

# Pilot Fatigue

*Dr. Ian Perry is a well known expert on aviation medicine. This article is the first of a two part series. Fatigue is a word that can mean many things to many people. It is a dirty word to certain people, a forbidden word, and one that cannot be spoken. Why? It is a word that when used in a diagnostic form, in an aviation scenario means a criticism of management. Anyone who gets into a "fatigued state", can only have got there by someone's mismanagement, someone working a "Roster from Hell", someone being made to fly through impossible days, nights or time zones. Dr Perry writes :*

**W**hat then is this word that cannot be spoken, we must define and understand what "it" is that comes between man and his machine.

I want us to be able to talk openly and freely. I want pilots to be able to discuss the subject without fear of management retribution. Some pilots have been told not to discuss fatigue with me, nor to tell flight ops inspectors about the problems of fatigue they experience.

Why all this fuss about one word, will it be you who pays out when the burning heap on the runway is put down to a fatigue accident. Remember what prompted the original Bader enquiry. All the pilots asleep on the flight deck. Well, it is happening again even more today. Pilots are flying further, longer, higher and in two's. Few aircraft have three crewmembers anymore.

ETOPS, 777, no agreement on FTL etc., means longer duty days, more time zones crossed, more hours flown a year. When Bader first looked at pilot's activities the annual hours flown was around 4-500. This is in the area of commercial airline operations. Today the Companies want every hour they can get so we are now up and on the legal stops in most cases, yes up to 900. Some companies, not necessarily in the UK, will not admit that they are over the limit. The flying hours are laundered. Man however can only tolerate so much. This brief paper is as much about "FTL" as it is about "Fatigue". The two of course go hand in hand. So what then is this word I want you never to forget. Let us define it, look at it scientifically, and get rid of the emotion and the hype.

I wrote my first paper on Pilot Fatigue in 1972. I then had the privilege to chair a NATO AGARD working group on Pilot Fatigue in 1973/4. There were only about 20 useful references on the subject available at that time.

In the NASA AME's Field Studies on Fatigue published last year in September, the number of useful references after 25 years had only gone up to about 50, and because they were Americans, they forgot about some of us over here. So I can give you about 60 useful references today. The basic subject however has not changed, so let us find a definition.

## A DEFINITION OF PILOT FATIGUE

In the biological sciences the word "fatigue" is used as a global concept to denote changes in bodily physiology a decrease in work output (either quantity or quality) and characteristic subjective feelings of tiredness or disinclination to work all of which are associated with a continuous activity. Bartley and Chute (1947) were first to state clearly these three components of "fatigue". They suggested the following nomenclature:

(a) Impairment: This is used to refer to specific tissue conditions, i.e. biochemical or physiological changes, associated with continued work.

(b) Work Output: A change, usually a decrement, in the quantity or quality of work, either physical or mental (often called "skill fatigue").

(c) Fatigue: The subjective feelings resulting from continued activity; this activity can be either mental or physical.

Workers in this age now generally accept this analysis of the global concept of fatigue into three components. Dr David Fryer (1971) in defining fatigue updating Bartley and Chutes analysis said that fatigue is a term which is difficult to define, but which may have three specific connotations:

(i) A decrease in the activity of a sense organ, nerve or muscle due to continued recent stimulation and activity.

(ii) Diminished ability to work, either physical or mental, as physiological or psychological consequence of previous and recent work.

(iii) A feeling of Weariness; a specific bodily feeling, due either to physiological exhaustion, boredom, loss of motivation or emotional factors.

Neither I, nor anyone else today can better this statement. In many statements all three effects have been clearly demonstrated but it is possible to find examples of situations where there is a change in the reported subjective state without an obvious accompanying change in work output. Similarly, in many field and laboratory situations a change in work output has been shown without subjects reporting any of the usual symptoms of fatigue.

Research has found that the subjective feelings of fatigue can be analysed into three distinct categories. Wolf (1967) defined these three factors as:

(a) Nervous Fatigue: This is characterised by such words tense, jumpy, keyed-up, and irritable. It appears to be a condition resulting from the continued activity of a well-motivated individual.

(b) Drowsy Fatigue: This is characterised by such words are tired, feel asleep, mentally sluggish. The drowsy condition appears to be a state of low motivation following a period of exertion.

(c) Exhaustion Fatigue. This is characterised by such words as physically tired, no energy, and aching muscles. It appears to be a consequence of continued physical exertion.

The relationship of these three subjective to motivation and to characteristics of task are shown in Table I below:

**TABLE I**

Summary of Theoretical Argument Concerning Three Factors of Subjective Fatigue as a Product of Motivation and Task Dimensions

Motivation	Task	
	Sedentary	Non-Sedentary
Low	Drowsy	
High	Nervous	Exhaustion

(From Wolf, 1967)

It has been said earlier that there may not be necessarily a decrease in work output with a simultaneous increase in the subjective feelings of fatigue. One possible explanation for this is that when one normally measures work output one does not assess the cost to the operator achieving a given level of performance. With continued activity it may well be that the operator needs to exert extra effort to maintain an acceptable level of performance, that is the "biological cost" of that level of performance increase. The importance of this concept is that as the effort or cost required to produce a given level of performance rises so the ability of the operator to cope with extra task demands is reduced. Hence should a fatigued pilot be presented with an emergency situation his/her "spare mental capacity" may be inadequate to cope fully with the demands of the situation.

Pilot fatigue can be defined therefore as those changes that affect an individual consequent upon continued activity. The changes are typically a deterioration in the pilots performance, or an increased cost or effort for a given level of performance, and characteristic subjective feelings which may include irritability, tenseness, mental sluggishness, tiredness and lack of energy. The exact pattern of effects will depend on whether the task is physical or mental and on the motivation of the pilot.

There are two levels of pilot fatigue, namely, acute and chronic. Acute fatigue is primarily induced by excessive mental and/or physical activity and its symptoms are related to specific factors in the work situation. It is normally dissipated by a period of sleep or of rest and recreation. However, if it is not relieved, such fatigue is prolonged from day to day and can lead eventually to a state of chronic fatigue. The term "nervous breakdown" is a state of chronic fatigue. For an individual suffering from chronic fatigue, the sensation of fatigue is intense and characteristically persists into the non-work period and not infrequently is present before work commences despite a period of sleep (Grandjean and Kogi, 1971). The following signs can be observed in affected persons:

- (a) A general weakness in drive and loss of initiative.
- (b) A tendency to depression associated with unmotivated worries.
- (c) Increased irritability and intolerance occasionally with unsociable behaviour.

Important tasks get relegated and unimportant problems become serious.

### 3. EFFECTS OF FATIGUE ON FLYING EFFICIENCY

To fly an effective, accurate and safe mission the aircrew should be well trained, alert and fit, both mentally and physically. Experimental studies with pilots in a flight simulator led people to develop the concept of skill fatigue. The main changes in performance due to skill fatigue can be summarised as:

- (a) A deterioration in the accuracy of timing of the components of the skilled task with a consequent decrease in the level of skill.
- (b) The pilot accepts lower standards of accuracy and performance on his own part without an appreciation that he is doing so.
- (c) A disintegration of the perceptual field so that the readings from individual instruments are no longer integrated into an overall pattern.
- (d) A narrowing of the pilots' range of attention so that some instruments or tasks (particularly the peripheral ones) are forgotten or ignored.

In World War II fatigued bomber pilots often flew at the correct height and speed but at strange angles. The overall effect of these changes is that the pilots' normal skill breaks down; he deals with the components of the skill and appears to lose the ability to integrate them into an overall accurate, smooth control task. It will be appreciated that not only is there a demonstrable fall in the level of performance, he takes unnecessary risks with a consequent reduction of safety margins, hence there is an increase in the probability of an incident or accident.

In addition there are likely to be feelings of subjective fatigue which may often take the form of an increased feeling of effort to achieve a given task and a heightened awareness of minor discomforts, aches and pains, not normally noticed. One particular finding from these studies was the sudden increase in errors at the end of flight as if the pilot felt that having accomplished the bulk

of the mission he could relax. My fear for years is that there will be a crash short of the runway or on the threshold.

These fatigue effects, both objective and subjective, apply particularly to an individual suffering from acute fatigue. If the condition becomes chronic other effects appear, particularly changes in the quality of decision making, motivation and morale. These moral effects spread beyond the actual flight situation so they affect the behaviour of both pilot and managers on the ground, particularly in the pre-flight planning stages.

Enquiries and observations show that the problems attributable to fatigue begin to appear after three or more days of continuous flying duties. A common finding was that more risks tended to be taken on the third and subsequent days. The risks taken were for the most part unnecessary.

An obvious common finding today is that where a Company is poorly organised or has crew deficiencies the effects of fatigue on that company effectiveness are more marked. Put an experienced pilot into the rostering department and things change. The "Rosters from Hell" disappear. When that person leaves, back come the problems.

In reviews of both civil and military accidents over the years, a lack of sleep appears to have been a significant contributing factor. One military unit when operating in Vietnam was investigated in some detail when its accident rate rose markedly above others in the same area. The unit concerned was at this time flying some 7,000 hours a month over an eight month period with an increasing accident rate reaching 48 in the month of the enquiry. A similar unit with the same monthly flying hour average and performing similar tasks had an average accident rate of 30. A comparison of the rest/sleep times for the two units show that over a period of three or four days individuals in the high-accident rate unit were fortunate to exceed 3 hours in every 24 hours. It was concluded that the high accident rate was due primarily to pilot fatigue due to the unit having been over-committed on a daily basis together with a continued disregard of the problems associated with fatigue.

As this was the only available detailed combat enquiry, a review of 120 military peacetime accidents in Europe over a 5-year period was made. The information available for study was 70 accident briefs and 50 accident reports. From the information available it was concluded that pilot fatigue was a major causal factor of some 15% of the accidents reviewed.

For the 50 accidents on which a full report was available, it was concluded that in some 20%, aviator fatigue was a major cause of the accident. An accidental observation during this study was that in many accident enquiries, pilot fatigue had not been adequately considered as a possible causal factor.

Pilot fatigue can be expected to affect the efficiency with which operations are conducted. The changes will be demonstrated in both the efficiency and accuracy with which a mission is flown and also in a company's flight safety record. We have to look at this military type of analysis if we are to get any clues as to how to prevent the same problems occurring in continuous air-line operations.

*(To be continued)*



# Pilot Fatigue

*Part 2 of Dr Ian Perry's article highlights some of the causes of pilot fatigue. 25 years on, NASA research has supported Dr Perry's own work on the subject. Perhaps now is the time to address the problem of "fatigued pilots" working longer hours. Dr. Perry writes:*

## CASUAL FACTORS

The causes or origins of the condition of fatigue are a very complex subject; rather than attempt to give prime cause it is more useful to look at antecedent events which singly or in combination are likely to lead to a condition of fatigue. A list of such factors is given in detail in Annex C. The main headings in such a list are:

1. Immediate or short-term workload.
  - 1.1 Aircraft factors
  - 1.2 Flight operation factors
  - 1.3 Aircrew factors
2. Duty Day Workload
  - 2.1 Duration of work and rest in duty day.
3. Long-term Workload
  - 3.1 Scheduling of work/rest cycles
  - 3.2 Flying duties
  - 3.3 Social and emotional factors
  - 3.4 Morale

The approach adopted in this listing is to sub-divide the total workload imposed on the pilot and to list related factors. Depending on the particular circumstances one of the factors in the list can be of predominant importance. For example, it might well be that the control system of the vehicle imposes considerable demands on the pilot with the result that even quite limited daily flying, which by other aircraft standards would be undemanding, imposes a considerable load on the individual. Alternatively, under high intensity operating conditions, even with an ideally designed vehicle, it is still possible that the disruption of normal work/rest cycles and a cumulative sleep deficit would induce a marked state of fatigue in a few days. In some cases the most important antecedent condition to the onset of fatigue can be found outside of the work situation. Difficult family circumstances, for example, can induce a state of fatigue, which becomes manifested in the work situation.

In any study of pilot fatigue the items presented in the factor list should be considered for relevance to the particular situation being investigated. Repeated surveys of pilots over the years always come up with the same factor list in a similar order of importance.

- (a) Instrument flying.
- (b) Air Traffic problems.
- (c) Limited visibility. Cloud flying at some stage in the flight.
- (d) Sleep.
- (e) Duration of flying duty day.
- (f) Monotony of mission.
- (g) Seating comfort.
- (h) Additional duties unrelated to flying.
- (i) Daily rest.
- (j) Aircraft vibration.

It will be seen that the ten items reported as most contributing to pilot fatigue come from all parts of the factor list thus demonstrating the complexity of the cause of fatigue and the need to consider all of the factors in any particular investigation before deciding on which factors are of particular relevance.

## DIAGNOSIS OF FATIGUE

It is possible to distinguish four different approaches to the

diagnosis of fatigue. These four methods can be listed as follows:

- (a) Identification of signs and symptoms by managers/check-pilots/company medical officers.
- (b) Specialist medical examination by aviation medically trained doctors.
- (c) Objective performance measures, by means of psychological or behavioural tests of the individual in the simulator or in-flight recording of the pilots' control and guidance performance.
- (d) Biochemical measures.

One of the duties of today's managers of aircrew personnel should be to identify individuals who seem to be in or approaching a fatigue condition and to decide how much further work, if any, they should be called upon to undertake. There is good anecdotal evidence that managers who are familiar with the pilots over a period of time and who themselves are familiar with the problems of flying can make a reasonable diagnosis of the fatigue state of their personnel. One of today's problems is that managers will not face up to these problems. This is often a reflection of their own ability or lack of it. There have been a few attempts to develop a systematic procedure for the rating by an observer of human fatigue (see for example Kashiwagi, 1971). As yet no generally accepted standardised procedure exists and the rating depends on the manager's experience of the tasks as well as the people he manages and of an awareness of the fatigue problems.

Any medical examination by manager/doctor/whoever, is basically one that looks for the following signs or symptoms:

- (a) Increased tendency to:
  - (i) Irritability.
  - (ii) Anxiety.
  - (iii) Making uncharacteristic mistakes and errors.
  - (iv) Insomnia.
  - (v) Depression.
  - (vi) Withdrawal from vocational and social undertakings and hobbies.
  - (vii) Over-use of pharmacological crutches, i.e. tobacco, alcohol, tranquillisers, and other drugs
- (b) A decrease in:
  - (i) Attention spans.
  - (ii) Libido.
  - (iii) Recent memory.
  - (iv) Co-operativeness.
  - (v) Acceptance of constructive criticism.
  - (vi) Interest in personal care and appearance.
  - (vii) Gut efficiency, which may result in indigestion, constipation and diarrhoea.

There is no clear cut dividing line between acute and chronic fatigue, hence the signs and symptoms are appropriate to either diagnosis but in the two conditions they will vary in intensity and duration. Chronic fatigue may occur at any time, especially when there is insufficient recovery time between periods of acute fatigue, but its diagnosis may be made more difficult by there being more obvious physical symptoms presented which may mask the underlying condition. In the early stages of chronic fatigue the signs and symptoms may develop insidiously and can, in some cases, resemble a neurotic depression. The diagnosis of fatigue requires that the doctor is aware of the possibility of fatigue occurring and is well acquainted

with everyone in his medical population. Any of the signs or symptoms given above may be the presenting one as well as possibly anorexia and weight loss.

Many Doctors are not well acquainted with the factors, which would lead them to identify fatigue. This finding is illustrated by accident reports in which there is normally inadequate consideration of aircrew fatigue as a contributing cause. The Doctors task is made more difficult by the tendency of well motivated aircrew to hide their fatigue, for example someone having early morning insomnia may appear to be the first person at work everyday in order to cover his early wakening. Often only in chronic fatigue will the individual admit, even to himself, that he is not fit for any more work.

Because of the difficulty of demonstrating beyond doubt the correctness of a diagnosis of fatigue, it may well happen that the Doctor refers his patient for specialist medical examination, perhaps to a neuropsychiatrist. The specialist's problem is to determine whether the list of tendencies given, is indicative of a fatigue state, or whether they are indicants of a psychoneurosis or of a physical disease. The problem of this differential diagnosis is beyond the scope of this paper although it should be said that there is no single unequivocal test for chronic fatigue which will distinguish it from other conditions, which may appear initially to present the same signs and symptoms.

In view of the difficulties in distinguishing pilot fatigue, many writers have pointed out the advantage that would be possessed by an objective test of fatigue. The underlying philosophy in such a suggestion is that a short psychological test of performance would indicate the individual's state of fatigue and, hence, his capacities for further work. Attractive though this idea is, research over the past 40 years has indicated both the practical difficulties of such a search and also the theoretical objections to there being an adequate solution. Although a large number of techniques have been tried, the search for a task which, in a relatively short time, would give a reading of the individual's fatigue state shows little sign of achieving a solution of value in field situations. It has been shown that the results of physical effort are easy to measure but that the effects of continued mental effort, when the physical load is relatively small, are much harder to demonstrate clearly and that predictions on the ability of the individual to continue working at a safe and effective level are very poor. The adaptive tracker developed at the now disappeared RAF Institute of Aviation Medicine was about the nearest we ever had to a test.

A general conclusion is that the best index of an individual's work output is best assessed by careful examination of his performance of his normal duty.

The subjective assessment of fatigue, by requiring the individual to complete a questionnaire, is a well-established technique and appears capable of yielding valid and useful answers. Short, simple questionnaires yield a measure of the individual's report on the three subjective fatigue factors. However, in practical situations, as against research studies, the individual may well not co-operate fully in giving his most honest and accurate answers but rather, depending on his motivation, make himself appear more or less fatigued than in reality he is. Air New Zealand has been developing very sensible practical measures along these lines, taking into account the pilot's motivation, before applying a solution.

The search for a biochemical measure of fatigue, is based on the assumption that people will show a consistent and measurable change in their internal body chemistry which is related to their present state and, hence, can be used as a predictor for the amount of work they can reasonably be expected to do in the near future. Although biochemical measures have shown changes following prolonged physical exertion, the assessment of the effects of mental or perceptual tasks has so far not produced techniques that can be applied readily in the field situation. Research studies have shown that there are wide differences between individuals in their biochemical response to working conditions and also that the response to a given working situation of any one individual, is subject to large variations from one occasion to another, hence any single biochemical measure or any collection of such measures is of little diagnostic value. Some recent work by the Finnish Air Force to be pub-

lished this year shows how this could be developed.

Most research studies that have attempted to relate biochemical changes to fatigue have used small numbers of subjects with repeated measures and with the subject's daily routine under the close observation (and sometimes control) of the research workers. Although many biochemists think that research in this area is very promising, my opinion at the present time is that biochemistry cannot supply a simple technique that could be used by the Doctor to help in the diagnosis of fatigue. Please may the present research on the biochemical studies of the correlates of fatigue be pursued urgently?

## PREVENTATIVE MEASURES

In general the pilots do need to be physically fit and have to develop habits calling for adequate rest, a moderated balanced diet and regular meaningful exercise. This requires adequate off-duty and recreational facilities. The aircrew should also be temperate with regard to the use of alcohol, tobacco and other drugs such as sleeping pills.

## FLIGHT TIME LIMITATIONS

It is inappropriate to consider only the 4 or 5 day period of rosters as being the duration of the high workload situation. In order to maintain effectiveness over a longer time-scale the concept of a "Duty-Day" must be instigated. The most practical duty day in the commercial airline environment is one of 12 hours duration in any period of 24 hours. The 12-hour period of rest and recuperation should be free from any other duty requirement so that all duties should be fitted into the 12-hour duty day. I wrote that 25 years ago, when you analyse it today using any criteria, you come up with the same figure.

The NASA-AME's Fatigue Counter Measure Group comes up with the same figure and they have spent thousands of \$ looking at the problem. The importance of adequate sleep, both in quality and quantity is still considered to be of great importance. I feel very proud to have chaired a group 25 years ago that suggested 12 hours, now NASA AME's say the same, that must surely say something about 12 hours.

A frequent comment during a series of unstructured interviews with senior pilots and managers is that there are problems of management relationships especially under conditions of stress, pilot shortage, aircraft problems, all of which lead to fatigue.

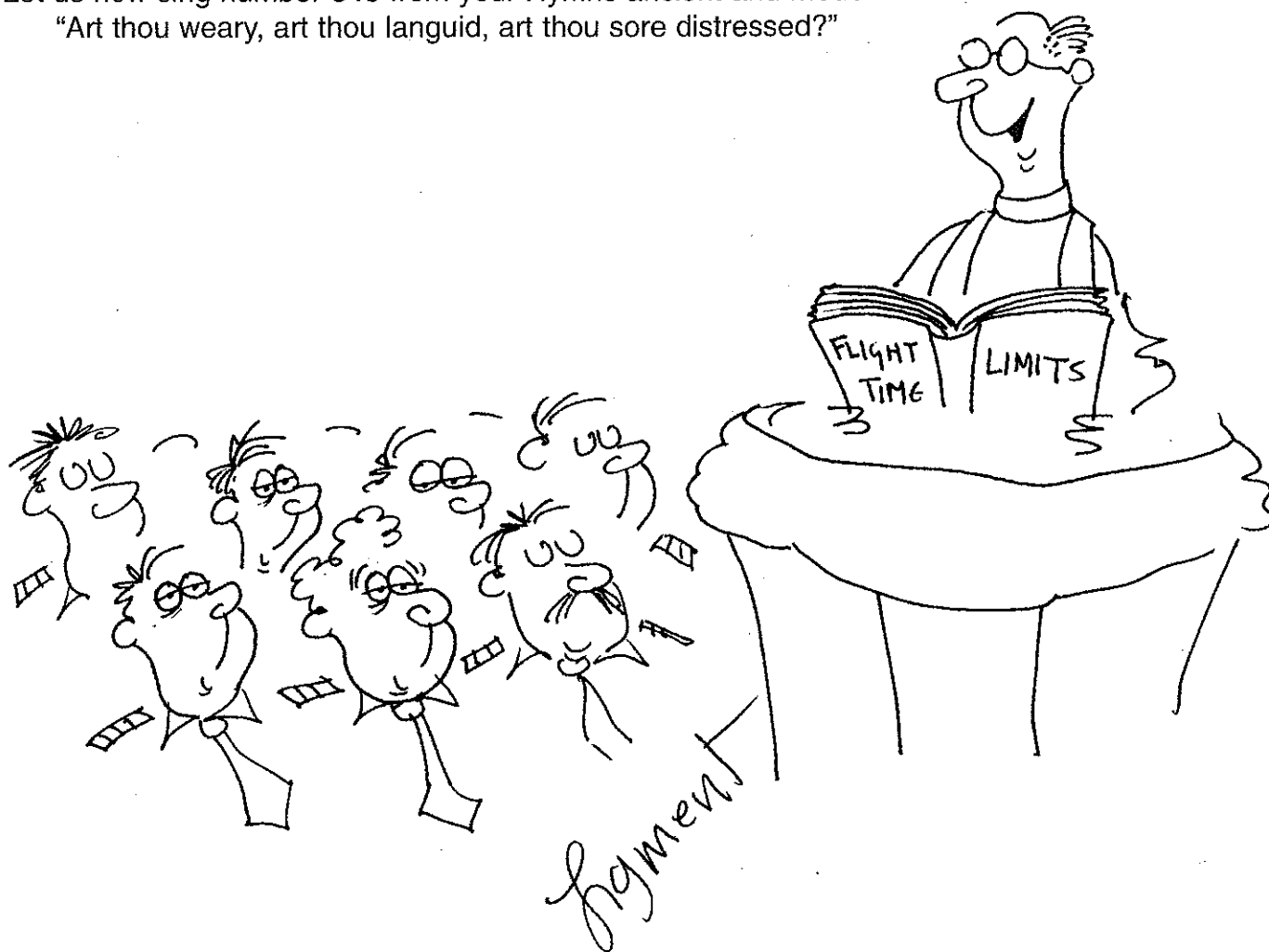
Time-zone changes must be carefully monitored. The monitoring must involve observation of sleep/rest cycles before, during and after such flights. It must be clearly laid down that adequate time is allowed for recuperation and/or adaptation before maximum activity is required if optimum performance is expected. This is not done where computerised rostering is undertaken.

My experience and studies indicate that there is a lack of knowledge on the part of many doctors, managers and other personnel responsible for aircrew, of the identification and assessment of fatigue. There is an urgent need for better training of such personnel in recognising the appropriate signs and symptoms and in their being aware of the need for such early identification, and to make recommendations for treatment and prevention. I consider that if such procedures were in place today, many of the pilots that my colleague's and I would never have been grounded and my concerns would be less.

I have found over the years during reviews of accidents/incidents that aircrew fatigue has received little, if any, consideration as a cause or contributing factor in many accidents/incidents. Such an omission could be prevented by a suitable training programme and also by better guidelines on accident/incident investigation forms. Such changes would be of considerable benefit in future analytical studies of aircrew fatigue as a casual factor in aircraft accidents or incidents.

More work still needs to be done in the design of modern aircraft with the pilot in mind. As man is an integral part of the system, he must be properly designed into the system and be able to operate at maximum efficiency. Specific areas where the man-machine interface has not received sufficient attention are instrument design, cockpit layout, control system design

Let us now sing number 348 from your Hymns ancient and modern  
 "Art thou weary, art thou languid, art thou sore distressed?"



and seat design. That 25-year-old statement still needs to be said again today.

In modern aviation practice one of the best preventative measures for fatigue is a good sensible roster.

With proper management and control many of the preventative measures already discussed may not be necessary. I have found from a series of unstructured interviews that many people considered that the fatigue problems would be prevented by good administrative procedures and man management. When morale is found to be low, so the fatigue and sickness rate goes up.

#### TREATMENT OF FATIGUE

One of the principal efforts of pilots and management should be devoted to the prevention of fatigue. However, should such a policy for any reason not be successful and acute or chronic fatigue be diagnosed, then suitable treatment should be instigated. Apart from the treatment of individuals who are fatigued there should also be an attempt to reduce further incidents of such conditions by, where possible, suitable administrative action.

Treatment of fatigue can be summarised by stating the two main requisites.

- (a) Rest.
- (b) Recuperation.

Some of the more severe cases of skill fatigue and of chronic fatigue may require temporary restriction of flight duties with sedation to ensure adequate sleep and rest. Advising an individual to go on leave or advising the management to require the individual to go on leave is also an acceptable means of treating fatigue, especially chronic fatigue. As a substitute for the individual taking leave and being responsible for his own therapy, he can be advised to take advantage of facilities for rest and recreation locally of which he might not be aware.

Adequate rest requires comfortable, quiet, sleeping facilities with adequate ambient temperature control together with the provision of opportunities for relaxation such as sports and social activities. The therapeutic aims of a rest and recuperation period should be borne in mind so that the individual does not become more fatigued by a hectic, over-indulgent period spent in different surroundings. Some modern short acting sleeping pills may be necessary to reconstitute a regular sleep cycle and pattern.

Treatment of severe chronic fatigue requires the individual to be totally removed from his flying environment. His treatment must be controlled by an aviation medicine trained Doctor. Ground Tours prevent people from becoming over-flown. I see more and more over-flying, with no ground jobs to put people in. As we fly pilots more and more, we must institute and organise some ground slots for these people.

The studies I have made have shown that fatigue is generally agreed to be an important problem in flying operations. Apart from the effects that such a condition has on efficiency, fatigue has also been found to be an important contributory factor in accidents/incidents, both in civil operations and in the combat environment. Many of the major causes of fatigue result from inadequate training on the part of those responsible for the well-being of aircrew. Such training in the causes and effects of fatigue would of themselves lead to the changes of organisation and procedures which would minimise the occurrence of fatigue. We must all get the Air New Zealand habit and be free to discuss the problem.

The recommendations I have made should themselves, if adopted, reduce the importance of pilot fatigue as a problem in general flying. Above all management must open its eyes, address the problem, look for the problem and prevent fatigue, rather than bury it, as they will surely bury some of their pilots and a lot of their passengers.