The cardiovascular fitness of airline pilots


I. Introduction 337
  BACKGROUND TO THE PROBLEM 337

II. Cardiovascular examination before acceptance for training 337
  A. DETECTION OF CARDIOVASCULAR DISEASE — HISTORY AND PHYSICAL EXAMINATION 337
  B. CORONARY ARTERY DISEASE — DETECTION OF LIABILITY 338
    1. Smoking 338
    2. Cholesterol 338
    3. Hypertension 338
    4. Cumulative factors 338
  C. ARRHYTHMIA 338
  D. VALVAR HEART DISEASE 338
  E. PERICARDIAL DISEASE 338
  F. CARDIOMYOPATHY 338
  G. CONGENITAL HEART DISEASE 338
  H. CARDIAC SURGERY 338
  I. PERIPHERAL AND CEREBROVASCULAR DISEASE 338
  J. CARDIOVASCULAR DISEASE SECONDARY TO PULMONARY DISEASE (COR PULMONALE) 338

III. Cardiovascular reassessment of licensed pilots 338
  A. HISTORY, EXAMINATION, AND ROUTINE ASSESSMENT 338
    1. Resting electrocardiogram 339
    2. Radiography 339
    3. Blood cholesterol 339
    4. Blood glucose 340
  B. CORONARY ARTERY DISEASE 340
    1. The asymptomatic pilot 340
    2. The symptomatic pilot 340
    3. Exercise testing 340
    4. Coronary arteriography 340
  C. HYPERTENSION 341
  D. ARRHYTHMIAS 341
  E. VALVAR HEART DISEASE 341

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F. PERICARDIAL DISEASE .... 341
G. CONGENITAL HEART DISEASE .... 341
H. CARDIAC SURGERY .... 341
I. PERIPHERAL VASCULAR DISEASE .... 342
   1. Peripheral arterial disease .... 342
   2. Peripheral venous disease .... 342
J. CEREBROVASCULAR DISEASE .... 342
K. PULMONARY HEART DISEASE .... 342
L. MEDICINES AND FLYING .... 342
M. ALCOHOL AND FLYING .... 342

IV. Advisory Panel on Cardiovascular Disease .... 342
   A. COMPOSITION OF ADVISORY CARDIAC PANEL .... 342
   B. PURPOSE OF PANEL .... 342
   C. APPLICATION OF ENDORSEMENTS (WAIVERS) .... 342

V. Advice to pilots on maintenance of health .... 343
(See also Appendix 2)

VI. Standards of medical examination and instrumentation .... 343
   A. PHYSICAL EXAMINATION .... 343
   B. MEASUREMENT OF BLOOD PRESSURE .... 343
      1. Method of recording .... 343
      2. Method of reading .... 343
   C. EXAMINATION OF URINE .... 344
   D. CHEST RADIOGRAPHS .... 344
   E. ELECTROCARDIOGRAPHY .... 344
      1. Resting electrocardiogram .... 344
      2. Exercise testing .... 344
   F. CORONARY ARTERIOGRAPHY .... 344
   G. ECHOCARDIOGRAPHY .... 344
   H. BLOOD LIPIDS AND GLUCOSE .... 344
      1. Serum cholesterol—initial examination .... 344
      2. Serum cholesterol—reassessment examination .... 344
      3. Fasting blood glucose .... 344

VII. Subjects for research .... 345
   A. ENVIRONMENT; PHYSIOLOGICAL AND BIO-
      CHEMICAL CHANGES IN FLIGHT .... 345
   B. USE OF DRUGS BY AIRCREW .... 345
      1. Hypnotics and sedatives .... 345
      2. Beta-adrenergic antagonists .... 345
   C. EFFECTS OF AUTONOMIC NERVOUS SYSTEM ON
      ELECTROCARDIOGRAM .... 345
   D. SMOKING AND CARBON MONOXIDE .... 345
   E. FOLLOW UP STUDIES .... 345

VIII. Recommendations .... 345

Appendix 1: Cholesterol .... 346
Appendix 2: Advice to aircrew on maintenance of cardiovascular health .... 347
Appendix 3: Acknowledgements .... 348
References .... 349
I: Introduction

The Working Party was convened by The Royal College of Physicians to examine the standards of cardiovascular fitness of airline pilots with specific reference to the place of electrocardiographic effort testing as mentioned in the Trident Crash Report (Civil Aircraft Accident Report 4/73, 1973). The final terms of reference of the Working Party were widened to include:

(a) Cardiovascular examination before acceptance for training (Section II).
(b) Cardiovascular reassessment of licensed pilots (Section III).
(c) Advice to pilots on the maintenance of health (Section V).
(d) Recommendations for research (Section VII).

Notice was given through the medical press and to the British Cardiac Society inviting evidence from any member of the medical profession with special interest or experience in these matters. Evidence was also taken from representatives of the Civil Aviation Authority, British Airline Pilots Association (BALPA), and from certain other individuals (Appendix 3).

In October 1975 the American College of Cardiology published the report of its Eighth Bethesda Conference on ‘Cardiovascular Problems Associated with Aviation Safety’, to be known hereinafter as the ‘Bethesda Report’ (American College of Cardiology, 1975). This report is extensive and valuable, setting out cardiovascular criteria relating to aviation safety recommended by a Panel of American Cardiologists. The ‘Bethesda Report’ can be regarded as a reference manual whereas this report should be considered more as an operational document.

BACKGROUND TO THE PROBLEM

The risks associated with travelling by air on a scheduled airline are now very small. In 1975 there were less than 500 passenger fatalities in 17 accidents to scheduled flights in the International Civil Aviation Organization member states. This is a standard accident rate of 0.13 fatalities per 100 million passenger miles. More than half the accidents occurred during the approach and landing phase and none was attributed to incapacitation of the pilot (Field et al., 1976).

In the past 15 years in the United Kingdom no scheduled aircraft has been lost solely because of incapacitation of the pilot during flight though the presumed myocardial infarction of the captain of the Trident G-ARPI which crashed in Staines in 1972 was judged to be partly responsible (Civil Aircraft Accident Report 4/73, 1973).

When incapacitation or death has occurred at the controls the flight deck emergency drill has usually avoided disaster (Buley, 1969; Orlandy, 1975). Aircraft with a single pilot present a separate problem.

All airline operators recognise their responsibility for maintaining the present high standards of health or even improving them. Medical examination and screening, however, cannot be expected to eliminate all possibility of acute cardiovascular illness in pilots. This underlines the need for a high level of efficiency in flight deck emergency drill.

‘Heart attacks’ which are one of the main concerns of this report are of particular importance in aviation medicine. Such ‘attacks’ may be episodes of myocardial infarction or of disabling but non-fatal arrhythmias. The initial episode may occur without warning and could result in complete destruction of the aircraft and the death of all passengers and aircrew.

The relative importance of cardiovascular problems in airline pilots is shown by the 1975 figure for loss of licence. During this year 65 pilots lost their licence, 41 on cardiovascular grounds. In 30 of these the abnormality was detected on routine investigation (Joy, 1977).

II: Cardiovascular examination before acceptance for training

Initial medical examination should aim to detect existing cardiovascular disease (including hypertension) and eliminate candidates who have an undue risk of developing cardiovascular disease before retirement at the usual age. The highest level of scrutiny is essential in order to reduce the risk of training those who might subsequently become unfit and later prove a liability.

A: DETECTION OF CARDIOVASCULAR DISEASE

History and physical examination

The candidate should be asymptomatic and should not have had any illness which might predispose to permanent cardiovascular damage. Special attention should be paid to a family history of hypertension, premature cardiovascular disease, or sudden death (Section II, B, 4).

Cardiovascular examination must be normal and in particular there must be no pathological heart sounds or pathological murmurs arising from the heart or great arteries. Blood pressure must be normal (Section VI, B, 2). The examination for acceptance to train should include: a record of body weight; a 12 lead electrocardiogram at rest; chest radiography; examination of the urine; blood count; serum cholesterol; random blood glucose; electrocardiographic exercise testing.
A submaximal exercise test is recommended because it provides a baseline should any suspicion of heart disease arise in the future (Doyle and Kinch, 1970). It may also unmask unsuspected coronary artery or myocardial anomalies in a minority of the applicants.

Echocardiography is not advised at present as the normal variants have yet to be defined.

B: CORONARY ARTERY DISEASE—DETECTION OF LIABILITY

(1) **Smoking**
Cigarette smokers as a group are twice as likely to have a fatal heart attack as those who do not smoke. Those under the age of 45 years who smoke 25 cigarettes or more a day have a tenfold to fifteenfold increased risk of death from coronary heart disease (Doll and Peto, 1976). Smoking is, therefore, an important risk factor which should weigh against an applicant’s acceptance to train.

(2) **Cholesterol**
Since the risk of coronary artery disease increases with serum cholesterol levels above 6.5 mmol/l (250 mg/dl) and these levels may be expected to increase with age, an age related scale is recommended. Applicants should be rejected with levels above 7.5 mmol/l (288 mg/dl) before the age of 25 years and above 8.5 mmol/l (327 mg/dl) between 25 and 35 years. No applicant should be rejected solely on one estimation. Few applicants would be eliminated on these grounds as less than 5 per cent of young men in the UK have such levels (Leonard et al., 1977). The reasons for these recommendations are given in Appendix 1.

(3) **Hypertension**
Candidates must have blood pressure within the normal range (Section III, C).

(4) **Cumulative factors**
Because of the limited data available specific recommendations on the relative importance of multiple risk factors could not be made. In assessing a candidate’s fitness for training, however, the additive effect of different factors (obesity, smoking, abnormal blood lipids, and a family history of premature cardiovascular disease) should be considered. A borderline abnormality of one factor may be acceptable if the other factors are within normal limits (Ellestad et al., 1975).

The presence of any of the following in any form disqualifies:

C: ARRHYTHMIA
Any conduction defect or arrhythmia, except sinus arrhythmia, and ectopic beats which disappear on effort.

D: VALVAR HEART DISEASE
Any evidence of valvar dysfunction.

E: PERICARDIAL DISEASE
Any evidence of active, recurrent, or established pericardial disease such as a friction rub, effusion, or tamponade. A previous history of acute disease with no recurrence in the preceding 3 years need not disqualify.

F: CARDIOMYOPATHY

G: CONGENITAL HEART DISEASE

H: CARDIAC SURGERY
Any form of surgical operation on the heart or great vessels. Certain conditions such as closure of simple persistent ductus arteriosus, without residual signs; simple ventricular septal defect without complications, or coarctation, should be referred to the Panel (Section IV, p. 342) for consideration because of the possibility of additional cardiac defects and myocardial abnormalities developing later (Jones and Ferrans, 1977; Somerville and Becú, 1977).

I: PERIPHERAL AND CEREBROVASCULAR DISEASE
Any evidence of peripheral vascular disease, arterial or venous, or cerebrovascular disease.

J: CARDIOVASCULAR DISEASE SECONDARY TO PULMONARY DISEASE
(Cor pulmonale).

III: Cardiovascular reassessment of licensed pilots
Although these recommendations are in general for pilots flying aircraft with more than one pilot, it is essential that cardiovascular standards of fitness for single pilot operations are as strict as those for multipilot operations.

A: HISTORY, EXAMINATION, AND ROUTINE ASSESSMENT
The frequency of cardiovascular assessment should be as recommended by the CAA: age 18 to 29 years, every 5 years; age 30 to 39 years, every 2 years; age 40 to 49 years, annually; age 50 years and over, every 6 months.

Whenever a pilot changes his employing authority, a full medical examination as for relicensing is indicated.
The cardiovascular fitness of airline pilots

The cardiovascular fitness of airline pilots

It is also recommended that pilots should not have to pay for any part of their routine medical examination.

Whenever questions of cardiovascular health arise or a cardiological opinion is sought, temporary withdrawal of licence may be indicated. Further investigations and decisions should be made as quickly as possible to resolve uncertainty (see Fig.).

Assessment of all cardiovascular symptoms and signs as well as of habits affecting health such as smoking is essential. Special attention should be paid to the following points especially if they have developed since the last examination: chest pain, breathlessness, syncope, and palpitation.

Every cardiovascular assessment should include: record of body weight, blood pressure, a 12 lead electrocardiogram at rest, chest radiography, examination of urine, blood count, serum cholesterol\(^1\), random blood glucose\(^1\).

(1) **Resting electrocardiogram**

The resting electrocardiogram must be normal (see III, D, 2 and 3; and VI, E). Equivocal changes may after investigation permit relicensing, possibly with an endorsement (waiver) (Fig. and Section IV).

(2) **Radiography**

Any cardiac enlargement, enlargement of the great vessels, calcification within the cardiac shadow, or abnormality of the lung fields or pulmonary vasculature should lead to temporary withdrawal of licence pending cardiological opinion.

(3) **Blood cholesterol** (Appendix 1)

Blood cholesterol examination should be made under standardised conditions by an accepted method. Any upward trend should be noted and considered in relation to other factors such as weight, cigarette smoking, blood pressure, and blood glucose. It must be remembered that hyperlipidaemia is not a disease but a possible indicator of future disease, and an undue increase in body weight may prove more important than a raised blood cholesterol. Values above the predicted normal allowing for age should lead to further assessment of the cholesterol level in 6 months (Slack et al., 1977).

If after all adverse risk factors have been corrected, the cholesterol continues to rise, this would not of itself indicate withdrawal of licence but suggests the need for more frequent review.

If the cholesterol is still raised after a further 6 months, an exercise electrocardiogram may be

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\(^1\) 2 yearly after 40 years.
advised. It is expected that the numbers involved are likely to be small. If the results are positive the pilot should be referred to the Advisory Panel for a decision regarding coronary arteriography or other examination. If the exercise electrocardiogram is negative, but the cholesterol remains raised after one year he should again be referred to the Panel. (See VI for details of cholesterol levels.)

(4) **Blood glucose**
A raised blood glucose requires confirmation and if still abnormal, temporary withdrawal of licence should follow pending referral for a consultant opinion.

**B: CORONARY ARTERY DISEASE**

(1) **The asymptomatic pilot**
Evidence of unequivocal cardiac infarction on the electrocardiogram demands withdrawal of licence but the pilot may appeal (see Fig. and Section IV) against the decision.

Any other abnormality on the routine electrocardiogram should lead to cardiological advice which may include exercise testing. If the exercise test is negative and there are no other symptoms or signs of cardiovascular disease, the pilot should be relicensed possibly with an endorsement (waiver). The exercise test should be repeated twice at 6-monthly intervals. If it remains negative and no symptoms or signs have developed in the interval, no further exercise tests are needed. If the test is positive, the pilot may choose either to see a cardiologist of his or his airline’s choice, before a final decision by the Advisory Panel (see Fig. and Section IV).

(2) **The symptomatic pilot**
Symptoms suspicious of cardiac disease require immediate evaluation and temporary withdrawal of licence until a definite diagnosis has been made.

(3) **Exercise testing**
Exercise testing should form no part of routine examination of the trained pilot because of poor reproducibility and specificity and the appreciable number of false positive results (Royal College of Physicians and British Cardiac Society, 1975). Though exercise tests do have some predictive value, their specificity in patients with symptoms of ischaemic heart disease cannot be extrapolated to healthy subjects or to those with doubtful manifestations of coronary disease (Most et al., 1968; Froelicher et al., 1973).

Furthermore, positive exercise testing does not invariably indicate coronary artery disease (Doyle and Kinch, 1970). A recent study of asymptomatic, apparently healthy flying personnel with electrocardiographic abnormalities on resting and exercise electrocardiograms showed that approximately 60 per cent had no evidence of coronary artery disease on angiography. This study reinforces the view that electrocardiographic abnormalities have poorer predictive value for coronary disease in asymptomatic, apparently healthy individuals than in a hospital population (Froelicher et al., 1973).

From this it may be argued that in order to prevent one pilot from jeopardising an aircraft, many healthy pilots would have to be retired prematurely after positive exercise tests. Even then not all dangerous disabilities would be detected by effort testing (Garrison and Gullen, 1972).

Nevertheless there is a good case for retaining exercise testing when the resting electrocardiogram is equivocal. This may be stated as follows:

(a) The development of a positive exercise test after previously normal results indicates a high risk of developing coronary artery disease (Doyle and Kinch, 1970). This emphasises the importance of the routine exercise test on entry for training.

(b) A strongly positive effort test suggests coronary disease requiring immediate withdrawal of licence and investigation with a view to treatment.

(c) A strictly negative effort test in subjects with equivocal symptoms or minor changes in the resting electrocardiogram of uncertain significance may be accepted as part of the evidence justifying return to flying duties, but a negative effort test should not be the sole factor justifying restoration of a pilot’s licence.

(4) **Coronary arteriography**
Because of the limitations of effort testing coronary arteriography will have a place in certain selected subjects where doubt still exists over symptoms, signs, resting electrocardiogram, the result of the effort test, or other investigations.

The Working Party does not recommend the routine use of coronary arteriography as a sequel to all positive or doubtful effort tests. In cases, however, where a pilot is referred to a cardiologist after suspicious changes on the resting electrocardiogram, and a positive or borderline exercise test, coronary arteriography may be advised for reasons of clinical management as well as for relicensing. The recommendation for relicensing will ultimately rest with the Advisory Panel.

Any lesion of the left main coronary artery, or a 50 per cent or greater narrowing of any of the three major coronary arteries (left anterior descending, left circumflex, and right coronary artery) or their major branches, indicates permanent withdrawal of
licence because of the progressive nature of the disease. Any lesion, however minor, should be assessed by the Advisory Panel. A normal coronary arteriogram and left ventricular angiogram may permit renewal of licence (Fig.) provided there is no history of angina, suggestion of paroxysmal conduction disturbance or arrhythmia, or any other disqualifying condition.

C: HYPERTENSION
Blood pressure should be measured under identical conditions at each examination (Section VI). Any substantial increase, allowing for age (Gifford et al., 1975), should lead to review in 6 months, with correction of such associated factors as inadequate rest periods, obesity, lack of exercise, cigarette smoking, and abnormal lipids. If, after correction of these factors and the elimination of other disease, the blood pressure remains above the normal for the age (see Section VI), antihypertensive therapy with a thiazide (and potassium where indicated), should be started under the supervision of the appropriate medical adviser, and the licence should be temporarily withdrawn until the pressure is controlled. The pilot should be allowed to fly again with an endorsement (waiver) requiring a complete review every 6 months.

On no account should sedatives be employed to lower blood pressure. Apart from thiazide and possibly potassium conserving diuretics other antihypertensive drugs are not permitted. Insufficient is known about the effects of beta-adrenergic blocking drugs on the central nervous system to give unqualified approval for their use, but an endorsement (waiver) with regular supervision might be used in individual cases. The Advisory Panel should be the final arbiter to make recommendations on the question of permanent loss of licence in those who fail to respond adequately to accepted antihypertensive therapy.

The discovery of adrenal tumour or important renal causes for hypertension are grounds for withdrawal of licence. After successful treatment the pilot should be referred to the panel for consideration of relicensing.

D: ARRHYTHMIAS
1: The following should disqualify: sinoatrial block; complete atrioventricular block whether caused by nodal or infranodal disease; bilateral bundle-branch lesion; left bundle-branch block; paroxysmal flutter or fibrillation; reciprocating junctional (atrioventricular) tachycardia with or without pre-excitation; frequent (5 or more/minute) and multiformal ventricular extrasystoles; ventricular tachycardia; and asymptomatic pre-excitation shown by electrophysiological examination as not being free from the risk of paroxysmal tachycardia or atrial fibrillation.

2: The following conditions might be acceptable after further evaluation: first and second degree atrioventricular block; frequent (5 or more/minute) atrial extrasystoles; infrequent unifocal ventricular extrasystoles; complete or incomplete right bundle-branch block; and atrioventricular dissociation associated with organic heart disease.

The detection of such lesions demands temporary withdrawal of licence before cardiological opinion and confirmation by the Panel. The use of continuous tape monitoring of the electrocardiogram for the detection of arrhythmias and other investigations such as electrophysiological studies may be advised.

3: The following conditions are acceptable: wandering pacemakers; isolated atrial extrasystoles; and intermittent junctional rhythms in the absence of sinoatrial disease.

E: VALVAR HEART DISEASE
Development of valvar heart disease since the previous examination excludes relicensing. Thus, development of a murmur indicates the need for investigation. This involves temporary loss of licence until the situation has been clarified. Development of rheumatic valvar disease disqualifies permanently.

F: PERICARDIAL DISEASE
Active pericardial disease (Section II, E) precludes the pilot from flying but in certain cases, such as acute virus pericarditis, this would only lead to temporary loss of licence provided attacks were not persistent or recurrent and there was no residual disease requiring surgical treatment which would lead to permanent loss of licence.

G: CONGENITAL HEART DISEASE
Theoretically all cases should have been detected at entry. If by chance congenital heart disease is detected at a subsequent examination the pilot should be referred for a cardiological opinion and to the Advisory Panel (see Section IV).

H: CARDIAC SURGERY
1. Any cardiac procedure other than those noted in Section II, H, indicates permanent withdrawal of licence; in particular, coronary artery bypass grafting, arterial grafting elsewhere, and prosthetic material of any type in the heart or arteries.

2. The insertion of a permanent pacemaker also disqualifies.
I: PERIPHERAL VASCULAR DISEASE
1. Peripheral arterial disease
Identification of peripheral arterial disease precludes relicensing because of the frequent association with coronary artery disease. Since the diagnosis of peripheral vascular disease can be difficult it should be confirmed by a consultant. On no account should a licence be permanently withdrawn without the advice of the Panel.

2. Peripheral venous disease
Peripheral venous disease should not preclude relicensing unless severe or associated with pulmonary embolism or pulmonary hypertension. Varicose veins or venous insufficiency below the knee need not exclude the pilot provided no evidence of pulmonary embolism or pulmonary hypertension exists. Diagnosis or suspicion of thrombophlebitis or a deep venous thrombosis in the leg requires immediate withdrawal of licence until at least 1 month after discontinuing anticoagulant therapy. No pilot should fly while on anticoagulant therapy. Any suspicion of pulmonary embolism requires referral for consultant advice.

J: CEREBROVASCULAR DISEASE
On suspicion of cerebrovascular disease the licence should be temporarily withdrawn and the pilot referred to an appropriate consultant. The following examples are conditions which preclude relicensing: cerebral, cerebellar or brain-stem infarction, transient ischaemic attack, amaurosis fugax, labyrinthine artery occlusion, internal carotid stenosis, hypertensive encephalopathy, recurrent vertigo, intracerebral or subarachnoid haemorrhage, arterial venous malformations (Dalen et al., 1975). This list is not exhaustive.

K: PULMONARY HEART DISEASE
The development of heart disease secondary to lung disease requires temporary withdrawal of licence and investigation.

L: MEDICINES AND FLYING
On no account should aircrew take any medicine currently dispensed on prescription for a cardiac condition without the prior knowledge and consent of the appropriate medical authority (CAA Aeromedical Information Circular 14, 1974).

M: ALCOHOL AND FLYING
The official requirements regarding alcohol consumption and flying are laid down in CAA Aeromedical Information Circular 122 (1973).

Undue consumption of alcohol must be avoided to prevent progressive impairment of judgement and deterioration of cardiovascular function. The first evidence of alcoholic heart disease may be an arrhythmia, such as atrial fibrillation. Prolonged high consumption of alcohol can have an unfavourable effect on blood lipids and cause heart failure secondary to cardiomyopathy (Demakis et al., 1974).

IV: The Advisory Panel on Cardiovascular Disease (Fig.)
The purpose of the Panel is to ensure that no licence is renewed or permanently withdrawn (on cardiovascular grounds) without the assessment of a group of experts.

The Advisory Panel should be an independent body that reports to the CAA as the licensing authority. The recommendations of the Panel must be unanimous. The decision rests with the licensing authority.

The administration of the Panel should be such that it can be convened centrally and at short notice. The exact administrative arrangements would have to be agreed with the various organisations involved.

A: COMPOSITION OF THE ADVISORY CARDIAC PANEL
1. Three cardiologists, one of whom should act as chairman, drawn from a panel of 12 cardiologists nominated by the Council of the British Cardiac Society which will ensure that none of the members has an official affiliation with any airline.
2. One representative of the British Airline Pilots Association (BALPA), medical or non-medical, to be selected by that organisation.

B: PURPOSE OF THE PANEL
1. To assess pilots who have developed equivocal symptoms or signs of cardiovascular disease and have either been referred by a cardiologist or opt to consult the Panel direct with a view to other tests such as coronary arteriography.
2. To assess pilots who have equivocal or abnormal electrocardiograms.
3. To advise on endorsements (waivers) for certain types of cardiovascular disorder which may permit relicensing under supervision and for the cancellation of an endorsement at the appropriate time.
4. To act as a ‘court of appeal’ when a pilot feels his licence has been unjustly withdrawn.

C: APPLICATION OF ENDORSEMENTS (WAIVERS)
An endorsement is a decision which allows a pilot, who has a minor disability or who is under specified treatment, to fly an aircraft.
Notwithstanding that the pilot fails to meet some particular medical standard, he may be issued with a medical certificate for a licence because it is deemed safe for him to fly under certain controlled conditions.

An endorsement should be entirely individual so that the terms may be appropriate to the circumstances. For example, the pilot might be confined to flying with a co-pilot, to daylight operations, to short haul operations, or to a particular type of aircraft. The following represent examples of possible medical criteria for an endorsement: (1) thiazide treatment for mild hypertension; (2) beta-adrenergic blocking drugs for mild hypertension; (3) equivocal resting electrocardiogram with negative exercise test; (4) uncomplicated persistent ductus arteriosus which, having escaped detection on entry, has subsequently been treated surgically.

The issue of an endorsement (waiver) should be granted only on the advice of the Panel.

V: Advice to pilots on maintenance of health
It is important that pilots understand that they have an active role to play in the maintenance of their health and that attention to health reduces the risks of loss of licence. In order to co-operate they must appreciate the known risk factors.

In Appendix 2 the Working Party has summarised its recommendations which should be given to all trainees and qualified pilots.

VI: Standards of medical examination and instrumentation
Maintenance of high standards in all phases of the medical examination is essential.

Ideally methods of examination should be standardised so that valid comparisons can be made from one examination to another.

The detection of subtle or early manifestations of cardiovascular disease and the wide variation of physiological signs demand experience and expertise consistent with specialist training.

The present system of centralised initial examination meets these requirements. But the current practice for reassessment of pilots, which is in the hands of 80 or more practitioners throughout the country, militates against the uniform high standards implicit in these recommendations.

Individual aspects of the examination are considered separately.

A: PHYSICAL EXAMINATION
To meet these criteria it is recommended that all physical examinations should be conducted by a limited number of examiners who hold a higher qualification in general internal medicine.

B: MEASUREMENT OF BLOOD PRESSURE
1. Method of recording
A well-maintained mercury sphygmomanometer is recommended (Conceição et al., 1976). The recording should be made in the semirecumbent position (45°), with the arm supported midway between the chest and the horizontal.

2. Method of reading
There is confusion with the reading of diastolic blood pressure (Gordon et al., 1976). There is no general agreement as to whether phase 4 (muffling of sounds) or phase 5 (disappearance of sounds) should be used (Short, 1976). For example, in the United States and the United Kingdom there has been alternating agreement and disagreement since 1939 (Medical Research Council, 1977). The World Health Organisation advocates the recording of readings at both phases. Recent American epidemiological studies have used phase 5 and this also has been accepted for a recent Medical Research Council co-operative study on the treatment of mild hypertension.

After careful consideration it is recommended that phase 5 should be used for all examinations but since phase 5 is not always precise both phases 4 and 5 should be recorded in the following way: 145/85-80 mmHg.

If the blood pressure is borderline two readings should be taken at 10-minute intervals on two separate days, that is 4 readings. One reading of casual blood pressure should never be assumed to indicate hypertension. Where apparent mild hypertension is detected, mean pressures should be obtained from frequent serial readings.

The Hawksley sphygmomanometer (zeromuddler) (Garrow, 1963) can be used in addition to the conventional sphygmomanometer during special assessment examinations.

The Working Party accept the Federal Aviation Authority's age-related recommendations (Gifford et al., 1975):

<table>
<thead>
<tr>
<th>Age group (y)</th>
<th>Not adjusted</th>
<th>Adjusted*</th>
</tr>
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<tbody>
<tr>
<td>20-29</td>
<td>140/88 mmHg</td>
<td>—</td>
</tr>
<tr>
<td>30-39</td>
<td>145/92 mmHg</td>
<td>155/98 mmHg</td>
</tr>
<tr>
<td>40-49</td>
<td>155/96 mmHg</td>
<td>165/100 mmHg</td>
</tr>
<tr>
<td>50 and over</td>
<td>160/98 mmHg</td>
<td>170/100 mmHg</td>
</tr>
</tbody>
</table>

*For an applicant at least 30 years of age whose reclining blood pressure is more than the maximal reading for his age and whose cardiac and kidney status, after complete cardiovascular examination, is found to be normal.
C: EXAMINATION OF URINE
Routine examination of the urine should be by accepted methods. The detection of proteinuria, glycosuria, or other abnormality requires confirmation and further assessment. If an abnormality is confirmed, temporary withdrawal of licence is indicated pending clarification.

D: CHEST RADIOGRAPHS
A standard 6-foot posteroanterior chest radiograph with lateral view is required. Oblique views are not acceptable. Any apparent cardiac enlargement, intracardiac calcification, enlargement of great vessels, or abnormality of the pulmonary vasculature requires referral for further advice.

E: ELECTROCARDIOGRAPHY
1. Resting electrocardiogram
A satisfactory routine 12 lead electrocardiogram is required with a minimum of 3 PQRST complexes in each lead, correct calibration, and a stable baseline free from 50 cycle interference. It is essential that tracings are recorded on machines that meet internationally acceptable standards such as those of the American Heart Association. Though not all the standards set by the Association are essential, they do however provide the best available guide. The draft recommendations of the International Electro-Technical Commission are equally acceptable but less well known.

Either single or multichannel machines may be used if they meet the necessary standards. Because the range of acceptable machines may change, an up to date list should be maintained by the CAA and circulated to all examiners. Among machines that currently meet the required standards are: the Hewlett Packard 1500B series, the Cambridge VS4 and Transrite-5, and Elema Minor C.

The resting electrocardiogram must be judged to be within acceptable normal limits by experts working in the central establishment as at present (Surawicz et al., 1975) (Section III, D).

The competence of medical practitioners in recording and recognising major abnormalities in the electrocardiogram, and in maintaining their equipment should be reviewed regularly. Sample tracings, including standardised calibrations should be submitted to the medical department of the CAA at yearly intervals. A uniform method for mounting electrocardiograms would be an advantage.

The present system by which all electrocardiograms are read centrally is commended in order to minimise delays, particularly where the normality of the tracing is being questioned and the pilot has been temporarily grounded.

2. Exercise testing
A submaximal treadmill test should be used for electrocardiographic effort testing. The procedure advised in the ‘Bethesda Report’ based on pre-determined end points of predicted age-related heart rate, ventricular arrhythmia, or limiting symptoms is recommended (Ellestad et al., 1975). Responses of heart rate and blood pressure should be measured in addition to the electrocardiogram (Sheffield et al., 1977). Exercise testing should be carried out only in those centres where initial examinations before training are performed in order to maintain a standard technique for purposes of comparison (Section II). Additional centres may subsequently be approved by the Panel. For details of method, equipment, procedure, and interpretation, the criteria of the ‘Bethesda Report’ are recommended (Ellestad et al., 1975).

F: CORONARY ARTERIOGRAPHY
Methods, assessment, and interpretation are given in the ‘Bethesda Report’ (Ellestad et al., 1975). Coronary arteriography should only be carried out at appropriate centres (Adams et al., 1973; Emanuel, 1975).

G: ECHOCARDIOGRAPHY
When advised by a cardiologist or the Panel, an ‘M’ Mode scan echocardiogram using a strip chart recorder should be used.

H: BLOOD CHOLESTEROL AND GLUCOSE
Blood cholesterol and glucose should be estimated by established techniques after a 12-hour fast. Equivocal readings allowing for age demand two additional estimations.

1. Serum cholesterol—initial examination
For the initial examination before training, cholesterol levels of above 7.5 mmol/l (288 mg/dl) up to age 25 years and 8.5 mmol/l (327 mg/dl) between the ages of 25 and 35 years that have been confirmed by at least one other examination should lead to rejection.

2. Serum cholesterol—reassessment examination
For the reassessment examination of trained pilots cholesterol levels above: 6.5 mmol/l (250 mg/dl) if multiple risk factors are present, 7.5 mmol/l (288 mg/dl) up to age 25 years, and 8.5 mmol/l (327 mg/dl) from 25 to 35 years, should be repeated and the mean results of three examinations taken (see Section III).

3. Fasting blood glucose
Fasting blood glucose in excess of 5 mmol/l (90 mg/
The cardiovascular fitness of airline pilots

100 ml) should lead to further assessment including glucose tolerance testing.

VII: Subjects for research

There are a number of areas where further information would be helpful. The following are recommended for consideration.

A: ENVIRONMENT; PHYSIOLOGICAL AND BIOCHEMICAL CHANGES IN FLIGHT

Little is known about the effect of flight schedules involving time zone changes on the physiological, biochemical, and circadian rhythms of aircrew (Carruthers et al., 1976). An example of altered environment in flight is the low humidity in the aircraft which tends to dry the mucous membranes of the pharynx. This leads to a sensation of thirst and increased secretion of antidiuretic hormones. Subsequently the individual tends to drink more. There is some uncertainty as to whether urine output is increased or decreased. A diuresis may be observed after long flights though the response of the kidney to circadian rhythm may confuse the issue.

B: USE OF DRUGS BY AIRCREW

1. Hypnotics and sedatives

Use of hypnotics by aircrew involves three problems: effectiveness, residual sequelae, and circadian activity. The management of disturbed sleep for aircrew needs careful consideration of hours of duty, and advice is needed especially for those aged 40 and over. So far the ideal hypnotic is not available. Only hypnotics with minimal residual effects on the central nervous system should be permitted. For instance, nitrazepam, which can have prolonged effects on performance, should never be used. Diazepam, which has a half life of 2 to 3 hours, may occasionally be employed (though its metabolites have a half life of 2 to 3 days). It may be argued that it is better for the pilot to have a good night's sleep with a sedative that will be wearing off when he begins the flight than to start the flight after a sleepless night with the prospect of steadily increasing fatigue.

2. Beta-adrenergic antagonists

These drugs present a problem almost as complex as hypnotics. Their action on the central nervous system needs further assessment, for little is known about their possible adverse effects on judgement and the critical faculties. It would be unwise to deny aircrew with mild hypertension the benefits of these drugs, but it would be still more unwise to give unqualified approval of their use. The employment of endorsements (waivers) offers a possible interim solution assuming that adequate supervision of the pilots concerned can be ensured.

C: EFFECTS OF AUTONOMIC NERVOUS SYSTEM ON ELECTROCARDIOGRAM

Impressive evidence is accumulating that autonomic influences can affect the electrocardiogram so that it may simulate coronary artery disease. This has considerable practical importance for pilots, and further research is needed to clarify the issue. In particular the effects of beta-adrenergic blockade in separating the ST and T wave changes of autonomic imbalance from those of coronary heart disease need further study, together with the possible camouflaging of ischaemic changes.

D: SMOKING AND CARBON MONOXIDE

Heavy cigarette smoking can lead to carboxyhaemoglobinics of up to 15 to 20 per cent (Astrup, 1972). It is important to know what effects this could have on pilots as such levels have been claimed to impair psychomotor function (Goldsmith and Landaw, 1968) but this is not universally agreed (Lawther, 1975). It is recommended that further studies be carried out on the effect of such levels of carboxyhaemoglobin on performance particularly at low atmospheric pressure.

E: FOLLOW-UP STUDIES

Pilots who have lost their licences for medical reasons should be followed closely to provide essential information on the validity of current screening methods.

Mild hypertension that would usually be treated does not commonly lead to loss of licence because of the endorsement (waiver) system. Follow-up of this group would be particularly important in the light of the impending results of the Medical Research Council Study on the treatment of mild hypertension.

Follow-up of all pilots flying with an endorsement (waiver) should be arranged in order to determine the value and limitation of this system.

VIII: Recommendations

The Working Party recommends that:

1. The medical examination before acceptance for training should be stringent. It is imperative to detect not only those who have disease at the time of the examination but also those who are at increased risk of developing cardiovascular disease during the next 30 to 35 years.

2. Regular medical examination of pilots is considered essential. Standards of examination and instrumentation should be the best available in order
to reduce the errors both of over diagnosis and omission.

3. Current methods of medical examination provide satisfactory screening. More detailed investigation for detection of cardiovascular disease could marginally increase the flight safety but only at the risk of withdrawing licences from fit pilots.

4. Efforts should be made to ensure that medical examinations are conducted with maximum efficiency, discretion, and speed.

5. Excessive investigations and serial testing procedures, particularly where interpretation of results is equivocal, should be avoided. Attention to these points (items 3, 4, and 5) would help to relieve much of the anxiety and frustration experienced by pilots who at times feel their career depends on the result of a single investigation, the interpretation of which may be a matter of dispute even among experts.

6. Health standards required for single pilot operations should not be lower than those for multi-pilot operations.

7. Medical examinations of trained pilots should be conducted by doctors (preferably of consultant status) who have higher qualifications in general internal medicine. In order to ensure uniformity and satisfactory standards, the number of medical examiners should be restricted and centralisation encouraged.

8. The frequency and the scope of cardiovascular examinations should be as follows:

<table>
<thead>
<tr>
<th>Age</th>
<th>Frequency of examination</th>
<th>To include:</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-29 years</td>
<td>Every 5 years</td>
<td>Record of weight</td>
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<tr>
<td></td>
<td></td>
<td>Blood pressure</td>
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<tr>
<td></td>
<td></td>
<td>Electrocardiogram</td>
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<tr>
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<td></td>
<td>Chest radiograph</td>
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<td></td>
<td></td>
<td>Examination of urine</td>
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<tr>
<td></td>
<td></td>
<td>Blood count and sedimentation rate</td>
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<tr>
<td></td>
<td></td>
<td>Blood cholesterol*</td>
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<tr>
<td></td>
<td></td>
<td>Blood glucose*</td>
</tr>
<tr>
<td>30-39 years</td>
<td>Every 2 years</td>
<td></td>
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<tr>
<td>40-49 years</td>
<td>Annually</td>
<td></td>
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<tr>
<td>50 years and over</td>
<td>Every 6 months</td>
<td></td>
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</tbody>
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NB (*) = 2 yearly after 40 years.

9. The routine medical examination of trained pilots should have three objectives: first, to ensure the safety of the pilot, his crew, and passengers; second, to detect the early signs of ill health so that treatment can be instituted, the prognosis improved, and the licence retained or restored whenever possible; and third, to give advice in simple terms on the maintenance of their health in order to keep pilots ‘fit and flying’ rather than ‘grumbling and grounded’.

10. The procedure outlined in the Figure should be followed in the event of the development of symptoms or signs of cardiovascular disease or abnormality on the electrocardiogram.

11. Electrocardiographs must be maintained meticulously and serviced regularly to ensure good quality tracings.

12. Effort testing should form part of the initial examination before acceptance for training but should not be performed as a routine in reassessment medical examinations.

13. Coronary arteriography should not be performed as a routine in the event of an electrocardiographic abnormality, symptoms, or positive exercise test. It should be undertaken only on the advice of a cardiologist or the Advisory Panel.

14. Any change of employing authority requires a complete cardiovascular examination.

15. An independent cardiovascular advisory panel should be available to assess difficult problems and to act in an appeal capacity, reporting their findings to the CAA.

16. Discrete use of the endorsement (waiver) system by the Panel should be encouraged in order to permit pilots who have certain minor cardiovascular disorders to retain their licences subject to appropriate limitations of flying duties. In these circumstances medical management and supervision in addition to regular reviews are essential.

17. Further research should be carried out in certain subjects preferably by the aeronautical establishments as suggested in the text of the Report.

In conclusion the Working Party emphasises that this Report is the result of many meetings at which evidence was taken from cardiologists, airline medical officers, BALPA representatives, service medical officers, and others. The recommendations of the Working Party will need modification in the light of future developments in cardiovascular disease. Thus the Report should be reviewed in not more than 5 years by the Royal College of Physicians and British Cardiac Society and thereafter as recommended.

Appendix 1

CHOLESTEROL

The validity of the serum lipid levels as a predictor of coronary heart disease is uncertain. However, the evidence from the three epidemiological studies comprising the Co-operative Pooling Project (Inter Society Commission for Heart Disease Resources, 1970) indicates that hypercholesterolaemia per se in young adults is associated subsequently with a high rate of coronary heart disease.

While it is not yet certain which serum lipid to measure, serum cholesterol concentrations are by
The cardiovascular fitness of airline pilots

far the easiest and most widely available. The most valuable reference is the recent analysis of the Framingham Study showing ‘likelihood ratios’ of various serum lipid fractions as predictors of coronary heart disease (Gordon et al., 1976). Low density lipoproteins (LDL) or LDL cholesterol are more exact means of expressing serum cholesterol concentrations but the precipitation techniques (or ultracentrifuge) are not generally available. High density lipoproteins (HDL) and HDL cholesterol require a heparin-manganese precipitation technique (or ultracentrifuge) and again these are not widely available.

Pronounced increase in serum cholesterol in young adults may indicate a familial risk. In these circumstances it is a good predictor of premature coronary artery disease.

With these considerations in mind the Working Party believes that the wisest course would be to include some measure of serum cholesterol (not other lipids) in order to screen young persons hoping to become airline pilots. The introduction of lipoprotein fractionation into screening could lead to even more difficulties and is not justified because of insufficient evidence about the predictive value of HDL in relation to coronary heart disease. Low density lipoprotein correlates closely enough with the total serum cholesterol at the level of 6.5 mmol/l and above.

Appendix 2

ADVICE TO AIRCREW ON MAINTENANCE OF CARDIOVASCULAR HEALTH

Coronary artery disease and high blood pressure (hypertension) are the most important cardiovascular diseases which threaten aircrew.

Coronary artery disease is a narrowing of the heart arteries causing reduced flow of blood to the heart muscle. This can cause heart attacks which may take the form of chest pain (angina), coronary thrombosis, myocardial infarction, or sudden death. The causes of coronary artery disease are not fully understood though several risk factors have been identified.

A heart attack can develop without warning in a person who appears to be in perfect health. In the case of the airline pilot, this may lead to the loss of licence possibly at the peak of his career, and very occasionally may cause a serious accident.

Certain factors such as raised blood pressure, obesity, and cigarette smoking increase the risk of heart attacks. Most risk factors can either be avoided or controlled. As there is evidence that preventive measures may improve a person’s chances of remaining fit until the normal age of retirement, such measures should provide powerful motivation for the pilot.

The comments that follow are a guide to the maintenance of general health and are particularly directed towards the prevention of coronary artery disease.

1. Rest and exercise

Adequate rest and exercise are important for good health. However, the demands of an airline pilot’s life, the complex interactions between his biological clock and the rigid airline schedules, coupled with multiple time zone changes, may result in adverse situations where either the pilot is deprived of sleep, or he wishes to sleep and is unable to do so. Most pilots develop their own techniques for handling such situations, but in cases where the problems become troublesome the airline medical adviser should be consulted. On no account should aircrew take any medical preparation on their own initiative without such advice.

Physical exercise promotes well-being and may have long-term value in preventing heart disease. Pilots who inevitably have to sit for long periods should take all the exercise they can when off duty though it is appreciated that their irregular hours may at times make this difficult. Walking is the most important natural exercise and should be undertaken whenever possible. Pilots who have kept up the practice of running, gymnastics, squash, and tennis should be encouraged to continue.

2. Obesity

Obesity can impair general health and appears to predispose towards heart disease. This is reflected in the higher premiums demanded by Life Insurance Companies for those who are overweight. Dietary restriction which may have to be rigorous at times is, therefore, advised. The main foods to restrict when dieting are fats and carbohydrates. Optimum weight can be obtained from weight tables or from the doctor. For most men this is the weight they were in their early 20’s, a time of peak physical fitness.

3. Diet

The amount of fat eaten in the United Kingdom has steadily risen during the past 30 years and it is known that populations with a high fat content in their diet tend to have a higher level of cholesterol in the blood than populations with a low fat intake.

Although the exact relation between blood cholesterol levels and the risk of coronary heart disease is not fully understood, it is reasonable to exercise discretion in the intake of fats, especially saturated fats, that is those from animal sources or hardened fats of vegetable or marine origins. A reduction of saturated fats in the diet is made more
pleasant by a partial substitution with polyunsaturated fats such as corn oil. The fat in the diet comes mainly from meat, dairy products, margarine, cooking fats, cakes, and pastries. A small reduction in all these foods could lead to a considerable reduction in total fat intake and will help to maintain ideal body weight.

4. Cigarette smoking
Cigarette smoking damages both the heart and the lungs. There is as yet no firm evidence that pipe and cigars have the same harmful effect, but cigarette smokers who change to pipe or cigars continue to inhale and may not, therefore, reduce the risk. Cigarette smokers are twice as likely to develop coronary artery disease as non-smokers. Heavy smokers, 25 or more/day, under the age of 45 years have a much higher risk of a coronary attack compared with non-smokers. The long-term risk of angina or a coronary attack is reduced in those who stop smoking and physical fitness generally is improved. The risk of a coronary attack rapidly falls and after approximately 10 years, approaches that of life-long non-smokers. It is therefore always worth giving up but better never to begin.

Constituents in tobacco smoke which affect the heart are nicotine and carbon monoxide. Nicotine makes the heart irritable. Carbon monoxide reduces the transport of oxygen to the tissues.

5. Alcohol
The amount of alcohol consumed is important. It has a high calorie value and regular heavy consumption is likely to lead to obesity. This is particularly true of beer, spirits, and sweet fortified wines; a light dry wine is most suitable from the point of view of caloric content. Alcohol in excess should be avoided for it not only impairs judgement but can affect the heart in some people.

6. Advice to senior pilots
A pilot who may be overweight and have smoked for many years may wonder if a change in these habits is still likely to be of benefit. There is good evidence that controlling obesity, stopping smoking, and undertaking a reasonable amount of exercise can not only increase his feeling of well-being but can also improve his chances of remaining fit.

Appendix 3

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The Working Party is grateful to all who have given evidence. The airlines and armed services medical officers were generous with their time and ideas, and the contributions of the British Airline Pilots Association (BALPA) representatives, outlining the views and problems of the pilot, contributed much to the Working Party’s understanding of their subject.

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