom various homogeneous sub-groups, each containing a considerable number, can be extracted.

However in the present state of research it is possible, however, to note tendencies towards the association of certain morphological characteristics with certain functional responses. It should be possible to meet these tendencies in various successive samples.

In 1965 Correnti and Scano carried out a preliminary research on the relations between morphological characteristics and functional values in groups of candidate pilots. For this purpose they recorded 18 somatometric data (from which were calculated the sum of the four diameters of the trunk, the lean arm perimeter, the skeleton index and the muscular index), the values of vital capacity and of timed vital capacity at rest, and the values of pulmonary ventilation, O_2 intake, heart rate during severe exercise (from which the ratios TVC/CV, Cal/L, VO_2/HR were calculated).

The statistical and graphic evaluation of the results recorded showed the peculiar formation of the groups, with the exclusion of extreme cases and therefore unsuitable for the study of correlations between variables of various kinds. In spite of this, the results show a tendency for the somatometric values to follow a pattern similar to that of the physiological variables considered, in particular the maximum O_2 intake.

4. THE PRESENT WORK

The Aerospace Medical Panel has dealt with the problems of the medical selection and control of aircrew on various occasions. Specialists' meetings have given rise to valuable publications contained in preceding AGARDograph and in Conference Proceedings:

CP-81	"Physical Fitness and Flying" and "The Ageing and Aged Aircrew"
CP-89	"Clinical Causes for Grounding"
CP-95 Part II	"Improved and Simplified Methods for the Clinical Evaluation of Aircrew"
CP-108	"The Use of Medication and Drugs in Flying Personnel"
CP-129	"Pathophysiological Conditions Compatible with Flying"
CP-133	"Clinical Psychology and Psychiatry of the Aerospace Operational Environment"

Interest in the subject is shown also by the active presence of a permanent Committee for Special Clinical and Physiological Problems in Military Aviation, stemming from a preceding Physiology Committee. Thanks to their long activity and to the scientific authority of their members, it has been possible to plan and carry out this survey.

Various considerations prompted the present work. The first is the conviction, based on long experience, that the evaluation of the cardiovascular and respiratory function is of considerable weight in the judgement of medical fitness for aircrew and that, in the sphere of this evaluation, functional tests properly speaking facilitate the solution of diagnostic questions and in particular make it possible to give a quantitative value to the judgement. The second is the knowledge that in all the Aviation Medicine Institutes functional circulatory and respiratory tests are carried out with the methods that are not always comparable and interpretations of the results that are not standardized. The third is that a survey as ample as possible of all that is being done in this field in the most advanced Aeromedical Institutes could faciliate the task of others that intend to improve the functional evaluation of their personnel. Finally, knowledge of the methods used may aid understanding of the results obtained by the individual laboratories and avoidance of causes of error.

With this intention, on the occasion of the 28th ASMP Meeting in Luchon, October 1971, it was decided to publish an AGARDograph entitled "Survey of current cardiovascular and respiratory examination methods in medical selection and control of aircrew". The study was proposed by the Committee on Special Clinical and Physiological Problems in Military Aviation and the Editorial Committee sent all the members of the ASMP, following my unofficial letters, a circular asking them to collaborate by sending descriptive and documentary material concerning functional evaluation. Attached to the circular was the general plan proposed for the work, approved by the Expert Advisers, Maj. Gen. E.Evrard and Maj. Gen. S.Fuchs, appointed by the ASMP.

Experts of Belgium, Canada, France, Federal Republic of Germany, Italy, Norway, Portugal, the United Kingdom and the Unites States of America responded to the invitation by sending papers valuable for their accuracy and wealth of data, though varying considerably in length in accordance with the diversity of the national norms and methods used. The Papers were complemented – on request – with clear illustrations that increased their documentary value. Some contributors adopted the schema proposed by the Editor; others preferred to follow the national norms, supplying chapters of the latter with or without introduction and explanatory comments.

In spite of these disparities, the Editor considered it preferable to modify the texts as little as possible and merely changed the position of some sentences and unified the title pages, titles and sections of the various chapters. He considered that detailed accounts of the techniques used to record the pulse, blood pressure, ECG, VCG and of the ways in which the muscular exercise tests are carried out, were extremely useful in a work of this type as they represented the first step towards the standardization and simplification that must be our aim.

Nearly all the contributions lack information on longitudinal studies that could confirm the reliability and evaluative capacity of the tests some time afterwards. This is probably due to the objective difficulties to which we have already referred.

To conclude this introductory chapter the Editor wished to acknowledge the valuable help he received from Maj. Gen. Heinz S.Fuchs, Commanding General, German Federal Armed Forces Medical Command, and Brig. Gen. Hubertus Grunhofer, Director, GAF Institute of Aviation Medicine, Furstenfeldbruck, who were so active in getting the work underway and who both sent interesting data. He is also grateful to Maj. Gen. E.Evrard, BAF, MC, and Maj. Gen. A.P.Gibert, FAF, MC, Director, Research and teaching Center of Aviation Medicine, Paris, who supplied him with material and helped him to obtain the respective national contributions, and to Col George Zinnemann, who assisted him in every way.

A word of special thanks to the Authors of the single chapters, whose competence and abnegation made the present work possible.

The Editor is especially indebted to Group Captain E.J.McGuire, RAF who kindly accepted to review the manuscript. His accuracy and his competent co-operation have improved not only the presentation of the text but also its intrinsic quality.

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CHAPTER 2

CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS CURRENTLY APPLIED IN MEDICAL SELECTION AND CONTROL OF B.A.F. AIRCREWS

by

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1. GENERAL INFORMATION

The book containing the tables of disorders and diseases causing unfitness for flying service, in use in the Belgian Air Force, includes the following articles on the respiratory organs and the respiratory function, given in the original language.

Article 4	alinéa 5	Antécédents
Article 13		Examen des organes respiratoires
Article 20	alinéa 2	Tuberculose
Article 20	alinéa 8	Robustesse
Article 31		Affections des organes respiratoires chez les Personnel navigant en service.

Textes relatifs à la fonction cardio-vasculaire

Article 4	alinéa 4	Antécédents
Article 15		Examen du système cardio-vasculaire
Article 20	alinéa 7 et 5	Faiblesse de complexion Obésité
	alinéa 8	Insuffisance de robustesse

Article 4 – Les candidats dont les antécédents personnels comportent une des affections ci-après sont déclarés immédiatement et définitivement inaptes au Personnel navigant pour autant que l'existence de ces antécédents soit nettement établie par l'anamnèse, l'examen médical et les examens spéciaux exécutés dans les conditions déterminées plus loin:

(1) . . . . .
(2) . . . . .
(3) . . . . .
(4) Syncopes répétées, lésions de l'endocarde ou du myocarde, crises répétées de tachycardie paroxystique, de fibrillation ou flutter auriculaire, maladies de Raynaud ou de Buerger, spasmes vasculaires et autres manifestations artéritiques ou vasculaires avérées.
(5) Tuberculoses pulmonaires, bronchites chroniques, emphysèmes, pleurésies à épanchement, pleurésies sèches de longue durée, asthmes et accès graves de rhumes des foins.

Article 13 – *Examen des organes respiratoires*

Outre les méthodes cliniques courantes, l'examen des organes respiratoires comprendra toujours un examen radiologique ou radioscopique.

Doivent entrainer l'élimination:

(1) . . . .

(2) Les difformités, tumeurs ou affections chroniques du nez ou du nasopharynx gênant sérieusement la respiration nasale. L'obstruction des voies aériennes provoquant une diminution de 50% de la perméabilité des fosses nasales de l'un ou de l'autre côté ou gênant le drainage d'un sinus est toujours éliminatoire.

Il y a lieu d'éliminer les porteurs de lésions susceptibles de provoquer des epistaxis répétés, ainsi que les anosmies, les parosmies et paresthésies.

(3) L'asthme bien établi, l'emphysème pulmonaire bulleux ou généralisé, la bronchite fétide, les bronchiectasies, les pneumoconioses, les mycoses pulmonaires et bronchiques et autre affections chroniques non tuberculeuses des bronches, des poumons ou des plèvres et séquelles importantes d'affections aigues de ces organes.

(4) Les pleurésies d'origine tuberculeuse ou d'étiologie indéterminée, les séquelles pleurales datant de moins de deux ans et celles plus anciennes qui, par leur situation ou leur étendue, peuvent gêner la ventilation pulmonaire ou l'exécution des missions aériennes en parfaite sécurité.

(5) L'exérèse pulmonaire partielle.

(6) Les tumeurs pulmonaires et médiastinales.

(7) Les affections d'organes non respiratoires entrainant soit une infection chronique de l'appareil respiratoire soit une perte importante de la fonction respiratoire.

Article 15 – *Examen du système cardio-vasculaire*

Les candidats seront soumis à des examens spéciaux permettant d'apprécier la fonction cardio-vasculaire. Celle-ci doit être telle que les sujets puissent resister aisement aux conditions penibles resultant du vol. A cet effect, la technique de l'examen comportera un certain nombre de mesures et de tests sont les elements feront l'objet de l'interpretation suivante:

(1) *Le pouls*

En position couchee: ne peut, en principe, depasser 84 pulsations par minute. En position verticale: le pouls immediatement apres la prise de position verticale, ne peut depasser 108 pulsations par minute.

Le pouls stabilise ne peut depasser 96 pulsations.

Les anomalies seront appreciees en fonction de l'examen clinique.

(2) *La tension sanguine*

La tension diastolique mesuree suivant le methods auxultatoire doit etre comprise entre 90 et 60 mm de mercure.

La tension systolique mesuree suivant la meme methode ne peut depasser 150 mm de mercure lors de l'examen initial et 160 mm lors de toute autre examen, ou etre inferieur a 100 mm de mercure. Lorsque les chiffres mesures depassent les limites superieures mentionnees ci-dessus, il entraineront, en principe, l'elimination s'ils persistent apres une demi-heur de repos en position couchee.

(3) *Une epreuve d'endurance*, permettant de juger de la resistance cardio-circulatoire a un effort prolonge et epuisant.

(4) *L'electrocardiographie*: L'electrocardiogramme sers toujours.prescrit et pris en considération, si:

(a) le pouls du sujet couché ne dépasse pas 50 pulsations par minute,
(b) le sujet présente des troubles du rythme cardiaque,
(c) les antécédents et l'examen du candidat plaident pour une affection cardiaque,
(d) le candidat a atteint ou dépassé l'âge de 40 ans.

Une téléradiographie du coeur sera prescrite en cas d'élargissement notable de l'aire cardiaque, décelé par l'examen clinique ou la radiographie. Les sujets dont le diamètre cardiaque traverse dépasse de 15% la normale, seront éliminés.

Doivent entraîner l'élimination: une list d'une page, qui énumère les affections entraînant l'élimination.

Article 20 – (8) *L'insuffisance de robustesse*

L'insuffisance de robustesse relève des données de l'examen morphologique et surtout de l'examen clinique. L'expert portera notamment toute son attention sur l'aspect fonctionnel des organes circulatoires et repiratoires. On tiendra compte de l'épreuve d'endurance, prévue à l'article 15, alinéa 1, 3.

2. METHODS

As regards the functional respiratory and cardio-circulatory tests, they are presented overleaf in tabular form for comparative purposes.

Methods	*Aim*	*Techniques for implementation*	*Limits of reliability*	*Evaluation of results*	*Weight conferred on each test*	*Remarks and references*
Respiratory System (1) *Routine examination*	Evaluation of mechanical efficiency of the respiratory sytem	*Apparatus*: Spirometer. Personnel: 1 technician. Time necessary to carry out each test plus calculations: ± 20 mins	*Apparatus*: Precision of reading through the scale: above 99%. Apparatus requires control of temperature; no recalibration necessary except speed of drum (once a month). Defects exceptional *Subject*: minimal co-operation required; coefficient of variation: about 5%.	The volumetric data are converted into BTPS and the latter into per cent of our own normal values (Ref. 1)	Values below 70% of the normal values are suspect and entail supplementary tests (see further). If below 60% of normal value: applicant rejected; a graduated F.P. is grounded and undergoes follow-up (investigation for emphysema, chronic bronchitis)	*Ref. 1*: Bande, J. AGARD Conf. Proc. No.25 (1957) *Ref. 2*: Bande, J. AGARD CP-81–71 (1971) *Ref. 3*: N.G.M. Orie: Pharmaco-dynamie des poumons et de l'arbre bronchique: L'exploration fonctionelle pulmonaire, éd. médicales Flammarion, 20, rue de Vaugirard, Paris VI° (1964) p.344 et sq.
(2) *Supplementary tests in cases of doubt*						
Bronchodilation test	Evaluation of spasmodic bronchoconstriction	Inhalation by aerosol of 2% Vaponefrine, IPPB during 5' followed by the same volumetric measurements as above. Time: ± 30 mins	idem	idem	If the FEV_1, or Tiffeneau test, increases by more than 10% with respect to its initial value the test is considered to be positive. Ref.3 (i.e. spasmodic bronchoconstriction) either chronic bronchitis or asthma. Applicant rejected. Graduated F.P. as above	

(Continued)

Methods	Aim	Techniques for Implementation	Limits of reliability	Evaluation of results	Weight conferred on each test	Remarks and references
Bronchoconstriction test	Evaluation of asthma suspected either by anamnestic data or by clinical findings	Inhalation of aerosol of 1% acetyl-choline IPPB during 2′ under 12 cm H_2O pressure.	idem	idem	If the FEV_1 or Tiff. decreases by more than 10% with respect to its initial value the test is considered to be positive (asthma). An applicant is rejected. A graduated F.P. as above.	Accidents: possible asthma-attack (2 cases in 150 tests): immediately relieved by Vaponefrine without other complications.
Other tests suggested: Airway – resistance measurements by the Dubois method: this method would probably be still more sensitive but requires a plethysmograph (cost: about 1,000,000 Bfr), 1 technician and 1 physician. Recalibration required each day and difficult. Time necessary for one test plus calcula.:ons: 60 minutes.						

(Continued)

Methods	*Aim*	*Techniques for implementation*	*Limits of reliability*	*Evaluation of results*	*Weight conferred on each test*	*Remarks and references*
Circulatory system *Routine examinations* Blood pressure (recumbent)	Common clinical evaluation	Manometer (preference given to mercury-manometer) Personnel: 1 physician (in case of necessity could be performed by a technician) Time necessary: 1–2 minutes	Apparatus: precision of reading of the scale: above 99% but precision of reading during the actual auscultatory measurement far less (errors of 0.5 cm Hg at least) No control of apparatus required nor recalibration. Subject: no cooperation required. Coefficient of variation usually 10 to 15% but in subjects with abnormally high values the reproducibility of the measurements might be worse (coeffieient variation 20%)	If systolic and diastolic pressures respectively equal or exceed 15 and ⁿ cm Hg a new measurement is performed after 30 minutes of rest.	Systolic and diastolic pressures respectively higher than 15 and 9 cm Hg entail rejection of an applicant. If the subject is graduated, further evaluations are carried out: control of pressure twice a week during 3 to 4 weeks (by the flight surgeon of the base). If the mean values remain high, blood-analyses (lipidogram-) and renal functions (creatinine clearance-) are asked (hospital-central laboratory). If systolic and diastolic pressures are respectively lower than 10 and 6 cm Hg the applicant is rejected in principle. A graduated F.P. will undergo follow-up and may be grounded during that tir .	References: these criteria proceed from the national regulations.

(Continued)

Methods	*Aim*	*Techniques for implementation*	*Limits of reliability*	*Evaluation of results*	*Weight conferred on each test*	*Remarks and references*
Step test of 5 minutes	Investigation of adaptability to heavy exercise	Subject has to step the bank up and down every 2 seconds during 5 minutes Step bank of 50 cm height Personnel: 1 technician Time necessary: 5 minutes for execution – 3 minutes for measurement	Subject: Cooperation required. Coefficient of variation within the same subject not known (see Reference)	Pulse rate taken after completion of exercise in number of beats during 30 seconds, three times. Each measurement is separated from the previous one by 30 seconds delay	Test only performed on applicants: subject is required to be able to execute the exercise during full 5 minutes. If the sum of the three pulse-rates (30 seconds) exceeds 220, the adaptability to exercise is considered unsatisfactory. The applicant is given the opportunity to repeat the test after 1 or 2 months. He is advised to submit himself to some training during that period. If at the end of this period the test yields again a score higher than 220, the applicant is rejected. (Reference 4)	*Ref. 4*: E.Evrard: Essai d'application du step test au contrôle médico-sportif et à la sélection des aviateurs La Médicine aéronautique t. VI, No.4, 1951 pp.301-307
Electrocardiogram	Common clinical evaluation	Electrocardiograph Personnel: 1 technician to take the trace, 1 cardiologist for evaluation.	*Apparatus*: Calibration: 1 millivolt yields deflection of 10 mm on the paper (to verify every day). Speed of trace: 25 mm/sec Subject: no cooperation required. Precision of readings: errors of about 0.5 mm (i.e. 20 millisec. and 0.05 millivolt) Reproducibility within subjects: not known but probably within the range of precision of reading?	See Reference 5	In applicants the following findings are causes of rejection: atrioventricular blocks of any degree (PR interval greater than 0.20 sec.) complete right bundle branch block. Wolf-Parkinson White syndrome, left bundle branch block, atrial flutter-fibrillation, right ventricular hypertrophy Extrasystoles which do not (disappear (or decrease) after exercise and Multifocal ventricular premature contractions are also causes of rejection. Applicants and graduated F.P. with S T and T wave changes:	

(Continued)

Methods	*Aim*	*Techniques for implementation*	*Limits of reliability*	*Evaluation of results*	*Weight conferred on each test*	*Remarks and references*
(electrocardiogram)					an ECG is taken 90 minutes after absorption of KCl (4 gr. per os): the ST – T abnormalities on the left precordial leads and limb leads 1 and 2 must disappear. If not the applicant is rejected. The graduated F.P. will be limited in its flying duties, or forwarded to further investigation (ECG after exercise, or after a β-blocking agent, possibly coronarography; ... etc.)	
Phonocardiogram	Record of the auscultatory findings	1 technician Evaluation by cardiologist		as for all auscultatory abnormalities	Common clinical evaluation All cases suspect of cardiac diseases or congenital defects will lead to rejection or grounding.	

(Continued)

Methods	*Aim*	*Techniques for implementation*	*Limits of reliability*	*Evaluation of results*	*Weight conferred on each test*	*Remarks and references*
Supplementary tests in cases of doubt: ECG after 3 minutes of exercise (step-test) or 90 minutes after KCl intake (4 gr per os)	Detection of coronary defects in cases of unspecified ST–T abnormalities	1 technician 1 cardiologist	*Apparatus*: Calibration: 1 millivolt yields deflection of 10mm on the paper (to verify every day). Speed of trace: 25 mm/sec Subject: no cooperation required. Precision of readings: errors of about 0.5 mm (i.e. 20 millisec and 0.05 millivolt) Reproducibility within subjects: not known but probably within the range of precision of reading?		the ST – T abnormalities on the left precordial leads and limb leads D_1, D_2 must disappear. If not the applicant is rejected. The graduated F.P. will be limited in its flying duties or grounded according to the results of the further investigations performed in specialized centers (ECG after exercise, after a β-blocking agent e.g. 40 mg "Inderal" per os with ECG trace 30 minutes later, possibly coronarography) or according to the clinical background (complaints f.i.)	
Other tests suggested:	measurement of oxygen consumption during exercise on an ergometer-cycle would provide more precise information than the step test. However this investigation requires trained personnel on the spot, and is of too long a duration for routine examinations. Moreover, the test is not specific of the circulatory system. Vecto-cardiography for those subjects with small R deflections or QS waves in precordial leads V_1, V_2, V_3 (differential diagnosis: myocardial infarction) or when differential diagnosis between right ventricular hypertrophy and incomplete right bundle branche block required.					

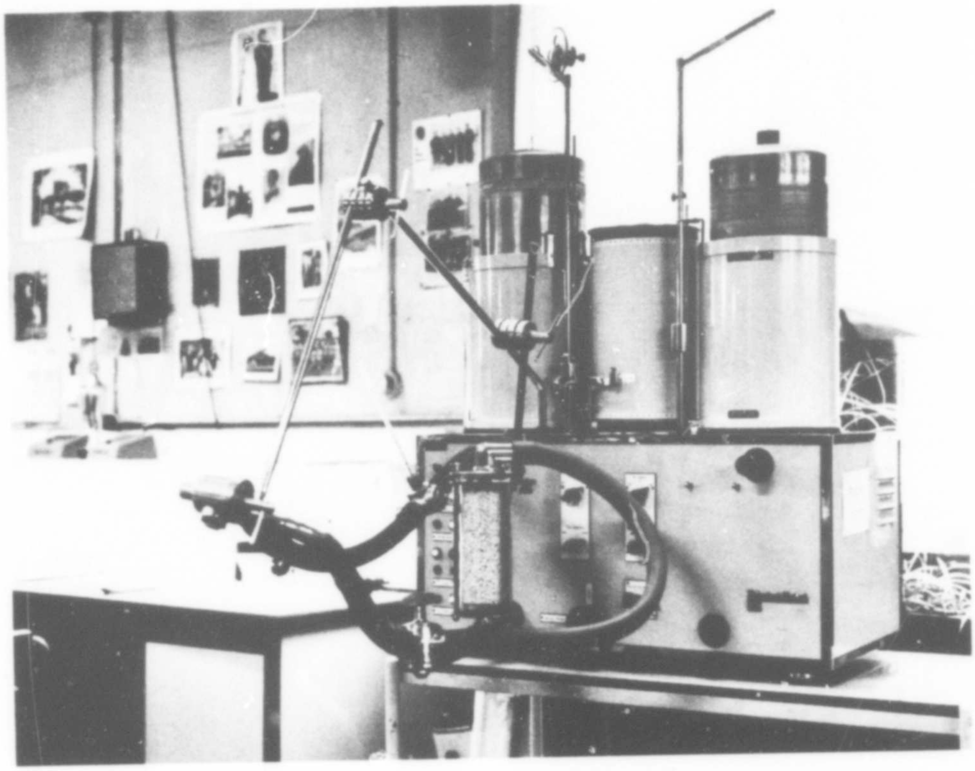

Fig.2.1 Modified Godart Pulmotest for spirometric tests of B.A.F. pilot aspirants

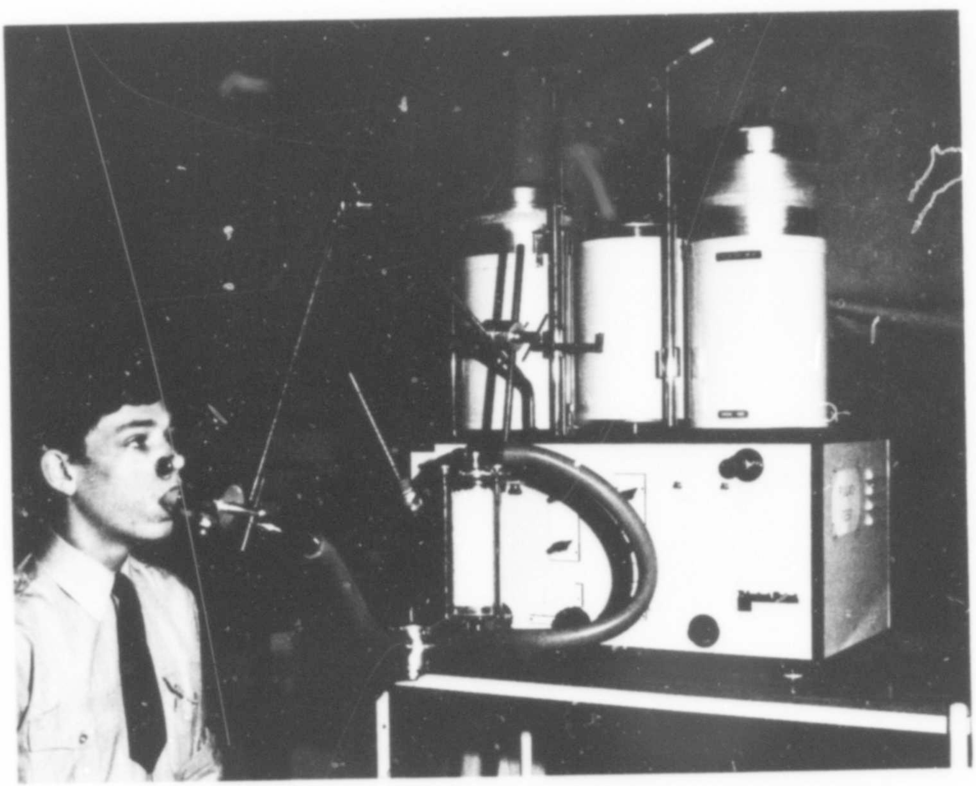

Fig.2.2 Spirometric test of B.A.F. pilot aspirant

CHAPTER 3

CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS CURRENTLY APPLIED IN MEDICAL SELECTION AND CONTROL OF CANADIAN ARMED FORCES

by

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1. GENERAL INFORMATION

The Canadian Armed Forces methods of selection and control of aircrew as related to the cardiovascular and respiratory examinations are indicated below:

Cardiovascular

(1) Selection – Physical examination
– Electrocardiography (CFMO 27-04 refers)

(2) Standards – Cardiovascular standards are reflected in Medical Standards for Canadian Armed Forces (CFP 154 Article 712)

(3) Control
- (a) Initial ECG on pilots, navigators, Air Observers and Flight Engineers are assessed by same cardiologist.
- (b) Annual physical examinations.
- (c) Serial ECG follow-up conducted every 4 years until age 35, and annually from 35 onwards. Referenced ECG's are interpreted by cardiologist who interprets initial ECG.

Respiratory

(1) Selection – Physical examination
– AP Chest X-Ray

(2) Standards – Respiratory standars are reflected in Medical Standards of Canadian Armed Forces (CFP 154 Articles 704, 705 – 710).

(3) Control – Annual physical examination
– Annual AP Chest X-Ray

The references referred to in this brief outline of subject matter are attached in the following pages.

2. REGULATIONS

712 **Heart and Vascular System**

(1) The causes for rejection for enrolment are:

- (a) major congenital heart disease;
- (b) rheumatic fever with carditis;
- (c) chronic rheumatic valvular disease of the heart;
- (d) myocardial infarction, coronary insufficiency (this will include cases with only electrocardiographic changes if these are very suspicious);
- (e) recurrent pericarditis;
- (f) persistent or recurrent arrhythmias such as paroxysmal atrial tachycardia, atrial fibrillation, atrial flutter, heart block (other than simple increase in PR interval, the so called first degree heart block);
- (g) thyrotoxic heart disease, or any history of severe heart involvement with thyrotoxicosis;
- (h) hypertension
  - (1) with cardiomegaly, shortness of breath on exertion, or electrocardiographic evidence of left ventricular hypertrophy,
  - (2) sustained blood pressure of over 150/90, or
  - (3) a blood pressure of under 100 systolic or under 60 diastolic with a puny build and a history of vertigo or syncope;
- (j) cardiomyopathy or any other unexplained true cardiac enlargement; care should be taken not to reject people with a simple bradycardia associated with moderate enlargement of the heart, the so called athlete's heart of the very fit, trained athlete;
- (k) aneurysm of any of the vessels;
- (m) Raynaud's disease;
- (n) thrombo-angiitis obliterans;
- (p) severe varicose veins and any case with varicose ulcers; and
- (q) any chronic edema of the ankles.

(2) Causes for rejection until recovery without sequelae are:

- (a) pericarditis, acute, viral, within three months; and
- (b) acute thrombophlebitis.

(3) Special consideration shall be given to:

(a) minor congenital heart disease which has been surgically corrected and ruled acceptable by a cardiologist; and
(b) other minor congenital cardiovascular disease ruled acceptable by a cardiologist.

3. METHODS

Electrocardiograms

General

(1) Electrocardiograms (ECGs) for Canadian Forces personnel shall be prepared in accordance with the techniques detailed in this order on the occasions listed in Annex A.

(2) Tracing shall be made in the number of copies indicated in Annex A, may be produced by photostating where adequate facilities exist, and shall be disposed of in accordance with Annex A. Extra copies are permissible for local requirements.

(3) Requisition for ECG shall be made using the form CF 2037, Request for Electrocardiogram.

(4) Immediate interpretation of tracings shall be rendered by a qualified physician in the following order of priority:

(a) CFMS Cardiologist or Internist.
(b) Civilian Consultant Cardiologist or Internist.

(5) ECGs on all aircrew shall be subject to an immediate interpretation in accordance with para 4 following which the original will be forwarded to the ECG Laboratory, Central Aircrew Medical Board, who shall provide a deferred interpretation using the report form shown at Annex D of this order. A copy shall be returned to the referring unit to be affixed to form CF 2038, Electrocardiographic Record.

(6) Every effort should be made to record non-urgent ECGs in the fasting state.

Leads Required

(7) All ECGs shall consist of:

(a) standard limb leads (I), (II), (III);
(b) a strip of lead (III) taken during deep held inspiration and labelled (III DI);
(c) augmented unipolar limb leads (aVR), (aVL) and (aVF);
(d) unipolar praecordial leads (VI) to (V6); and
(e) any other leads specifically requested by ECG LAB/CAMB, Consultant Cardiologist or Internist.

Mounting

(8) All tracings shall be mounted on form CF 2038, with careful attention to the following requirements:

(a) A strip of each lead except lead (II) showing at least two complexes with an even baseline, and a strip of lead (II) at least 15 cm long are required in all cases.
(b) All tracings shall be mounted on the face of the form.
(c) Each strip of tracing must show a record of standardization at the very beginning of the strip.
(d) If necessary, tracings may be made at one-half Normal Standardization (N/2), but they must be so designated.
(e) Tracing shall be affixed to the form CF 2038 by means of a rubber cement, photographic mounting material or double-sided adhesive cellulose tape.
(f) Each lead is to be clearly identified by means of symbols inscribed on the tracings.
(g) Great care shall be taken to ensure that the tracings are correctly marked and mounted.

CFMS INDICATIONS FOR ELECTROCARDIOGRAMS

Aircrew °	DISPOSAL	
	Original	*Duplicate*
1. All Regular Force, ROTP, URTP candidates at 1 Med Sell U (2 PSUO.IOS.) 2. Every four years prior to age 35 as part of annual examination of fitness for flying. 3. Annually from 35 years of age onward. 4. All auxiliary aircrew on enrolment.	°° ECG LAB CAMB	CF 2034
Non-Flying 1. All ranks, at age 35 if CF 2034 does not contain an ECG recorded after 32 years of age. 2. Annually all ranks at age 40 and onward.	CF 2034	CFHQ for Surg. Gen. Recs.
Clinical 1. For clinical purposes 2. When requested as part of clinical or long term ECG survey.	CF 2034 As required	Remain with and be disposed of with hospital clinical records.

° Once an individual has been included in the programme, as aircrew, he shall continue in the programme throughout his service regardless of of any change in employment	°° CAMB Electrocardiographic Laboratory, Cardiovascular Unit, Victoria Hospital, London, Ontario.

CFP 175(2) CFMO 27-04

REQUEST FOR ELECTROCARDIOGRAM
SHALL BE ATTACHED
TO THIS AREA

ELECTROCARDIOGRAM recorded at ________ ________ FASTING Yes ☐ No ☐
Time Date

INTERPRETATION:

Signature ______________________________

Date ______________________________

CFP 175(2) CFMO 27-04

REQUEST FOR ELECTROCARDIOGRAM

PRIORITY: Routine Urgent Immediate PATIENT AMBULATORY: Yes No FASTING: Yes No

Height Ins	Weight Lbs	Blood Pressure	Name	
		ELECTROLYTE DISTURBANCE:	SIN	Age
CHEST WALL Thick Medium Thin	DRUGS Digitalis Quinidine Pronestyl		Ward	Date of Requisition
			Unit	

CLINICAL DIAGNOSIS:

SPECIAL LEADS AND TECHNIQUES: (Specify)

NOTE: Routine ECG will be made in the morning with the patient fasting whenever possible.

(attending Physician)

ANNEX D

CANADIAN FORCES INSTITUTE OF AVIATION MEDICINE

CENTRAL AIRCREW MEDICAL BOARD

TORONTO, ONTARIO

Date

The electrocardiogram of

SIN ________________ Rank ____________ Name ______________________________

of ________________ taken at ____________________________ on ________________

Unit | Unit | Date

was interpreted as follows:

Signature ____________________________

for CO, CFIAM

THIS FORM IS TO BE ATTACHED TO FORM CF 2038 CONCERNED AND FILED IN FORM CF 2034

Respiratory System: Regulations

705 Nose

(1) The causes for rejection for enrolment are:

(a) *Nasal Mucosa and Airway*
(1) chronic atrophic rhinitis with ozena,
(2) severe allergic rhinitis, vasomotor rhinitis or hay fever, and
(3) severe recurrent nasal polyps.

(b) *Sinuses*
(1) recurrent acute or chronic sinusitis due to infection, allergy or severe mechanical deformity, and
(2) choanal atresia or stenosis.

(c) *Septum*
Chronic large symptomatic perforation (crustings, whistle, chronically infected).

(2) Causes for rejection until cured or corrected are as follows:

(a) *Nasal Mucosa and Airway*
(1) infectious or allergic vasomotor rhinitis and airway problems, correctible by reasonable conservative measures, and
(2) minimal degree of nasal polyps.

(b) *Sinuses*
Acute or correctible sinus disease due to a mechanical deformity correctible by surgery.

(c) *Septum*
Correctible deformities, causing airway obstruction.

706 Pharynx, Trachea, Esophagus and Larynx

(1) The causes for rejection for enrolment are:

(a) *Pharynx*
(1) leukoplakia, and
(2) chronic pharyngitis.

(b) *Larynx*
(1) chronic hypertrophic laryngitis,
(2) neoplasms, recurrent polyps and vocal nodules,
(3) granuloma or ulceration, and
(4) laryngeal palsy, sensory or motor.

(c) *Trachea*
(1) tracheostomy or tracheal fistulae, and
(2) severe asthmatic problems.

(d) *Esophagus*
(1) organic disease, ulceration, achalasia and varices, reflex esophagitis, and
(2) any chronic disease which causes interference with function of the airway, swallowing or speech.

(2) Causes for rejection until cured or corrected are:

(a) chronic tonsilitis;
(b) acute laryngitis; and
(c) acute tracheitis.

710 Lungs and Chest Wall

(1) The causes for rejection for enrolment are:

(a) moderate or marked deformity of thoracic cage (e.g., kyphoscoliosis, pectus excavatum, etc.);
(b) active pulmonary or pleural tuberculosis within five years;
(c) idiopathic pleurisy with effusion within five years, with tuberculin conversion;
(d) chronic bronchitis, emphysema, bronchiectasis;
(e) pneumoconiosis, other fibrotic changes in the lungs, (e.g., sarcoidosis) or pleura;
(f) bronchial asthma in adult life or severe hay fever;

(g) cystic disease of the lungs, (e.g., mucoviscidosis);
(h) spontaneus pneumothorax;
(j) tumours of the lung or rib cage; and
(k) lobectomy, more than one lobe.

(2) Causes for rejection until further study indicates recovery without disqualifying sequela are:

(a) pneumonia or pneumonitis within two months;
(b) acute bronchitis;
(c) active fungus disease of the lungs (e.g., histoplasmosis); and
(d) history of lobectomy of only one lobe for a non-tuberculous non-malignant lesion (until pulmonary function assessment).

CHAPITRE 4

ETUDE DES METHODES COURANTES D'EXAMENS CARDIO-VASCULAIRES ET RESPIRATOIRES POUR LA SELECTION ET LE CONTROLE MEDICAL DU PERSONNEL NAVIGANT EN FRANCE

par

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I EXPLORATION CARDIOVASCULAIRE

Le pilotage d'avions à très hautes performances, type Mirage III ou IV ou le pilotage d'avions civils supersoniques (Concorde) exige que le personnel navigant soit choisi de façon à ce que la sécurité en vol soit au maximum. Au cours de ces vols, l'appareil cardiovasculaire est l'appareil le plus sollicité par le stress aérien, d'où l'intérêt de pratiquer une surveillance cardiovasculaire rigoureuse.

L'examen clinique est capital; il doit être minutieux. L'auscultation cardiaque attentive recherchera l'apparition d'un souffle systolique ou diastolique, modification des bruits du coeur, la survenue de bruits anormaux. La palpation des pouls dans les différents territoires sera systématique pour apprécier la qualité du pouls.

L'interrogatoire sera minutieux, à la recherche de dyspnée d'effort, de précordialgies, de douleurs à la marche dans les jambes, d'absences, etc...

L'examen cardiovasculaire sera complété par deux techniques d'investigation courante:

- un électrocardiogramme,
- des mécanogrammes cardiaques.

A. Etude Electrocardiographique

L'électrocardiogramme est fait à chaque visite semestrielle; nous utilisons un appareil Hellige à 6 dérivations simultanées. L'utilisation d'un appareil à 6 pistes est importante car cet appareil permet de pratiquer en peu de temps un électrocardiogramme (5 minutes) et de ce fait ne retarde pas le déroulement de l'expertise. L'enregistrement simultané des 6 pistes est intéressante pour les épreuves d'effort, car elle permet d'avoir en un temps donné toutes les anomalies constatées sur les différentes dérivations.

L'électrocardiogramme fait à chaque visite semestrielle pourra nous faire découvrir:

(a) *Aspect de bloc de branche*

L'apparition d'un bloc de branche droit complet ou d'un bloc de branche gauche est éliminatoire. Par contre, les aspects de bloc droit incomplet sont fréquemment rencontrés et nous paraissent compatibles avec l'aviation, si la durée totale de QRS ne dépasse par 12/100 sec., si l'aspect de bloc en V 1 du type rSr' reste immuable ou disparaît lors de l'épreuve de Flack (ou endurance test) à 40 mm de mercure. En effet, une étude statistique faite au Centre Principal d'Expertise Médicale du Personnel Navigant de Paris a montré que ces aspects de bloc droit incomplet étaient retrouvés chez 12% des candidats à l'admission, que cette fréquence était d'autant plus grande que les sujets à examiner étaient jeunes.

Aussi peut-on considérer que très souvent ces aspects de bloc droit incomplet susceptibles de disparaître sous l'influence de la rotation du coeur, malgré l'hypertension ventriculaire droite provoquée par la manoeuvre de Flack, ne sont qu'un aspect purement physiologique de l'électrocardiogramme juvénile.

(b) *Le syndrome de Wolff Parkinson White* est rencontré. Au Centre Principal d'Expertise Médicale du Personnel Navigant de Paris, nous avons observé 44 fois cette anomalie électrocardiographique. Il observations étaient de type A., 33 étaient de type B., 36 syndromes de Wolff Parkinson White étaient permanents, 8 étaient intermittents. Il nous a paru intéressant d'insister sur ces Wolff Parkinson White intermittents par le nombre relativement élevé et par leur difficulté diagnostique, l'anomalie électrocardiographique disparaissait après l'effort et réapparaissait au repos.

Nous avons chiffré la prévalence du syndrome de Wolff Parkinson White à 1,6/1000. Nos chiffres concordent avec les autres statistiques:

- Sears et Manning (1962) – 3/1000
- Averill (1960) – 2,8/1000
- Smith (1964) – 1,3/1000

En France, les candidats porteurs de cette anomalie électrocardiographique sont déclarés inaptes à l'emploi du personnel navigant. Cette inaptitude nous paraît justifiée par le risque de mort subite, le risque non négligeable de crises de tachycardie paroxystique, en raison de la coexistence possible d'affections familiales de diagnostic difficile comme la cardiomégalie et surtout de la cardiomyopathie obstructive.

(c) *Apparition de troubles du rythme* (arythmie complète, flutter, etc...) Ces troubles du rythme sont éliminatoires.

(d) *Découverte électrocardiographique* d'un infarctus sans symptomatologie clinique. Au CPEMPN de Paris, de 1968 à 1971, nous avons découvert 9 infarctus du myocardique passés inaperçus par le patient.

(e) *Atypies de la repolarisation*

Il est souvent difficile d'affirmer l'origine coronarienne d'atypies de la repolarisation lorsque celles-ci ne sont pas accompagnées d'une symptomatologie clinique évocatrice.

Nous pratiquons à un pilote, porteur de ces anomalies électrocardiographiques:

- une épreuve d'anoxemie en caisson à dépression (palier de vingt minutes à l'altitude de 5.000 mètres). Le point d'impact de cette hypoxie n'est pas forcément comme on le croyait une anoxemie myocardique, mai plus vraisemblablement une hypoxie des cellules nerveuses dont l'effort se fait sentir sur le myocarde par l'intermédiaire du sympathique,
- injection sous-cutanée de 0,6 mg de Tartrate d'ergotamine,
- ingestion de 6 grammes de chlorure de potassium,
- une épreuve d'effort à la bicyclette ergométrique en pratiquant des charges progressives; cette épreuve d'effort est très importante.

Nous considérons comme pathologique une sous-dénivellation du segment ST; une négativation de l'onde T mais un abaissement du point J demande à être discuté.

Les études comparatives faites entre les épreuves d'effort et la coronographie ont montré des discordances. Vu l'innocuité de la coronographie, nous pensons que dans les cas de doute de l'intégrité coronarienne, il faut savoir demander une coronographie sélective suivant la technique de Jones.

B. Etude Méconographique

L'idée d'enregistrer graphiquement les pulsations carotidiennes ou de l'apexogramme n'est pas récente puisqu'elle avait été déjà réalisée au XIXème siècle par Chauveaux, Marey et Mackensky. Mais si de tels enregistrements avaient été précieux pour les physiologistes, ils n'avaient été que de peu d'utilité pratique pour le clinicien. C'est la possibilité de transformer les phénomènes à étudier en variations électriques sans inertie qui a permis de reprendre l'étude des mécanogrammes et d'en tirer des indications précieuses pour le clinicien et pour nos experts du personnel navigant.

Ce sont des techniques non sanglantes, facilement reproductibles à chaque expertise; en plus ce sont des tracés que l'on inclut dans le dossier de chaque pilote permettant ainsi la comparaison d'une expertise à l'autre.

Les mécanogrammes cardiaques nous apportent les renseignements de trois ordres:

- analyse des souffles cardiaques précisant la variété de la cardiopathie par la phonocardiographie,
- étude de la distensibilité artérielle par le carotidogramme,
- mesure chronocardiographique mesurant un index de débit systolique et d'apprécier la contraction du muscle myocardique.

(a) *Analyse des souffles cardiaques*

L'auscultation cardiaque aidée des examens complémentaires que sont l'électrocardiogramme et la radiographie cardiaque permet d'affirmer l'organicité d'un souffle diastolique, et parvient dans la majorité des cas à affirmer l'organicité ou l'anorganicité d'un souffle systolique. Dans quelques cas de souffle systolique la clinique se trouve en défaut; dans ces cas vu l'importance du diagnostic d'organicité pour la détermination d l'aptitude au personnel navigant, il parait utile de s'aider de techniques non sanglantes que sont les mécanogrammes cardiaques.

1. L'appareil que nous utilisons au CPEMPN de Paris est un appareil Thomson Telco; cette armoire se compose:

   1.1 d'un oscilloscope doté d'un écran rémanent de 50 cm. de diagonale, à haute luminosité avec 8 canaux où sont analysés les renseignements,

   1.2 de différentes chaines de mesure:
   un électrocardiogramme avec les 12 dérivations classiques,
   une chaine de pression avec un capteur de pression à quartz piézoélectrique permettant de recueillir un carotidogramme, ou un apexogramme ou un pouls veineux jugulaire,
   une chaine de phonocardiographie avec 6 filtres: 35 Hz, 70 Hz, 140 Hz, 280 Hz, 560 Hz, 1.120 Hz,

   1.3 un équipement d'enregistrement avec un enregistreur photographique avec 6 vitesses de 2,5 mm sec à 100 mm sec., équipé de huit galvanomètres. Les 8 spots lumineux sont enregistrés sur une pellicule photographique de 12 mètres de long,

   1.4 d'une chaine de son pour l'enseignement.

2. Les techniques mécanographiques employées dans le service sont les suivantes:

2.1 phonocardiogramme pris au niveau d'auscultation du souffle systolique,

2.2 l'étude du carotidogramme porte sur 2 éléments:
- étude de la morphologie du tracé,
- étude des chronologies des divers accidents de la courbe, temps d'ascension, temps de demi-ascension et durée de l'éjection ventriculaire gauche.

Mais ces temps doivent être corrigés en fonction du rythme par l'abaque de Pernod et Carré.

2.3 apexogramme,

2.4 épreuves dynamiques comprenant:
- la manoeuvre de Valsalva permet d'affirmer que le souffle systolique est d'origine gauche ou droite. Dans le souffle d'origine droite, le sou'fle prend à la fin de l'épreuve son intensité maximum, alors qu'à l'inverse pour le souffle d'origine gauche, il ne devient maximum que cinq systoles suivant l'arrêt de l'épreuve.
- épreuves pharmacodynamiques avec prise de tracés après: épreuve au nitrite d'amyle ou l'isuprel complétée par les épreuves aux substances vasopressives (aramine, méthoxamine).

Donc, à la fin de nous tracés, il est possible de conclure schématiquement si le souffle systolique est d'obstruction ou de régurgitation, s'il est droit ou gauche.

	Souffle d'obstruction ou anterograde	*Souffle de regurgitation ou rétrograde*
Morphologie	– losangique	rectangulaire
Chronologie	– naît à distance de B1 – n'atteint pas B2	holosystolique va de B1 à B2
Après pause extrasystolique	– renforcé	non renforcé
nitrite d'amyle	– renforcé	diminué
isuprel	– renforcé	diminué
aramine ou méthoxamine	– diminué	augmenté

3. *Résultats*

Etudions les différents types de souffle systolique que l'on peut rencontrer en visite d'admission ou en visite révisionnelle.

3.1 Les souffles systoliques anorganiques

(i) Le souffle infundibulopulmonaire ou souffle de Tripier-Devic est très fréquement rencontré chez les jeunes candidats ayant un élasticité artérielle très grande. C'est un souffle systolique siégant au foyer pulmonaire dans la région parasternale gauche à la partie interne du 2ème ou 3ème espace intercostal. Le mécanisme du souffle est l'engouffrement du sang dans un orifice pulmonaire jouant le rôle de rétrécissement fonctionnel.

Les critères mécanographiques seront ceux d'un soufle d'obstruction droit.

Du point de vue morphologique, on remarquera que le souffle est protosystolique accolé au ler bruit, decrescendo et laisse libre le méso et la télésystole.

(ii) Les souffles cardiopulmonaires (souffle de Potain), rencontrées plus rarement, ne naissent pas au niveau d'un orifice du coeur et varient considérablement avec les phases du cycle respiratoire et la position du patient.

Ils sont perçus dans le région endopexienne. Ils peuvent être inspiratoires et expiratoires ou uniquement inspiratoires.

Sur les tracés, le souffle n'a aucun caractère précis et ceci se comprend en fonction de son mécanisme. Il varie de morphologie d'une systole à l'autre et varie en fonction du cycle respiratoire. La pharmacodynamie n'apporte rien de précis et ceci se conçoit bien.

3.2 *Souffles systoliques organiques*

(i) Le rétrécissement aortique

Le phonocardiogramme montre que c'est un souffle d'obstruction gauche avec les critères que nous avons décrits plus haut.

Quelques nuances phonocardiographiques sont propres à la sténose aortique:
disparition de la composante aortique du 2ème bruit,

- constatation d'un claquement protosystolique (ou click) d'éjection qui se rencontre dans certains cas.

Le carotidogramme du rétrécissement aortique présente du point de vue morphologique une série de crenelures (images en crêtes de coq ou en dent de scie) à la partie terminale de la branche ascendante et une disparition de l'incisure catacrote. Du point de vue chronologique, on note une augmentation du temps d'ascension, du temps de demi-ascension et du temps d'éjection systolique. Sur l'apexogramme du rétrécissement aortique, on remarque une augmentation de l'onde A. On peut même aller plus loin, des corrélations les plus précises entre l'importance du gradient ventriculo-aortique et le cartidogramme ont été établies dans lequel le temps de demi-ascension et le temps d'éjection varient significativement en raison directe du gradient. Ici cinq critères de sévérité ont pu être proposés: extinction de B1 au foyer aortique, présence d'un B4, chronologie tardive des vibrations maxima du souffle, allongement du temps de demi-ascension au-delà de 0,06 seconde. Le rétrécissement est d'autant plus serré que l'enregistrment comporte un nombre plus grand de ces critères.

(ii) La cardiomyopathie obstructive réalisant un obstacle à l'éjection ventriculaire gauche doit être systématiquement recherchée à la visite d'admission en raison de la fréquence des morts subites chez le sujet jeune porteur de cette cardiopathie.

Le tracé du phonocardiogramme visualisera un souffle d'obstruction du type gauche.

Le carotidogramme joue un rôle essentiel dans le diagnostic; il comporte sur la partie descendante après une brusque descente, suivie d'un creux, une nouvelle onde positive moins élevée que la première surnommée par Braunwald "systolic bulge". Ce signe n'est pas pathognomonique puisqu'en étudiant les tracés de 1.000 pilotes nous l'avons rencontré chez 25 sujets indemnes de toute anomalie. L'apexogramme présente une onde A et une bifidité du plateau systolique et c'est un argument important pour le diagnostic.

Mais nous voudrions insister sur la pharmacodynamie: un sujet ne peut rien avoir à l'état basal et l'épreuve au nitrite d'amyle fait découvrir les anomalies mécanographiques. Nous prendrons pour exemple un pilote de Mirage III porteur d'une onge Q ample, inexpliquée en D2, D3, VF et sur le précordium gauche; seule l'épreuve au nitrite d'amyle a fait apparaître le souffle systolique et l'anomalie au carotidogramme.

(iii) L'insuffisance mitrale

Les caractères phonocardiographiques sont ceux d'un souffle de régurgitation gauche. Ce souffle enregistré à la pointe est de tonalité aigue, ce qui explique souvent la difficulté de son enregistrement. Il existe des variations morphologiques en particulier: le souffle au lieu d'être holosystolique peut être decrescendo et très souvent il n'est que télésystolique laissant libre la proto et la mésosystole. Devant tout souffle télésystolique, il faut penser à l'insuffisance mitrale.

Le carotidogramme est normal et à l'apexogramme on enregistre une onde F aigue, pointue contemporaine d'un B3 au phonocardiogramme.

Nous voudrions placer icic les triolets, bruits ou clics mésosystoliques suivis ou non d'un souffle télésystolique. Les épreuves pharmacodynamiques permettent de reverser dans la pathologie mitrale ces clics mésosystoliques longtemps attribués à une origine extracardiaque. Ces clics mésosystoliques sont souvent ignorés et pris pour un dédoublement du 2ème bruit; l'intérêt de la phonocardiographie est de pouvoir les visualiser.

(iv) Le souffle systolique de la communication interventriculaireenregistré au niveau de l'endapex est un souffle de régurgitation gauche. Il existe quelquefois un dédoublement de B2 traduisant un retard de la composante pulmonaire P2 sur la composante aortique A2.

(v) Le phonocardiogramme du souffle de la communication interauriculaire est celui d'un souffle d'obstruction droit traduisant une sténose pulmonaire fonctionnelle. Il existe un dédoublement du deuxième bruit dont le caractère principal est sa fixité par rapport aux mouvements respiratoires.

(vi) La sténose pulmonaire isolée, c'est-à-dire avec un septum interauriculaire et interventriculaire intacts, donne un souffle d'obstruction droit maximum aux 2ème et 3ème espaces intercostaux gauches. Mais la morphologie est différente du souffle d'obstruction droit des souffles infundibulopulmonaires; ici il est à maximum méso et télésystolique dépassant A2 qui peut être noyé dans le souffle mais n'atteint pas P2.

(vii) Les mécanogrammes sont bien en retrait par rapport à la clinique dans le diagnostic d'une coarctation aortique. La clinique est riche avec un souffle systolique endapexien et entendu dans l'espace interscapulovertébral, augmentation de la tension artérielle aux membres supérieurs, artères fémorales faiblement perçues, développement d'une circulation anastomotique décelable cliniquement se traduisant par des érosions costales sur la radiographie pulmonaire.

Les mécanogrammes peuvent individualiser 2 souffles: l'un est le souffle de débit donc protosystolique, l'autre celui de l'obstacle est télésystolique mais d'obstruction augmenté par l'épreuve au nitrite d'amyle qui le déplace dans le protosystole.

Le tracé du pouls fémoral est retardé par rapport au pouls radial.

Nous voyons que l'oreille est souvent prise en défaut pour affirmer l'origine d'un souffle systolique; l'expert du personnel navigant doit, devant tout souffle systolique, pratiquer des mécanogrammes cardiaques. Ceux-ci permettent de typer le souffle et peuvent dans certains cas apprécier le degré du retentissement (tableau, page 38).

(b) *Le carotidogramme témoin de la distensibilité artérielle*

Il apparait séduisant d'essayer d'apprécier la distensibilité de la paroi artérielle par un procédé physique tel que le carotidogramme.

Le carotidogramme est recueilli grâce à un capteur à variation d'inductance. Cette technique est facile, non sanglante et de ce fait facilement reproductible à chaque expertise semestrielle du personnel vanigant. Le carotidogramme normal est fait d'une montée rapide (onde pulsion) suivie d'une descente (onde de réflexion) se terminant par l'incisure catacrote, l'incisure étant suivie d'une deuxième onde ou onde dicrote.

Avec l'âge, nous avons constaté deux éléments: d'une part des variations morphologiques et d'autre part des variations du rapport $\frac{I}{A}$.

1. *Variations morphologiques*

Avec l'âge, la morphologie de la courbe du carotidogramme se modifie, la montée se fait moins rapidement et le deuxième sommet systolique progresse le long du segment descendant jusqu'à dépasser le premier sommet et aboutir au tracé type anacrote.

Sur 1.000 pilotes, avec Pernod, nous avons étudié par tranche d'âge de 10 ans, 1.000 carotidogrammes. Ce type anacrote est peu fréquent dans le groupe de sujets âgés de 18 à 29 ans puisqu'il est rencontré 0,34%.

Ce type augmente légèrement dans le groupe des sujets âgés de 30 à 39 ans puisqu'il est de 2,80%. Mais dans le groupe de 40 à 50 ans, le tracé anacrote est de 14,25%. Donc 15% des pilotes âgés de 40 ans ont un tracé de type anacrote, témoin d'une modification de l'élasticité de la paroi artérielle.

2. *Etude du rapport* $\frac{I}{A}$

En même temps que surviennent ces modifications avec l'âge, le rapport hauteur de l'incisure (I) sur amplitude de l'onde pulsatile (A) augmente. Avec Nogues, nous avons mesuré chez 250 pilotes le rapport $\frac{I}{A}$. Dans les trois groupes d'âge moyen différent, le rapport progresse avec l'âge.

Premier groupe: nombre de sujets : 100 (âge 17 à 29 ans)
moyenne d'âge: 21 ans

$\frac{I}{A} = m\ 21 + 2$ $\quad m\ 21 = 0{,}437 \pm 0{,}020$

Deuxième groupe: nombre de sujets : 70 (âge 30 à 52 ans)
moyenne d'âge: 41 ans

$\frac{I}{A} = m\ 41 \pm 2$ $\quad m\ 41 = 0{,}569 \pm 0{,}023$

Troisième groupe: nombre de sujets : 80 (âge 32 à 78 ans)
moyenne d'âge: 53 ans

$\frac{I}{A} = m\ 53 \pm 2$ $\quad m\ 53 = 0{,}586 \pm 0{,}020$

A titre indicatif, dans ce dernier groupe, nous avons relevé 20 sujets de 60 à 70 ans dont le rapport moyen est à 0,590 et 7 sujets au-dessus de 70 ans dont le rapport moyen est à 0,640.

Nous n'avons pas étudié le degré de signification par tranches de 10 ans d'âge, réservant cette recherche à l'exploitation d'un plus grand nombre de tracés. Cependant, entre les trois groupes analysés, le test T a montré une différence:

significative	m 21 – m 41	T = 8,74	++
significative	m 21 – m 53	T = 10	+++
non significative	m 41 – m 53	T = 1,08	

Nogues, au Centre d'Etude et de Recherche de Médicine Aéronautique, a étudié la signification de ce rapport $\frac{I}{A}$ sur modèle hydraulique. Les variations de volume d'un segment artériel (carotide de boeuf) ont été suivies à fréquence fixe pour des volumes d'éjection et des résistances périphériques différents. L'onde du pouls analysée par la rhéopléthysmographie présente une morphologie comparable à celle observée chez l'homme.

On peut donc conclure que le rapport $\frac{I}{A}$ du carotidogramme, rapport de la hauteur de l'incisure catacrote sur l'amplitude de l'onde pulsatile, est un reflet de la distensibilité artérielle.

Expérimentalement, ce rapport augmente lorsque l'élasticité du système hydraulique diminue ou lorsque les résistances périphériques augmentent; pour une même pression diastolique, le rapport $\frac{I}{A}$ augmente lorsqu'on diminue l'élasticité des parois du modèle ou lorsque les résistances à l'éjection augmentent. La perte de la distensibilité artérielle apparaît ainsi comme pouvant être liée:

- soit à un facteur dégénératif pariétal propre au segment interrogé,
- soir à un facteur périphérique, obstacle à l'écoulement liquidien.

Par ailleurs, sur le modèle l'amplitude de l'onde dicrote apparaît d'autant plus faible que la distensibilité artérielle est diminuée.

Ainsi est souligné à nouveau l'intérêt de l'étude du rapport $\frac{I}{A}$ du carotidogramme qui permet au clinicien de se faire rapidement une idée de la distensibilité du système artériel.

(c) *Etudes chronocardiographiques*

Puisque les intervalles du chronocardiogramme varient selon l'importance de l'atteinte myocardique, il était logique de chercher à savoir s'il existait une corrélation entre ces différents intervalles et les données hémodynamiques apportées par le cathétérisme cardiaque et la cinéangiographie ventriculaire; c'est ce qu'ont fait: Weissler (1970) Aronow (1971) pour l'étude de la contraction du muscle myocardique, mais auparavant, il nous faut rappeler les différentes mesures que l'on pratique en chronocardiographie,

- T 1: intervalle électromécanique allant du point Q de l'électrocardiogramme au point C de l'apexogramme.
- T 2: ou intervalle préexpulsif allant du point C de l'apexogramme au point E de la courbe carotidienne. Cet intervalle préexpulsif se divise en deux parties: T2A ou contraction préisométrique du point C de l'apexogramme à la fermeture des valves mitrales, c'est-à-dire sur le phonocardiogramme aux première composantes rapides de B1 et T2B, ou contraction isométrique, de la fermeture mitrale au point E de la courbe carotidienne.
- T 3: ou temps d'éjection systolique, du point E à l'incisure catacrote du carotidogramme.

Mais ces mesures doivent être corrélées en fonction du rythme cardiaque.

Divers types de correction ont été proposés: grâce à l'analyse automatique de 500 carotidogrammes passés sur ordinateur, nous avons démontré que les formules de correction n'étaient pas valables. Nous avons proposé des abaques grâce à des droites de régression dont les équations sont les suivantes:

- une qui s'applique au-dessus de 30 ans:

$$S = 0.108\ RR + 19{,}09$$

- l'autre qui s'applique de 30 à 59 ans:

$$S = 0.108\ RR + 19{,}89$$

Et l'influence du sexe féminin en une seule formule valable de 18 à 49 ans:

$$-S = 0.114\ RR + 20$$

(RR + S) étant comptés en centièmes de seconde.

Ces différents temps (T1, T2, T3) permettent:

1. *Mesure du débit systolique*

Nous utilisons la formule d'Agress et Wegner, c'est-à-dire:

- débit systolique = $1{,}8\left(\frac{T\ 3}{T\ 2}\right)^2 + 27$.

	Souffle infundibulo pulmonaire	*Souffle cardio pulmonaire*	*R.A.*	*C.M.O.*	*I.M.*	*C.I.A.*	*C.I.V.*	*R.P.*
Phonocardiogramme	Obstruction droit	Variabilité	Obstruction gauche	Obstruction gauche	Réfurgitation gauche	Obstruction droit	Régurgitation gauche	Obstruction droit
Carotidogramme	N	N	(1) anomalies morphologiques (2) anomalies chronologiques	Bulge	N	N	N	N
Apexogramme	N	N	Onde A	(1) bifidité (2) Onde A	Onde F	N	N	N

2. *Mesure de la contraction du muscle myocardique*

Siegel et Sonnenblick ont montré que lors de la phase isovolumétrique, c'est-à-dire pendant la courte période où la pression ventriculaire gauche augmente, alors que les sigmoides aortiques sont encore fermées, la contractilité peut être appréciée en établissant la courbe de variation de la dérivée de la pression $\frac{dP}{dT}$ en fonction de la pression ventriculaire gauche P. L'extrapolation linéaire de cette courbe a une pression nulle permet de définir la VEC maximum, ou vitesse des éléments contractiles maximum, qui est un bon indice de la contractilité.

Allemand (1972) a trouvé une corrélation entre cet indice de Siegel et Sonnenblick $\left(\frac{dP}{dT}\ \text{P.I.I.}\right)$ et la fraction d'éjection mesurée par chronocardiographie

$$F - E = -10\left(\frac{T1 + T2}{T3}\right) + 105\ .$$

Donc, dans notre expertise du personnel navigant, nous pouvons mesurer très rapidement T1, T2 et T3; et ces trois mesures chronocardiographiques nous donnent le débit systolique et un indice de contraction du muscle myocardique.

En conclusion: Les mécanogrammes cardiaques sont obligatoires devant toute expertise du personnel navigant et, étant dans le dossier, constituent une preuve médico-légale. Actuellement, on peut les demander en mesurant la distensibilité artérielle, et par les méthodes chronocardiographiques mesurer un index de débit systolique et apprécier la contraction du muscle myocardique.

II EXPLORATION FONCTIONNELLE RESPIRATOIRE

Dans l'aviation militaire, les normes françaises d'aptitude à l'emploi du personnel navigant comportent l'intégrité clinique et radiologique de "l'appareil respiratoire" et aussi "l'intégrité fonctionnelle de la cage thoracique".

Il est donc fait appel au cours des visites d'aptitude aux techniques d'exploration fonctionnelle respiratoire (E.F.R.) qui ont connu un grand développement au cours de ces dernières années.

En pratique, l'E.F.R. est le plus souvent utilisée pour des navigants confirmés qui contractent un affection respiratoire au cours de leur carrière.

L'E.F.R. permet de savoir si le navigant est récupérable lorsque sa maladie est guérie.

Dans certains cas elle est également nécessaire alors de la visite de sélection à l'entrée dans le Personnel Navigant.

Les laboratoires des services de Pneumo-Phtisiologie nous offrent actuellement de grandes possibilités d'E.F.R. qui peuvent être classées de la façon suivante:

la ventilation, c'est-à-dire la mobilisation des volumes et débits gazeux par les poumons est étudiée par la spirographie.

la mécanique ventilatoire, c'est-à-dire l'état des résistances élastiques parenchymateuses, et appréciée par les mesures de compliance dynamique.

les échanges gazeux sont appréciés par l'étude des gaz du sang artériel et par l'étude de la diffusion à l'oxyde de carbone.

l'hémodynamique pulmonaire peut enfin être appréciée facilement par le microcathétérisme ou cathétérisme flotté des cavités droites et des artères pulmonaires.

Ce court résumé ne mentionne pas toutes les possibilités techniques de l'E.F.R. mais schématise les principales étapes de la fonction respiratoire que l'on peut être amené à explorer.

Nous n'envisagerons que celles qui nous paraissent pouvoir concerner le Personnel Navigant.

A. Etude de la Ventilation: Spirographie

La spirographie permet l'étude des volumes et débits ventilés.

(a) *Paramètres étudiés*

1. *Volumes*: volume courant Volume d'air introduit à chaque inspiration et chassé à chaque expiration.

Volume de réserve inspiratoire: différence entre une inspiration forcée et une inspiration ordinaire.

Volume de réserve expiratoire: différence entre une expiration ordinaire et une expiration forcée.

Volume résiduel (VR) - Formé de deux composants "l'air alvéolaire" et "l'espace mort", on ne peut le lire directement sur le spirogramme car il échappe aux movements respiratoires. Il est apprécié indirectement par le temps d'homogénisation de l'hélium dans l'air pulmonaire.

De ces mesures, on peut déduire:

- la capacité vitale (CV), somme du volume courant et des volumes de réserve inspiratoire et expiratoire,
- la capacité pulmonaire totale (CT), somme de la capacité vitale et du volume résiduel.

2. *Débits*: Volume expiratoire maximum seconde (V.E.M.S.). Le sujet étant en inspiration forcée, c'est le volume d'air expulsé durant la première seconde d'une expiration forcée déclenchée brutalement.

Ventilation maxima minute: elle est obtenue en faisant faire des mouvements respiratoires d'amplitude maxima, à un rythme de 30 mouvements minute environ.

L'épreuve n'est pratiquée que 20 secondes environ et le résultat rapporté à la minute. Outre le débit minute, on apprécie la valeur du volume de réserve expiratoire qui est diminué les états emphysémateux, réalisant le "signe du créneau".

3. *Coefficients et Indices*

Les mesures de volumes et débits permettent de calculer certains indices. Les plus utilisés sont:

$$\text{Coefficient de Tiffeneau} = \frac{\text{VEMS}}{\text{CV}} .$$

Il rend mieux compte que le VEMS de l'état de perméabilité bronchique.

$$\text{Indice de Cournand} = \frac{\text{VR}}{\text{CT}} .$$

Il renseigne sur l'état de la distension pulmonaire.

4. *Epreuves pharmacodynamiques*

Les volumes et surtout les débits peuvent être modifiés après inhalation de certains agents pharmacodynamiques: acétyl-choline, aleudrine.

En médicine aéronautique est surtout utilisé le test à l'acétyl-choline pour détecter les terrains asthmatiques.

Il consiste à mesurer les modification du VEMS après inhalation de doses croissantes d'acétyl-choline: 250, 500, 1.000, 1.500 ou 3.000 microgrammes.

(b) *Matériel et Techniques*

Sur le plan pratique, la mesure des différents paramètres spirographiques ci-dessus exposés se fait en 3 temps indépendants:

- Mesure des volumes et débits à l'exception du volume résiduel,
- Mesure du volume résiduel,
- Test à l'acétyl-choline.

1. *Mesures des volumes et débits à l'exception du volume résiduel*

1.1 *Matériel*

Nous utilisons le "Pulmotest Godart". Cet appareil comporte deux cloches d'une capacité de 9 litres chacune pouvant fonctionner de façon séparée.

Un système de soupape permet cependant de faire communiquer les deux cloches au cours de l'examen.

Le plus souvent, le sujet est relié à une cloche utilisée pour les mesures spirographiques, la deuxième cloche est remplie d'oxygène et assure grâce à une soupape, la compensation en oxygène consommé. Ceci permet la mesure de la consommation d'oxygène.

Les épreuves se font en circuit fermé sur lequel se trouve un bac à chaux sodée pour l'absorption du CO_2.

Pour annuler les résistances du circuit et le poids de la cloche, il existe dans le circuit une circulation d'air assurée par une pompe réglable.

Les mouvements des deux cloches sont inscrits sur un cylindre enregistreur situé entre elles. Le volume et la surface de section des cloches est telle qu'une variation d'hauteur de 1 cm enregistrée sur le cylindre enregistreur correspond à une variation de volume de 300 cc.

La lecture des volumes est donc directe et très facile. Ceux-ci peuvent être appréciés à ± 30 cc (soit 1 mm sur le papier enregistreur).

Le cylindre enregistreur peut tourner à 3 vitesses différentes:

30 mm/minute soit 0,5 mm/sec.
60 mm/minute soit 1 mm/sec.
1200 mm/minute soit 20 mm/sec.

Cette dernière vitesse permet de mesurer de façon satisfaisante le VEMS.

Enfin l'appareil comporte un système de ventilation afin d'éviter toute surchauffe. Un thermomètre permet d'ailleurs de connaître la température dans le circuit de ventilation.

Cet appareil peu encombrant est très robuste. Les pannes sont très rares et en règle peu importantes, vites et facilement réparées.

Le maniement est très simple. Il peut être assuré par une infirmière.

1.2 *Technique*

L'examen se fait chez un sujet assis, de façon très confortable, de façon a être très libre de ses mouvements respiratoires.

Ce dernier est relié au spirographe par un embout buccal et on lui demande de respirer normalement de façon à avoir le volume courant et la consommation d'oxygène au repos. Ensuite il effectue trois CV et trois VEMS. Les meilleurs résultats sont retenus.

2. *Mesure du volume résiduel*

Il est obtenu en faisant respirer au sujet un mélange gazeux contenant des quantités connues d'air et d'hélium. Au bout d'un certain temps de l'ordre de 3 minutes, l'hélium est réparti de façon homogène dans les poumons du malade et le circuit de l'appareil. Le volume résiduel est calculé automatiquement par un computeur relié au spiromètre.

En pratique la cloche étant remplie d'une quantité connue d'air et d'hélium, le sujet à tester respire jusqu'à ce que les chiffres du computeur automatique deviennent stables. Les chiffres lus sont ceux de la capacité pulmonaire totale. Il faut y retrancher la capacité vitale pour avoir le volume résiduel.

La mesure des différents volumes et débits y compris celle du volume résiduel demande environ 30 minutes. La lecture des résultats sur le papier enregistreur, le calcul des indices, leur transcription environ 10 minutes.

Ces temps peuvent être raccourcis de 5 à 10 minutes par un manipulateir très expérimenté et si le sujet s'adopte très bien au spirographe.

Nous n'avons jamais observé d'accident.

Par contre l'hyperventilation que réalise l'examen peut déclencher une crise de tétanie chez les spasmophiles.

Il s'agit toujours d'un incident mineur, sans conséquence qui cède en arrêtant l'examen et en laissant le sujet quelques secondes en apnée.

3. *Test à l'acétyl-choline*

Il a pour but de mettre en évidence un aptitude asthogène latente.

Il consiste à faire 3 VEMS de référence puis à faire inhaler des doses croissantes d'acétyl-choline. Après chaque inhalation, 3 VEMS sont effectués et on observe les modifications. Nous avons choisi les doses de 500, 1.000, 2.000 et 3.000 microgrammes.

Pour réaliser ces doses nous mettons une solution d'acétyl-choline au 1/50 dans un aéroliseur relié à une cuve à spirographie graduée en litres.

Chaque litre d'aérosol d'acétyl-choline envoyé dans la cloche contient 200 microgrammes d'acétyl-choline. Le sujet est relié à la cuve au moyen d'une valve permettant inspiration dans la cloche, expiration vers l'extérieur. On lui fait inhaler ainsi 2,5 litres de mélange de la cloche soit 500 microgrammes d'acétyl-choline et on mesure ensuite le VEMS.

Au besoin on recommence en faisant:

5 litres soit 1000 microgrammes
10 litres soit 2000 microgrammes
15 litres soit 3000 microgrammes

Pour éviter que l'inhalation d'acétyl-choline ait une action irritative mécanique, nous faisons au début de l'épreuve, avant les VEMS de référence, une aérolisation de trois minutes d'Hexanium.

4. *Test à Ventoline*

Lorsque le test à l'acétyl-choline est positif, nous apprécions toujours sa réversibilité sous broncho-dilatateur (Ventoline).

La réalisation du test à l'acétyl-choline demande environ 30 minutes. Nous n'avons jamais observé d'accident. Là encore les spasmophiles peuvent présenter des manifestations tétaniques. L'acétyl-choline peut également provoquer une petite crise d'asthme chez les asthmatiques, mais l'inhalation d'Aleudrine ou Ventoline apporte rapidement un soulagement.

(c) *Résultats*

Des différentes mesures effectuées, nous retenons les meilleures. Nous les comparons à des chiffres théoriques établis sur de grandes séries de sujets sains.

En France, on utilise volontiers les tables établies par les experts de la C.E.C.A. (Communauté Européenne Charbon et Acier) ou les tables de Graimprey qui donnent les paramètres spirographiques théoriques en fonction de la taille et de l'âge.

Cette analyse permet d'établir un des diagnostics spirographiques suivants:

- sujet normal,
- syndrome restrictif, caractérisé par une diminution de la capacité vitale,
- syndrome obstructif avec chute du VEMS et surtout avec chute du coefficient de Tiffeneau,
- syndrome de distension alvéolaire dominé par l'augmentation du volume résiduel aux dépens de la capacité vitale,
- syndrome mixtes associant de façon variable deux ou trois des éléments précédents,
- test à l'acétyl-choline positif (chute du VEMS de 15% ou plus pour une dose de 3.000 microgrammes au moins) témoin d'un terrain asthmatique.

Nous serons beaucoup plus bref sur les autres techniques qui sont à la fois complexes à mettre en oeuvre et d'indication beaucoup plus rare dans le Personnel Navigant.

B. Gazométrie Arterielle

Elle est utilisée pour dépister les insuffisances respiratoires latentes. Elle comport la mesure de la saturation artérielle (SaO_2), des pressions partielles de O_2 et CO_2 (Pa O_2, Pa CO_2) et du pH.

(a) *Prélèvements*

Les prélèvement sont faits à la fémorale pour les gazométries simples avec une seringue à usage unique et des aiguilles à usage unique type Yale Microlance Becton Dickinson $186^{1/2}$ – 40/12.

Pour les gazométries avec épreuve d'effort, le prélèvement est fait à l'humérale avec un trocart de Gournand laissé en place pendant l'effort (pédalage).

Tous nos prélèvements sont réalisés sous anesthésie locale en évitant au maximum une hyperventilation préalable à l'examen.

La ponction humérale est la plus difficile et doit être pratiquée par un médecin expérimenté.

Incidents – les ponctions sont parfois suivies d'hématomes qui ont toujours été sans gravité.

(b) *Epreuve d'effort*

Elle est réalisée grâce à une bicyclette ergométrique, adaptable sur le lit de prélèvement. L'effort de pédalage peut être effectué en position allongée, le trocard huméral restant en place.

(c) *Dosage*

Ils sont effectués à l'aide d'un hémoréflecteur pout la saturation d'oxygène, d'une chaîne "Radiomètre" pour les pressions partielles et le pH.

La manipulation de ces appareils est assez délicate et doit être réalisée par un personnel de laboratoire bien entraîné. Les électrodes à pH – $PaCO_2$ – PaO_2 doivent être refaités régulièrement.

(d) *Résultats*

Nous ne pouvons donner toutes les possibilités de résultats variables avec les différents cas cliniques observés en pneumologie.

En ce qui concerne l'insuffisance respiratoire légère que l'on peut être amené à rechercher chez le personnel navigant, il faut retenir les notions suivantes:

- la mesure de la saturation en oxygène ne suffit pas à démasquer les hypoxies légères,
- la Pa O_2 est plus sensible,
- dans les hypoxies légères du premier stade de l'insuffisance respiratoire l'épreuve d'effort peut améliorer Sa O_2 et Pa O_2 en améliorant le rapport ventilation/perfusion.

C. Etude de la Capacité de Diffusion

Sa mesure présente un intérêt majeur chez les sujets ayant présenté une sarcoïdoise ou chez lesquels on soupçonne une fibrose pulmonaire.

D'une façon générale, chaque fois que l'on soupçonne un bloc alvéolocapillaire, nous utilisons la diffusion du CO en apnée.

La capacité de diffusion du CO ou DCO exprimée en ml/minute/mmHg est donnée par la relation suivante:

$$DCO = \frac{\text{Débit CO en ml/mn de l'alvéole au capillaire}}{\text{Pression alvéolaire moyenne en CO} - \text{Pression Capillaire en CO}}$$

ce qui s'écrit:

$$DCO = \frac{VC \text{ ml/mn}}{PACO - PcCO}.$$

La totalité du CO passant dans le sang se combine avec l'hémoglobine.

On part donc du principe que la pression partielle de CO dans le plasma est pratiquement nulle.

(a) L'appareillage utilisé comporte:

- un spirographe de précision,
- un sac contenant le mélange gazeux à inspirer,
- un sac de prélèvement de l'air expiré.

Ces deux sacs sont contenus chacun dans une enciente en plastique transparente, séparée l'une de l'autre. Les variations de volumes de ces enceintes peuvent être transmises au spirographe:

- un analyseur rapide de CO,
- un analyseur rapide d'hélium,
- un système de tuyau et de soupapes commandé par un clavier manuel permettant de relier le sujet au spirographe ou aux sacs, et les sacs aux analyseurs rapides.

(b) *Principe*

A la fin d'une expiration forcée, on fait inhaler pendant une inspiration unique un mélange gazeux de composition connue en CO.

Après l'inspiration forcée, le sujet fait une apnée de 10 secondes pendant laquelle une certaine quantité de CO quitte les alvéoles et passe dans le sang. Cette quantité est d'autant plus importante que la capacité de diffusion est plus grande. A la fin de l'apnée (ce qui est très réglée), le sujet fait une expiration forcée dont un échantillon recueilli et analysé donne la concentration alvéolaire terminale en CO. L'échantillon à analyser est prélevé après expulsion d'au moins 600 ml d'air (volume de rinçage des espaces morts). Aussi cet échantillon peut être considéré comme représentatif de l'air alvéolaire.

(c) Les paramètres à calculer sont:

1. Débit minute du CO diffusé.

   Il est calculé à partir de:
   - la concentration de l'air alvéolaire au début et en fin d'apnée,
   - le volume gazeux alvéolaire, c'est-à-dire Volume inspiré + Volume résiduel - Espace mort.

2. La pression partielle moyenne en CO du capillaire. Elle est tenue pour négligeable.

3. La pression partielle alvéolaire moyenne en CO. Elle varie évidemment pendant l'apnée et doit être calculée en fonction des Pp CO alvéolaire initiale et terminale.

   La pression partielle alvéolaire en CO au début de l'apnée est calculée à partir de la concentration d'Hélium que fait partie du mélange inspiré, et qui lui ne diffuse pas du tout.

(d) *Les résultats*

La capacité de diffusion normale varie selon les paramètres ventilatoires des individus. Elle se situe entre 20 à 40 ml/mn chez les sujets normaux.

La capacité de diffusion en pratique est calculée par la formule de Krogh qui tient compte de différents facteurs de correction:

$$DLCO = \frac{VA\ (STPD)}{(PB \cdot 47) \cdot t} \cdot \log \frac{FACO}{FE\ CO}$$

VA	=	Volume alvéolaire (exprimé en mesure STPD)
PB	=	Pression barométrique
47	=	Pression vapeur d'eau
t	=	Temps de l'épreuve ramené à 60 secondes
FACO	=	Concentration de CO dans l'alvéole au début de l'apnée
FECO	=	Concentration de CO dans l'air expiré.

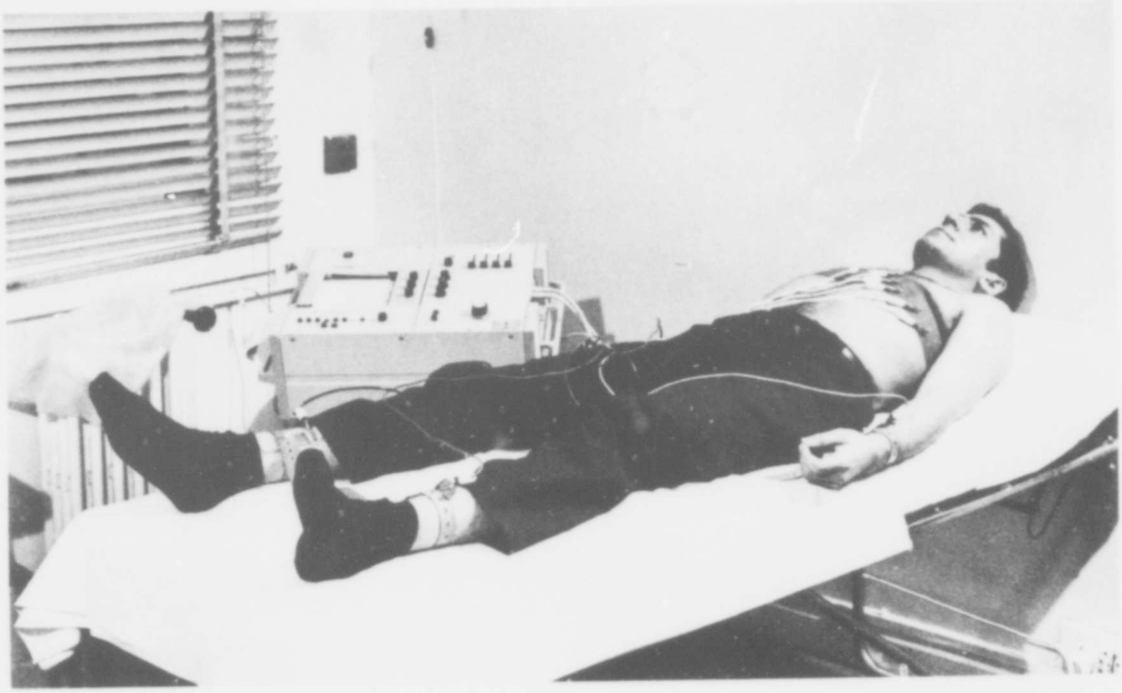

Fig.4.1 Prise d'un électrocardiogramme

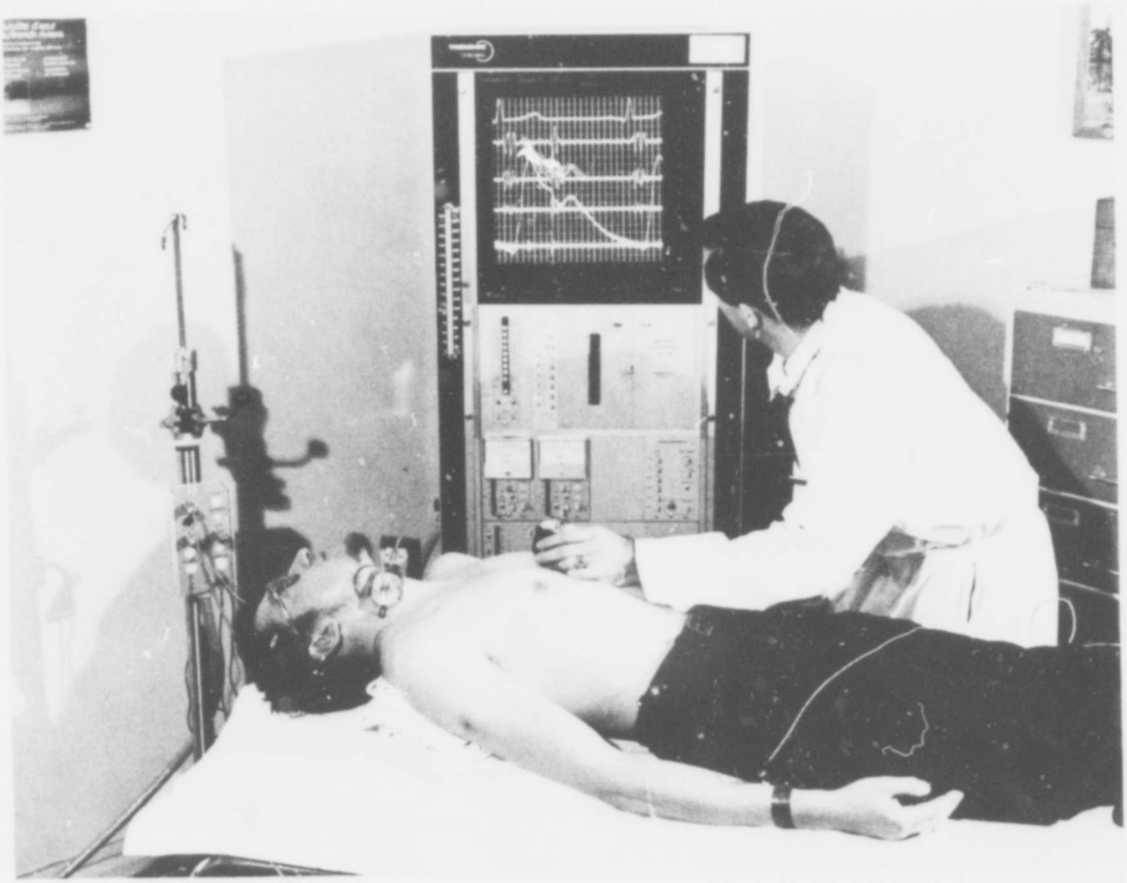

Fig.4.2 Prise d'un tracé mécanographique (carotidogramme, phonocardiogramme avec 6 bandes de fréquence, électrocardiogramme)

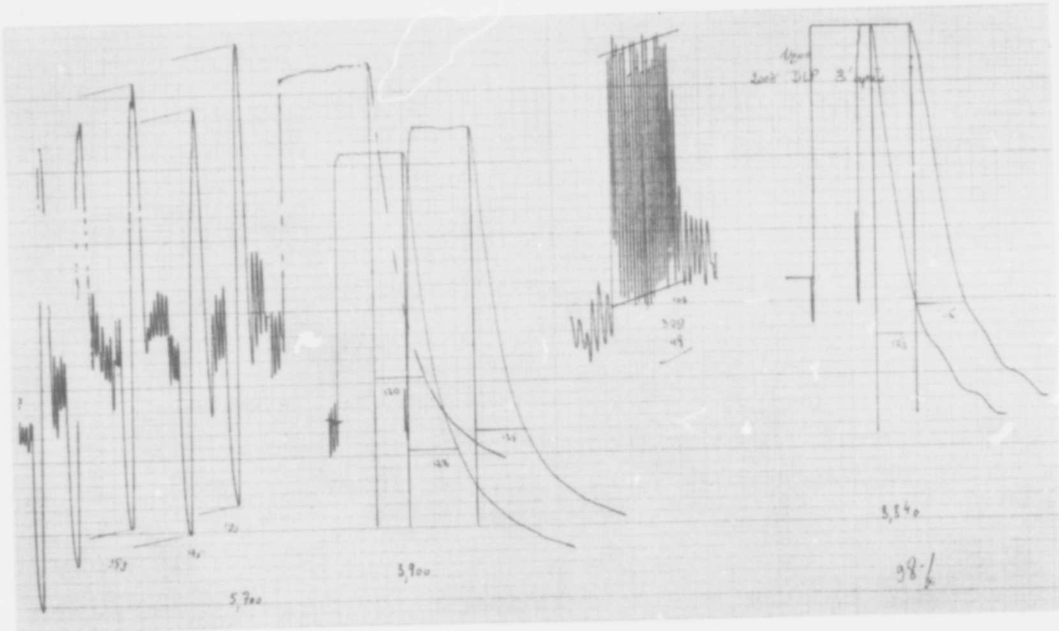

Fig.4.3 Spirographie
De gauche à droite: – Courbes de capacité vitale, courbes de VEMS
– Enregistrement d'une ventilation maxima
– Courbes de VEMS après inhalation de 200 gamma de poussière

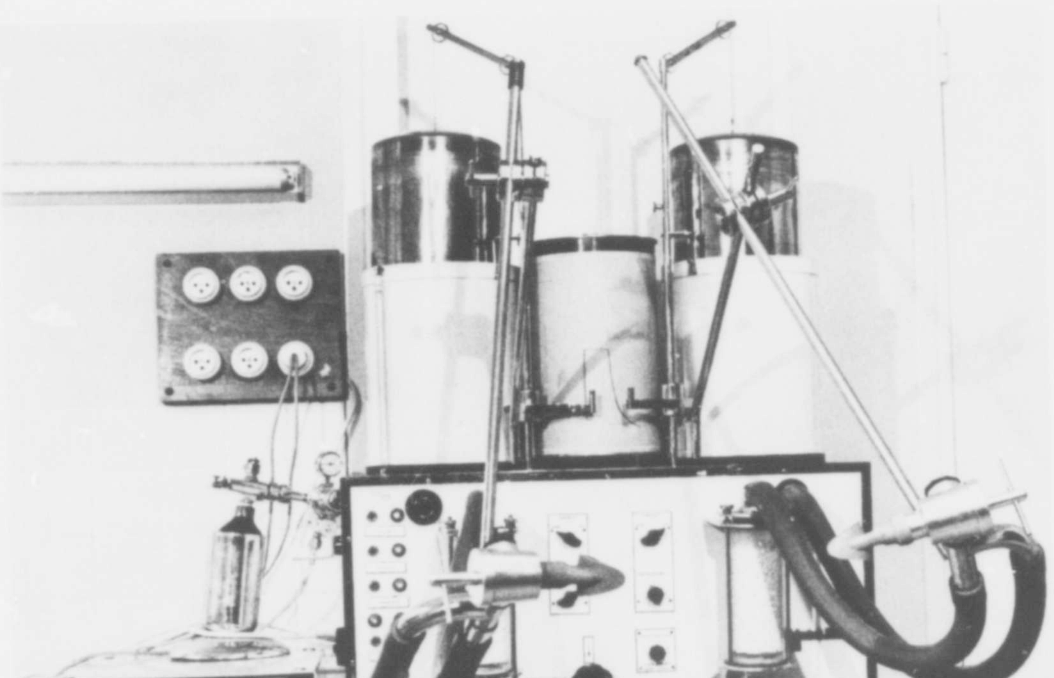

Fig.4.4 Matériel pour spirographie
De gauche à droite: – Computeur automatique pour mesure du volume résiduel.
La bouteille à hélium a été posée dessus
– Pulmotest avec ses 2 cloches et entre-elles le tambour enregistreur

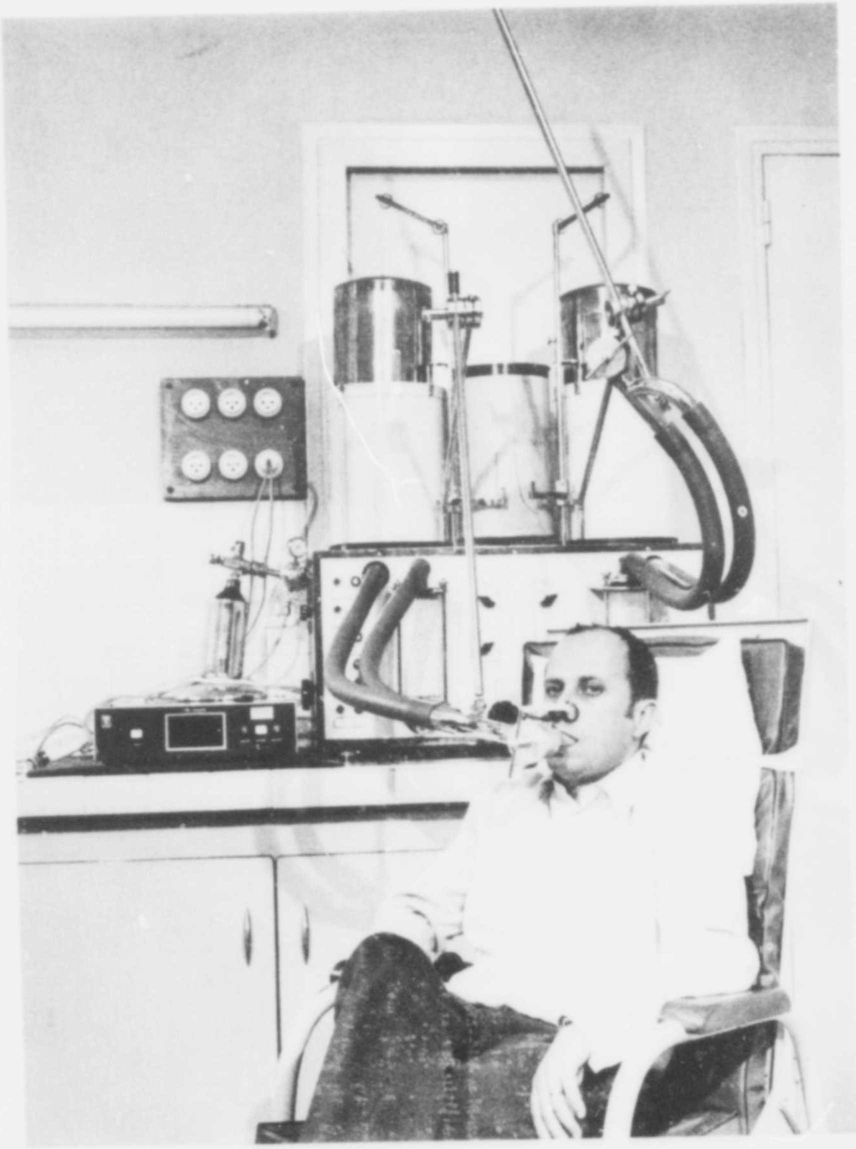

Fig.4.5 Sujet effectuant une spirométrie

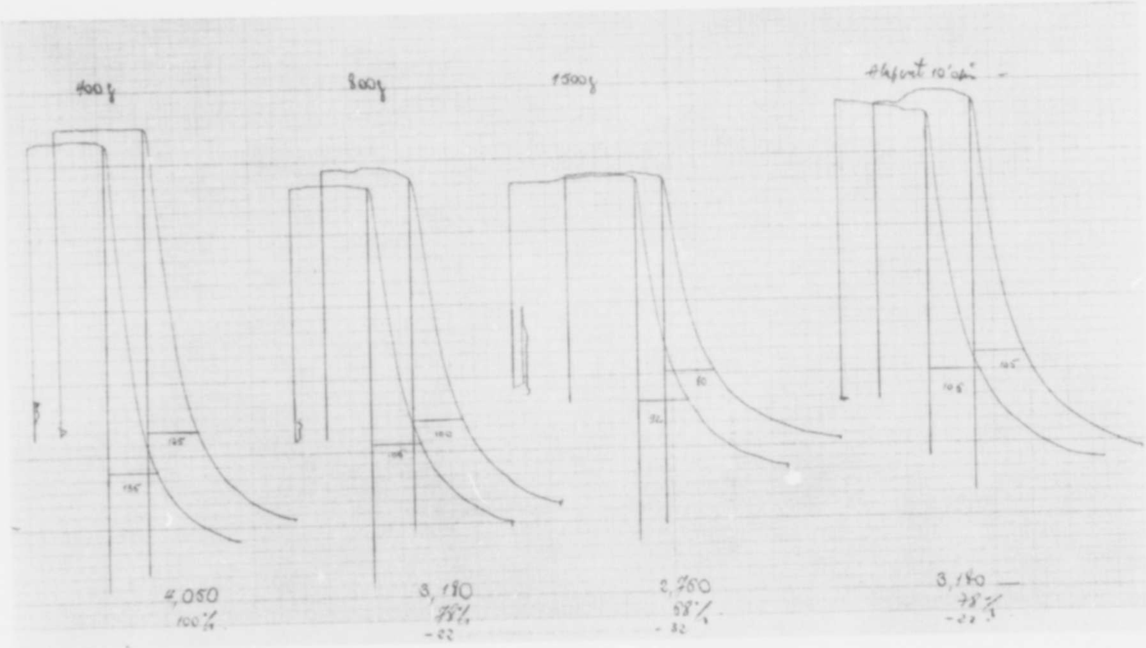

Fig.4.6 (Même malade que la figure 4.1.) Test à l'acetyl choline.
A 1500 gamma on note une chute du VEMS de l'ordre de 32%.
Le trait horizontal représente une seconde de déroulement.
Le trait vertical représente le volume obtenu dans la première seconde d'expiration forcée.

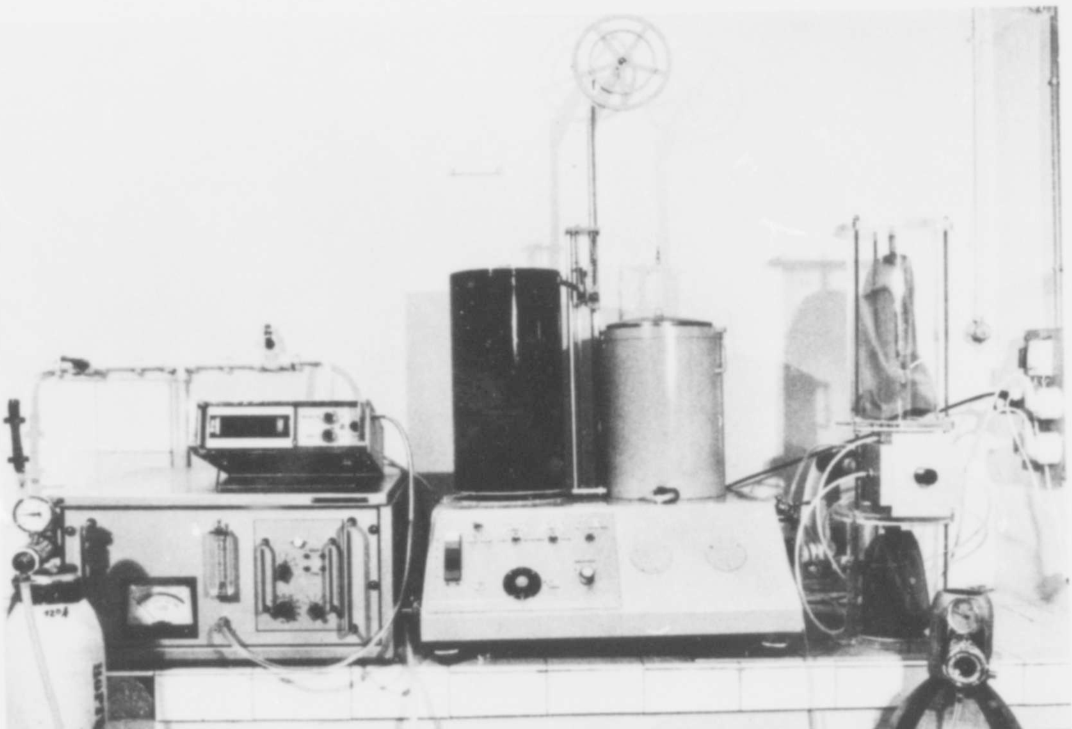

Fig.4.7 Matériel pour l'étude de la diffusion au CO.

A gauche: analyseurs d'hélium en haut, et de CO en dessous
Au milieu: spirographe sur le clavier de commande de répartition et prélèvement gazeux
A droite: sacs inspiratoires et expiratoires

CHAPTER 5

CARDIOVASCULAR AND PULMONARY FUNCTION TESTS AT THE GERMAN AIR FORCE INSTITUTE OF AVIATION MEDICINE

by

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(including a study on incidence and interpretation of cardiac rhythm disturbances in aircrew of the GAF, by Capt. A.Dietz, GAF, MC, and Col H.W.Kirchhoff, GAF, MC of the German Air Force Institute of Aviation Medicine, Fürstenfeldbruck)

SUMMARY

Cardiovascular function tests at the German Air Force Institute of Aviation Medicine.

	1971	1972
ECG rest and after workload	3 583	3 019
ECG Tilt Table	56	122
Phonocardiogram	57	45
Pulse curve registration	27	23
Ergometry (bicycle)	336	223
Ergometry (treadmill)	32	29
Ergometry (bicycle) with ECG	589	624
Ergometry (treadmill) with ECG	56	34
Ergospirography	74	46

We have never had any accidents during these examinations.

A. CARDIOVASCULAR FUNCTION TESTS

1. ECG – Program

Test condition	*Method*	*Program*
At Rest	Routine examination	Leads I, II, III, aV_R, aV_F, aV_L, $V_1 - V_6$
At Rest	Probat. examination Procedures (Valsalva, Carotid Sinus) Drugs	Leads I, II, III, aV_R, aV_F, aV_L, $V_1 - V_6$
At Rest	Dr Fenyves	Vectocardiography
O_2-Deficiency	Metabograph 14%, 12%, 10%	Leads, I, II, III, aV_R, aV_L, aV_F, $V_1 - V_6$
After Workload	Master Step Test	Leads I–III, $V_4 - V_6$
After Workload and O_2-Deficiency	Master Step Test in Low Pressure Chamber	Leads I–III, $V_4 - V_6$
ECG *during* Workload	Treadmill Ergometer	$V_1 - V_6$
Orthostatic Test	Tilt Table	Leads I–III, $V_4 - V_6$

2. Performance Tests

Test condition	*Method*	*Program*
Erogometer Workload	Steady-State-Conditions 100 Watt, 40 RPM	Oxygen Uptake Carbon Dioxide Elimination Respiratory Quotient Respiratory Minute Volume Respiratory Equivalent Heart Rate Blood Pressure Oxygen Pulse
Ergometer Workload	Vita-Maxima Beginning with 100 Watt. Increases by 25 Watt up to Performance Limit	Oxygen Uptake Carbon Dioxide Elimination Respiratory Quotient Respiratory Minute Volume Respiratory Equivalent Heart Rate Blood Pressure Oxygen Pulse
Treadmill Ergometer	Steady-State-Conditions 10°, 12°, 3 km/h	Oxygen Uptake Carbon Dioxide Elimination Respiratory Quotient Respiratory Minute Volume Respiratory Equivalent Heart Rate Blood Pressure Oxygen Pulse
Treadmill Ergometer	Vita-Maxima Increase of Rate resp. Angle of Inclination up to Performance Limit	Oxygen Uptake Carbon Dioxide Elimination Respiratory Quotient Respiratory Minute Volume Respiratory Equivalent Heart Rate Blood Pressure Oxygen Pulse
Ergometer	Performance Pulse Index (E.A.Müller)	Heart Rate

3. Pheripheral Circulatory Regulation Tests

Test condition	*Method*	*Program*
At Rest	Physical Analysis of Circulation (Wezler/Böger)	Stroke Volume Cardiac Minute Volume Elastic Resistance Pulse Wave Velocity Heart Action Cardiac Output Heart-rate Systolic Blood Pressure Diastolic Blood Pressure
Ergometer Load	Ergometer 100 Watt 40 RPM	Heart Rate Systolic Blood Pressure Diastolic Blood Pressure
Treadmill	10° – 15° 3 – 4 km/h	Hear Rate Systolic Blood Pressure Diastolic Blood Pressure
Orthostatic Test	Tilt Table	Heart Rate Systolic Blood Pressure Diastolic Blood Pressure ECG
At Rest	Determination of Haemodynamics (Blumberger)	Cardiac Isometric Contraction and Ejection Time

4. Special Examination Procedures

Test condition	*Method*	*Program*
At Rest and during Hypoxia	Rheography according to Schuhfried	Plethysmography Mean Peripheral Blood Content of Particular Extremities
At Rest	Venous Pulse Recording (Altmann)	Venous Pulse
At Rest	Arterial Pulse Recording according to Boucke/Brecht	Carotid Femoral Pulse and Small Arteries
At Rest	Phonocardiography	Registration of Cardiac Sound with Several Filters

B. EVALUATION OF THE CARDIOVASCULAR SYSTEM

I An exact study of the cardiovascular system is an important part of Flying Fitness Examinations at the German Air Force Institute of Aviation Medicine.

II Any u/t (undergraduate training pilot without wings), pilot or any other aircrew is required to pass a routine examination of the cardiovascular system to evaluate whether he is fit for flying duties (i.e. Routine Cardiovascular Examination).

This examination includes a routine check of pulse rate, blood pressure and electrocardiogram at rest and after adequate physical stress by a double MASTER Step Test. ECG during these procedures include STANDARD -, GOLDBERGER- and WILSON leads (I II III; aVR aVL aVF; V1 V6); recorded simultaneously. This examination is usually combined with a physical examination by a Cardiologist in order to compare history and physical examination with the results of the cardiovascular tests. This physician will decide if the person examined is fit for flying in accordance with German Air Force Standards as far as the cardiovascular system is concerned or in case of pathological findings if he has to be grounded.

III In case of doubtful results (in approximately 30% of all cases examined) the Cardiologist requests additional cardiovascular tests for further evaluation (i.e. Special Cardiovascular Examination). These tests include additional pulse, blood pressure, and ECG studies under different conditions (ergometry, low pressure chamber etc.) and phonocardiogram. If these results remain doubtful the subject will be grounded temporarily and a re-examination within 3, 6 or 12 months will be arranged.

The Flight Surgeon will obtain information of these findings and instructions to initiate appropriate measures.

IV During the prescribed Routine Examination with ECG at rest and after physical stress it is planned to replace the double MASTER Test with bicycle ergometry of 100 Watt and 50 revolutions per minute for a period of 5 minutes.

The advantage of physical stress by ergometry will be a well defined reproducible factor in accordance with an ECG recording during work. The Special Examination will probably be augmented by Ultrasound or Echography of heart volume, evaluation of structural heart changes and Ultragram.

V These prescribed physical examinations of the cardiovascular system will be tested in 3 different Laboratories with the following installations:

1. **Cardiovascular Laboratory**

(a) Electrocardiography

2 ea 6-channel ECGs

(b) Work performance apparatus

Round stairs for Master Step Test

2. **Physical Stress Laboratory**

(a) Electrocardiography

1 ea 8-channel ECG
1 ea 6-channel ECG
2 ea 3-channel telemetric ECGs.
1 ea 1-channel ECG recorder
1 ea Vectrocardiograph

(b) Ergometry

4 ea Bicycle Ergometers
1 ea Treadmill Ergometer

(c) Spirography

1 ea Spirograph (Metabograph)

(d) Tilt Table for orthostatic examinations.

3. **Low Pressure Chamber Laboratory**

Low pressure chamber to be installed temporarily with apparatus from Physical Stress Laboratory in accordance with the requested Special Examination.

C. EVALUATION OF PULMONARY FUNCTION

I The purpose of the pulmonary function tests is primarily case finding. They do not provide sufficient evidence to justify disqualification of an applicant for the issue of renewal of a licence or rating without further thorough investigation of the respiratory system. Pulmonary function tests do not provide a diagnosis of pulmonary disease but can only determine characteristic patterns of altered pulmonary function. Nevertheless, the values obtained from relatively simple spirographic measurements are often diagnostically useful per se. If not, they represent the proper initial approach to the diagnosis. Abnormal values suggest the proper direction for additional, more precise examination of the candidate.

II The evaluation of pulmonary function forms part of the first complete medical examination of the candidates applying for flying training or rating. It is also included in the re-examinations of candidates for the renewal of licences or ratings at a frequency of not more than every three years up to the age of forty and thereafter every year.

III In candidates who have no personal history of cardio-pulmonary disease and who do not present any signs or symptoms or organic diseases of the structures of lungs, mediastinum or pleura, only simple spirographic tests are carried out. The recorded values (spirogram, vital capacity, maximal and mid-expiratory flow rate) provide a basis for the evaluation of the ventilatory function of the lungs and of the overall mechanical function of lungs and thorax. If the values are normal and no symptoms or clinical or radiologic findings or cardio-pulmonary disease are present, no further pulmonary function tests are carried out. If abnormal values are found, the tests are repeated after administration of bronchodilator drugs to disclose spastic bronchiolar obstruction. In almost every case the finding of a "restrictive" or "obstructive" or "combined" ventilatory disorder is just the confirmation and quantification of the clinical findings. The quantification of these functional abnormalities of the respiratory system supports the making of decisions relating to the assessment of medical fitness. Occasionally, the simple spirographic tests disclose unsuspected pulmonary disorders in an initial state.

IV The evaluation of pulmonary function in medico-legal matters involving pulmonary disability following a disease or accident incurred while on duty is performed with methods testing all aspects of pulmonary function which are relevant in the special case. These special lung function tests are also used to determine the degree of pulmonary disability in connection with the granting of a waiver. In general, the special lung function tests are only performed in candidates in whom the clinical diagnosis of pulmonary disease (mostly chronic diseases of the airways, the structures of the lungs or pleura) is made. These tests can determine on an objective basis the presence or absence of functional impairment, its nature and the severity of the disturbance. The expertise given will help to decide whether the degree of abnormality is compatible with the claim of pulmonary disability and compensation or with the requirements for granting a waiver.

V (a) Routine screening studies of pulmonary function

Spirography
Spirogram (air trapping)
Vital capacity
Forced expiration
- forced expiratory volume, % of vital capacity in 1 sec
- maximal expiratory flow rate
- mid-expiratory flow rate.

If abnormal values are found, the tests are repeated after administration of bronchodilator drugs.

(b) Special studies of pulmonary function

Spirography
Lung volumes
- inspiratory reserve volume
- tidal volume
- expiratory reserve volume
- residual volume
- functional residual capacity
- thoracic gas volume (body plethysmograph)

Pulmonary ventilation
- frequency of breathing
- minute volume of breathing
- maximal voluntary ventilation

Distribution of inspired gas and pulmonary capillary blood flow
- helium distribution test
- single-breath CO_2-test
- estimation of respiratory dead space (Riley Technique)

Arterial blood
- O_2 partial pressure and saturation
- CO_2 partial pressure
- pH
- standard bicarbonate

Mechanics of breathing

pressure-volume curves
pulmonary resistance
work of breathing
static compliance of lung
specific compliance of lung
airway resistance (body plethysmograph)
maximal inspiratory and expiratory forces.

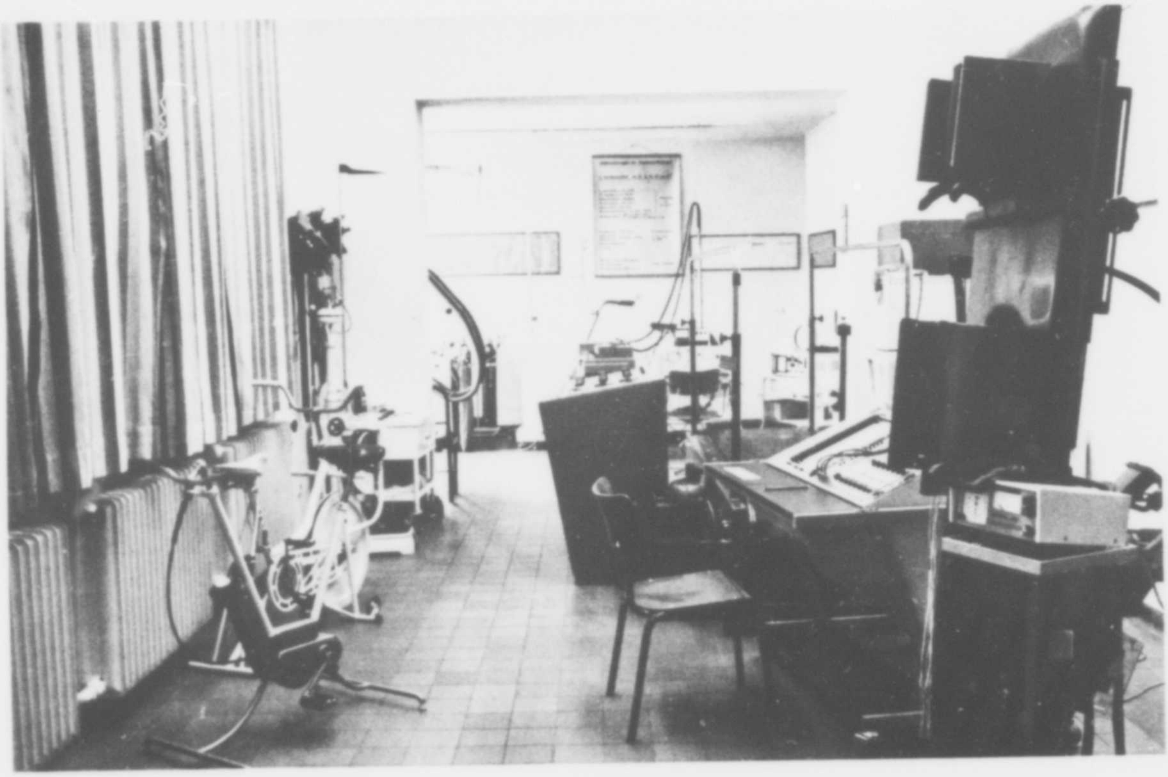

Fig.5.1 Physical stress laboratory

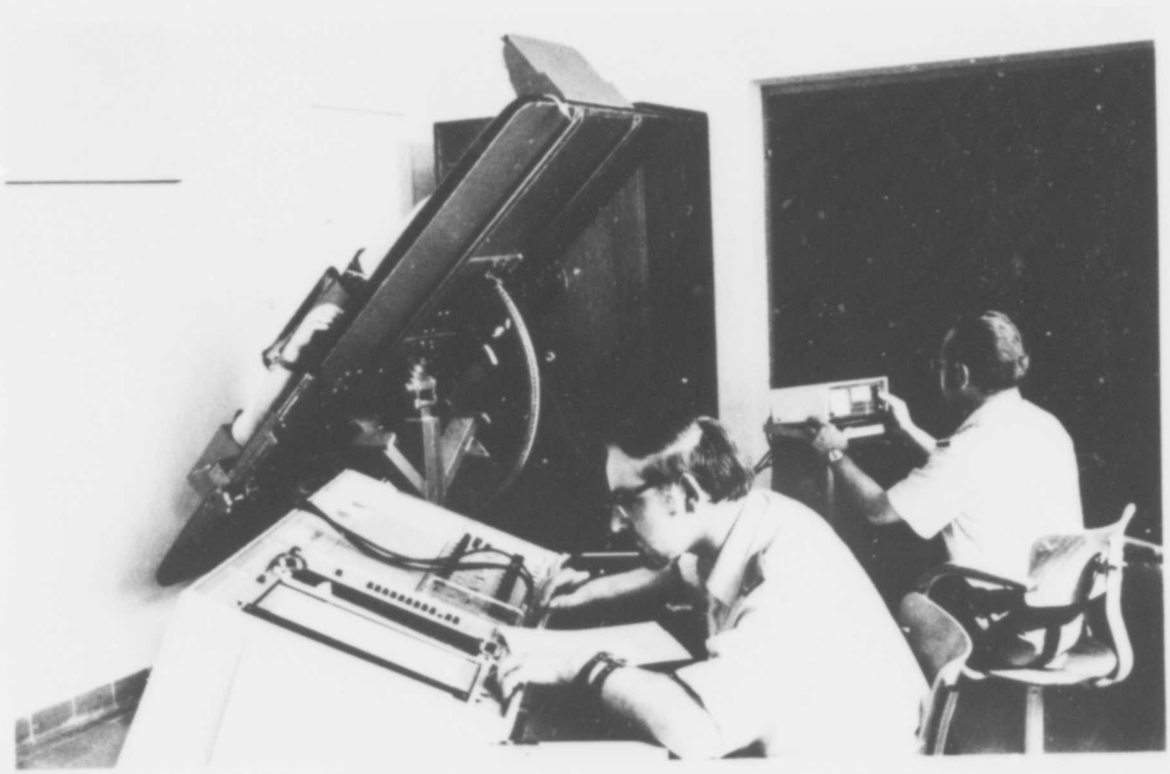

Fig.5.2 Tilt table. Registration of pulse rate, blood pressure and ECG

Fig.5.3 Bicycle ergometry

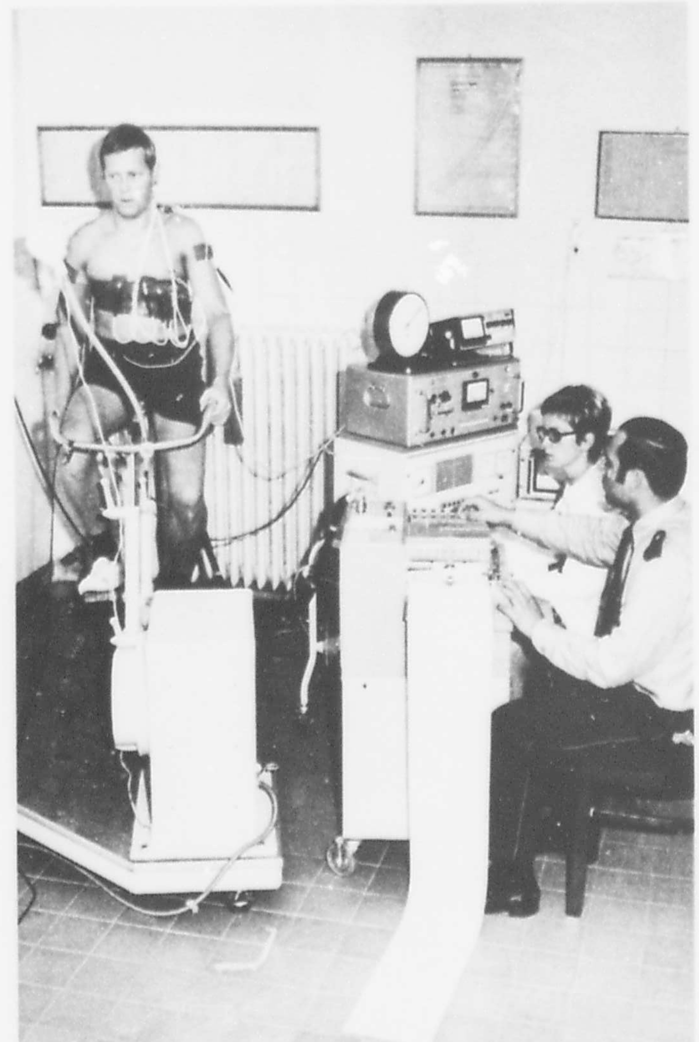

Fig.5.4 Bicycle ergometry
During workload with registration of ECG and blood pressure

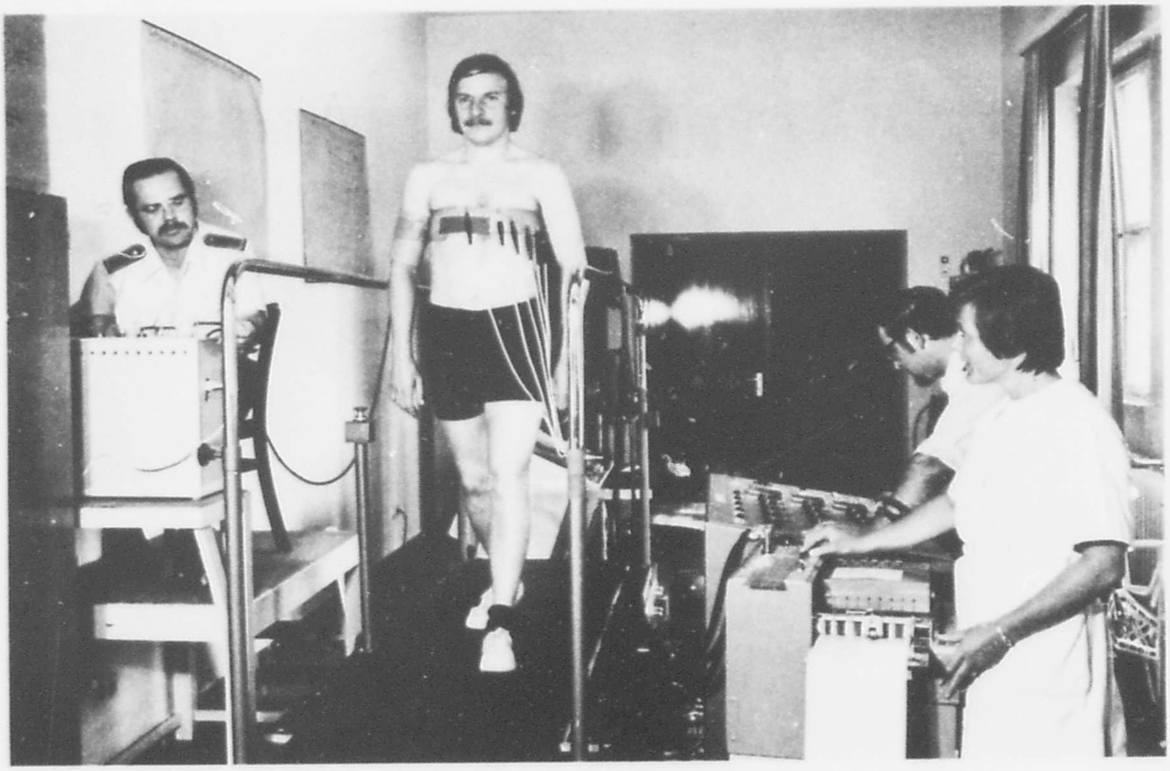

Fig.5.5 Treadmill ergometry. During workload with ECG registration

Fig.5.6 Ergospirography. With simultaneous registration of cardiovascular functions (physical stress laboratory)

Fig.5.7 Face mask with pneumotachometer. (Lung function testing with the open system)

Fig.5.8 Lung function test apparatus (open system)

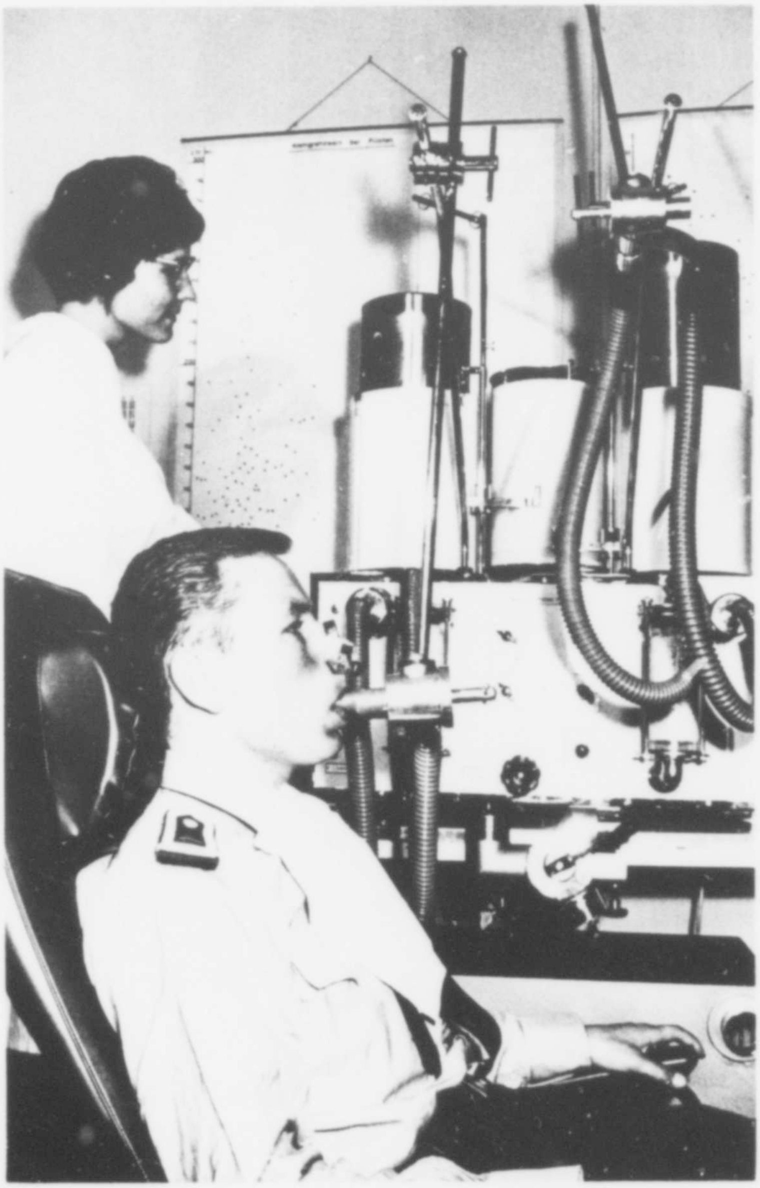

Fig.5.9 Lung function test apparatus (closed system)

STUDY ON INCIDENCE AND INTERPRETATION OF CARDIAC RHYTHM DISTURBANCES IN AIRCREWS OF THE GERMAN AIR FORCE

by

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Aside from alterations of the ST -T segment, cardiac rhythm disturbances are the most frequent ECG findings deviating from the standards in flying fitness examinations. Of 2100 subjects examined at the German Air Force Institute of Aviation Medicine in 1970, 87 had arrhythmias in the routine ECG.

Often it is very difficult to comment on the importance and prognosis of such ECG anomalies in these predominantly healthy and carefully monitored subjects, since assessment criteria for the most part stem from clinical experience.

Only extensive studies of this category of persons[26], observations of rhythm disturbances in cardiac healthy people[16,18,28,38,42,10], particularly in athletes during ergometer work[27,15,24] and examinations with the telemetric[35] or the long-term ECG[36] revealed that nearly all arrhythmias known from clinical experience may also occur in persons having no symptoms of a cardiac disease.

In evaluating these ECGs the physician examining aircrews must partially consider aspects different from those applied to the normal population. He is essentially confronted with three problems:

(1) Is there a possibility of haemodynamic consequences to the circulatory system when certain forms of arrhythmia occur, in other words, will sequelae of specific arrhythmias endanger the pilot?

(2) Are these rhythm disturbances a symptom of an existing cardiac or extra-cardiac illness?

(3) Must certain rythm disturbances be classified as premonitory phenomena of cardiac disease, which might become manifest later on?

The first point includes some disturbances of the heart rhythm the occurrence of which is not compatible with flying duty.

The second group is more difficult to assess: there are no disease-specific arrhythmias, disturbances of this nature may be completely absent even in severe cardiac diseases.

As far as the third group is concerned there are still differences in opinion about rhythm disturbances pointing to an alteration of the myocardium which in the course of time develops into a disease.

The present survey is intended to give information about recent experiences in the assessment of arrhythmias. It must consider the assessment problems of these ECG anomalies in flying personnel, a relatively young, healthy group of persons under close medical supervision, exposed to a variety of psychic and physical stress factors in the line of duty.

(a) *Premature contractions*

In flying fitness examinations premature contractions are the most frequent type of arrhythmias. Out of 2100 persons examined by ECG (Standard-, Goldberger- and Wilson leads V1 - V6 at rest and after Master Test) at the German Air Force Institute of Aviation Medicine 1.43% revealed ventricular and 0.9% supraventricular premature beats. Examinations employing long-term ECGs over a period of 24 hours revealed ventricular premature beats in even 29% of all cardiac healthy persons and supraventricular premature beats in 19% (Ref.42).

For their assessment their place of origin seems to be important. Some authors are, however, of the opinion that atrial premature beats are a sign of an impaired atrial myocardium[17,35].

Wenger suggests a connection between increased workload of one ventricle and ectopic localization, e.g. more frequent left-ventricular premature beats during arterial hypertension[39].

Long-term ECT studies by Hinkle revealed a predominance of supraventricular premature beats in cardiac healthy subjects with an average age of 55 years[18], whereas in subjects with a lower average age[10,42,2] ventricular premature beats are clearly in the majority. From this fact it may be concluded that the occurrence of supraventricular premature beats could be directly related to the aging process of the heart.

We also found an additional occurrence of supraventricular premature beats in persons we noticed in the routine ECG because of ventricular premature beats, predominantly in the higher age groups[10].

In principle it must be emphasized, that even in cardiac healthy subjects premature beats may occur in all places of origin.

In the opinion of most authors[20,37,25,1] more than one ventricular foci must be considered as pathologic. Hiss found only one case among 67,000 healthy members of flying personnel[19].

According to our studies the fact of the occurrence of multifocal ventricular premature contractions is not as important as their frequency. We found these rhythm disturbances, even though very rarely appearing in the long-term ECG of cardiac healthy young pilots[9,10].

Our observations, that simultaneously occurring supraventricular and ventricular premature beats are not uncommon in long-term ECG recordings of healthy subjects, testify to the fact that a number of heterotopic foci may be located in the heart without a provable disease. We also found this combination in routine ECGs of cardiac healthy subjects (4 of 2100 subjects), whereas multifocal ventricular premature beats during such short-term recordings have not been registered here.

Differentiation is often difficult between mutifocal ventricular premature beats and unifocal ones, which change their configuration only under different states of conduction, the so-called multiformed premature beats[39]. The reason for this may also be found in the fact that even with unchanged place of origin and the same heart rate the coupling interval may fluctuate considerably during long-term observation[10], a condition which not seldom leads to fusion beats without there being a parasystole. We found multiformed ventricular premature beats also in long-term ECGs of cardiac healthy persons and in ergometer ECGs during increased stress without there being a defective conduction system.

We did not record parasystoles in aircrews examined by us, nor in long-term ECG recordings. Hiss found 18 cases in 67,000 cardiac healthy persons but considered the percentage to be higher in a cardiac healthy population[19]. This opinion is also shared by other authors[37,20].

An early onset of premature beats, the so-called "R on T-phenomenon" which causes severe paroxysmal tachycardia particularly during myocardial infarction[4], should hardly occur in healthy persons[20,25].

In our observations ventricular and supraventricular premature beats often occurred in the descending part or at the end of the T-wave of the preceding normal heart beat, but never earlier. A high degree rhythm disturbance was not caused in this way.

This mechanism could, however, have a bearing in already existing premature beats with short coupling interval under conditions leading to a temporary Q–T lengthening, such as hypoxia[33], hyperventilation[30] and intra-thoracic high pressure. A premature contraction could fall into the vulnerable period of the preceding beat and trigger a tachycardia. A pilot with such types of premature beats would be an increased risk as operator of high performance fighter aircraft and should fly only with a co-pilot.

A QRS-complex of ventricular premature beats above 0.16 sec considered by some authors as an indication of myocardial damage[17] does not have any pathologic importance, judging from our experience.

An increase of premature beats during exercise is predominantly found in persons with coronary insufficiency because ectopic foci originate particularly in the vicinity of hypoxic myocardial areas. In persons suffering from coronary insufficiency typical ST–T alterations can most likely be reproduced during adequate exercise on the ergometer. Such a diagnostic approach is of importance, since an increase or a first appearance of premature beats is also found in cardiac healthy subjects[24,20] and since disappearance of premature beats during exercise will also occur in persons suffering from an organic cardiac disease. Therefore premature beats with short coupling intervals will often disappear only at higher heat rates and during increasing frequency premature beats with long coupling intervals will fall into the absolute refractory period of the normal heart beats, which follow in quicker sequence.

Immediately following the exercise, premature beats can also be observed in healthy persons, since the disposition of the conduction system for heterotopic stimulus formation increases during this vegetative change-over phase.

The number of premature beats per minute in persons without signs of a cardiac disease is without importance just as the presence of a bigemini, trigemini, 2:1 premature beats etc. Especially the latter forms of arrhythmia were not infrequent in our examinees immediately after exercises, without other conspicuous findings becoming evident. We also observed premature beats two in a row in cardiac healthy subjects examined by us. It is particularly true for the assessment of premature beats that from their appearance in the ECG alone no pathological meaning may be derived. Also their haemodynamic importance in a relatively young and well monitored group of persons such as aircrews is not great. A final statement can only be made in connection with detailed overall clinical findings.

(b) *Heterotopic Supraventricular and Ventricular Rhythms*

During phases of rest and sleep, during long-term ECG recordings, immediately after exercise in the ergometer ECG, and when carrying out provocation tests we frequently observe a P-flattening or P-inversion with partly considerable frequency decrease in cardiac healthy persons without the P R interval becoming shorter than 0.12 sec. As causes for this the following points are mentioned:

A vagotonically conditioned wandering of the pacemaker in the sinus node[37,25], into the atrium and the region of the A–V node[14], reflex influences on the atrial conduction[20] and in case of P-inversion also a pacemaker in the coronary sinus[34] or an A V rhythm with retrograde A V block[20].

Fluctuations of the vegetative tonus and vagal influence hardly cause an A V dissociation, a wandering pacemaker or even an A–V rhythm, as observed by us primarily in long-term ECGs and when conducting provocation tests.

Evidently young asthenics having such disturbances in the ECG at rest rather tend to collapse with bradycardic pulse, which may also be triggered by mechanisms which occur when flying a high performance aircraft. Thus, cases with bradycardic collapse during high-pressure breathing[40] and while testing pressure suits[41] have been reported. Syncopes of this nature can above all be induced through the Valsalva maneuver with its vegetative and haemodynamic effects. The intra-thoracic high pressure is also essentially effective in the genesis of other rhythm disturbances, in collapse during sports activities, but especially in previously damaged hearts[20].

Duvoisin was able to cause a syncope through Valsalva maneuver in 30.5% of 200 healthy young men[13].

Dermksian found cardiac rhythm disturbances in 68% of his experimentally caused syncopes, of which 58% were induced by holding the breath in orthostatic position[7].

These facts lead themselves only partially for a screening test relating to a disposition to vasovagal syncopes[6]. Arrhythmias of this kind, however, indicate the necessity of thorough examinations.

Moreover, this disposition seems to disappear with increasing age and body weight[6,10].

Essential in the assessment of military flying fitness is the appearance of paroxysmal tachycardias. According to the regulations of the German Air Force, appearance of this arrhythmia in the ECG will be considered evidence of medical disqualification from flying duty. The reason is to be found in a considerable decrease of the cardiac output which may lead to symptoms of reduced cerebral blood flow in tachycardias of a higher degree. Even though tachycardia appears in healthy subjects, these cases confront us mostly with vegetatively instable, asthenic persons in whom a tendency for orthostatic regulatory disturbance is further increased. Furthermore the partly threatening subjective feelings during a critical flying situation, which might have only been released by tachycardia, may further compromise the reactive ability of the pilot.

Whereas 62% of all persons having supraventricular paroxysmal tachycardias have a sound heart[37], the ventricular form is more seldom found in this group of persons[11,32,8].

Hiss and Lamb, however, consider premature beats 3 in a row to be paroxysmal tachycardias and they only found one case in 67,000 healthy men[19]. During long-term observations we recorded such premature beats in two of 52 cardiac healthy men whose ECG at rest had already indicated premature beats.

Suspension from flying without additional clinical findings seems to be unjustified in these cases. These consecutive premature beats are like the multifocal ones more a quantitative problem and have apprently a serious prognosis only if they occur more often.

The electrocardiographically proved appearance of atrial fibrillation and flutter will also be cause for suspension from flying status in the German Air Force. Aside from the Haemodynamic effects and the subjective strange feeling, the danger of emboli, the development of cardiac insufficiency and the primary disease have a bearing on this decision.

In the cases of so-called idiopathic atrial fibrillation, no signs of damage or functional decrement can be proved on the heart[11,29,14,20,37]. The danger of embolism is believed to be non-existent, the attacks are of only short duration and very frequently caused by vagal influence. A basic disease is not found. The cardiac output is said to be undiminished during the paroxysm[23], and the danger of cardiac insufficiency does not exist.

Recently several case histories showing such rhythm disturbance have been described in aerospace medicine literature and upon thorough examination some subjects were even returned to unrestricted flying status[3,5].

(c) *Disturbances of Conduction*

S–A blocks are particularly found when conducting provocation tests and under other vagal influences in asymptomatic persons. These blocks are generally interrupted by escape beats and have no influence on flying fitness without further clinical findings. A first degree A–V block appearing in higher age groups and existing unchanged throughout exercise requires preclusion of a degenerative myocardial process. In many cases it is the residual phenomenon of a former inflammation of the conduction system, for instance during myocarditis, and will not restrict flying fitness if inflammation symptoms are no longer existent and if cardiac performance is unimpaired, all the more since this persisting status will not cause any haemodynamic alterations.

The so-called functional first degree A–V block in juveniles, which will return to normal during exercise, is conditioned by a predominant vagotonus and has no pathological significance. Observations of these functionally conditioned conduction disturbances sometimes revealed an increase of the blocks in the sense of a Wenckebach-phenomenon during further increase of the vagotonus, for example during phases of sleep and rest, but also during provocation tests[8]. So far a Wenckebach-periodicity in cardiac healthy persons has been reported relatively seldom in literature[31,12,20,21].

The behaviour of the P–R interval in these subjects testifies to an indistinct transition between first degree A–V block and second degree A–V block, type I. In cases where the isolated Wenckebach-phenomenon and also possibly a Wenckebach-periodicity is found during ECGs at rest or in provocation ECGs of otherwise inconspicuous and efficient subjects with a relative or absolute P–R lengthening, this form of block is only a more pronounced form of vagotonia which leads to a first degree A–V block in disposed persons. It will not impair military flying fitness.

Blocks of higher degrees are not found in cardiac healthy subjects. In all cases they seem to be an expression of a severe organic damage or an inherited disturbance of the conduction system[25,37,20].

These are some of the few rhythm disturbances which will already be considered disqualifying for military flying duty on account of their appearance in the ECG. In most cases, however, further diagnostic criteria must be applied for the assessment of arrhythmias, attaching great importance to the original vegetative status of the examinee. When granting authorization to fly, the dangers of an aggravation of these arrhythmias under conditions of high performance flying must be considered, problems, which in the rest of the population will only come to bear in extreme situations.

SUMMARY

A study of cardiac healthy persons by modern ECG-recording techniques revealed that nearly all arrhythmias known from clinical experience appear within this group.

In interpreting certain rhythm disturbances more emphasis should be attached to the frequency rather than to the fact of their occurrence.

In the present survey of an evaluation based on routine ECGs our findings during flying fitness examinations at the German Air Force Institute of Aviation Medicine have been compared with studies of other authors. Clinical criteria for arrythmia assessments have been reviewed for application in apparently cardiac healthy subjects.

The specific situation of the pilot in military aviation and the importance of arrhythmias in determining military flying fitness are discussed.

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CHAPTER 6

CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS FOR FUNCTIONAL EVALUATION OF IAF AIRCREWS

by

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1. GENERAL INFORMATION

The tests in question here are applied for the purposes of the selection and control, periodical or extraordinary, of flying Personnel in the Italian Air Force.

In the case of periodical control, they are applied only to jet pilots, except in the case of extraordinary examinations.

They are also applied for the purpose of selecting candidates for third degree civil flying licences, candidates to become helicopter pilots of other Armed Forces of the nation, pupils of the Aeronautical Technical Institute, etc.

The methods currently applied are the result of twenty year's experience at the respiratory and cardiovascular physiology laboratories of the Italian Air Force Study and Research Centre of Aviation and Space Medicine.

The tests are applied only to subjects who have passed the general clinical and the following examinations:

- chest fluororoentgenography,
- rest ECG,
- chemical laboratory (urines, glycemia, axotemia, blood cells count, hemochromometry, syphilis serodiagnosis),
- anthropometrical,
- otorhinolaryngologic (including audiometry and vestibular functionality),
- ophthalmologic,
- neuropsychiatric (including EEG),
- odontostomatologic.

These tests, like all the clinical examinations, are carried out by specialized medical personnel of the Air Force, at the A.F. Medico-legal Institutes.

Subjects who pass the first general screening, which lasts one day, undergo on the two following days selection and psychological and psychoaptitudinal tests, in addition to the cardiovascular and respiratory functional evaluation tests with which we are concerned here.

The complete series of tests comprises:

A. Static respiratory tests,
B. Exercise test,
C. Hypoxia test,
D. Tilt table test.

It is necessary, in this connection, to give the following details: the static respiratory tests are applied to all subjects, except for the measurement of the residual volume, which is carried out only in particular cases (see under the respective item).

The exercise test is carried out with different methods according to the type or category to which the subject in question belongs (see under the respective item).

The hypoxia test is applied to all subjects, with invariable method.

The tilt table test is applied only in particular cases. In fact, after an initial trial period, it was suppressed for practical reasons, which will be discussed in the respective section.

From performance in all the tests a score out of a hundred is obtained (reduced to 65 points in those cases in which the exercise test is eliminated, see further on).

This score is changed into an evaluation which is added to the ones obtained from the medical examination and the psychological and psychotechnical tests, in order to express a final judgement on fitness in general, and on the level of a particular fitness of the examinee.

Before going on to describe the ways in which the different tests are carried out, it should first be stated that a different weight is given to the three tests that contribute to the determination of the score (the tilt table test having been excluded). The maximum scores are as follows: 15 points out of 100 go to the results of the static respiratory tests, 35 to the exercise test and 50 to the hypoxia test.

The considerable weight given to the hypoxia test is based on experience which teaches that this test, as well as being an indication of the specific reaction of the organism to hypoxia, has the characteristics of an actual test of cardio-circulatory functionality, revealing in some cases troubles of the right intraventricular conduction or other imperfections that are not detectable with an electrocardiographical examination in normal conditions, as carried out during the cardiologist examination.

2. METHODS

A. Static Respiratory Tests

The static respiratory tests are carried out on the subject standing, by means of a spirometer in closed circuit filled with 100% oxygen.

Alternatively the pneumotachographical system can also be used, with breathing of ambient air.

In both cases the spirograms are recorded and attached to the documentation concerning the subject.

After a period of about five minutes for the subject to get accustomed (made necessary by use of the nose-clip and the mouth-piece), and in any case not before the ventilation is stabilized, as regards both frequency and amplitude, the following parameters are measured:

- Pulmonary ventilation in conditions of rest, in order to determine the tidal volume,
- Vital Capacity,
- Time Vital Capacity.

The vital capacity is measured a suitable number of times, in order to be able to determine the maximum value. It is generally carried out by making a maximum expiration which follows a maximum inspiration. However, in doubtful cases, it may also be determined by adding a maximum inspiration and a maximum expiration (taking away the tidal volume doubled) carried out in successive phases and with a normal breathing phase in between.

On the basis of the parameters recorded we obtain the components of vital capacity (reserve inspiratory volume, tidal volume, reserve expiratory volume) and VEMS (maximum expiratory volume in the first second), from which the Tiffeneau index is obtained (VEMS/CV).

All the values recorded at ATPS, are reduced to BTPS.

The comparative standard theoretical values for subjects of the same sex, stature and age, are obtained from special tables and nomograms prepared on the basis of a vast number of cases collected at the Aviation and Space Medicine Study and Research Centre. These values call for periodical updating, in practice about every ten years.

On the basis of the percentage differences between real values and theoretical values, a score is assigned in accordance with the following table:

Vital Capacity

(M stands for the theoretical value)

from M + 10% to higher values	:	10 points
from M − 1% to M + 9%	:	8 points
from M − 2% to M − 9%	:	6 points
from M − 10% to M − 19%	:	4 points
from M − 20% to M − 30%	:	2 points

For values 30% and more less than M , the judgement of unfitness will be considered, keeping in mind also the result of other tests.

VEMS (ratio between real VEMS/VC and theoretical VEMS/VC)

from M + 10% to higher values	:	5 points
from M + 5% to M + 9%	:	4 points
from M + 4% to M	:	3 points
from M − 1% to M − 5%	:	2 points
from M − 6% to lower values	:	0 points

In particular cases (evaluation of pathological subjects, or subjects suspected as being such, for medico-legal purposes) the functional residual capacity is determined (reserve expiratory volume plus residual volume) from which the residual volume is calculated.

This test is carried out with the nitrogen mixing technique. The mixing curve of the nitrogen contained in the lungs with the oxygen contained in the closed-circuit spirometer is determined by means of an N_2-meter.

The residual volume (expressed at BTPS) is found by subtracting the reserve expiratory volume.

The Total Pulmonary Capacity and the emphysema index (ratio between residual volume and total pulmonary capacity) are calculated from the residual volume. The standard control values are taken from the tables published by the Coal and Steel Community.

In particular cases, that is when it is desired to determine, by difference, the volume of trapped air, if any, the Functional Residual Capacity is recorded with the plethysmographic method.

It should be pointed out that, to have a reliable indication in this direction, the tests must be repeated several times, since, with both methods, errors up to 15 - 20% are admissible.

If necessary (suspected restrictive syndromes, bronchial spasms, etc.) the measurements of the functional residual capacity are repeated after administering a bronchodilator.

B. Exercise Test

The exercise test aims at determining the metabolic performance, as well as the cardiocirculatory and respiratory response of the organism during muscular work. This test, subjecting the organism to a submaximal effort, also aims at measuring the commitment and therefore the level of motivation of the candidate.

This applies to the type of test given to pilot candidates. In fact there are two ways of carrying out the exercise:

(1) exercise with increasing loads to the point of exhaustion (pilot candidates),

(2) exercise with a fixed load for periodical and extraordinary controls.

One of the two following apparatuses is used in the exercise test:

(a) bicycle-ergometer,
(b) treadmill.

If the bicycle-ergometer is used, the subject must carry out the work at the rate of 60 pedal thrusts a minute.

If a treadmill is used, the work may be done by adopting a constant slope or a constant speed.

In the case of the constant slope, it is fixed at what is considered the optimal value of 25%, equal to an angle of inclination of 13° 54'.

The speed to be given the belt is expressed by the following formula:

$$V = \frac{L}{P} \times 15$$

where V = speed in km/h , L = amount of work in kgm/sec , P = body weight in kg . The constant 15 is obtained by dividing 3.6 (conversion factor from m/sec to km/h) by 0.24 (sine 13° 54').

A special table avoids the application of this calculation.

If we resort to the system of constant speed (fixed at 6 km/h) and variable slope, the angle of inclination i to be given to the plane of the belt is obtained with the following formula:

$$\text{sine } i = 0.6 \frac{L}{P}$$

where L and P are the same values as in the preceding formula.

In this case, too, special tables are available.

Advantages and disadvantages of the two methods

The bicycle-ergometer method is certainly the more suitable one, owing to the certainty it gives that the subject actually carries out the work desired, provided the instrument is exactly calibrated and the subject keeps up the pace, which is ensured by the special indicator or warning light by which the subject will take care to regulate himself.

In the case of the treadmill, tests carried out by means of analysis of the photograms of a filming of the operation showed that an actual implementation of the estimated muscular work (that is an actual summing of shifts of the individual's centre of mass upwards up to a value equal to the one required in relation to the weight of the individual himself) is obtained only if the subject takes steps of suitable length and, obviously, does not support part of his weight on the handrails.

Furthermore, in the constant slope system, which is the one most frequently used, the performance of single individuals is also influenced by the speed which varies according to the weight.

Implementation of the test

The test with increasing loads is carried out according to the following pattern:

Time	Work in kgm/sec
First 30 sec	5
from 31 to 60 sec	10
2nd minute	15
3rd minute	20
4th minute	25
5th minute and following	30

The subject, with nose-clip and mouth-piece, sitting on the bicycle-ergometer undergoes, to begin with, the determination in conditions of rest of the following parameters: respiratory rate, pulmonary ventilation at ATPS, determination of the percentage of oxygen and that of carbon dioxide present in the air expired, systolic and diastolic humeral blood pressure, heart rate.

The length of this initial period comprises about five minutes of stabilization as well as three minutes for the measurement of the parameters, from which average values at rest are obtained.

The pulmonary ventilation in open circuit is determined by means of a two-cylinders spirometer with alternative recording. The oxygen content in the air expired is determined by means of the direct-reading Beckman oxymeter (to be carried out every 10 seconds). Carbon dioxide is measured by means of an infrared CO_2-meter.

Blood pressure is measured by means of the auscultatory method with Riva-Rocci sphygmomanometer and heart rate is measured for 10 seconds every minute by means of a thoracic electrocardiographic lead.

When carrying out routine tests it is usual to omit measuring the output of CO_2 and in this case the metabolic production of calories is calculated on the basis of oxygen consumption and the estimated caloric equivalents.

As alternative techniques the closed circuit systems with breathing of 100% O_2 and chemical absorption of the CO_2 expired, can be used, with recording of the spirogram, the slope of which gives also oxygen consumption.

Furthermore the test can also be carried out with the pneumotachographic method, with the advantage that all respiratory resistance is eliminated (which is obviated at present with the use of tubes of considerable diameter). In this type of technique gas analyzers are used (CO_2-meter and polarographic oxymeter with Kreuzer's electrode), with direct written recording of the O_2 consumption and of CO_2 output in the expiration phase only.

During the working phase and in the following period of rest (see further on), the parameters are recorded separately every minute.

The following values are obtained from these parameters:

- Ventilation at BTPS,
- Respiratory rate,
- Percentage consumption of O_2,
- Respiratory ratio,
- Equivalent in calories (Kilo calories per litre of O_2 consumed with a given respiratory ratio),
- Oxygen consumption (in litres at STPD),
- Kilo calories produced.

Furthermore the following indexes are calculated:

- Calory/litres ratio (ratio between the number of Kilo calories produced in a minute and pulmonary ventilation in litres at BTPS).
- Oxygen pulse (that is ratio between oxygen consumption at STPD in ml/min and heart rate).

Should it not be possible to determine the respiratory ratio, since it is not possible, for practical reasons, to determine the output of carbon dioxide, estimated respiratory ratios are taken (sufficiently reliable for practical purposes) of 0.80 at rest and during the first half minute of work, 0.85 in the second half minute of work, 0.90 at the 2nd minute, 0.95 at the 3rd, 1.00 at the 4th if following, to which there correspond respective calory equivalents of 4.801, 4.862, 4.924, 4.985 and 5.047 Kilo calories per liter of oxygen (at STPD) consumed.

The work is carried on till exhaustion is reached, which happens on an average after 5 -7 minutes of total work.

When work ends a period of rest follows lasting for 9 minutes (except for particular cases), during which the same parameters are recorded.

The score is assigned on the basis of the maximum consumption of oxygen, the ratio between VO_2 max and HR max, the ratio between calories/litres and the maximum arterial pressure at the end of the work. The total amount of work carried out is also taken into account.

The table of evaluation used is the following:

Maximum VO_2

over 3500 ml/min:	5 points
from 3499 to 3000:	4 points
from 2999 to 2500:	3 points
from 2499 to 2000:	2 points
under 2000:	no point

Ratio VO_2/HR (highest value)

21 and over:	10 points
between 20.9 and 16:	8 points
between 15.9 and 14:	6 points
between 13.9 and 11:	4 points
between 10.9 and 9:	2 points
under 9:	no point

Ratio calories/liters (highest value)

0.260 and above:	10 points
between 0.259 and 0.230:	8 points
between 0.229 and 0.200:	6 points
between 0.199 and 0.180:	3 points
under 0.180:	no point

Value of the systolic blood pressure at the end of the work
(periods of work above 5 minutes)

from 160 to 180 torr:	10 points
from 150 to 159:	6 points
from 140 to 149:	4 points
values under 140:	no point
values between 181 and 195:	8 points
valules between 196 and 210:	4 points
values above 210:	no point

(For values under 140 torr or above 210 the judgement of unfitness is taken into consideration.)

For periodical control purposes, the test consists in carrying out, after a suitable period to become accustomed, work equal to 10 kgm/sec for 10 minutes. If this constant work test is used, the rest phase is eliminated.

In view of the lack of homogenity of the subjects (while candidates have an average age of between 18 and 20, pilots are up to 50 years of age, after which the test is no longer carried out), a score is assigned (up to 35/100) on a clinical basis, taking the age of the subject into account.

C. Hypoxia Test

The hypoxia test is used not only to determine the physiological response of the subject to hypoxia, but also as a sensitized test of cardiac functionality. It can, in fact, reveal the existence of functional troubles (particularly of the right intraventricular conduction) which are not at all or barely detected by an electrocardiographic examination carried out in normal conditions. For this reason the test is given a relative weight of 50/100 in the score.

This test consists in submitting the subject to the simulated altitude of 5500 m a.s.l. (379 torr) in a low pressure chamber. The altitude is reached at the speed of ascent of 500 m/min.

The parameters are recorded after a period of adaptation of 15 minutes.

At the end of the test, recompression is carried out at such a speed (from 200 to 300 m/min) as not to cause barotraumatic phenomena.

Alternatively the test can be carried out with the low oxygen mixture technique. In this case the subject is made to breathe, by means of a mouth-piece, a low oxygen mixture containing 9.5% of oxygen in nitrogen. The partial pressure of the oxygen in this mixture corresponds to the pressure at the altitude of about 6200 m a.s.l. (exactly 6185).

This difference as compared with the simulated altitude used in the low pressure chamber was introduced as a result of experience which shows that the effects of a low oxygen mixture are less marked than those of decompression, the oxygen partial pressure being equal.

The simulated altitude of 5500 m was adopted for physiological reasons. It is well known, in fact, that at this altitude we pass from the zone of complete compensation to that of incomplete compensation.

Also in the case of the use of low oxygen mixture, the tests are carried out 15 minutes after the subject begins to breathe the mixture.

Parameters recorded

All the parameters are measured (1) at sea level and (2) at the simulated altitude.

These parameters are:

Respiratory rate,
Pulmonary ventilation (at BTPS),
Heart rate,
Systolic and diastolic blood pressure,
Complete electrocardiographic plotting of thoracic leads.

If the test is carried out in the low pressure chamber, a paper and pencil test, the *sensitized calculation test*, can also be given. This consists in having a series of subtractions carried out, starting from a number fixed by the operator and gradually subtracting the numbers. The latter are indicated in each square not directly, but with a symbol the key to which is supplied separately.

Points are assigned on the basis of the percentage differences between the values obtained under normal conditions and the ones obtained in hypoxia, with regard to ventilation, heart rate and systolic blood pressure (for a maximum total of 40/100). Ten other points are assigned to the electrocardiogram on the basis of the clinical judgement of the specialist.

Pulmonary ventilation

increase of more than 50%:	6 points
between 36 and 49%:	8 points
between 15 and 35%:	10 points
between -5 and +14%:	4 points
decrease of 6% and more:	2 points

Heart rate

increase of over 60%:	2 points
between 46 and 59%:	4 points
between 31 and 45%:	8 points
between 20 and 30%:	15 points
between 5 and 19%:	10 points
variation between +4 and -10:	4 points
decrease of over 10%:	2 points

Blood pressure

increase between 25 and 35%:	10 points
increase between 16 and 24%:	12 points
increase between 5 and 15%	15 points
variation between +4 and -4%:	8 points
increase of over 35% and decrease between 5 and 15%:	4 points
decrease of more than 15%:	2 points

D. Overall Evaluation

To be judged fit, the subject must obtain the necessary minimum score in each test (that is, over half of the maximum score). Furthermore he is not judged fit if his total score is under 60/100.

The final judgement, which is added to those obtained in the psychological and psychoaptitudinal tests and in the clinical examination, consists of the assignment of a judgement and a mark from 1 to 6.

If the maximum score is equal to 100/100, the following table is used:

Score (out of 100)	*Judgement and mark*
60 – 65	1 (sufficient with 1)
66 – 72	2 (sufficient with 2)
73 – 79	3 (good with 1)
80 – 86	4 (good with 2)
87 – 93	5 (excellent with 1)
94 – 100	6 (excellent with 2)

If the muscular exercise test is not carried out, and therefore the score is expressed in 65/65, the following table is used:

Score (out of 65)	*Judgement and mark*
31 – 42	1 (sufficient with 1)
43 – 47	2 (sufficient with 2)
48 – 51	3 (good with 1)
52 – 56	4 (good with 2)
57 – 60	5 (excellent with 1)
61 – 65	6 (excellent with 2)

E. Appendix

TILT TABLE TEST

This test has been dropped owing to the physical discomfort it involved and the psychological resistance aroused in subjects owing to the fact that they have to be strapped to the table.

It consisted in keeping the subject for 5 minutes in a clinostatic position, for 5 minutes in an orthostatic position a + 65° (or about $+0.9G_z$ and $+0.4G_x$) and in an upside-down position a − 65 (or at about $-0.9G_z$ and $+0.4G_x$), again for 5 minutes.

The test which, generally, reveal orthostatic vaso-depression, consisted in determining, and comparing, heart rate, pulmonary ventilation, respiratory rate, humeral blood pressure.

The upside-down position was used exclusively for experimental purposes, and was never taken into consideration in selection and control examinations.

The data obtained, to which reference has been made above, plus others, yielded in experimental tests on the cardiac output (seen to be reduced in the orthostatic position and increased in the upside-down position, as compared with the clinostatic position) are not such as to allow this test to be considered a valid and useful test, for the purposes of selection and control examinations of the physiological response of man to variations in G

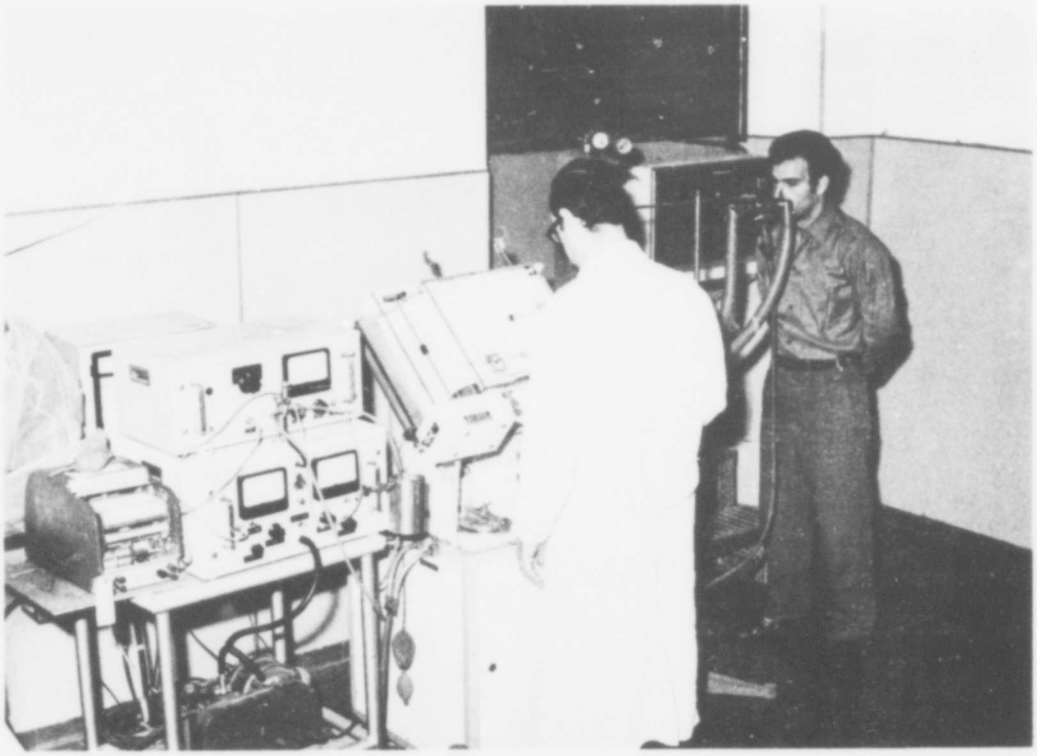

Fig.6.1 Static respiratory tests. Pulmonary ventilation. Vital Capacity and Timed Vital Capacity are being recorded with the closed circuit spirometer. The apparatus on the left are employed to determine Functional Residual Capacity with the nitrogen mixing method

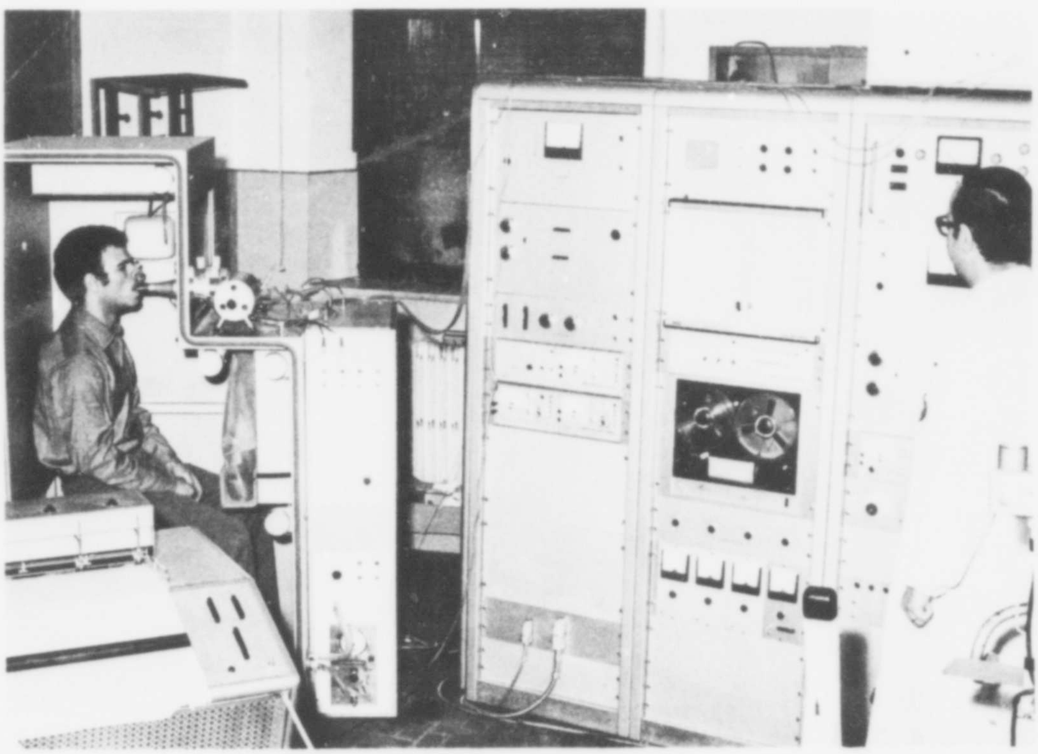

Fig.6.2 Static respiratory tests. Determination of functional residual capacity by the plethysmographic method. The application of both plethysmographic and nitrogen-mixing methods may be applied for the determination of "trapped air"

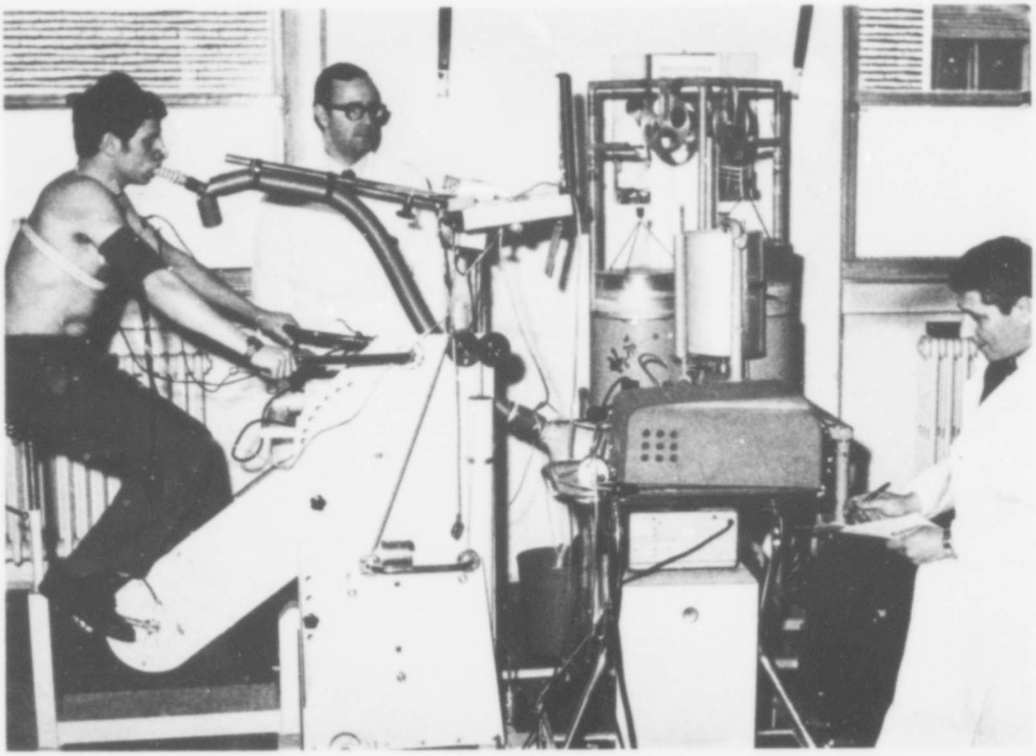

Fig.6.3 Exercise test. Exercise test being performed on a bicycle ergometer. On the right side: an operator is reading oxygen concentration in the expired air by means of an oxymeter, behind which one can see the double bell spirometer for continuous recording of pulmonary ventilation

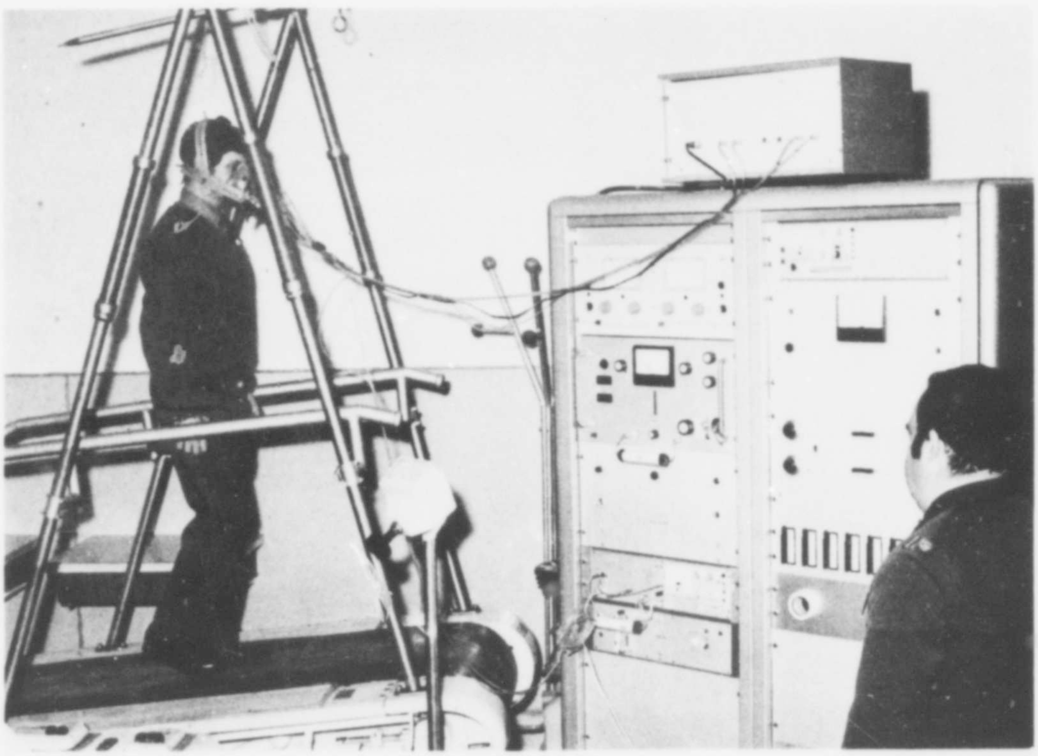

Fig.6.4 Exercise test. Exercise test being performed on the treadmill. Expired gases concentrations are recorded by means of the electronic apparatus Pulmorex (on the right)

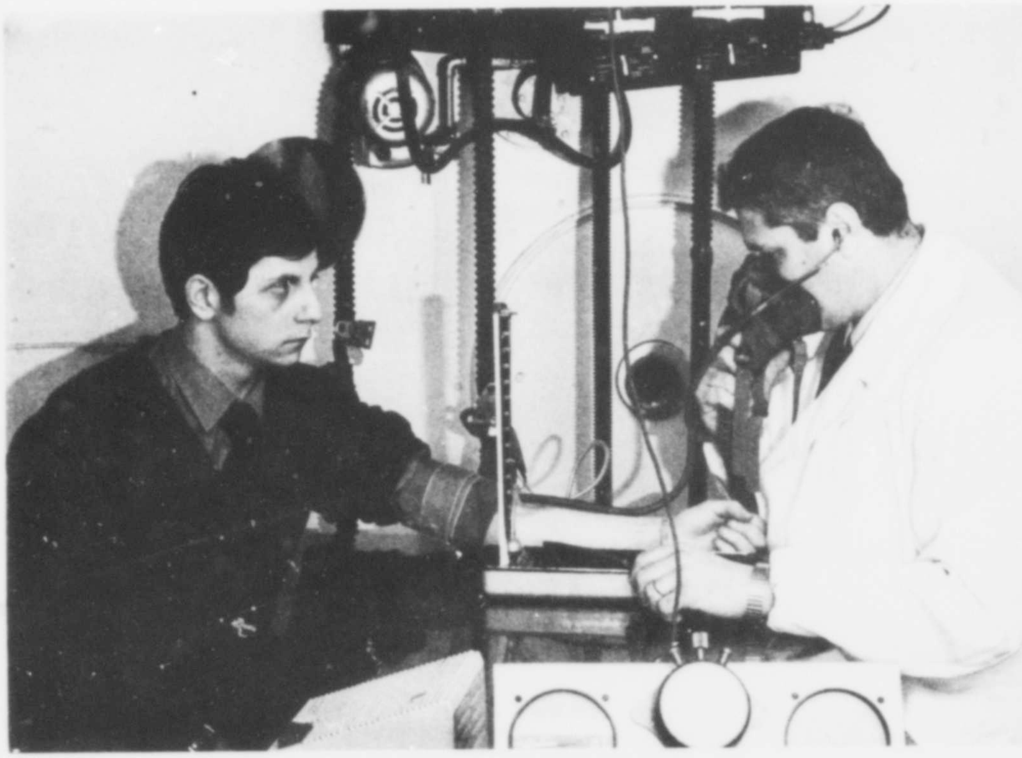

Fig.6.5 Hypobaric test in the low pressure chamber

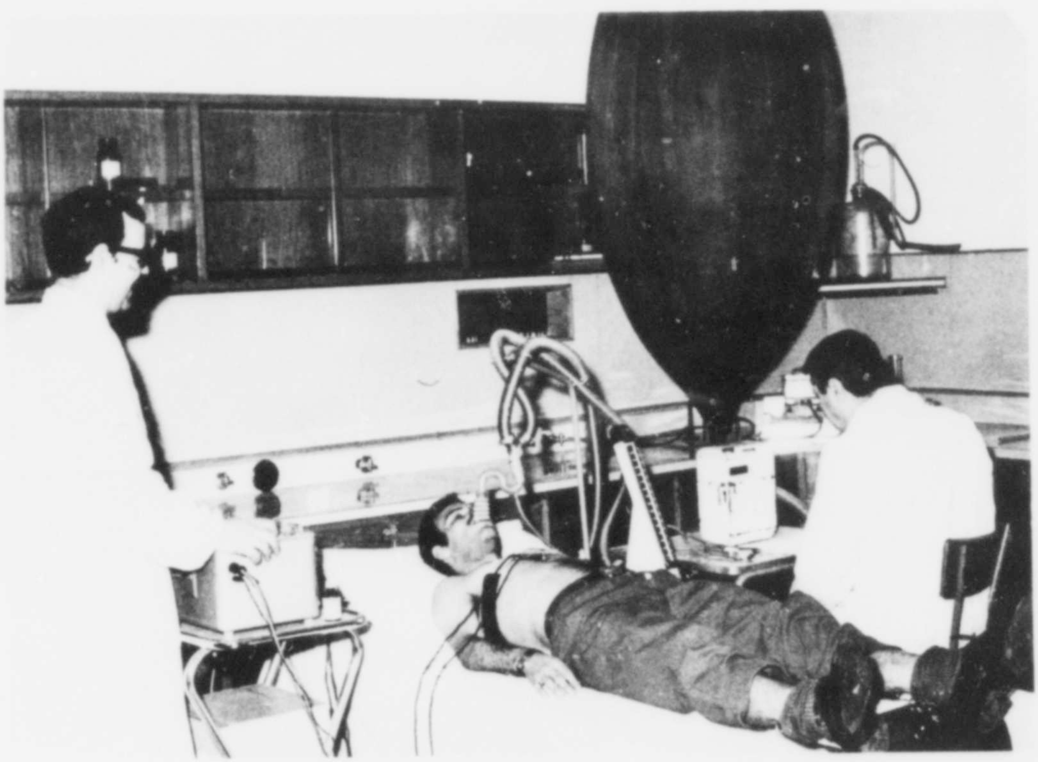

Fig.6.6 Hypobaric test, low oxygen mixture method. Note the balloon containing the gaseous mixture breathed by the subject. The operator on the left is recording the ECG, the other on the right is recording subject's ventilation

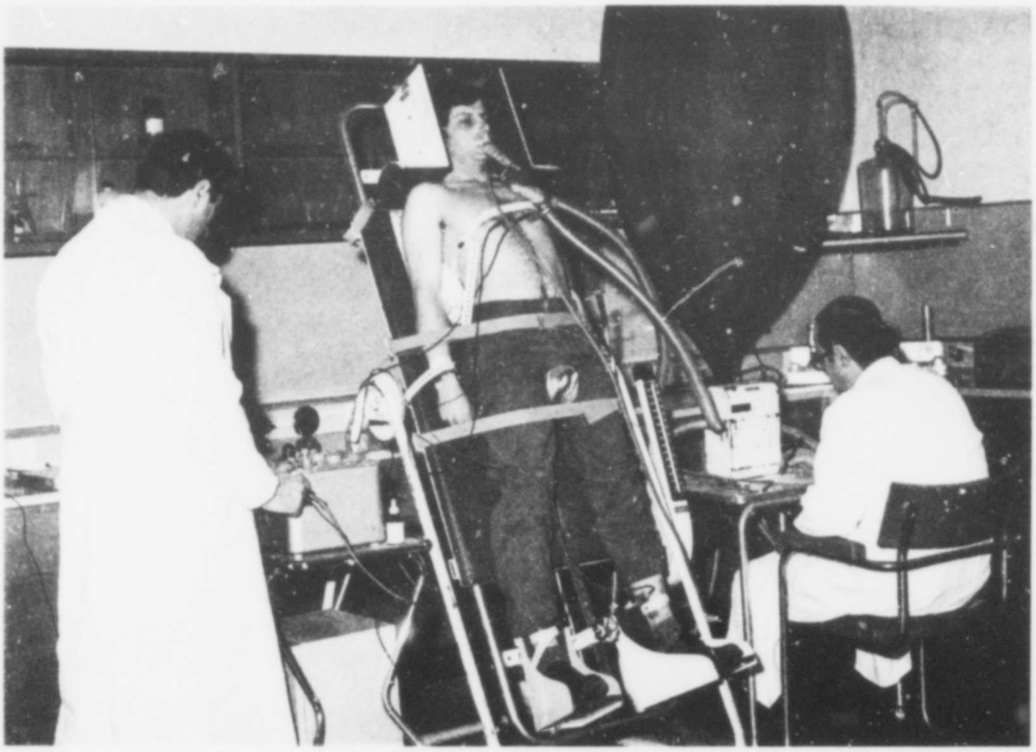

Fig.6.7 Tilt table test. ECG and pulmonary ventilation are being recorded by the two operators (respectively on the left and on the right side). Note how the subject is strapped on the table, and is supported by a bicycle saddle, in order to obtain muscular relaxation

CHAPTER 7

CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS USED IN ROYAL NORWEGIAN AIR FORCE

by

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Surgeon General, R.No.A.F., at the date of this work

A. GENERAL INFORMATION

All the aircrew in R.No.A.F. are examined every year on the different air bases by the flight surgeon.

All applicants are examined by the Military Medical Board for Flying Personnel at the Institute of Aviation Medicine. Up to the age of 40, the pilots have to meet at the Board every 6th year; after the age of 40, all aircrew have to meet at the same Board every 3rd year.

The ECG (12 leads) at rest and after exercise has to be recorded at every examination at the Medical Board. During the annual examination at the base level, only ECG at rest is required.

Every year a physical exercise test according to Åstrand is carried out. At the Medical Board the Vitalograph is also used to examine lung function.

Haemoglobin, erythrocyte sedimentation rate and serum cholesterol are determined every year. The standards used are the ones in the US Air Force Manual 160-1.

It is only the Surgeon General or the Deputy Surgeon General who can sign the medical certificates for military flying personnel.

B. METHODS

1. ECG at rest and after an exercise, sufficient to give a heart frequency of at least 120 beats per minute. A bicycle-ergometer is used and the ordinary 12 leads are recorded before and after the exercise. The test takes about 15 minutes.

   A technician is in charge of the test, and a Medical Doctor should be present.

2. A physical test is made once a year on a bicycle-ergometer, based on a moderate constant load for 6 to 10 minutes until a steady heart rate is reached. From this frequency maximum oxygen consumption is calculated.

   (Reference: Lars Hermansen: Ergometri, Universitets-forlaget, Oslo, 1971; P.O.Åstrand, Acta Physiol. Scand., 1960, suppl. 169.)

   Orientation for the subject and the test takes about 15 minutes. Example (ref. the enclosed tables which are taken from L.Hermansen): a subject has cycled on a load 900 kpm per minute, and has got a final pulse of 140. From Table 1 3.6 is multiplied by 1.00 (Table 4) for a 25 year old man; 3.6 (Table 5) gives combined with his body weight, for instance 70 kg, a score of 51 ml/kg minute as maximum oxygen uptake.

   We have given some figures to express bad, average, good physical conditions.

3. Peak expiratory flow (PEF) is measured on ordinary equipment (rapid excursion of a pointer), mainly by means of the "Vitalograph".

   We no longer use vital capacity or Flack tests. Tests 1 and 2 are used extensively in R.No.A.F. ECG, bicycle-ergometer or corresponding equipment, spirometers, will of course be required.

TABLE 1

Calculation of Maximum Oxygen Consumption from Measurement of the End Heart Rate of Work (steady state)

	Maximum O_2 consumption l/min										
Pulse rate (steady state)	300 kpm/min	600 kpm/min	900 kpm/min	1200 kpm/min	1500 kpm/min	*Pulse rate (steady state)*	300 kpm/min	600 kpm/min	900 kpm/min	1200 kpm/min	1500 kpm/min
120	2.2	3.5	4.8			145		2.4	3.4	4.5	5.6
121	2.2	3.4	4.7			146		2.4	3.3	4.4	5.6
122	2.2	3.4	4.6			147		2.4	3.3	4.4	5.5
123	2.1	3.4	4.6			148		2.4	3.2	4.3	5.4
124	2.1	3.3	4.5	6.0		149		2.3	3.2	4.3	5.4
125	2.0	3.2	4.4	5.9		150		2.3	3.2	4.2	5.3
126	2.0	3.2	4.4	5.8		151		2.3	3.1	4.2	5.2
127	2.0	3.1	4.3	5.7		152		2.3	3.1	4.1	5.2
128	2.0	3.1	4.2	5.6		153		2.2	3.0	4.1	5.1
129	1.9	3.0	4.2	5.6		154		2.2	3.0	4.0	5.1
130	1.9	3.0	4.1	5.5		155		2.2	3.0	4.0	5.0
131	1.9	2.9	4.0	5.4		156		2.2	2.9	4.0	5.0
132	1.8	2.9	4.0	5.3		157		2.1	2.9	3.9	4.9
133	1.8	2.8	3.9	5.3		158		2.1	2.9	3.9	4.9
134	1.8	2.8	3.9	5.2		159		2.1	2.8	3.8	4.8
135	1.7	2.8	3.8	5.1		160		2.1	2.8	3.8	4.8
136	1.7	2.7	3.8	5.0		161		2.0	2.8	3.7	4.7
137	1.7	2.7	3.7	5.0		162		2.0	2.8	3.7	4.6
138	1.6	2.7	3.7	4.9		163		2.0	2.8	3.7	4.6
139	1.6	2.6	3.6	4.8		164		2.0	2.7	3.6	4.5
140	1.6	2.6	3.6	4.8	6.0	165		2.0	2.7	3.7	4.5
141		2.6	3.5	4.7	5.9	166		1.9	2.7	3.6	4.5
142		2.5	3.5	4.6	5.8	167		1.9	2.6	3.5	4.4
143		2.5	3.4	4.6	5.7	168		1.9	2.6	3.5	4.4
144		2.5	3.4	4.5	5.7	169		1.9	2.6	3.5	4.3
						170		1.8	2.6	3.4	4.3

TABLE 2

Oxygen Uptake in Relation to Work in Watt or kpm/min

watt	kpm/min	liter/min
50	300	0.9
100	600	1.5
150	900	2.1
200	1200	2.8
250	1500	3.5
300	1800	4.2
350	2100	5.0
400	2400	5.7

TABLE 3

Factor for Heart Rate

Heart rate	*Factor*
210	1.12
200	1.00
190	0.93
180	0.83
170	0.75
160	0.69
150	0.64

TABLE 4

Factor for Age when Maximum Heart Frequency is not Known. Maximum O_2 – Uptake is Multiplied by this Factor

Years	*Factor*
15	1.10
25	1.00
35	0.87
40	0.83
45	0.78
50	0.75
55	0.71
60	0.68
65	0.65

TABLE 5

Table for Calculation of Maximum Oxygen Consumption (ml/kg min) from Maximum Oxygen Consumption (liter/min) and Body Weight in kg

Oxygen consumption liter/min

Body weight kg	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
50	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76
51	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
52	29	31	33	35	37	38	40	42	44	46	48	50	52	54	56	58	60	62	63	65	67	69	71	73
53	28	30	32	34	36	38	40	42	43	45	47	49	51	53	55	57	58	60	62	64	66	68	70	72
54	28	30	31	33	35	37	39	41	43	44	46	48	50	52	54	56	57	59	61	63	65	67	69	70
55	27	29	31	33	35	36	38	40	42	44	45	47	49	51	53	55	56	58	60	62	64	65	67	69
56	27	29	30	32	34	36	38	39	41	43	45	46	48	50	52	54	55	57	59	61	63	64	66	68
57	26	28	30	32	33	35	37	39	40	42	44	46	47	49	51	53	54	56	58	60	61	63	65	67
58	26	28	29	31	33	34	36	38	40	41	43	45	47	48	50	52	53	55	57	59	60	62	64	66
59	25	27	29	31	32	34	36	37	39	41	42	44	46	47	49	51	53	54	56	58	59	61	63	64
60	25	27	28	30	32	33	35	37	38	40	42	43	45	47	48	50	52	53	55	57	58	60	62	63
61	25	26	28	30	31	33	34	36	38	39	41	43	44	46	48	49	51	52	54	56	57	59	61	62
62	24	26	27	29	31	32	34	35	37	39	40	42	44	45	47	48	50	52	53	55	56	58	60	61
63	24	25	27	29	30	32	33	35	37	38	40	41	43	44	46	48	49	51	52	54	56	57	59	60
64	23	25	27	28	30	31	33	34	36	38	39	41	42	44	45	47	48	50	52	53	55	56	58	59
65	23	25	26	28	29	31	32	34	35	37	38	40	42	43	45	45	48	49	51	52	54	55	57	58
66	23	24	26	27	29	30	32	33	35	36	38	39	41	42	44	45	47	48	50	52	53	55	56	58
67	22	24	25	27	28	30	31	33	34	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57
68	22	24	25	26	28	29	31	32	34	35	37	38	40	41	43	44	46	47	49	50	51	53	54	56
69	22	23	25	26	28	29	30	32	33	35	36	38	39	41	42	43	45	46	48	49	51	52	54	55
70	21	23	24	26	27	29	30	31	33	34	36	37	39	40	41	43	44	46	47	49	50	51	53	54
71	21	23	24	25	27	28	30	31	32	34	35	37	38	39	41	42	44	45	46	48	49	51	52	54
72	21	22	24	25	26	28	29	31	32	33	35	36	38	39	40	42	43	44	46	47	49	50	51	53
73	21	22	23	25	26	27	29	30	32	33	34	36	37	38	40	41	42	44	45	47	48	49	51	52
74	20	22	23	24	26	27	28	30	31	32	34	35	36	38	39	41	42	43	45	46	47	49	50	51
75	20	21	23	24	25	27	28	29	31	32	33	35	36	37	39	40	41	43	44	45	47	48	49	51

(Continued)

TABLE 5 (continued)

Oxygen consumption liter/min

Body weight kg	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
76	20	21	22	24	25	26	26	29	30	32	33	34	36	37	38	39	41	42	43	45	46	47	49	50
77	19	21	22	23	25	26	27	29	30	31	32	34	35	36	38	39	40	42	43	44	45	47	48	49
78	19	21	22	23	24	26	27	28	29	31	32	33	35	36	37	38	40	41	42	44	45	46	47	49
79	19	20	22	23	24	25	27	28	29	30	32	33	34	35	37	38	39	41	42	43	44	46	47	48
80	19	20	21	23	24	25	26	28	29	30	31	33	34	35	36	38	39	40	41	43	44	45	46	48
81	19	20	21	22	23	25	26	27	28	30	31	32	33	35	36	37	38	40	41	42	43	44	46	47
82	18	20	21	22	23	24	26	27	28	29	30	32	33	34	35	37	38	39	40	41	43	44	45	46
83	18	19	20	22	23	24	25	27	28	29	30	31	33	34	35	36	37	39	40	41	42	43	45	46
84	18	19	20	21	23	24	25	26	27	29	30	31	32	33	35	36	37	38	39	40	42	43	44	45
85	18	19	20	21	22	24	25	26	27	28	29	31	32	33	34	35	36	38	39	40	41	42	44	45
86	17	19	20	21	22	23	24	26	27	28	29	30	31	33	34	35	36	37	38	40	41	42	43	44
87	17	18	20	21	22	23	24	25	26	28	29	30	31	32	33	34	36	37	38	39	40	41	43	44
88	17	18	19	20	22	23	24	25	26	27	28	30	31	32	33	34	35	36	38	39	40	41	42	43
89	17	18	19	20	21	22	24	25	26	27	28	29	30	31	33	34	35	36	37	38	39	40	41	43
90	17	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	36	37	38	39	40	41	42
91	16	18	19	20	21	22	23	24	25	26	27	29	30	31	32	33	34	35	36	37	38	40	41	42
92	16	17	18	20	21	22	23	24	25	26	27	28	29	30	32	33	34	35	36	37	38	39	40	41
93	16	17	18	19	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	37	38	39	40	41
94	16	17	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
95	16	17	18	19	20	21	22	23	24	25	26	27	28	29	31	32	33	34	35	36	37	38	39	40
96	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	38	39	40
97	15	16	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
98	15	16	17	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	36	37	38	39
99	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
100	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38

(Continued)

TABLE 5 (continued)

Oxygen consumption liter/min

Body weight kg	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0
50	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
51	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118
52	75	77	79	81	83	85	87	88	90	92	94	96	98	100	102	104	106	108	110	112	113	115
53	74	75	77	79	81	83	85	87	89	91	92	94	96	98	100	102	104	106	108	109	111	113
54	72	74	76	78	80	81	83	85	87	89	91	92	94	96	98	100	102	104	106	107	109	111
55	71	73	75	76	78	80	82	84	85	87	89	91	93	95	96	98	100	102	104	105	107	109
56	70	71	73	75	76	79	80	82	84	86	88	89	91	93	95	96	98	100	102	104	105	107
57	68	70	72	74	75	77	79	81	82	84	86	88	89	91	93	95	96	98	100	102	104	105
58	67	71	72	74	74	76	78	79	81	83	84	86	88	90	91	93	95	97	98	100	102	103
59	66	68	69	71	73	75	76	78	80	81	83	85	86	88	90	92	93	95	97	98	100	102
60	65	67	68	70	72	73	75	77	78	80	82	83	85	87	88	90	92	93	95	97	98	100
61	64	66	67	69	70	72	74	75	77	79	80	82	84	85	87	89	90	92	93	95	97	98
62	63	65	66	68	69	71	73	74	76	77	79	81	82	84	85	87	89	90	92	94	95	97
63	62	63	65	67	68	70	71	73	75	76	78	79	81	83	84	86	87	89	90	92	94	95
64	61	63	64	66	67	69	70	72	73	75	77	78	80	81	83	84	86	88	89	91	92	94
65	60	62	63	65	66	68	69	71	72	74	75	77	78	80	82	83	85	86	88	89	91	92
66	59	61	62	64	65	67	68	70	71	73	74	76	77	79	80	82	83	85	86	88	89	91
67	58	60	61	63	64	66	67	69	70	72	73	75	76	78	79	81	82	84	85	87	88	90
68	57	59	60	62	63	65	66	68	69	71	72	74	75	76	78	79	81	82	84	85	87	88
69	57	58	59	61	62	64	65	67	68	70	71	72	74	75	77	78	80	81	83	84	86	87
70	56	57	59	60	61	63	64	66	67	69	70	71	73	74	76	77	79	80	81	83	84	86
71	55	56	58	59	61	62	63	65	66	68	69	70	72	73	75	76	77	79	80	82	83	85
72	53	56	57	58	60	61	63	64	65	67	68	69	71	72	74	75	76	78	79	81	82	83
73	53	55	56	58	59	60	62	63	64	66	67	68	70	71	73	74	75	77	78	79	81	82
74	53	54	55	57	58	59	61	62	64	65	66	68	69	70	72	73	74	76	77	78	80	81
75	52	53	55	56	57	59	60	61	63	64	65	67	68	69	71	72	73	75	76	77	79	80

(Continued)

TABLE 5 (continued)

Oxygen consumption liter/min

Body weight kg	3.9	4.0	4.1	4.2	4.3	4.4.	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0
76	51	53	54	55	57	58	59	61	62	63	64	66	67	68	70	71	72	74	75	76	78	79
77	51	52	53	55	56	57	58	60	61	62	64	65	66	68	69	70	71	73	74	75	77	78
78	50	51	53	54	55	56	58	59	60	62	63	64	65	67	68	69	71	72	73	74	76	77
79	49	51	52	53	54	56	57	58	59	61	62	63	65	66	67	68	70	71	72	73	75	76
80	49	50	51	53	54	55	56	58	59	60	61	63	64	65	66	68	69	70	71	72	74	75
81	48	49	51	52	53	54	56	57	58	59	60	62	63	64	65	67	68	69	70	72	73	74
82	48	49	50	51	52	54	55	56	57	59	60	61	62	63	65	66	67	68	70	71	72	73
83	47	48	49	51	52	53	54	55	57	58	59	60	61	63	64	65	66	67	69	70	71	72
84	46	48	49	50	51	52	54	55	56	57	58	60	61	62	63	64	65	67	68	69	70	71
85	46	47	48	49	51	52	53	54	55	56	58	59	60	61	62	64	65	66	67	68	69	71
86	45	47	48	49	50	51	52	53	55	56	57	58	59	60	62	63	64	65	66	67	69	70
87	45	46	47	48	49	51	52	53	54	55	56	57	59	60	61	62	63	64	66	67	68	69
88	44	45	47	48	49	50	51	52	53	55	56	57	58	59	60	61	63	64	65	66	67	68
89	44	45	46	47	48	49	51	52	53	54	55	56	57	58	60	61	62	63	64	65	66	67
90	43	44	46	47	48	49	50	51	52	53	54	56	57	58	59	60	61	62	63	64	66	67
91	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	62	63	64	65	66
92	42	43	45	46	47	48	49	50	51	52	53	54	55	57	58	59	60	61	62	63	64	65
93	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61	62	63	65
94	41	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	59	60	61	62	63	64
95	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61	62	63
96	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	63
97	40	41	42	43	44	45	46	47	48	49	51	51	53	54	55	56	57	58	59	60	61	62
98	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
99	39	40	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61
100	39	40	41	42	43	44	45	45	47	48	49	50	51	52	53	54	55	56	57	58	59	60

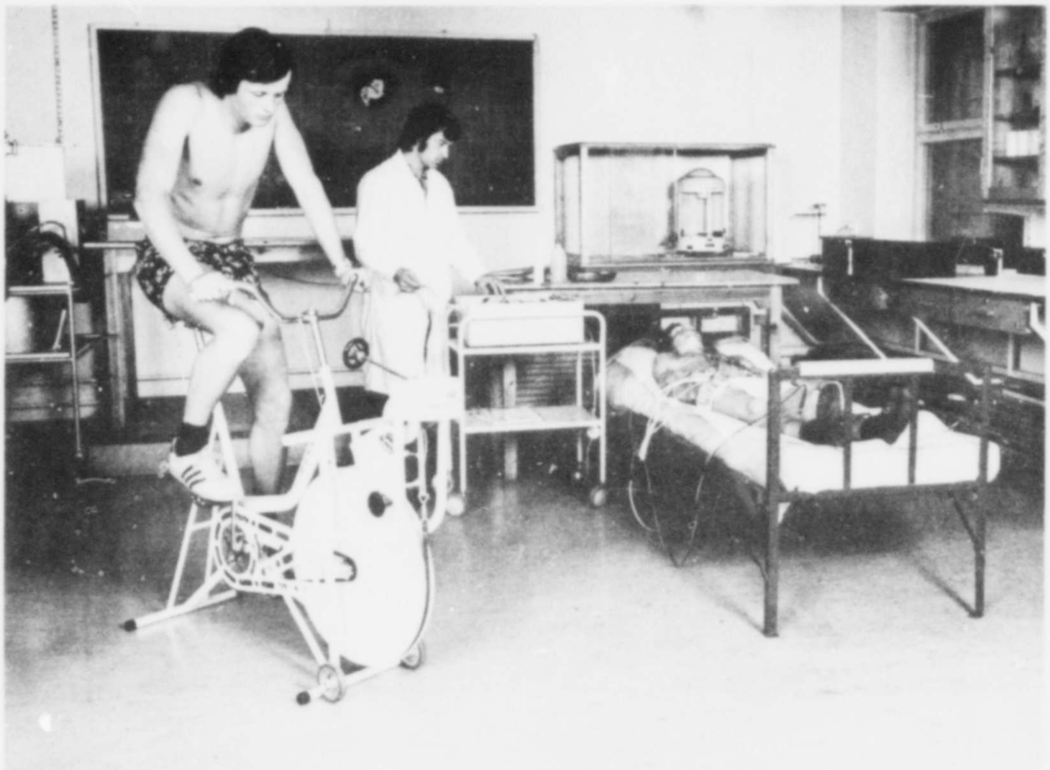

Fig.7.1 Recording of 12-lead ECG

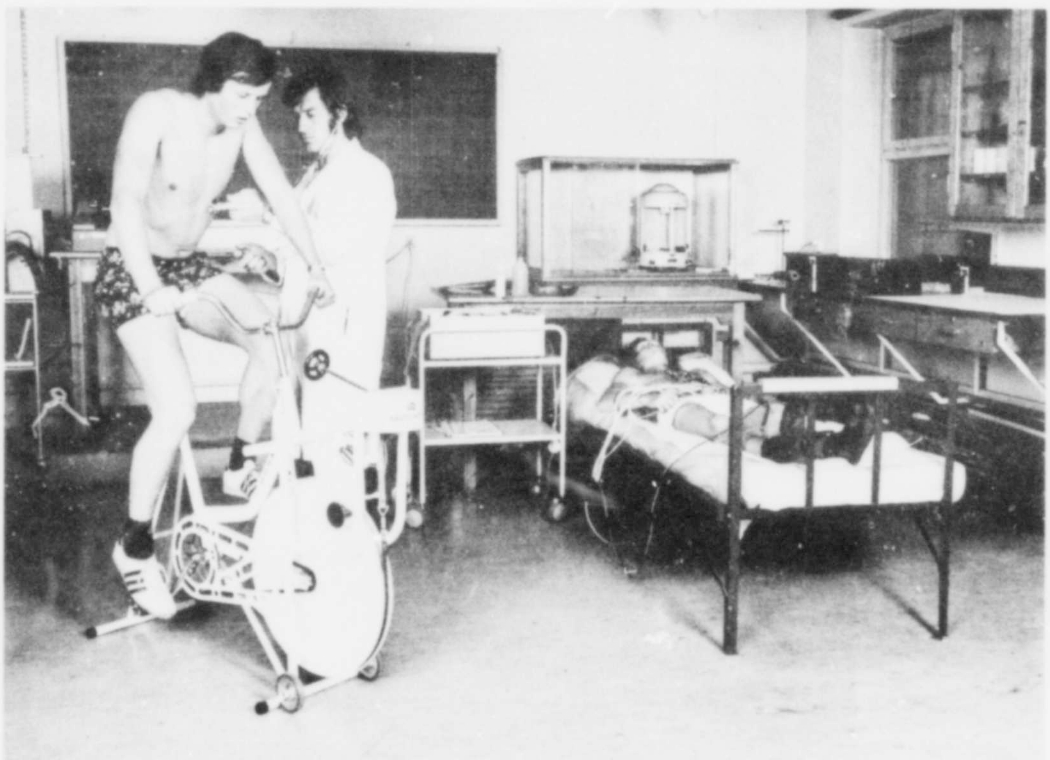

Fig.7.2 Muscular exercise test

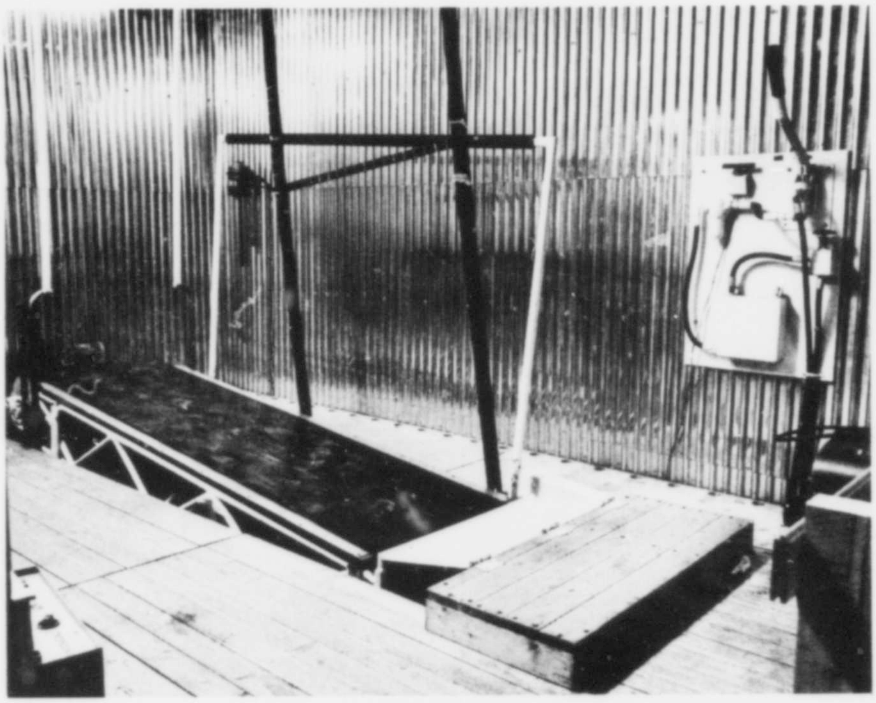

Fig.7.3 Treadmill and controls panel

Fig.7.4 Spirometric evaluation by means of the "Vitalograph"

CHAPTER 8

CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS FOR THE MEDICAL SELECTION AND CONTROL OF PORTUGUESE AIR FORCE AIRCREWS

by

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A. GENERAL INFORMATION

Since the Air Force Medical Service (DSS) was founded in 1956, the existence of a medical department supporting the DSS has become necessary, having medical selection functions and periodic control over all the flying personnel. This department received the name of Medical-Psychological Centre (CMP) and was installed, temporarily within the DSS facilities.

Although it met with some difficulties to begin with, the CMP has always performed its functions, even with the revision examinations number increasing year after year. However some problems demanding an imperious solution, such as the shortage of facilities and the need for specialized personnel have become evident.

The increase in work can be seen from the revision examination graphics. From 1957 to 1960 about 400 examinations per year were performed; from 1961 to 63 almost 500 per year; in 1964 — 800; in 1965/66 — 1000 per year; 1967 — 1200; 1968 — 1400; 1969 — 1600 and 1970 — 1500.

The reason was the enlargement of the Air Force boards, creating an increasing need for recruiting flying personnel and at the same time calling for greater vigilance over the other personnel, owing to the personnel psycho-physiological situation in combat areas, as well as the tropical conditions in the regions to which they are detached.

In the beginning of 1971, the CMP was transferred to new facilities. In that year, 2100 examinations were performed and the year after, 2350.

With the new CMP facilities permitting the use of highly specialized equipment, we think that the methods used in aeromedical studies — namely in the respiratory and cardiovascular field — will soon be comparable to most similar European centres. Considering the service needs and the Portuguese Air Force aircraft types, particular attention is being given to the psychological factor during the selection of flying personnel.

B. METHODS

Nowadays, the examinations performed at the CMP, for the purpose of aircrew medical selection and control, as regards the respiratory and cardiac functions are the following:

(a) *Respiratory function examination*

(1) *Clinical* — with the man seated and standing in perfect thoracic symmetry, the spinal column straight and the upper limbs in the same position, the thorax examination is carried out to find any uni or bilateral thoracic strains, and the routine measurements are made (anteroposterior diameter, thoracic perimeters at the nipple level during the maximum expiration and inspiration). Afterwards, the palpation, percussion and auscultation of the pleuro-pulmonary fields are carried out, and all impairments are noted.

(2) *Radiological examination* — always made in every admittance and revision, the patient standing erect in front and inspiring. A careful study of the pulmonary areas and the mediastinum lymph nodes is carried out and, when necessary, also oblique and in profile radiographs are performed. The thoracic radioscopy is not normally made unless to clear up some little detail about respiratory kinetic or other things, such as the diaphragm or chest wall movements. Special studies of tomography bronchography or bronchoscopy are performed only upon specific medical appointment, the same happening with the exfoliative cytology of the bronchial tree.

(3) *Dynamic respiratory function examination* — for some time the vital capacity estimation and the Tiffeneau test were carried out, but nowadays the respiratory function examination is not made for the aforesaid reasons.

(4) *Expectoration examination* — Normally not performed. Fresh microscopic examinations, bacteriological and parasitological, are requested only in very special cases.

(b) *Cardiac function examination*

(1) *Clinical* — routine semiological examinations are performed on subject standing and recumbent before and immediately after a little effort. The alterations observed on the heart murmurs and sound due to the position changes and respiratory movements, are reported, and the existing sounds are localized and their characteristics noted.

(2) *Blood pressure and pulse measurements* — Examinations performed with the man seated and preferably using the auscultatory method.

(3) *Electrocardiogram* – In the three classic leads and in case of doubt, with complementary derivations, exercise and anoxemia tests, etc. If necessary other examinations can be made (vectorcardiography, ballistocardiography, phonocardiogram, venous pressure or circulatory speed). At present we have no equipment to study blood gases.

(4) *Neuro-circulatory test* – Schneider index estimation.

It can be observed that the methods used in the cardiovascular and respiratory study are predominantly of a clinical character. As was explained in A, it has not yet been possible to standardize a set of functional tests, though we expect to do so very soon. Naturally it is considered that there is an imperative need for these tests although in the Portuguese Air Force no accident or incident due to cardio-circulatory or respiratory failure of the flying personnel has been reported. The low inaptitude rate due to the same reasons, observed in the pilots subject to revisions, must also be noted.

CHAPTER 9

CARDIOVASCULAR AND RESPIRATORY EXAMINATIONS FOR MEDICAL SELECTION AND CONTROL OF RAF AIRCREWS

The Editor thanks Group Capt. E.J.McGuire, RAF, Ministry of Defence, D.D. Av. Med., who kindly obtained for him a copy, updated to 1973, of the Royal Air Force Manual AP 1269A "Assessment of Medical Fitness", from which the following pages are taken.

CARDIOVASCULAR SYSTEM

History

0701. Careful enquiry should be made into the past history of the candidate with regard to certain symptoms, the most important of which are:

(a) Pain and breathlessness.
(b) Palpitation.
(c) Fainting attacks or giddiness.
(d) Previous heart trouble ("weak" or "strained" heart).
(e) Rheumatic fever, chorea, or "growing pains".

0702. *Pain and Breathlessness*. Pain associated with the heart is usually substernal in position. The examiner should enquire whether symptoms of discomfort or pain are associated with exertion, and whether breathlessness occurs when walking or hurrying on the level, or ascending inclines or stairs. It should be remembered that breathlessness may be mistaken for emotional hyperventilation attacks.

0703. *Palpitation*. A history of palpitation, starting and ceasing abruptly, and not related to muscular exertion or precipitated by emotional stress, is suggestive of paroxysmal tachycardia or other arrhythmia. The examiner should enquire about associated symptoms of distress or a feeling of faintness.

0704. *Fainting Attacks or Giddiness*. If there is a history of fainting attacks or giddiness, the examiner should enquire about associated phenomena, such as the length of time since the last meal. Certain adolescents may experience sensations of faintness, giddiness or dizziness when standing up suddenly after a period of prolonged sitting or laying. Such symptoms are caused by transient circulatory instability.

0705. *Previous Heart Trouble ("Weak" or "Strained" Heart)*. A history of long periods of inactivity imposed because of supposed weak or strained heart is now less frequent that it used to be but, if such a history is given, the examiner should enquire in detail about the symptoms experienced at the time, whether rest was given at home or in hospital, how long enforced rest was necessary, and what period was spent away from school or associated with restricted activities at the school. Sometimes the diagnosis of weak or strained heart may have been made as a result of tachycardia, ectopic beats, or both, occurring during a period of rapid growth about the time of puberty.

0706. *Rheumatic Fever, Chorea, or "Growing Pains"*. The process of growth does not cause pain and thus a history of joint pains in childhood could be the effects of acute rheumatism. It is worth remembering that 50% of patients who have developed carditis from acute rheumatism have no history of rheumatic infection. A definite description of chorea is, of course, of considerable significance in this respect.

Examination of Pulse and Blood Pressure

0707. *Pulse*. The quality and amplitude of the pulse, and the condition of the arterial wall are estimated by palpating the right brachial artery with the thumb of the right hand. The pulsations of the brachial and femoral arteries should always be compared and any differences recorded. Irregularity of the pulse is usually caused by sinus arryhythmia or ectopic beats which disappear on exercise. In all cases of doubt an electrocardiograph record is essential (see para 0712).

0708. *Pulse Response Test*. The pulse response test consists of three parts:

(a) The Sitting Pulse. This is measured by counting the number of beats in 15-second periods until a minimum constant rate has been obtained; this is then multiplied by four and the result recorded in beats per minute.

(b) Pulse Response to Change of Posture. The individual is instructed to stand up slowly and the stop watch is started simultaneously. The number of beats from the 6th–10th second is noted, multiplied by twelve and recorded as the standing pulse in beats per minute.

(c) Pulse Response to Exercise (Exercise Tolerance Test).
   (1) An exercise tolerance test rarely provides information that cannot be obtained during the general medical examination and is of no value in the detection of heart disease. It is useful in special cases, usually to confirm the results of other parts of the examination.
   (2) The test is carried out as follows:
      (a) The pulse is taken for 15 seconds with the candidate standing. The number of beats is multiplied by four and the result recorded as the pulse rate per minute.
      (b) The candidate then places one foot on a chair at least 15 inches in height, and raises himself until both feet are on the chair and he is standing upright on the chair. He then lowers first one foot then the other to the floor. He repeats this sequence 20 times in 60 seconds.
      (c) The pulse rate is then taken for 15 seconds, multiplied by four and recorded as the pulse rate per minute after exercise.

CHAPTER 9

CARDIOVASCULAR AND RESPIRATORY EXAMINATIONS FOR MEDICAL SELECTION AND CONTROL OF RAF AIRCREWS

The Editor thanks Group Capt. E.J.McGuire, RAF, Ministry of Defence, D.D. Av. Med., who kindly obtained for him a copy, updated to 1973, of the Royal Air Force Manual AP 1269A "Assessment of Medical Fitness", from which the following pages are taken.

(d) He stands still and 45 seconds later, i.e., one minute after the completion of the exercise, the pulse is again taken for 15 seconds. The number of beats is multiplied by four and the result recorded as the pulse rate per minute. Any dyspnoea or distress is noted and recorded.

0709. *Estimation of Blood Pressure.* There are certain points to be observed in the technique for taking blood pressure readings. Examiners are advised to adopt the following methods which were recommended by a committee appointed by the Cardiac Society of Great Britain, in their "Report on the Method of Measuring Arterial Blood Pressure":

(a) Position of the Individual. The subject should be allowed time to recover from any recent exercise or excitement. He must be comfortable and may be either lying or sitting. The arm, relaxed and comfortably supported at the side, must be laid bare to the shoulder to avoid any constriction by a rolled-up sleeve and to facilitate proper application of the armlet.

(b) Application of the Cuff. The cuff, completely deflated, should be applied with the middle of the rubber bag over the inner side of the arm, and its lower edge one inch above the joint of the elbow. It should fit closely and evenly round the arm to avoid bulging at the sides when it is inflated. In fat subjects special care is necessary to prevent bulging.

(c) Determination of the Systolic Pressure by Palpation. A preliminary approximate reading of the systolic pressure should be taken as a check on auscultation. The unusual instance of a case with a silent gap will not then be missed. In such a case after the first sounds have been heard, there is an auscultatory gap below which the sounds reappear. The pressure in the armlet should be raised quickly in steps of 10 mm Hg until the radial pulse ceases to be felt, and then allowed to fall rapidly.

(d) The Application of the Stethoscope. The brachial artery should be located by palpation, and the stethoscope applied lightly over it, just below but not in contact with the cuff. The hand may be pronated or upinated according to the position yielding the stronger brachial pulse.

(e) Determination of the Systolic Pressure by Auscultation. After inflating the cuff quickly to a pressure about 30 mm Hg above the level of the systolic pressure as found by palpation, auscultation should be conducted during slow deflation. The systolic pressure is the highest level at which successive sounds are heard.

(f) Determination of the Diastolic Pressure. With the pressure continuing to fall slowly and uniformly the sound increases to a maximum intensity and then decreases, at first gradually and later suddenly, and soon disappears. The point where the loud clear sounds change abruptly to the dull and muffled sounds should be taken as the diastolic pressure.

(g) Recording Blood Pressure Readings.
   (1) To obtain uniformity of results recorded by different observers at different times, the conditions under which the blood pressure is taken should be noted, and the following information recorded:
      (a) Position — lying or sitting.
      (b) Pulse rate at the time of reading. This is most important.
      (c) The arm used.
   (2) The results should be recorded as follows:

      BP: 124/74 (Lying, P.68, right and left arms).

0710. Physical activity or apprehension just before the examination may produce abnormally high figures. To minimize these effects, the candidate should be allowed to rest for 10 to 15 minutes before his blood pressure reading is taken. At least three readings should be taken, and the lowest recorded. The cuff should not be kept inflated longer than is necessary to take the readings and must be deflated between readings.

Examination of Heart

0711. *Heart.* Before examining the heart itself it is important to inspect the fingers, neck, thoracic cage and upper abdomen for the presence of finger clubbing, excessive pulsation, scoliosis, kyphosis, chest flattening or sternal depression. Evidence of any of these must be recorded in conjunction with the general examination.

(a) Size of Heart. The heart is first examined with the candidate standing, the stethoscope being placed in turn on the second interspaces to the right and left of the sternum (aortic and pulmonary areas), along the left border of the sternum to the level of the fifth rib (tricuspid area), and over the cardiac apex (mitral area). The position of the apex beat, and incidentally the presence of any thrill, are found by the examiner placing his hand over the left fifth intercostal space in the nipple line; the middle finger should be then moved about until the maximal thrust is felt. This point is measured from the mid-sternum and recorded in relation to the intercostal space, e.g. "3 inches, 4th left interspace". When the size of the heart is in doubt, a radiograph should be taken.

(b) Sounds. The heart should always be auscultated with the candidate first in the standing position and then lying in the left lateral position. Unless the sounds are perfectly normal, further auscultation should be carried out after exercise, such as touching the toes with the fingers ten times in rapid succession from the erect position with the arms extended above the head. The effect on duplication of either sound should be noted. The terms "blurred", "muffled", or "impure" should not be applied to the first and second sounds, which should be described as normal, shorter or longer than normal, or softer or louder than normal.

(c) Murmurs. If a murmur is present the time of its occurrence in the cardiac cycle, the position of its maximum intensity and the direction of radiation should be noted. A record should be made of any alteration in a murmur caused by exercise, change of posture, or respiration.

0712. *Electrocardiography*. A resting ECG is to be recorded for all candidates for aircrew, air traffic control and gliding duties, including pre-selection candidates. An ECG may also be recorded for other personnel when there is doubt about the cause of an irregular or very slow pulse. Thirteen leads are to be recorded at rest:

(a) Three standard leads – 1, 2 and 3.

(b) Lead 3 after deep inspiration.

(c) Three augmented leads – a VR, a VL and a VF, and

(d) Six precordial leads – V1 to V6 inclusive.

Assessment

0713. *History*. An assessment should not normally be made on the history alone but only in conjunction with the general examination. However, if a candidate has a history of acute rheumatic fever in the absence of carditis or other sequelae, he can be accepted for ground or flying duties if any of the following circumstances apply:

(a) He is over the age of 25 years.

(b) He is under the age of 25 years but:
(1) He has had 5 years of continuous penicillin prophylaxis;
or
(2) It is 10 years since the attack, no treatment having been given.

0714. *Pulse*

(a) Sitting Pulse. Rates of 48 per minute and below are occasionally recorded in very athletic persons. Rates of over 84 per minute are probably caused by emotional stress but an organic cause must be excluded. Tachycardia of nervous origin which persists does not warrant higher than P3. Emotional tachycardia usually slows down during the examination, and the general physique and the response to tests for physical efficiency are satisfactory. It is never advisable to accept as fit for flying duties a candidate with a sitting pulse which is persistently over 100, and it is rarely advisable to accept one with a pulse rate persistently over 90. If tachycardia is found, the candidate should be re-examined after a reasonable time has been allowed for the pulse rate to settle. If the pulse rate fails to settle, the temperature should be taken. A candidate who appears to meet the standard except for persistent tachycardia should be assessed as temporarily unfit and re-examined after an appropriate interval. Well marked slowing of the heart rate during forced expiration suggests that any tachycardia is emotional in origin.

(b) Standing Pulse. The standing pulse should not exceed the sitting rate by more than 24 beats per minute.

(c) Exercise Tolerance Test. The pulse rate after exercise should not exceed the sitting pulse rate by more that 36 beats per minute. A greater rise than this may be found in emotional individuals who produce a circulation rate unduly high for the exercise performed, or may be due to some type of cardiovascular inefficiency such as defective output per beat, poor vasometer tone, or defective central control of the cardiovascular system as a whole. One minute after the completion of the exercise the pulse rate should have returned approximately to the normal level.

0715. *Blood Pressure*. Blood pressure readings should always be considered in relation to the other results of the cardiovascular examination and the general examination. The readings vary with the posture of the individual and may alter to some extent while he remains motionless. When the blood pressure estimations are done by the auscultatory method certain difficulties and fallacies, some of which are discussed in para 0709, must be borne in mind. The diastolic pressure is more stable than the systolic, but in at least ten per cent of individuals it is impossible to estimate it by the auscultatory method with any degree of accuracy. This is especially evident in individuals with low diastolic pressures in whom a correct reading would be most helpful. Caution is, therefore, necessary in assessing the results of blood pressure examinations, and exaggerated importance should not be given to small variations in systolic or diastolic levels. Of blood pressure in general it may be stated that increased cardiac output causes a rise in the systolic pressure and a smaller rise in the diastolic pressure, and that diminished output produces a greater fall in the systolic than in the diastolic pressure. Alterations in the peripheral resistance affect mainly the diastolic level, and increased resistance causes a rise, and decreased resistance a fall. The average blood pressure in RAF flying personnel is 125/77. These figures are unaffected by the height of an individual provided that the body-build is normal. An abnormal body-build is a factor affecting blood pressure, the underweight group tending to give lower readings and the overweight group higher readings than the average. Age between 18 years and 40 years has little effect on blood pressure; over 40 years the increasing frequency of arterial disease causes a gradual but steady rise in the average pressure as age increases. In the healthy individual that rise is slight or absent.

(a) Systolic Pressure
  (1) Increase. The emotional factor is of great importance, especially at the first examination. It affects mainly the systolic pressure, and readings as high as 160 mm Hg are relatively common when a candidate is first seen. An increased pulse rate is often found in conjunction with this high systolic pressure, and is a further indication of cardiovascular instability and a nervous disposition. Such findings can often be ignored if there is no evidence of cardiovascular or renal disease, the diastolic level is between 70 mm Hg and 90 mm Hg, and the temperature is satisfactory. A candidate with a persistently high systolic pressure who gives a history of any condition suggestive of renal disease should be accepted only after investigation of the renal efficiency has been reported as within normal limits.
  (2) Decrease. Systolic pressures of 105 mm Hg, or even lower are sometimes found in healthy individuals. The combination of a low normal systolic pressure with a low diastolic level, and even minor degrees of cardiovascular inefficiency, usually implies that these individuals have an increased liability to syncopal attacks.

(b) Diastolic Pressure
  (1) Increase. A diastolic pressure over 90 mm Hg may be purely temporary, the result of some toxic or similar cause, or it may be permanent. In either case the condition nearly always requires special investigation. The importance of the findings varies to some extent with the age of the subject and with the period during which he is hoping to serve. When selecting candidates for short periods of service, too much stress should not be laid on this point alone if the remainder of the examination is satisfactory and investigation of renal function discloses no abnormality. The presence of a diastolic pressure over 100 mm Hg in serving flying personnel over the age of forty should be viewed with suspicion and investigation initiated. It is usually inadvisable to permit flying duties if the diastolic pressure is 110 mm Hg or over; however a consultant opinion will be required.
  (2) Decrease. A diastolic pressure below 70 mm Hg should be regarded in the same light as a low systolic level, calling for increased caution but not alone sufficient cause normally for an assessment of unfitness for flying duties. Persistently low diastolic pressures, e.g. below 60 mm Hg, are rarely found in normal individuals and, if associated with anything but the highest standards of physical and temperamental efficiency, should be regarded as a bar to employment on flying duties.

0716. *Pulse Pressure*. The pulse pressure is the difference between the systolic and the diastolic pressures, and is the rise in pressure produced by ventricular systole. It normally ranges between 30 mm and 50 mm Hg.

(a) Increase. Apart from organic disease, a high pulse pressure is often found in highly strung individuals. In these cases, a good working rule is that pulse pressures of 50 or over with a diastolic pressure of over 90 mm or under 60 mm Hg are unsatisfactory.

(b) Decrease. Low pulse pressures of 30 mm Hg or below suggest the presence of pathological causes and should be viewed with considerable suspicion. The condition occurs in impaired myocardial efficiency from any cause, and in some types of valvular disease of the heart.

0717. *Heart*. Organic defects of the heart indicate unsuitability for selection for flying training even if they are causing no symptoms. Duplication of the first sound may be heard in normal hearts and should not be confused with a true presystolic murmur. Congenital heart lesions are frequently asymptomatic and the existence of such a condition may first be suspected at a candidate's initial medical examination. Characteristically, an innocent cardiac murmur is usually but not invariably apical, midsystolic, soft, short and may disappear or become less loud on sitting up. If there is any doubt in the examiner's mind regarding any murmur, consultant opinion should be sought before acceptance. A diastolic murmur almost invariably means that an organic lesion is present.

0718. Congenital Heart Lesions Corrected by Surgery. Because of modern advances in cardiac surgery, candidates with certain congenital cardiac lesions which have been successfully corrected may be considered for acceptance for service, including aircrew training.

(a) Patent Ductus Arteriosus. A candidate who has had an uncomplicated patent ductus successfully and permanently closed, either by ligation alone or by ligation and division, can be accepted for service anywhere in the world and possibly for full flying duties.

(b) Atrial Septal Defect. The primum type is not acceptable, but if a secundum type of atrial septal defect has been closed and there is no pulmonary hypertension or cardiac enlargement present, it would be reasonable to accept the candidate for service anywhere in the world and also probably for flying duties. Subsequently, periodical examination of the individual would be necessary.

(c) Coarctation of the Aorta. This condition is more difficult to assess, but if a candidate has a coarctation of the aorta successfully repaired not less than five years previously, if he meets the service requirements for blood pressure, ECG and heart size, and if his femoral pulses are palpable and not delayed, he might be considered fit for acceptance.

RESPIRATORY SYSTEM

Assessment of Candidates for RAF Service

0801. *Pulmonary Tuberculosis.* A history of pulmonary tuberculosis in a candidate will probably be a bar to acceptance unless medical evidence is available that the disease has been quiescent and inactive for four years; such evidence should be obtained from the candidate medical practitioner and the case should then be referred to the Consultant Advisor in Chest Diseases at CME for opinion.

0802. *Bronchitis, Pneumonia or Pleurisy*

(a) Frequent attacks of bronchitis during childhood are often suggestive of infantile asthma and require careful assessment; a candidate should not be accepted for flying duties unless he has been free from all infections since puberty and clinical examination of the chest is entirely clear. A history of a single mild attack of bronchitis is not significant.

(b) Attacks of uncomplicated pneumonia can usually be ignored, especially if there has been a lapse of five years or more since the last attack and the candidate is free of all chest symptoms. Chest X-ray will reveal any sequelae of pneumonia not detected on physical examination and if present will require assessment in their own right.

(c) A history of pleurisy with an effusion is suspect of a primary tuberculous effusion and if this has occurred less than two years previously, will mean temporary rejection. A history of more than two years since the effusion will be acceptable for gound duties, providing the chest X-ray is normal. Effusions complicating pneumonia have no special significance providing resolution is complete.

(d) The history of an operation for empyema in the past does not in itself constitute a reason for downgrading, provided that the lungs are now healthy and pulmonary function within normal range.

0803. *Asthma or Hay Fever.* A history of asthma or hay fever in childhood renders a candidate unfit for aircrew duties, but probably fit for ground duties, providing the attacks have not occurred after puberty. Attacks of asthma continuing and/or occurring for the first time after puberty usually means rejection for all RAF service. Mild infrequent attacks of hay fever occurring after puberty, while unsuitable for aircrew selection, may be considered for ground duties.

0804. *Spontaneous Pneumothorax.* Candidates who give a history of a spontaneous pneumothorax should be referred to the Consultant Adviser in Chest Diseases for opinion, as acceptability for flying or ground duties depends on the type of treatment given, the number or such occurrences and the period of time elapsed since the last occurrence.

0805. *Clinical Examination.* A normal clinical examination of the lungs is to be made and recorded.

0806. *Radiographs of the Chest.* A radiographic examination of the chest must be carried out as a routine part of the medical examination of each candidate for aircrew duties and on entry to the RAF of ground personnel; thereafter radiographs of the chest should be carried out in accordance with AP 1269, para 1347. Chest radiographs are taken on miniature film when possible, but any abnormality suspected on the miniature film warrants a full size chest radiograph and the opinion of a radiologist or physician.

0807. *Opinion of the Consultant Adviser in Chest Diseases.* Definite evidence of disease of the lungs, mediastinum of pleurae indicates unsuitability for employment, certainly for flying duties and probably for ground duties, but the opinion of the Consultant Adviser in Chest Diseases should be obtained at CME in cases of doubt.

Assessment of Trained Serving Personnel

0808. *Introduction.* The following notes will be found to be useful in the assessment of trained or serving personnel who have developed respiratory disease.

0809. *Pulmonary Tuberculosis.* Serving personnel who have contracted pulmonary tuberculosis may be returned to duty when, in the opinion of the Consultant Adviser in Chest Diseases, the condition is considered to be quiescent and likely to remain so while on duty. Certain limitations of category will, however, be required; it is usual for such persons to be kept under regular supervision in a home service category for approximately 18 months followed by a UK and Western Europe category for a further 18 months, following which a world wide category can be expected. Aircrew personnel can expect a return to a limited flying category three months after discharge from hospital, with the prospect of a full flying category approximately two years after discharge from hospital, but with the same geographical limitations as stated above.

0810. If it is considered that these requirements cannot be met, then invaliding from the Service will probably be advised at an earlier date.

0811. *Asthma.* Serving personnel developing asthma will require to be assessed as to the controllability of the condition; those requiring continued medication with antihistamines, bronchodilators and/or steroid therapy are unlikely to continue flying duties. Ground personnel who develop asthma will need to be assessed in the light of frequency of attacks, controllability and suitability for a world wide category.

0812. *Bronchitis.* Recurrent attacks of bronchitis and/or pneumonia – providing they leave no permanent lung damage – are not an indication for downgrading, but once bronchitis develops into the chronic state, fitness for world wide service becomes unlikely.

0813. *Spontaneous Pneumothorax.* Trained aircrew personnel experiencing a spontaneous pneumothorax require pleurodesis before returning to flying duties. Ground personnel are advised pleurodesis only after a recurrence of a spontaneous pneumothorax. All such cases should be referred for treatment and advice to the RAF Chest Unit, Midhurst.

ASSESSMENT OF CANDIDATES FOR FLYING DUTIES

Introduction

1701. A candidate for flying duties is not to be assessed as physically efficient unless the examination as a whole suggests that he is capable of withstanding the severe stress entailed in flying for prolonged periods in peace or war, at high altitudes in all climates, and in all weathers.

1702. In assessing these qualities, there are two main considerations: the candidate should be physically fit for service in any part of the world, and he must possess those attributes which enable him to fly as a member of an aircrew and to fight in an air battle. The basic requirements of fitness are the same for all classes of aircrew, except for visual acuity and visual judgement.

Common Causes of Rejection for Flying

1703. Generally, the following disabilities indicate unsuitability for air work, necessitating rejection or calling for specialist opinion or cure before acceptance:

(a) Nervous Instability.
- (1) Nervous trouble or breakdown; "brain fever".
- (2) Severe headache, especially migraine.
- (3) Fits, epilepsy, even so-called "faints".
- (4) Sunstroke or heat-stroke.
- (5) Head injury or concussion (including "knock-out").
- (6) Insomnia, nightmares, sleep-walking, bed-wetting.
- (7) Habit spasms, tics.

(b) Respiratory Insufficiency.
- (1) "Lung trouble" or consumption.
- (2) Chronic affections such as recurrent bronchitis or "winter cough", asthma, hay fever.
- (3) Pleurisy, particularly with effusion.
- (4) Pneumonia and empyema.

(c) Circulatory Insufficiency.
- (1) A history of "heart disease" or prolonged rest or abstention from games due to a "weak" or "strained" heart.
- (2) Rheumatic fever, chorea, recurrent attacks of "rheumatism" or recurrent sore throats which may have caused a carditis. See para 0713 concerning a history of rheumatic fever.
- (3) Shortness of breath, palpitation, praecordial pain, exhaustion, faintness or giddiness associated with effort or with change of posture.

0221 *Decompression Training on Selection for High-Altitude Flying.* (From Chapter "Medical Inspections") On selection for high-altitude flying, all general duties personnel are required to undergo indoctrination in the use of oxygen systems in a decompression chamber. The unit MO is to inspect such personnel and certify on Form 624 that the individual is free from infection and is fit to undergo decompression. The form 624 is to be taken to the testing unit by the individual concerned.

CHAPTER 10

CURRENT CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS IN MEDICAL SELECTION AND CONTROLS OF AIRCREWS IN THE UNITED STATES ARMY

by

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A. GENERAL INFORMATION

If the individual is currently on active duty with the United States Army he has, de facto, successfully passed a physical examination for appointment, enlistment, or induction. Medical fitness standards for such a physical examination are enumerated in Chapter 2, AR 40-501. If, then, an individual desires to participate in flying duties with the United States Army, he must successfully pass a second physical examination which conforms to medical fitness standards for flying duty in the United States Army.

The Army recognizes three classes of standards for flying duty. Class 1 standards apply to individuals being considered for selection for aviator training. Class 2 standards apply for individuals being considered for training or duty as air traffic controllers, rated military pilots being considered for return to duty in a flying status, and for Army aviators undergoing annual medical examination. Class 3 standards apply to individuals ordered by competent authority to participate in regular and frequent aerial flights who are not engaged in the actual control of the aircraft. Chapter 4, AR 40-501, enumerates the medical fitness standards for each of these three classes, but in most instances does not specify the means of making the diagnoses listed.

Chapter 11, AR 40-501, entitled "Medical Examination Techniques", provides a guide for use in the medical evaluation. Appendix IX, AR 40-501, specifies the scope of the medical examination and the means of recording it upon General Services Administration Standard Form (SF) 88. All flying physical examinations are Type B (Reference AR 40-501, Chapter 10-16c(1)).

Chapter 11 and Appendix IX, AR 40-501, provide some guidance concerning the thoroughness of the physical examination, but provide only minimum standards.

To accomplish a Class 1 or initial Class 2 flying physical examination, the individual must complete a Report of Medical History, General Services Administration Standard Form 93. Items 8, 9 and 15–24 relate to cardiovascular and respiratory phenomena. The individual signs the Report of Medical History, certifying that the information is true and complete to the best of his knowledge. This Report of Medical History is reviewed by the physician examining the patient. Abnormalities are explored in detail and comment is made upon the same form by the examining physician and signed.

For subsequent medical examinations, an SF 93 is not required.

B. METHODS

Those portions of the physical examination which relate to the cardiovascular and respiratory systems are:

(a) Height and weight are measured and recorded.

(b) Body temperature is measured and recorded.

(c) The eyegrounds are examined ophthalmoscopically.

(d) AR 40-26, paragraph 7(3), specifies that personnel undergoing any routine physical examination will receive a tuberculin skin test unless one has been administered within the previous six months.

(e) Lungs and chest wall are examined physically. In Chapter 11, AR 40-501, the examiner is instructed to carry out a thorough systematic physical examination of the lungs and chest wall to include evaluation of peripheral findings which may reflect pulmonary disease, such as the presence of cyanosis or digital clubbing.

Specific mention is made about flying personnel on whom thoracic surgery has been performed. It is essential that both preoperative and postoperative pulmonary function studies be accomplished so that subsequent eligibility for return to flying duties may be more intelligently determined. In addition, after thoracic surgery, and in case of a history of spontaneous pneumothorax, flying personnel will be evaluated in a low pressure chamber, to include rapid decompression with a Flight Surgeon in attendance, prior to return to flying duties.

These standards specified in Chapter 4, AR 40-501, indicate that lobectomy is disqualifying for a Class 1 examination, but can be acceptable for Class 2 and Class 3 examinations provided that the one second vital capacity is 75% or greater and maximum breathing capacity is 80% or greater.

History of spontaneous pneumothorax is disqualifying for Class 1 physical standards. Class 2 and 3 standards specify that an individual may be found fit for Class 2 or 3 physical standards if the spontaneous pneumothorax is a single incidence, has not occurred within the preceding three months, and if clinical evaluation shows complete recovery with full expansion of the lungs, normal pulmonary function studies, no additional lung pathology, nor other contraindication to flying.

(f) The heart is examined by inspection, palpation, and percussion of the chest wall for signs of cardiac abnormalities. Chapter 11, AR 40-501, advises the examiner that careful auscultation of the heart using both the bell and diaphragm stethoscopes is necessary to accomplish a thorough auscultatory examination. As a minimum, the examiner must listen in the second right interspace, second left interspace, lower left sternal border and cardiac apex. The subject is to be examined in the supine position, while lying on the left side, and in a sitting position leaning slightly forward. In the latter position, auscultation should be performed at the end of a full expiration.

(g) The vascular system is examined. Chapter 11, AR 40-501, recommends that blood pressure be taken in the legs when simultaneous palpation of the pulses in upper and lower extremities reveals a discrepancy in pulse volume or amplitude.

(h) A routine twelve lead electrocardiogram is required for all flying physical examinations. AR 40-501 indicates that abnormal slowing of the pulse, fall in blood pressure, or alteration in cerebral circulation resulting in fainting or syncope because of digital pressure on either carotid sinus is a cause for medical unfitness for flying duty. This regulation also specifies that an unsatisfactory orthostatic tolerance test is a cause for unfitness for flying duty. In practice, digital massage of the carotid sinus, and the orthostatic tolerance test are conducted only if indicated by history or routine physical examination.

(i) A posteroanteior chest X-ray is used to assess cardiac size, pulmonary vascularity, and evidence of disease of the pulmonary parenchyma and chest wall. If evidence of disease is detected on this initial screening X-ray, additional views, lateral, oblique, apical Lordotic, and if necessary, X-ray with contrast medium in the esophagus are to be taken to establish a firm diagnosis and the extent of pathology.

(j) Some type of serological test for syphilis is required.

(k) Blood pressure is recorded three ways: With the subject seated, recumbent, and after three minutes standing. The arm is held at heart level. Chapter 11, AR 40-501, provides specific recommendations about the conduct of this study and recommends determination in accordance with the recommendations of the American Heart Association. For individuals below 35 years of age, a sitting blood pressure of 139/90 is the highest acceptable reading. For individuals 35 years of age and older, a blood pressure of 149/90 is the highest acceptable reading. Any abnormal reading should first of all be reviewed to determine if the reading is artificially high because of some peculiarity of the technique. If the elevation is found to be real, it must be rechecked twice daily, morning and afternoon for three consecutive days. Any systolic blood pressure below 90 mm Hg and any diastolic blood pressure below 60 mm Hg are considered disqualifying.

(l) Pulse is recorded
  (1) With the subject seated and at rest.
  (2) With the subject recumbent and at rest.
  (3) After standing for three minutes.
  (4) Immediately after exercise; the nature and severity of the exercise is unspecified.
  (5) Two minutes after exercise.

Any resting pulse rate between 50 and 99 beats per minute is considered to be within normal limits. If the pulse exceeds these limits, the sitting pulse is recorded twice a day, morning and afternoon for three days.

(m) Body build is recorded. For the purpose of US Army physical examinations, obesity is defined in Appendix I(8), AR 40-501, as the excessive accumulation of fat in the body manifested by poor muscle tone, flabbiness and folds, bulk out of proportion to body build, dyspnea and fatigue upon mild exertion, and frequently accompanied by flat feet and weakness of the legs and lower back. In Chapter 4, AR 40-501, the regulation specifies that though an individual's weight is within the maximum limits prescribed, he will be found medically unfit for any flying duty when the medical examiner considers that the excess weight in relation to the bony structure and musculature would adversely affect flying efficiency or endanger the individual's well being if permitted to continue in flying status.

(n) The history, physical examination, aptitude tests, and psychological tests are reviewed, and a determination is made regarding the adaptability of the individual for duty in military aviation. If the individual is not found to be satisfactory, a summary of the defects responsible for his failure is included on the SF 88.

(o) The final procedure in the medical examination of the initial applicant for flying training or aeronautical designation is the determination of the applicant's adaptability rating for military aeronautics (ARMA). This evaluation, conducted by a Flight Surgeon, aviation medical officer, or some other designated and qualified medical officer who is completely familiar with the requirements of military aviation, takes into consideration all the facts obtained by the medical, psychological, and psychiatric histories, and by the general physical, neurological, and special examinations. In addition, the examinee's zeal for flying and his maturity, stability, and drive in the face of the obvious hazard and hardships of military aviation are determined. The examiner is required to evaluate the individual's adaptability for a role in military aviation. A rating of satisfactory or unsatisfactory is required. In the case of an unsatisfactory ARMA the reason or reasons must be listed in space 73 on the Standard Form 88. The ARMA is an evaluation of the overall adaptability of an individual for military aeronautics and is not intended to predict success or failure in aviation training or subsequent military flying.

C. PHYSICAL STANDARDS

Heart and Vascular System (AR 40-501, Section XI)

Heart (2–18)

The causes for rejection for appointment, enlistment, and induction are:

(a) All organic valvular diseases of the heart, including those improved by surgical procedures.

(b) Coronary artery disease or myocardial infarction, old or recent or true angina pectoris, at any time.

(c) Electrocardiographic evidence of major arrhythmias such as:

(1) Atrial tachycardia, flutter, or fibrillation, ventricular tachycardia or fibrillation.

(2) Conduction defects such as first degree atrioventricular block and right bundle branch block. (These conditions occurring as isolated findings are not unfitting when cardiac evaluation reveals no cardiac disease.)

(3) Left bundle branch block, 2d and 3d degree AV block.

(4) Unequivocal electrocardiographic evidence of old or recent myocardial infarction; coronary insufficiency at rest or after stress; or evidence of heart muscle disease.

(d) Hypertrophy or dilatation of the heart as evidenced by clinical examination or roentgenographic examination and supported by electrocardiographic examination. Care should be taken to distinguish abnormal enlargement from increased diastolic filling as seen in the well conditioned subject with a sinus bradycardia. Cases of enlarged heart by X-ray not supported by electrocardiographic examination will be forwarded to The Surgeon General for evaluation.

(e) Myocardial insufficiency (congestive circulatory failure, cardiac decompensation) obvious or covert, regardless of cause.

(f) Paroxysmal tachyeardia within the preceding 5 years, or at any time if recurrent or disabling or if associated with electrocardiographic evidence of acclerated A–V conduction (Wolff-Parkinson-White).

(g) Pericarditis; endocarditis; or myocarditis, history or finding of, except for a history of a single acute idiopathic or coxsackie pericarditis with no residuals, or tuberculous pericarditis adequately treated with no residuals and inactive for 2 years.

(h) Tachycardia persistent with a resting pulse rate of 100 or more, regardless of cause.

Vascular System (2–19)

The causes for rejection for appointment, enlistment, and induction are:

(a) Congenital or acquired lesions of the aorta and major vessels, such as syphilitic aortitis, demonstrable atherosclerosis which interferes with circulation, congenital or acquired dilation of the aorta (especially if associated with other features of Marfan's syndrome), and pronounced dilatation of the main pulmonary artery.

(b) Hypertension evidenced by preponderant blood pressure readings of 150-mm or more systolic in an individual over 35 years of age or preponderant readings of 140-mm or more systolic in an individual 35 years of age or less. Preponderant diastolic pressure over 90-mm diastolic is cause for rejection at any age.

(c) Marked circulatory instability as indicated by orthostatic hypotension, persistent tachycardia, severe pheripheral vasomotor disturbances and sympatheticotonia.

(d) Peripheral vascular disease including Raynaud's phenomena, Buerger's disease (thromoboangiitis obliterans), erythromelalgia, arteriosclerotic and diabetic vascular disease. Special tests will be employed in doubtful cases.

(e) Thrombophlebitis

(1) History of thrombophlebitis with persistent thrombus or evidence of circulatory obstruction or deep venous incompetence in the involved veins.

(2) Recurrent thrombophlebitis.

(f) Varicose veins, if more than mild, or if associated with edema, skin ulceration, or residual scars from ulceration.

Miscellaneous (2–20)

The causes for rejection for appointment, enlistment, and induction are:

(a) Aneurysm of the heart or major vessel, congenital or acquired.

(b) History and evidence of a congenital abnormality which has been treated by surgery but with residual abnormalities or complications, for example: Patent ductus arteriousus with residual cardiac enlargement or pulmonary hypertension; resection of a coarctation of the aorta without a graft when there are other cardiac abnormalities or complications; closure of a secundum type artrial septal defect when there are residual abnormalities or complications.

(c) Major congenital abnormalities and defects by the heart and vessels unless satisfactorily corrected without residuals or complications. Uncomplicated dextrocardia and other minor asymptomatic anomalies are acceptable.

(d) Substantiated history of rheumatic fever or chorea within the previous 2 years, recurrent attacks of rheumatic fever or chorea at any time, or with evidence of residual cardiac damage.

Height, Weight, and Body Build (Section XII)

Height (2–21)

The causes for rejection for appointment, enlistment, and induction are:

(a) For appointment

(1) Men. Regular Army Height below 66 inches or over 80 inches. Other Height below 60 inches or over 80 inches.

(2) Women. Height below 58 inches or over 72 inches.

(b) For enlistments and induction

(1) Men. Height below 60 inches or over 80 inches for Army and Air Force.

(2) Men. Height below 60 inches and over 78 inches for Navy and Marine Corps.

(3) Women. Height below 58 inches or over 72 inches.

Height (2–22)

The causes for rejection for appointment, enlistment, and induction are:

(a) Weight related to height which is below the minimum shown in Table I, Appendix III for men and Table II, Appendix III for women.

(b) Weight related to age and height which is in excess of the maximum shown in Table I, Appendix III for men and Table II, Appendix III for women. See Chapter 7 for special requirements pertaining to maximum weight standards applicable to women enlisting for and commissioned from Army Student Nurse and Army Student Dietician Programs.

Body Build (2–23)

The causes for rejection for appointment, enlistment, and induction are:

(a) Congenital malformation on bones and joints.

(b) Deficient muscular development which would interfere with the completion of required training.

(c) Evidences of congenital asthenia (slender bones; weak thorax; visceroptosis; severe, chronic constipation; or "drop hear" if marked in degree).

(d) Obesity. Even though the individual's weight is within the maximum shown in Table I or II, as appropriate, Appendix III, he will be reported as medically unacceptable when the medical examiner considers that the individual's weight in relation to the bony structure and musculature, constitutes obesity of such a degree as to interfere with the satisfactory completion of prescribed training.

Lungs and Chest Wall (Section XIII)

General (2–24)

The following conditions are causes for rejection for appointment, enlistment and induction until further study indicates recovery without disqualifying sequelae:

(a) Abnormal elevation of the diaphragm on either side.

(b) Acute abscess of the lung.

(c) Acute bronchitis until the condition is cured.

(d) Acute fibrinous pleurisy, associated with acute nontuberculous pulmonary infection.

(e) Acute mycotic disease of the lung such as coccidioidomycosis and histoplasmosis.

(f) Acute nontuberculous pneumonia.

(g) Foreign body in trachea or bronchus.

(h) Foreign body of the chest wall causing symptoms.

(i) Lobectomy, history of, for a nontuberculous non-malignant lesion with residual pulmonary disease. Removal of more than one lobe is cause for rejection regardless of the absence of residuals.

(j) Other traumatic lesions of the chest or its contents.

(k) Pneumothorax or history thereof within 1 year of date of examination if due to simple trauma or surgery; within 3 years of date of examination if of spontaneous origin. Surgical correction is acceptable if no significant residual disease or deformity remains and pulmonary function tests are within normal limits.

(l) Recent fracture of ribs, sternum, clavicle, or scapula.

(m) Significant abnormal findings on physical examination of the chest.

Tuberculous Lesions (2-25)

The causes for rejection for appointment, enlistment, and induction are:

(a) Tuberculosis, active at any time within the past two years, in any form or location. A positive tuberculin skin test without other evidence of active disease is not disqualifying. Individuals taking prophylactic chemotherapy because of recent skin test conversion are not disqualified.

(b) Rescinded.

(c) Substantiated history of one or more reactivations or relapses of pulmonary tuberculosis, or other definite evidence or poor host resistance to the tubercle bacillus.

Nontuberculous Lesions (2-26)

The causes for rejection for appointment, enlistment, and induction are:

(a) Acute mastitis, chronic cystic mastitis, if more than mild.

(b) Bronchial asthma, except for childhood asthma with a trustworthy history of freedom from symptoms since 12th birthday.

(c) Bronchitis, chronic with evidence of pulmonary function disturbance.

(d) Bronchiectasis.

(e) Bronchopleural fistula.

(f) Bullous or generalized pulmonary emphysema.

(g) Chronic abscess of lung.

(h) Chronic fibrous pleuritis of sufficient extent to interfere with pulmonary function or obscure the lung field in the roentgenogram.

(i) Chronic mycotic diseases of the lung including coccidioidomycosis; residual cavitation or more than a few small sized inactive and stable residual modules demonstrated to be due to mycotic disease.

(j) Empyema, residual sacculation or unhealed sinuses of chest wall following operation for empyema.

(k) Extensive pulmonary fibrosis from any cause, producing dyspnea on exertion.

(l) Foreign body of the lung or mediastinum causing symptoms or active inflammatory reaction.

(m) Multiple cystic disease of the lung or solitary cyst which is large and incapacitating.

(n) New growth of breast; history of mastectomy.

(o) Osteomyelitis of rib, sternum, clavicle, scapula, or vertebra.

(p) Pleurisy with effusion of unknown origin within the previous 2 years.

(q) Sarcoidosis.

(r) Suppurative periostitis of rib, sternum, clavicle, scapula, or vertebra.

Mouth, Nose, Pharynx, Trachea, Esophagus, and Larynx (Section XIV)

Mouth (2-27)

The causes for rejection for appointment, enlistment, and induction are:

(a) Hard palate, perforation of.

(b) Harelip, unless satisfactorily repaired by surgery.

(c) Leukoplakia, if severe.

(d) Lips, unsightly mutilations of, from wounds, burns, or disease.

(e) Ranula, if extensive.

Nose (2-28)

The causes for rejection for appointment, enlistment, and induction are:

(a) Allergic manifestations
  (1) Chronic atrophic rhinitis.
  (2) Hay fever if severe; and if not controllable by antihistamines or by desensitization, or both.

(b) Choana, atresia, or stenosis of, if symptomatic.

(c) Nasal septum, perforation of:
  (1) Associated with the interference of function, ulceration or crusting, and when the result of organic disease.
  (2) If progressive.
  (3) If respiration is accompanied by a whistling sound.

(d) Sinusitis, acute.

(e) Sinusitis, chronic, when more than mild:
  (1) Evidenced by any of the following: Chronic purulent nasal discharge, large nasal polyps, hyperplastic changes of the nasal tissues, or symptoms requiring frequent medical attention.
  (2) Confirmed by transillumination or X-ray examination or both.

Pharynx, Trachea, Esophagus, and Larynx (2-29)

The causes for rejection for appointment, enlistment, and induction are:

(a) Esophagus, organic disease of, such as ulceration, varices, achalasia; peptic esophagitis; if confirmed by appropriate X-ray or esophagoscopic examinations.

(b) Laryngeal paralysis, sensory or motor, due to any cause.

(c) Larynx, organic disease of, such as neoplasm, polyps, granuloma, ulceration, and chronic laryngitis.

(d) Plica dysphonia ventricularis.

(e) Tracheostomy or tracheal fistula.

Other Defects and Diseases (2-30)

The causes for rejection for appointment, enlistment, and induction are:

(a) Aphonia.

(b) Deformities or conditions of the mouth, throat, pharynx, larynx, esophagus, and nose which interfere with mastication and swallowing of ordinary food, with speech, or with breathing.

(c) Destructive syphilitic disease of the mouth, nose, throat, larynx, or esophagus.

(d) Pharyngitis and nasopharyngitis, chronic, with positive history and objective evidence, if of such a degree as to result in excessive time lost in the military environment.

Heart and Vascular System (4–15) – uptodated 10 August, 1971

The causes for unfitness for flying duty Classes 1, 1A, 2 and 3 are the causes listed in paragraphs 2–18, 2–19 and 2–20, plus the following:

(a) Abnormal slowing of the pulse, fall in blood pressure, or alteration in cerebral circulation resulting in fainting or syncope because of digital pressure on either carotid sinus (abnormal carotid sinus reflex).

(b) A substantiated history of paroxysmal supraventricular arrhythmias such as paroxysmal atrial tachycardia, nodal tachycardia, atrial flutter, and atrial fibrillation.

(c) A history of rheumatic fever, or documented manifestation suggestive of rheumatic fever within the preceding 5 years.

(d) A history of paroxysmal ventricular tachycardia.

(e) Transverse diameter of heart 15 percent or more greater than predicted by appropriate tables.

(f) Blood pressure below 90 systolic or 60 diastolic.

(g) Unsatisfactory orthostatic tolerance test.

(h) Electrocardiographic
  (1) Borderline ECG findings until reveiwed by the Surgeon General.
  (2) Left bundle branch block.
  (3) Persistent premature contractions, except in rated personnel when unassociated with significant heart disease or recurrent tachycardia.
  (4) Right bundle branch block unless cardiac evaluation reveals the absence of cardiac disease and that the block is presumably congenital.
  (5) Short P–R interval and prolonged QRS time (Wolff-Parkinson-White syndrome-) or other short P–R interval syndromes predisposing to paroxysmal arrythmias. In cases involving Class II or Class III examinations, a complete cardiac evaluation including ECG's will be forwarded to the Surgeon General for review.

Height, Weight and Body Build

Height (4–16)

The causes of medical unfitness for flying duty Classes 1, 1A, 2 and 3 are:

(a) Classes 1, 1A and 2. Height below 64 inches or over 76 inches.

(b) Class 2, Air Traffic Control, male. Height below 60 inches or over 76 inches.

(c) Class 2, Air Traffic Control female. Height below 60 inches or over 72 inches.

(d) Class 3
  (1) Female. Height below 60 inches or over 72 inches.
  (2) Male. Height below 62 inches or over 76 inches.

Weight (4–17)

The causes of medical unfitness for flying duty Classes 1, 1A, 2 and 3 are:

(a) Weight for males which does not fall within the limits prescribed in Table III, Appendix III;

(b) Weight for females which does not fall within the limits prescribed in Table III, Appendix III except that maximum weight may not exceed 180 pounds.

Body Build (4–18)

The causes of medical unfitness for flying duty Classes 1, 1A, 2 and 3 are the causes listed in paragraph 2–23 plus the following:

Obesity. Even though the individual's weight is within the maximum shown in Table III, Appendix III, he will be found medically unfit for any flying duty (Classes 1, 1A, 2 and 3) when the medical examiner considers that the excess weight, in relationship to the bony structure and musculature, would adversely affect flying efficiency or endanger the individual's well being if permitted to continue in flying status.

Lungs and Chest Wall (4–19)

The causes of medical unfitness for flying duty Classes 1, 1A, 2 and 3 are the causes listed in paragraphs 2–24, 2–25, 2–26 and 4–27g plus the following:

(a) Lobectomy
  (1) Classes 1 and 1A – Lobectomy, per se.
  (2) Classes 2 and 3 – Lobectomy.
    (a) Within the preceding 6 months.
    (b) With a value of less than 80 per cent of the predicted vital capacity (app VI).
    (c) With a value of less than 75 per cent of exhaled predicted vital capacity in 1 second (app VI).
    (d) With a value of less than 80 per cent of the nredicted maximum breathing capacity (app VI).
    (e) With any other residual or complication of lobectomy which might endanger the individual's health and well being or compromise flying safety.

(b) Coccidioidomycosis unless healed without evidence of cavitation.

(c) Pneumothorax, spontaneous.
  (1) Classes 1 and 1A. A history of spontaneous pneumothorax.
  (2) Classes 2 and 3. Spontaneous pneumothorax except a single instance of spontaneous pneumothorax if clinical evaluation shows complete recovery with expansion of the lung, normal pulmonary function, no additional lung pathology or other contra-indication to flying is discovered and the incident of spontaneous pneumothorax has not occurred within the preceding 3 months.

(d) Pulmonary tuberculosis and tuberculous pleurisy with effusion.
  (1) Classes 1 and 1A. Individuals taking prophylactic chemotherapy.
  (2) Classes 2 and 3 – during period of drug therapy or with impaired pulmonary function greater than outlined in (a)(2) above.

(e) Tuberculous pleurisy with effusion.
  (1) Classes 1 and 1A. Tuberculous pleurisy with effusion, per se.
  (2) Classes 2 and 3. Tuberculous pleurisy with effusion until 12 months after cessation of therapy.

Mouth, Nose, Pharynx, Larynx, Trachea, Esophagus

Mouth (4–20)

The causes of medical unfitness for flying duty Classes 1, 1A, 2 and 3 are the causes listed in paragraph 2–27 plus the following:

(a) Any infectious lesion until recovery is complete and the part is functionally normal.

(b) Any congenital or acquired lesion which interferes with the function of the mouth or throat.

(c) Any defect in speech which would prevent clear enunciation over a radio communications system.

(d) Recurrent calculi of any salivary gland or duct.

Nose (4–21)

The causes of medical unfitness for flying duty Classes 1, 1A, 2 and 3 are the causes listed in paragraphs 2–28 and 4–27 plus the following:

(a) Acute coryza.

(b) Allergic rhinitis
  (1) Classes 1 and 1A. Any substantial history of allergic or vasomotor rhinitis, unless free of all symptoms since age 12.
  (2) Classes 2 and 3. Allergic rhinitis unless mild in degree and considered unlikely to limit the examinee's flying activities.

(c) Anosmia, parosmia and paresthesia.

(d) Atrophic rhinitis.

(e) Deviation of nasal septum or septal spurs which result in 50 per cent or more obstruction of either airway, or which interfere with drainage of the sinus on either side.

(f) Hypertrophic rhinitis (unless mild and functionally asymptomatic).

(g) Nasal polyps.

(h) Perforation of the nasal septum unless small, asymptomatic, and the result of trauma.

(i) Sinusitis
  (1) Classes 1 and 1A. Sinusitis of any degree, acute or chronic. If there is only X-ray evidence of chronic sinusitis and the history reveals the examinee to have been asymptomatic for 5 years, this X-ray finding alone will not be considered as rending the individual medically unfit.
  (2) Classes 2 and 3. Acute sinusitis of any degree.

Pharynx, Larynx, Trachea, Esophagus (4–22)

The causes of medical unfitness for flying duty Classes 1, 1A, 2 and 3 are the causes listed in paragraph 2–29 plus the following:

(a) Any lesion of the nasopharynx causing nasal obstruction.

(b) A history of recurrent hoarseness.

(c) A history of recurrent aphonia or a single attack if the cause was such as to make subsequent attacks probable.

D. EXAMINATION TECHNIQUES

Section VII **Chest and Lungs** (11–9)

(a) A thorough examination will include a complete history, careful physical examination, and necessary X-ray and laboratory studies. In screening examinations the history and X-ray studies are the most immediately revealing examination techniques.

(b) It must be remembered that several disqualifying diseases such as tuberculosis and sarcoidosis may not be detectable by medical examination and the absence of abnormal physical signs does not rule out disqualifying pulmonary disease. Such diseases as well as others (neoplasms and fungus infections) may be detected only by chest roentgenogram.

(1) Medical examination should be carried out in a thorough systematic fashion as described in any standard textbook on physical diagnosis. Particular care should be taken to detect pectus abnormalities, scoliosis, wheezing, persistent rhonchi, basilar rales, digital clubbing, and cyanosis since any of these findings require additional intensive inquiry into the patient's history if subtle functional abnormalities or mild asthma, bronchitis, or bronchiectasis are to be suspected and evaluated.

(2) There should be no hesistancy in expanding the history if abnormalities are detected during medical examination or in repeating the medical examination if chest-film abnormalities are detected.

(c) The standard PA chest film must be included in any complete medical examination and is sufficient in most instances provided it is interpreted carefully. Particular attention must be given to the hila and the areas above the 2d anterior ribs since these areas may be abnormal in the presence of normal spirometry. For flying personnel on whom thoracic surgery is performed it is essential that both preoperative and postoperative pulmonary function studies be accomplished so that subsequent eligibility for return to flying duties may be more intelligently determined. In addition, flying personnel will be evaluated in a low pressure chamber (to include rapid decompression), with a flight surgeon in attendance, prior to return to flying duties after thoracotomy, and in cases of a history of spontaneous pneumothorax.

(d) Of the several conditions that are disqualifying for initial induction there are three which are most often inadequately evaluated and which result in unnecessary and avoidable expense and time loss following induction. These three are asthma (to include "asthmatic bronchitis"), bronchiectasis, and tuberculosis. Specific comment in amplification of previous paragraphs follows:

(1) Asthma. In evaluation of asthma, a careful history is of prime importance since this condition is characteristically intermittent and may be absent at the time of examination. Careful attention to a history of episodic wheezing with or without accompanying respiratory infection is essential. If documentation of asthma after age 12 is obtained from the evaluee's physician this should result in rejection even though physical examination is normal. Ventilatory studies should be done but normal results may be obtained during remissions.

(2) Bronchiectasis. Individuals who report a history of frequent respiratory infections (colds) accompanied by purulent sputum or multiple episodes of pneumonia should be suspected of bronchiectasis. This diagnosis can be further supported or suspected by a finding of posttussive rales at one or both bases posteriorly or by a finding of lacy densities at the lung base on the chest film. If bronchiectasis is considered on the basis of history, medical findings or chest film abnormalities, confirmatory opinions should be sought from the examinee's personal physician or the examinee should be referred to the appropriate chest consultant for evaluation and recommendations.

(3) Tuberculosis. Active tuberculosis is often asymptomatic and often not accompanied by abnormal physical findings unless the disease is advanced. If only such manifestations as hemoptysis or draining sinuses, are looked for, most cases of tuberculosis will be missed. The most sensitive tool for detection of early pulmonary tuberculosis is the chest film. Any infiltrate, cavity, or nodular lesion involving the apical or posterior segments of an upper lobe or superior segment of a lower lobe should be suspected strongly of being tuberculosis. It is thus imperative that all routine chest films be completely scrutinized by an experienced radiologist. Many tuberculous lesions may be partially hidden or obscured by the clavicles. When any suspicion of an apical abnormality exists an apical-lordotic view must be obtained for clarification. It is neigher practical nor possible in most instances

to determine whether or not a tuberculous lesion is inactive on the basis of single radiologic examintion. For all these reasons, any patient suspected of tuberculosis should be referred to a qualified chest consultant or to an appropriate public health clinic for evaluation. It is not feasible to carry out diagnostic skin tests and sputum studies in a medical examination station.

Section VIII **Cardiovascular** (11-10)

(a) Blood pressure. Blood pressure will be determined with the individual relaxed and in a sitting position with the arm at heart level. Current experience is that "low blood pressure" has been very much overrated in the past and, short of symptomatic postural hypotension, a normal individual may have a systolic blood pressure as low as 85–90 mm. Concern with blood pressure, thus, is to detect significant hypertension. It is mandatory that personnel entrusted to record blood pressure on examinees be familiar with situations that result in spurious elevation. It is only reasonable that a physician repeat the determination in doubtful or abnormal cases and insure that the proper recording technique was used. Artificially high blood pressure may be observed:

(1) If the compressive cuff is loosely applied.

(2) If the compressive cuff is too small for the arm size. (Cuff width should be approximately one-half arm circumference. In a very large or very heavily muscled individual this may require an "oversize cuff.)

(3) If the blood pressure is repetitively taken before complete cuff deflation occurs (trapping of venous blood in the extremity results in a progressive increase in recorded blood pressure).

(4) Prolonged bed rest will not precede the blood pressure recording; however, due regard must be given to physiologic effects such as excitement and recent exercise. Limits of normal for various age groups and applicants are defined in appropriate sections of AR 40-501. No examinee will be rejected as the result of a single recording. When found, disqualifying blood pressures will be rechecked for 3 consecutive days in the morning and afternoon of each day and carefully recorded. While emphasizing that a diagnosis of elevated blood pressure not be prematurely made, it seems evident that a single "near normal" level does not negate the significance of many elevated recordings.

(5) Blood pressure determination will be made in accordance with the recommendation of the American Heart Association. The systolic reading will be taken as either the palpatory or auscultatory reading depending on which is the higher. (In most normal subjects the auscultatory reading is slightly higher.) (Diastolic pressure will be recorded as the level at which the cardiac tones disappear by auscultation.) In a few normal subjects, particularly in thin individuals and usually because of excessive stethoscope pressure, cardiac tones may be heard to extremely low levels. If the technique can be ascertained to be correct and there is no underlying valvular defect, a diastolic reading will be taken in these instances at the change in tone. Variations of blood pressures with the position change should be noted if there is a history of syncope or symptoms to suggest postural hypertension. Blood pressure in the legs should be obtained when simultaneous palpation of the pulses in upper and lower extremities reveal a discrepancy in pulse volume or amplitude.

(b) Cardiac auscultation. Careful ausculation of the heart is essential so that significant cardiac murmur or abnormal heart sound will not be missed. Experience has shown that significant auscultatory findings may not be appreciated unless both the bell and diaphragm portions of the stethoscope are used in examination. As a minimum, attention should be directed to the second right interspace, second left interspace, lower left sternal border, and cardiac apex; Patients should be examined in the supine position, while lying on the left side, and in the sitting position leaning slightly forward. In the latter position auscultation should be performed at the end of a full expiration remaining attuned for a high-pitched diastolic murmur of aortic valve insufficiency.

(c) Cardiac murmurs. There are no absolute rules which will allow the physician to easily distinguish significant and innocent heart murmurs. For practical purposes, all systolic murmurs which occupy all or nearly all of systole are due to organic cardiac problems. Similarly, any diastolic murmur should be regarded as evidence of organic heart disease. Experience has taught that the diastolic murmur of aortic valve insufficiency and mitral valve stenosis are those most frequently missed. Innocent murmurs are frequently heard in perfectly normal individuals. In an otherwise normal heart a slight to moderate ejection type pulmonary systolic murmur is the most common of all murmurs. When accompanied by normal splitting and normal intensity of the components of the second heart sound, such a murmur should be considered innocent. A particularly pernicious trap for the attentive physician is the thin chested young individual in whom such a pulmonary ejection murmur is heard and who, in recumbancy, demonstrate persistent splitting of the second heart sound. Such a combination suggests the possibility of an atrial septal defect. In such a situation a change from persistent splitting to normal splitting of the second heart sound as the patient sits or stands for practical purposes denies the possibility of atrial communications. Awareness of this minor point will prevent an overdiagnosis of such lesions. Other innocent murmurs which are commonly misinterpreted as evidence of organic heart disease include extra cardiac cardiorespiratory noises, surface contact friction noises in the thin-chested individual, venous hums, and isolated supraclavicular arterial bruits of blood flow in the subclavian arteries. Final interpretation of a murmur must be based on cumulative evidence of history, examination, chest X-rays, and electrocardiogram. In doubtful cases additional opinions should be solicited by appropriate consultation request.

(d) Chest X-ray. In most cases a simple posterior anterior chest X-ray will suffice to adequately assess cardiac size and pulmonary vascularity. A misdiagnosis of cardiac enlargement is commonly encountered in the thin-chested individual whose heart, although normal, is limited in anterior-posterior extent and appears broad in lateral dimension. Thus, a final indictment of cardiac enlargement can not be made on the basis of a PA chest X-ray alone. In such cases, and in cases requiring additional consultation for unresolved areas of concern, X-ray views should be obtained in PA, lateral, and both right and left anterior oblique views with barium in the esophagus. Such X-rays allow a more critical evaluation and definitive interpretation. At times it may be necessary to assess cardiac size and the amplitude and vigor of cardiac pulsation by fluoroscopic examination.

Section IX **Electrocardiogram** (11–11)

(a) Electrocardiograms should be accomplished routinely on all the following individuals:

(1) Those in whom medical history or clinical findings are suggestive of cardiac abnormalities.

(2) Examinees with a sitting pulse rate of 50 per minute or less.

(3) Examinees who have reached their 40th birthday or are older.

(4) Applicants for flying training and all flying personnel.

(5) Applicants for service academies.

(6) Personnel who are being examined for retirements.

(b) In those individuals the electrocardiogram obtained serve not only to diagnose and screen for possible heart disease but as a base line for future comparison. It is imperative then that a proper technique of recording the electrocardiogram be followed.

(1) The routine ECG will consist of 12 leads, namely standard leads 1, 2, 3, a VR, a VL, a VF, and the standard precordial leads V_1 through V_6 recorded at 25 mm per second. All artifacts and machine problems must be eliminated.

(2) Care must be taken in the proper placement of the precordial electrodes. It is important that the precordial electrodes across the left precordium are not carried along the curve of the rib but maintained in a straight line. Special care must be taken in the placement of the first precordial lead so as to avoid beginning placement in the third interspace rather than the fourth. Electrode paste must not be smeared from one precordial position to another. A standardization mark should be included in each lead recorded.

TABLE OF WEIGHT

Table of Militarily Acceptable Weight (in pounds) as Related to Age and Height for Males – Initial Procurement

Height (inches)	*Minimum (regardless of age)*	*Maximum*					
		16–20 years	*21–24 years*	*25–30 years*	*31–35 years*	*36–40 years*	*41 years and over*
60	100	163	173	173	173	168	161
61	102	171	176	175	175	171	166
62	103	174	178	178	177	173	169
63	104	178	182	181	180	176	171
64	105	183	184	185	185	180	175
65	106	187	190	191	190	185	180
66	107	191	196	197	196	190	185
67	111	196	201	202	201	195	190
68	115	202	207	208	207	201	195
69	119	208	213	214	212	206	200
70	123	214	219	219	218	211	205
71	127	219	224	225	223	216	210
72	131	225	231	232	230	224	216
73	135	231	239	238	237	230	223
74	139	237	246	246	243	236	229
75	143	243	253	253	251	243	235
76	147	248	260	260	257	250	241
77	151	254	267	267	264	256	248
78	153	260	275	273	271	263	254
*79	159	266	281	279	277	269	260
*80	166	273	288	286	284	276	267

* Applies only to personnel enlisted, induced or appointed in Army and enlisted or induced into Air Force. Does not apply to Navy or Marine Corps.

Table of Acceptable Weight (in pounds) as Related to Age and Height for Army Aviation

Height (inches)	*Minimum (regardless of age)*	*Maximum*					
		16–20 years	*21–24 years*	*25–30 years*	*31–35 years*	*36–40 years*	*41 years and over*
60	100	137	143	116	148	151	152
61	102	142	148	151	153	155	156
62	103	147	153	156	158	160	161
63	104	151	157	160	162	164	165
64	105	156	162	165	167	169	170
65	106	169	166	169	171	173	174
66	107	165	171	173	175	177	178
67	111	169	175	178	180	182	183
68	115	173	179	182	184	186	187
69	119	177	183	185	187	189	190
70	123	180	186	189	191	193	194
71	127	184	190	193	195	197	198
72	131	187	193	196	198	200	201
73	135	190	196	199	201	203	204
74	139	193	199	202	201	206	207
75	143	196	202	205	207	209	210
76	147	198	204	207	209	211	212

PULMONARY FUNCTION PREDICTION FORMULAS – ARMY AVIATION

1. Predicted Vital Capacity (Baldwin)
   $27.63 - (0.112 \cdot \text{age}) \cdot \text{height in cm}$

2. Predicted Maximum Breathing Capacity (Motley)
   $\left(97 - \frac{\text{age}}{2}\right) \cdot \text{body surface area (in m}^2\text{)}$

THE AMERICAN HEART ASSOCIATION FUNCTIONAL CAPACITY AND THERAPEUTIC CLASSIFICATION

1. Function Capacity Classification
   Class I. Patients with cardiac disease, but without resulting limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitation, dyspnea or anginal pain.
   Class II. Patients with cardiac disease resulting in slight limitation of physical activity. They are comfortable at rest. Ordinary physical activity results in fatigue, palpitation, dyspnea or anginal pain.
   Class III. Patients with cardiac disease resulting in marked limitation of physical activity. They are comfortable at rest. Less than ordinary activity causes fatigue, palpitation, dyspnea or anginal pain.

2. Therapeutic Classification
   Class A. Patients with cardiac disease whose physical activity need not be restricted.
   Class B. Patients with cardiac disease whose ordinary physical activity need not be restricted, but who should be advised against severe or competitive physical efforts.
   Class C. Patients with cardiac disease whose ordinary physical activity should be moderately restricted, and whose more strenuous efforts should be discontinued.
   Class D. Patients with cardiac disease whose ordinary physical activity should be markedly restricted.
   Class E. Patients with cardiac disease who should be at complete rest, confined to bed or chair.

CHAPTER 11

CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS FOR MEDICAL SELECTION AND CONTROL OF USAF AIRCREW

by

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A. GENERAL INFORMATION

The methods used for cardiopulmonary evaluations are commonly used but not well standardized within US Air Force aeromedical services.

The following information regards methods utilized at the School of Aerospace Medicine, which serves as a referral center for aircrew members with difficult medical problems.

A large portion of the effort of SAM's Aeromedical Consultation Services is devoted to the early detection of heart disease in flying personnel. The basic foundation of this activity is a USAF requirement for a baseline electrocardiographic recording upon entry into flying training, at age 35 and annually, thereafter. Duplicate records of all these ECGs in flying personnel are forwarded to a Central ECG Library, established at USAFSAM in 1957, for review by a qualified cardiologist. Pertinent extracts from USAF publications concerning standard methods of record and mounting the ECG are collected in Part B. The standardization of the mounting procedure for the 12-lead electrocardiograms has proved to be of great advantage in the expeditious review of the tracings and in microfilming the records to reduce storage space. It is also advantageous to require that routine ECGs be recorded in the resting, fasting state. When serial changes in the ECG record are noted (or, less commonly, when a symptom of possible heart disease is reported), the next step in evaluation is usually the performance of a double Master's exercise test. In an attempt to achieve uniformity in the conduct of this test, the Central ECG Library mails a set of instructions to the base concerned. Our criteria for the interpretation of results are included. Aircrew members suspected of having heart disease are then referred to USAFSAM for further evaluation. For each patient, the resting tracing and double Master's is repeated. After review of these tracings by the attending cardiologist, the patient is allowed to perform a maximum exercise tolerance test on the treadmill. Other medical centers may use bicycle ergometers for this purpose, but we find the treadmill more satisfactory for our population. (Few American adults are experienced in bicycle riding, and give poorer performances than on the treadmill.)

Each of our subjects at USAFSAM also has a vectorcardiogram recorded using a modified Frank lead system which displays the P, QRS and T loops in the frontal, horizontal and sagittal planes. Our standardized method of mounting the vectorcardiogram is illustrated by the attachment. Polaroid photographs are taken in each plane with specific enlarged used to demonstrate the T and T-loops.

These are in essence the standard cardiovascular studies performed for patients referred on medical consultations service, i.e. fasting, resting, ECG, VCG and treadmill maximum exercise tolerance test. The use of the precordial map as a routine procedure has been discontinued. Phonocardiogram and apex cardiogram are available if indicated. It is hoped in the future to have a non-invasive method of estimating coronary blood flow utilizing an isotope such as potassium; however, it is unlikely that this would be utilized as a routine procedure. Patients manifesting abnormal electrocardiographic changes or other findings suspect of coronary artery disease may be offered elected coronary cineangiography via cardiac catheterization. The cardiac catheterization laboratory was established at USAFSAM in January 1971 and there are now new facilities. Although coming into greater use in many medical centers, this procedure is not a part of our routine evaluation. In perspective it should be pointed out that only the resting ECG is required in conjunction with periodic medical examinations at our Air Force bases and that only 1 2% of the flying population is evaluated at USAFSAM each year. We do encourage all medical facilities to establish a capability for performing the double Master's test.

With regard to pulmonary functions for the past two years these have been included as a part of the periodic examination USAF wide beginning at age 39. Equipment and techniques are not standardized but the values most frequently obtained are the vital capacity (for evidence of restrictive disease) and the forced expiratory volume in one second (for evidence of obstructive disease). The maximum voluntary ventilation is routinely added on patients evaluated at USAFSAM. The equipment we use for this purpose is described in Part B.5. If a broncho-spastic element is suspected these studies are performed before and after the use of a bronchodilator. A consideration which has not been defined precisely is the point at which pulmonary disease may become in itself a hazard to the safe performance of flying duty by the individual. Our approach to date has been to subject the patient to blood gas studies at simulated altitudes in a low pressure chamber; 12,000 feet is usually chosen for this purpose and the percent oxygen saturation determined. The choice of 12,000 feet was felt to represent a reasonable stress, enough above the theoretical maximum that would be routinely experienced to insure that if blood gases were acceptable at that altitude, there would be safety in day-to-day exposure.

B. METHODS

1. The Electrocardiograph Machine

(1) *Setting up the ECG Machine*

Plug in the ECG machine and allow 5 minutes for the machine to warm up before hooking up the patient.

Ground the machine to a suitable object (plumbing if possible). Poor grounding may cause 60 cycle or a wandering baseline.

With the lead selector set at Standard, adjust the standardization 10 mm – 1 mv (check while recording to make sure standardization stays at 1 mv).

(2) *Instruction to the Patient*

Have the patient report in the fasting state (if requested by the doctor) for his ECG studies.

Patient must disrobe from the waist up and turn up his trouser legs several times.

Patient must be in the recumbent position, (on his back), completely relaxed, and not touching anything (such as a bed post, wall, machine, etc.).

(3) *Attaching Limb Leads to the Patient*

Place one (1) electrode on each arm (about two inches above the wrist) and one (1) electrode on each leg (two inches above the ankle).

Apply paste evenly so as not to extend past the electrode. Electrode must be snug but not too tight.

Attach patient cable to patient as follows (making sure not to cross the cable leads).

Cable "LA" to the left arm electrode.
Cable "RA" to the right arm electrode.
Cable "LL" to the left leg electrode.
Cable "RL" to the right leg electrode.
Cable "C" to be used for chest electrodes.

(4) *Recording the Limb Lead Tracing*

- Turn on Insto. switch.
- Center the stylus on the paper.
- Turn on the paper drive.
- Mark the lead being run. (Refer to Lead Marking System)
- Standardize several times between complexes.
- Turn Insto. off.
- Turn paper drive off.

(5) *Attaching Precordial Electrodes*

(a) The six (6) chest (precordial) leads are positioned as follows:

V1 fourth interspace at right sternal border.
V2 fourth interspace at left sternal border.
V3 positioned between V2 and V4.
V4 fifth interspace at mid-clavicular line.
V5 fifth interspace at shoulder line.
V6 fifth interspace at mid-axillary line.

(b) DO NOT LET ELECTRODE PASTE TOUCH BETWEEN CHEST ELECTRODES.

(c) The same recording procedure is used for chest leads as was described for the limb leads.

S.O.P. for Routine ECG's with 4-Channel Poly-Viso Machine

(1) Prepare patient as described in general instructions.

(2) Turn on machine (master switch and one switch for each channel), make sure that ground wire is connected. Let machine warm up while patient is being prepared.

(3) Turn all leads to Std. and press master Std. button several times. Assure that correct standardization is present (1 mv = 1 cm).

(4) After standardization has been assured, the following strips (about 12 inches each) will be run. Standardize each strip two or more times.

(a) II, I, II, III.
(b) II, aVr, Avl, Avf.
(c) II, V1, V2, V3.
(d) II, V4, V5, V6.

(5) Be sure of the proper placement of each precordial (V) lead.

(6) Have the physician monitor the tracing before the double Master's test is performed.

(7) When tracing is completed, turn off machine (all switches), unhook patient and clean off electrode paste, then clean the electrodes.

(8) The tracing must be labeled with the patient's name, rank, age, date and the patient identification number.

2. Master's Two Step Test

(1) *General*

Cardiac stress tests are used for the purpose of cardiac disease not detectable by other means. Such a test should not be done indiscriminately in the presence of a resting abnormal electrocardiogram (ECG) or clinically established cardiac disease. It should not be performed in the presence of premonitory pains of impending myocardial infarction or in a subject experiencing the first episode of angina. The latter event may represent acute infarction.

If it is elected to perform an exercise tolerance test, it should be done in a standardized manner that permits comparative clinical evaluation. A complete 12-lead resting ECG (I, II, III, aVr, aVl, aVf and 6 V leads) should be taken prior to testing. The standard test is given according to the method of Master. The subject makes a given number of trips across two standard steps in accordance with age, sex, and weight. Each of the two steps is 9 inches high, 8 to 10 inches deep, and 18 to 27 inches wide. An ascent or trip is made by going up one side of the two steps and down the other. The return trip constitutes the second ascent. With a single two-step test, the number of ascents must be completed in a minute and a half; with the double two-step test, twice the number given for the single test, the number of ascents is completed in three minutes.

The test is performed in the fasting state with smoking interdicted for several hours. Preferably the patient should not be under the influence of cardiovascular drugs at the time of the test. If so, medication should be indicated on the data sheet.

The object of the test is to detect changes in the post-exercise ECG that were not present in the resting tracing. For this purpose it is desirable to record before and after exercise a minimum of leads I, II, aVf and precordial leads V_4, V_5 and V_6. These should be recorded immediately after exercise, two minutes and five minutes after exercise. In the event the tracing has not returned to normal by five minutes, subsequent records should be taken until the tracing has returned to its resting level.

(2) *Preparation of Patient*

(a) With the patient recumbent, connect the limb leads in the usual manner.

(b) Using the precordial leads place electrodes B, C and D over the V_4, V_5 and V_6 positions respectively.

(c) Attach a blood pressure cuff and stethoscope to one arm.

(3) *Procedure*

(a) Take 3 baseline blood pressure readings.

(b) Place the lead selectors as follows.

A – I
B – II
C – AVf
D – V

(c) Run a 12 inch baseline strip, standardizing the record two or more times.

(d) Reset the lead selectors as follows:

A – I
B – V
C – V
D – V

(e) Repeat step (c).

(f) Disconnect the patient cable from the machine.

(g) Obtain the number of trips which the patient must make across the steps.

(h) Have the patient to walk over the steps at a rate at which he will complete the prescribed number of trips in exactly three minutes (1 1/2 for single Masters).

(i) After the exercise is completed, return the patient to the bed and immediately repeat steps (b), (c) and (d) along with taking the blood pressure.

(j) The recording of blood pressure and ECG must be repeated at two and five minutes post exercise.

TABLE 1

Standard Number of Ascents for Males

Table for Single Masters
(Twice as Many Trips for Double Masters

Weight (lbs)	*Age in Years*												
	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69
40–49	35	36											
50–59	35	35	32										
60–69	31	33	31										
70–79	28	32	30										
80–89	26	30	29	29	29	28	27	27	26	25	25	24	23
90–99	24	29	28	28	28	27	27	26	25	25	24	23	22
100–109	22	27	27	28	28	27	26	25	25	24	23	22	22
110–119	20	26	26	27	27	26	25	25	24	23	23	22	21
120–129	18	24	25	26	27	26	25	24	23	23	22	21	20
130–139	16	23	24	25	26	25	24	23	23	22	21	20	20
140–149		21	23	24	25	24	24	23	22	21	20	20	19
150–159		20	22	24	25	24	23	22	21	20	20	19	18
160–169		18	21	23	24	23	22	22	21	20	19	18	18
170–179			20	22	23	23	22	21	20	19	18	18	17
180–189			19	21	23	22	21	20	19	19	18	17	16
190–199			18	20	22	21	21	20	19	18	17	16	15
200–209				19	21	21	20	19	18	17	16	16	15
210–219				18	21	20	19	18	17	17	16	15	14
220–229				17	20	20	19	18	17	16	15	14	13

3. Vectorcardiogram

(1) *General*

The heart is a three dimensional organ situated in a volume conductor. It is electrically active, and under ordinary conditions, the events of its electrical cycle occur in a very definite pattern and sequence. For this reason the electrical events themselves may be considered as occurring in three dimensions. In addition they may be considered to oscillate between zero and some definite electrical value. When viewed in one plane from the surface of the volume conductor, the successive instantaneous positions of the electrical waves describe a series of loops (P, QRS, &T), each of which is composed of an infinite number of vectors having both magnitude and direction. When viewed simultaneously from three mutually perpendicular planes (frontal, sagittal and transverse), the three dimensional character of the electrical activity may be observed.

The conditions described above may be closely approximated with human subjects through the use of a system consisting of an electrically balanced bipolar reference, the proper amplifiers, an oscilloscope and photographic equipment.

(a) The Vectorcardiograph – This system is composed primarily of 3 sub units, the vectorcardiograph proper, a control and subject identification unit and a magnetic tape recorder. Locate these components and become familiar with the various switches, knobs etc. on the vectorcardiograph proper, this will include the main power switch, amplifier power, sensitivity, (on amplifier) gain control, mode, filter, calibrate, plane selector, scope controls, camera shutter control, and dot intensity modulator controls. On the control unit this will include main power, standby, manual-automatic.

start, record, stop, reset, time control, and subject identification numbers; On the tape recorder this will include main power, drive, record, stop, rewind, and microphone controls.

(b) Instrumenting Subject – See the attachment on electrode placement.

(2) *Calibration of the System*

(a) Activate the main power switches for all three sub units.

(b) Also activate the VCG amplifier power; power and standby switches on control unit, and set the tape control knob to manual.

(c) After allowing sufficient time for warm-up set all three gain control knobs to the OFF position; the mode switch to DIRECT; the filter switch to FILTER-IN; the plane selector to FRONTAL; and the calibrate switch to ON.

(d) Viewing through the camera eye piece, turn the left gain control to IX. Position the line observed, along the graduated horizontal axis of the scope.

(e) Adjust the length of this line to 3.2 cm by turning the sensitivity control (on DC amplifier) in the appropriate direction. When the proper length is obtained turn the gain control OFF.

(f) Repeating step (d), turn the center gain control to IX. Position the line along the graduated vertical axis of the scope.

(g) As in (e), adjust the length of this line to 3.2 cm with the sensitivity control on the appropriate DC amplifier. When completed turn the gain control OFF.

(h) Next, set the VCG plane selector in either the sagittal or transverse positions.

(i) While viewing through camera eye piece, turn the appropriate gain control to IX. Position this line along the proper axis and adjust its length to 3.2 cm as stated before.

(j) Turn all 3 gain control knobs to IX, and the plane selector to FRONTAL.

(k) Position one end of the oblique line obtained at a corner in the grid system and expose the film.

(l) Without removing the picture, set the plane selector to sagittal. Using the same horizontal and vertical lines as a reference place the oblique line in such a position that it will make a perfect X with the previous exposure.

(m) Make a double exposure with the line so positioned and remove the picture.

(n) Check the calibration (X) to insure that a 30 mm square will be obtained if the legs are joined.

NOTE: As described here, pictures are taken with a polaroid camera.

(3) *Procedure*

(a) With the patient properly instrumented make a 45-second recording of the calibration signals. During this time identify the patient by name, rank, serial number, age, height, weight, and the date. Also identify the specific VCG method employed.

NOTE: For this recording the tape control switch should be set at manual. The recorder is controlled from this panel by activating the proper switches (e.g. start, record, stop, etc.).

(b) Turn the tape control switch to automatic.

(c) Set the patient identification data on the automatic digitalizing unit as follows:

Patient Number
– Year
Month Day Reel number

(d) Turn calibrate switch OFF and make a 60-second recording of the subject's VCG. This is accomplished by activating the RESET, START and RECORD switches respectively. After the proper time, the automatic operation will stop the recorder.

(e) Set the dot intensity modulator to a frequency of 400 cps; check frequency to see that this frequency is maintained.

(f) Take pictures of the subject's VCG. The gain settings used may vary with some subjects however, as a general rule the following settings will be used:

FRONTAL	SAGITTAL	TRANSVERSE
1X	1X	1X
6X	6X	6X
8X	8X	8X

At the 1X setting the entire complex (P, QRS and T loops) must be taken. At the 6X level the T loop is of prime importance. At the 8X level the P loop is isolated. All pictures must be labeled as to their size and the plane which they represent.

(g) After the complete set has been taken the gain controls are returned to the 1X position.

(h) Turn on the automatic sweep control and take a picture of the VCG in each plane as it sweeps across the scope.

If the automatic sweep is not available this may be accomplished by rotating the manual horizontal position knob at a steady rate.

(i) When this has been done disconnect the subject and close the system down by shutting OFF all of the main power switches.

NOTE: Never close the system down with the calibrate switch ON.

4. Treadmill

(1) *General*

The treadmill is a maximum exercise tolerance test. It is performed only in the presence of a physician monitor and only after a properly run and approved double Masters. In the conduct of the test the subject is required to walk at a rate of 3.3 mph until he is at or near his point of maximum physical exertion. To facilitate reaching this point within a reasonable amount of time, the angle of the treadmill is increased by 1% (or 2/3°) each minute to a maximum of 24%. Blood pressure and the ECG are continually monitored during the run. During the last minutes of the subject's effort, he is required to breathe through a unidirectional valve and collections of his exhaled air are made.

Electrocardiography is recorded from three simultaneous mutually perpendicularly leads oriented in left to right (X), superior to inferior (Y), and posterior to anterior (Z) directions. The ECG date is displayed immediately upon an oscilloscope for inspection by a radiologist, is recorded continuously on ECG paper (although the paper speed is varied to condense portions of the record) and is also recorded on analog electromagnetic tape for later computer storage and analysis. As certain individuals manifest labile repolarization changes with body positions it is important to record an adequate base line tracings in the recumbent and upright positions as well as throughout exercise and until recovery is complete, usually at 8 minutes post exercise.

(2) *Instrumenting Subject*

(a) The ECG lead system employed consists of several anodized silver electrodes. The proper placement of these is shown in Figure 1.

NOTE: It is necessary for a good quality tracing, to have skin impedances of 10,000 r or less. This may be accomplished by cleaning each electrode position with acetone and subsequently removing the dead skin by light sanding.

(b) When the X, Y, and Z leads have been properly connected, plug the junction box into the bed side receptical.

(c) Have the subject to assume a recumbent position and connect him to a 4-channel recorder in the conventional manner.

(3) *Procedure*

(a) With the bed side recorder, run a baseline strip consisting of the following lead combinations.

STRIP 1	STRIP 2
V_5	V_2
I	I
II	II
AVF	AVF

(b) With the remote recorder, run a short strip (2 inches) of 1 mv standardizations. Then run a 12 in strip of the X, Y, and Z leads to serve as a supine baseline. Measure and record the heart rate.

(c) Attach a blood pressure cuff to the subject's left arm and record his blood pressure.

(d) Move the subject to the treadmill and record a baseline ECG the heart rate and blood pressure in the standing position.

(e) Explain the mounting and collection procedure to the subject.

(f) Call the physician monitor.

(g) On instruction from the physician, start the treadmill and the remote recorder. Run the recorder at 10 mm/sec and instruct the subject to mount the treadmill.

(h) After 40 seconds have elapsed begin taking both blood pressure and ECG readings.

NOTE: The ECG should be recorded at the standard 25 mm/sec. After a 15-second tracing has been recorded resume recording at 10 mm/sec.

(i) Measure the heart rate and elevate the mill.

(j) This procedure is repeated during the last 20 seconds of each minute that the subject continues.

(k) When the subject completes his last minute, stop and lower the treadmill. When the treadmill halts completely, record an immediate ECG and blood pressure.

(l) Move the subject back to the bed and a supine position. Immediately reconnect him to the bed side recorder.

(m) Run recovery tracings at 2.5 and 8 minutes post exercise. With the remote machine record a 15-second strip at 25 mm/sec (measure heart rate) with the bed side machine repeat the baseline strips at each recovery time and record the blood pressure.

(n) When the 8th minute recovery has been recorded, disconnect the subject and wash the electrodes.

List of Equipment and System Layout

A. Audio:

(1) Select the correct record and reproduce modules with proper frequency determining units.

(2) Connect the mike to "mike" input on the RCA amplifier.

(3) Take the signal off the 4 ohm taps in the back of the RCA amplifier and connect it to the low impedance on the impedance matching box (banana plugs).

(4) Take the signal off the direct reproduce and go into the 600 ohm input on the speaker.

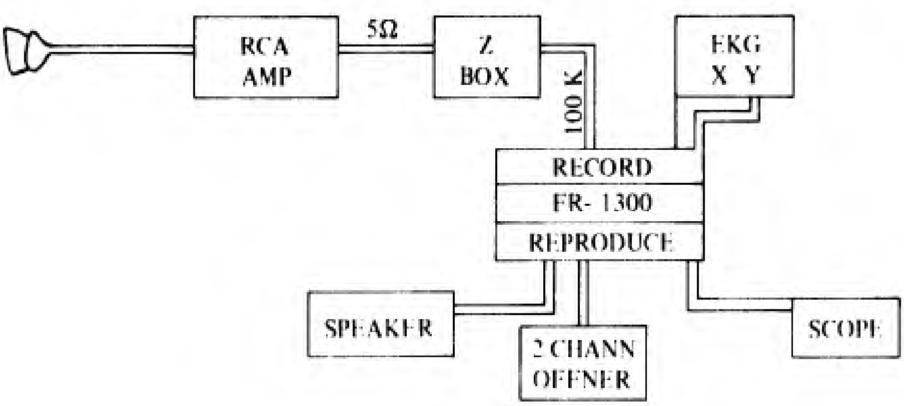
B. Other Connections:

(1) Connect the EKG from the monitor jack on the Sanborn preamplifier to the desired FM record module on the FR-1300 for both the X and Y axix.

(2) Connect the 2 channel Offner to the reproduce jack on channel No.1 for slow time code reference.

(3) Connect the scope input to either EKG channel reproduce module to monitor the calibrations and EKG.

C. Block Diagram:



Preliminary Procedures

(1) Check the tape speed to see if it is 7½ IPS.

(2) Check the tape modules to make sure the proper ones are plugged in (one direct audio and two FM EKG channels).

(3) Turn on all equipment for warm-up.

(4) Check to see if the Time Code is present and can be reproduced.

(5) Check audio reproduction and set the volume control at the desired level on the RCA amplifier.

(6) Identify the subject on the tape.

(7) Calibrate the tape recorder with 150 pulses from the EKG machine. (Be sure the subject is unplugged and the INSTO switch is in the ON position).

DO NOT TURN TAPE POWER OFF TILL THE END OF THE RUN.

(8) Plug the subject back into the EKG machine.

Operational Procedures

All important events of any significance will be recorded in two ways. You will verbally record all events or conditions on the audio channel on the FR-1300 and also mark these on the Time Code readout of the Offner. The following information is some of the more important data needed.

(1) Identification of the subject and the Time of the beginning of identification.

(2) Time of calibrations; (Beginning Time: 150 pulses).

(3) Time of the recumbent baseline. (Beginning Time: minimum of two minutes).

(4) Time of the standing baseline. (Beginning Time: minimum of two minutes).

(5) End of each minute of exercise and recovery.

(6) Any notations the Doctor may feel are important.

(7) Any action on the part of the subject which might help the Doctor or computer section whenever the tape is reproduced.

BE SURE TO GET 45 SECONDS ECG ON IMMEDIATE RECOVERY AND 1½ MINUTES AFTER THE 8TH MINUTE OF RECOVERY.

(8) Time of the End of Run.

5. **Respirometer**

For pulmonary evaluation a 9 liter respirometer is used. This closed circuit apparatus, having one-way valves, free breathing valve and by-pass and a CO_2 absorbent cartridge, allows the following measurements:

vital capacity and lung volume fractions,
maximum breathing capacity,
timed vital capacity,
midexpiratory flows,
O_2 uptake in basal conditions and during mild exercise.

With numerous suitable accessories, the respirometer permits electronic recording of respiratory excursions, single-breath diffusing measurements, open-circuit residual volume determinations etc.

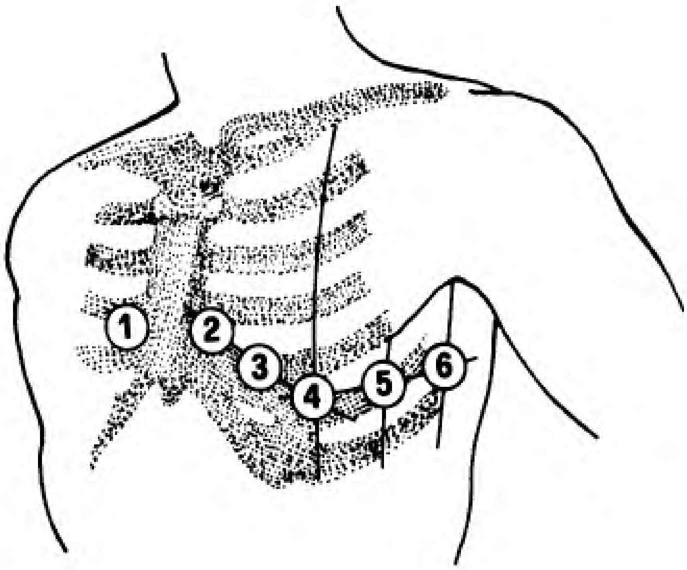


Fig.11.1 Precordial lead positions
V1 – 4th Interspace adjacent to right sternal border
V2 – 4th Interspace adjacent to left sternal border
V3 – Halfway between V2 and V4
V4 – 5th Interspace in mid clavicular line
V5 – Same level as V4 in anterior axillary line
V6 – Same level as V4 in mid axillary line

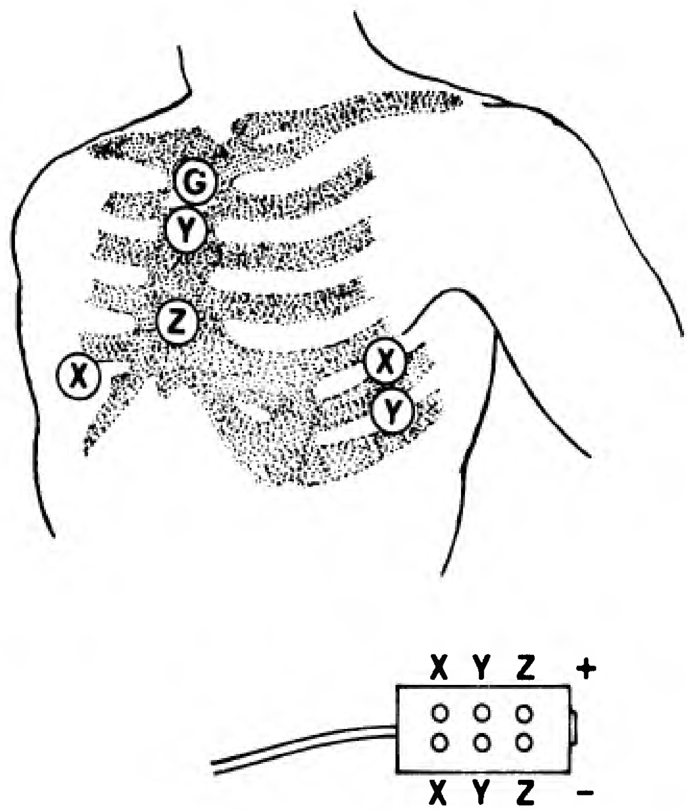


Fig.11.2 "Walk around box". Placement of chest electrodes
X+ – lead in the V5 position
X– – lead in the V5 position but to the right side of body
Y+ – lead in the 6th interspace right under V5
Y– – lead in the 2nd interspace on the sternum
Z+ – lead in the 4th interspace on the sternum
Z– – lead in the 4th interspace but on the patients back
Ground lead in the 1st interspace tight above Y – (see above drawing)

NOTE: If patients baseline tracing is good, but starts to wander while he is walking the treadmill, check to see that the electrodes are not rubbing against the patients elbs. This happens frequently in very thin patients.

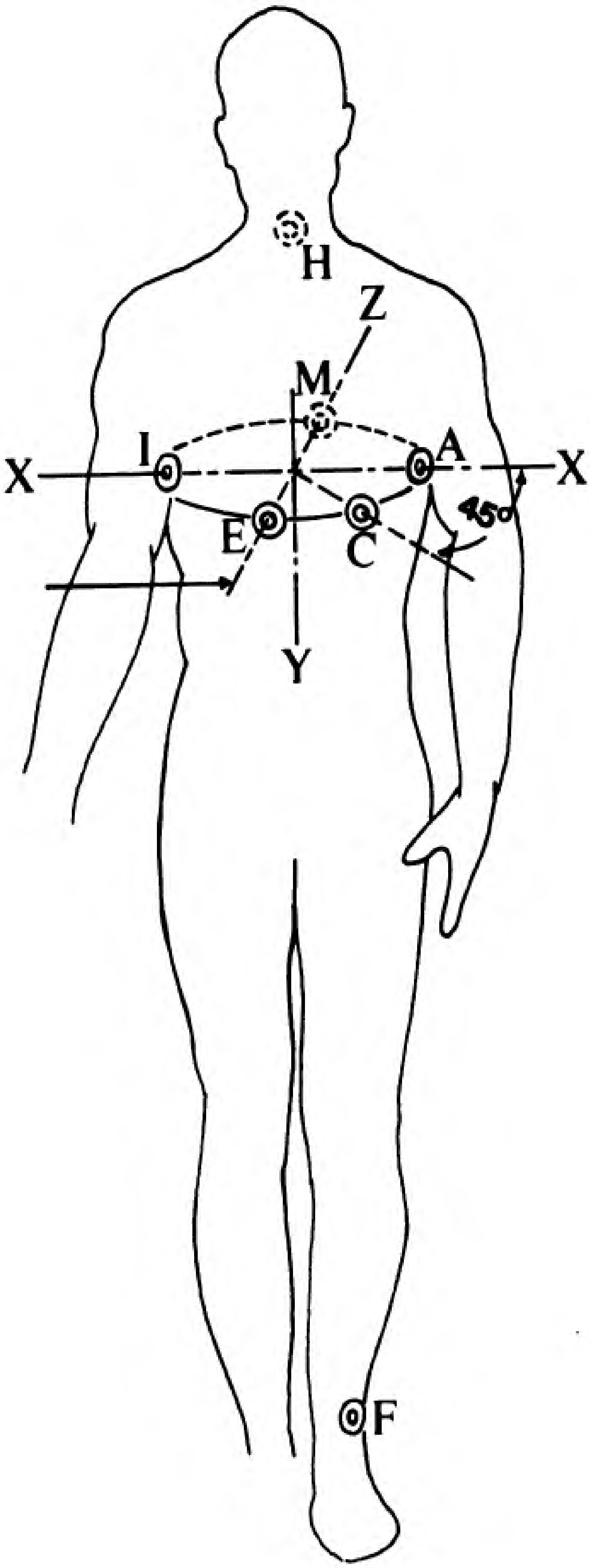


Fig.11.3 Vectorcardiography. Placement of electrodes I, M, A, C, E, on plane thru 5th intercostal. Z represents the midline

CHAPTER 12

SUMMARY OF CARDIOVASCULAR AND RESPIRATORY EXAMINATION METHODS CURRENTLY IN USE AT US NAVAL AEROSPACE MEDICAL INSTITUTE

by

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INTRODUCTION

The diagnostic procedures described herein constitute the basic non-invasive armamentarium of the cardiopulmonary laboratory at the Naval Aerospace Medical Institute, Pensacola, Florida. The mechanics of the methodology will not be discussed, inasmuch as the techniques utilized in the performance of the studies are universally standardized; nor will invasive techniques (cardiac catheterization, angiography, bronchoscopy, etc.) be discussed as these are not available locally. The latter are done on appointment/referral basis at other Naval medical facilities.

Except for the screening tests, done on all individuals, the examination procedures described are done only on the problem cases referred for diagnosis.

METHODOLOGY

1. Electrocardiography, Routine

(a) Screening: Baseline twelve lead electrocardiograms are done on all individuals processed through the Aviation Examining Division. These tracings are done on a Hewlett-Packard 1515B recorder which has provision for recording three individuals simultaneously. These electrocardiograms are microfilmed and maintained as a permanent file.

(b) Clinical: For all clinical investigative purposes a twelve lead electrocardiogram is recorded in the fasting state utilizing the Hewlett-Packard 1500A direct writer electrocardiograph and the Ampex tape deck.

2. Electrocardiography, Stress

(a) Harvard step: A twenty inch step used at the rate of twenty steps per minute in cadence with a metronome. The standard duration of exercise is three minutes but this may be modified to a shorter or longer period as necessary. Leads, I, II, III, AVF and V2, 4-6 are recorded simultaneously in two groups on a Sanborn 964 four-channel recorder at standard speed and deflection. A timed sequence of tracings consists of the baseline, immediate post-exercise and at one, two, three, five, seven and ten minutes after cessation of exercise.

(b) Treadmill: A Quinton treadmill is used to produce a heart rate 85% of that predicted for the age of the individual, using the Bruce protocol. (See Table 1.)

TABLE 1

Multistage Exercise Capacity Test According to the Method of Bruce

Stage	*Speed (mph)*	*Grade (%)*
1st	1.7	10
2nd	2.5	12
3rd	3.4	14
4th	4.2	16
5th	5.0	18
6th	5.5	20
7th	6.0	22

Each stage is maintained for three minutes. The patient then progresses without interruption to the next stage on the treadmill to provide a continuous period of stress. Total time: 21 minutes; total distance: 1.42 miles.

The lead system and sequence are the same as those used for the Harvard step, recorded on a Hewlett-Packard 7754A four-channel recorder and the Ampex 1300 tape recorder. During exercise oxygen uptake is measured by means of the Beckman oxygen analyzer and monitoring is by means of the Sanborn 768-100 monitor.

(c) Dynamic electrocardiography: The Avionics Biomedical Division Holter Electrocardiocorder Model 350 and the Composite Electroscanner are used for extended monitoring. Monitoring is done on the ground and in-flight, as indicated.

3. **Vectorcardiography**

(a) The vectorcardiogram is obtained from a Sanborn 1507A Vector Programmer. Frontal, horizontal and left sagittal loops are inscribed at intervals of 2.5 milliseconds, employing the Frank lead system, photographed using a Polaroid camera. Simultaneous monitoring is done on the Sanborn 768-100 monitor. Recording is also done on the Ampex FR 1300 tape deck.

4. **Ballistocardiography**

(a) An Astrospace Air Suspension Bed is used to obtain ultra low-frequency ballistocardiograms. Recording is done on a Sanborn 964 four channel recorder, the additional three channels used for the electrocardiogram, carotid pulse and heart sounds.

5. **Pulmonary Function Studies**

(a) Screening is done on the Ohio 842 Spirometer, a solid state integrated computing circuitry which provides digital readout for vital capacity, forced expiratory volume (one second/vital capacity, mid-expiratory flow rates (200–1200), maximum mid-expiratory flow rates (25–75%), peak flow and maximum volume velocity.

(b) More discrete studies are performed on the Ohio 2322 system. This includes complete resting spirometry, nitrogen washout (single breath and steady state), and closing volumes. Data are inscribed on an integrated X–Y plotter for analysis of flow-volume loops.

6. **Echocardiography**

(a) Echocardiograms are performed on selected cases for investigation of specific problems. The equipment consists of a cart-mounted Picker Echocardioscanner (Tektronix Type 564B storage oscilloscope) with an integrated Polaroid camera assembly.

With this equipment abnormalities of cardiac structure (valvular defects, etc.) and cardiac output can be determined.

7. **G-Stress Tolerance Studies**

(a) Problems involving intolerance to G-stress can be studied by means of a lower-body negative pressure device, used as an adjunct to tilt-table studies.

8. **Cardiac X-rays**

(a) Postero-anterior, lateral and right and left lateral views are taken, with barium swallows for the latter three.

9. **Biochemical Studies**

(a) A complete multiphasic screen is done for indications of existing disease and a survey of risk factors predisposing to cardiovascular disease.

10. **Automatic Blood Pressure Recording**

(a) Pressures are obtained in the recumbent position utilizing the Air Shields recorder. This is a semi-automatic system necessitating recording by hand.

11. **Fundus Photos**

(a) Retinal photos are taken with the Zeiss Fundus Camera

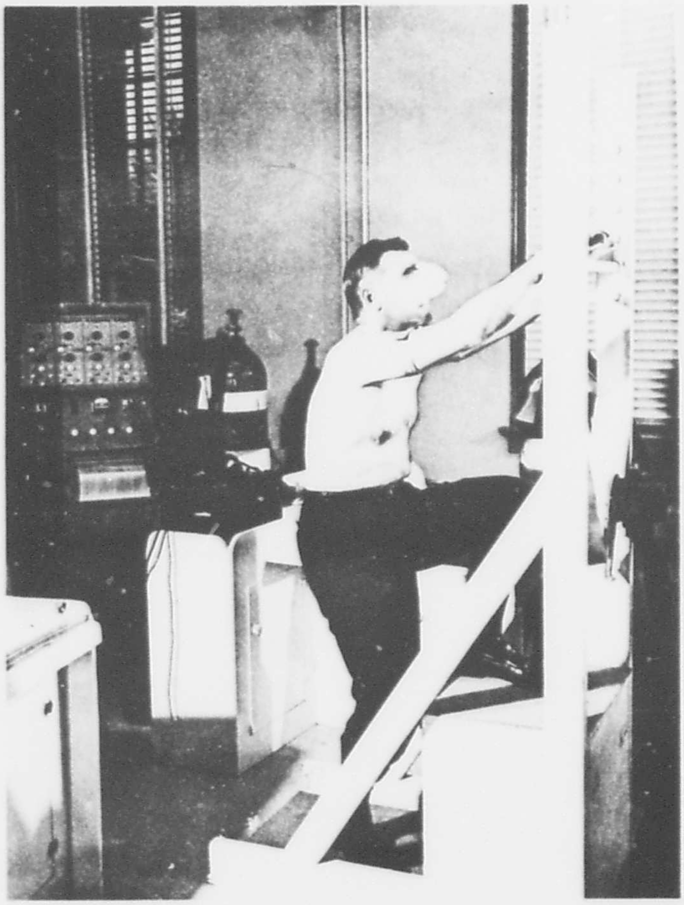

Fig.12.1 Step test

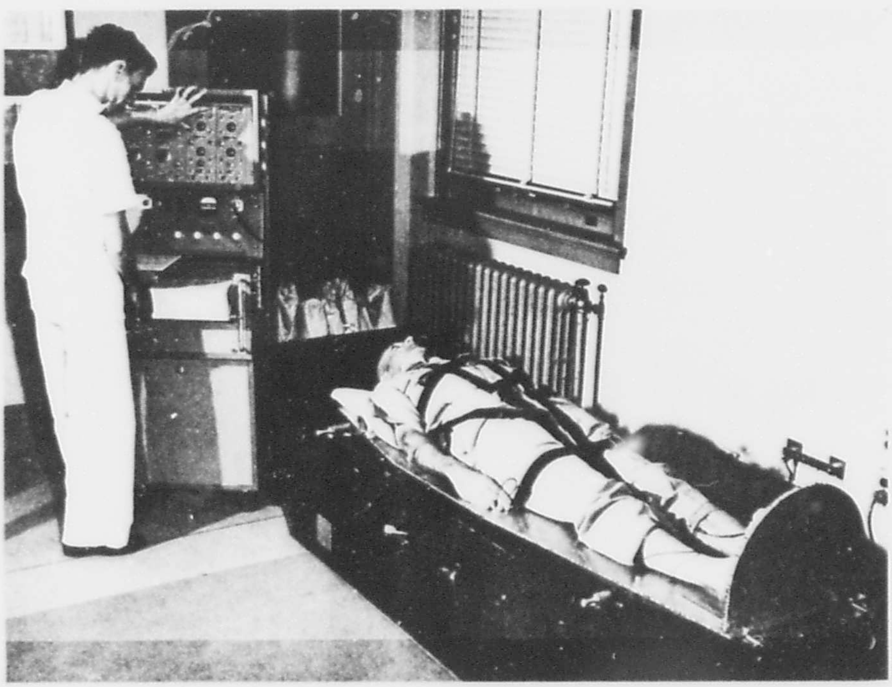

Fig.12.2 Astrospace air suspension ballistocardiograph

CHAPTER 13

CONCLUDING REMARKS

by

Aristide Scano

CONCLUDING REMARKS

(1) Functional cardio-vascular and respiratory evaluation is a chapter now firmly established in many fields of medicine. These systems in fact, are explored (mainly but not exclusively, by means of physical exercise tests):

- in sport medicine to judge basic qualities, to evaluate the results of training and an athlete's possibilities of recuperation;
- in anaesthesiology and surgery to measure the functional reserves before and after an operation;
- in legal medicine to evaluate the amount of the damage;
- in occupational medicine to prevent impairments caused by work and the environment;
- in pneumophthisiology to quantify the condition of the patient and follow the evolution of the disease and the benefits of treatment.

In all these cases the general principle is applied that the efficiency of a machine, living or inanimate, is explored and measured by submitting it to an effort of known and, in many cases, fixed amount of duration.

(2) Before admitting clinically healthy candidates to flying training, most Institutes for the medical selection and control of aircrews belonging to NATO countries apply some kind of functional respiratory and cardiovascular tests in order to quantify as far as possible the efficiency of these organs. They often apply the same tests, or similar ones, in keeping with the age and conditions of the subject, during the control examinations of aircrews carried out at intervals that vary in the different countries.

(3) Some countries limit themselves to the ECG recorded immediately after a light exercise and some spirometric measurements, others make provision for more exacting tests (V_{02} max, hypoxia) in the admission phase. Nearly all have prescribed precise norms of registering the pulse, measuring the blood pressure in various positions of the body (this is also a functional test, even though of little weight), recording the ECG, etc. These norms are practically uniform in all countries. Less well defined are all the physical exercise tests, though two tendencies are evident: moderate exercise with steady state and maximum exercise tests interrupted at the point of exhaustion. According to our experience, the second yield clearer and more convincing results but they are applicable only to young and healthy subjects. There are wider differences of technique, on the other hand, in the related fields of hypoxia and pharmocological tests, though here too there is a common trend.

(4) Are functional tests of real use in the aeromedical field? The question is raised insistently by those in charge of medical selection when a high number of candidates have to be examined, owing to the time "wasted" in carrying out the tests correctly. The fact that the more significant and simple tests are carried out as a matter of routine by all Aviation Medicine Institutes and that the more complex and precise ones are carried out to clarify difficult cases, testifies to general recognition of their usefulness. We are of the opinion that opposition to the tests is due in some cases to the fact that unless they are carried out very carefully and interpreted by experts, they may cause mistaken judgements. But this objection applies to nearly all medical examinations.

(5) Another objection raised against these tests is that there is a danger in applying them indiscriminately. Our survey enables us to affirm, however, that the subject does not run any risk when a complete clinical examination has been carried out before-hand and the test is in proportion with the age and physical conditions of the subject. The answers of the experts, reported in the various chapters, are convincing on this point.

(6) We hope that the material reported in the Survey, for which we thank the contributors once more for their competent and valuable collaboration, will be useful to extend our knowledge in this sector of physiology applied to aviation medicine, and facilitate its progress and the continuation of joint efforts towards the goal of standardization.