by ARIS CARPOUSIS, M.D. • AOPA 20847

Alcohol And Flying: MORTAL ENEMIES

The effects of intoxicants on pilots may astonish you—the brain and nervous system have found to be impaired as much as 18 hours after inhalation. Altitude compounds the danger

The role of alcohol as the possible cause of serious accidents in air transportation was brought to the fore in a very striking way on Aug. 8, 1947.

A DC-3 that was being tested with a heavy load of equipment crashed into Bowery Bay near LaGuardia Airport in New York when an engine failed on takeoff. Three of the five crew members—the pilot, copilot, and mechanic—were drowned; the other two survived. The autopsies revealed large quantities of alcohol in the liver of the captain, with smaller yet intoxicating amounts in the bodies of the other two airmen.

The airline contended that the presence of alcohol in the bodies of those who died was caused by the rupture of a 10-gal. alcohol tank used for deicing propellers and windshields, the contents of which were gulped and inhaled before drowning. The tank had been located overhead in the cockpit.

This interpretation seems plausible since the amount of alcohol found in the liver of the captain was so great that he would have been incapacitated before takeoff had he been drinking that heavily. Furthermore, the mechanic was a total abstainer, and many witnesses established the fact that the other two crew members had not been drinking.

Following this accident, however, considerable discussion took place in aviation circles regarding the frequency of drinking among civilian pilots. Several Congressmen threatened to set up an investigating committee and to sponsor a regulation requiring spot checks to detect the presence of alcohol in the blood of air crews before going on duty. The New York District Attorney threatened to require an official examination of pilots using LaGuardia Airport a half hour before takeoff to disclose traces of alcohol in their blood.

Although airline officials uphold the principle that pilots should not use alcohol either on duty or before flights, they strongly opposed the control measures. The opposition was based on the fact that the present disciplinary action is sufficiently severe and that a code of honor exists among airline pilots that forbids drinking 18 hours before or while on duty.

A survey of the regulations of 10 U. S. airlines regarding the use of alcoholic beverages by flight crews was made. There was unanimity in regard to the rule that all airmen must refrain from the use of alcohol while on duty and that violation of the regulation constitutes a basis for immediate suspension or dismissal. All companies stated that they do not allow flying personnel to frequent public bars or cocktail lounges while in uniform even though they are not drinking. In addition, all of the companies stated that no alcoholic liquors should be consumed within a definite time limit before going on schedule, takeoff, or flight duty.

There was, however, some difference in regard to this limit. Two companies placed the time limit at 12 hours, while the remainder required an interval of 24 hours to have elapsed since the last drink before going on duty. The airline pilots' union does not defend an airman if it can be proved he was drinking just before or while on duty.

The chief ingredient that accounts for the physiological effects of all distilled spirits or alcoholic beverages is ethyl alcohol. It is produced by the fer-

CHART E

The relationship between alcohol in the blood and degree of intoxication. The chart shows the way in which behavior may be influenced by varying amounts of alcohol in the blood. For the average person 0.05 per cent alcohol (2 oz. of whiskey or two bottles of beer) constitutes a questionable range, but beyond that amount every person will be influenced to some degree.

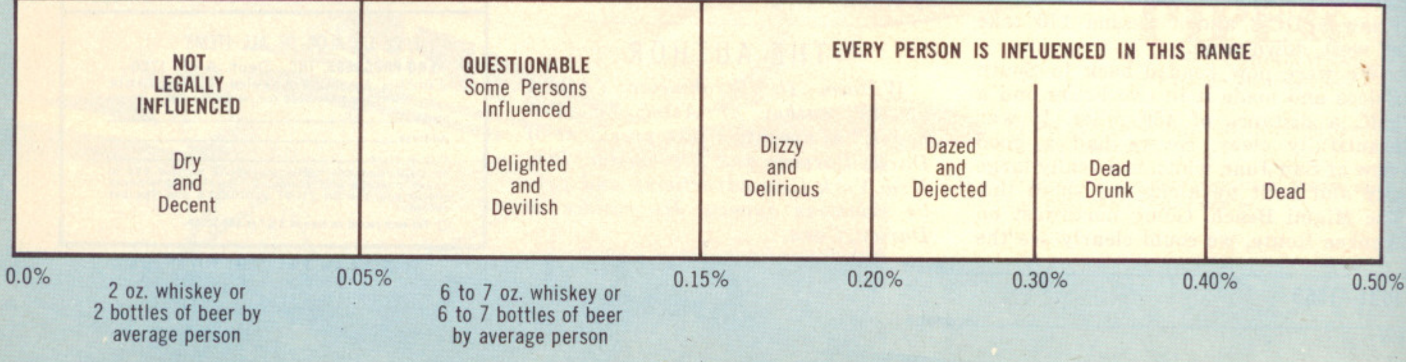
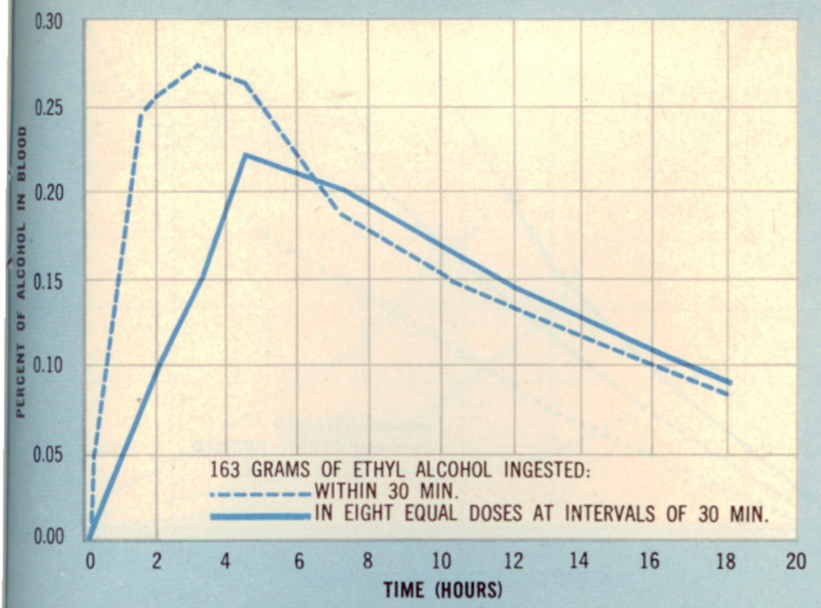


CHART A



The relation between concentration of alcohol in the blood and the rate of consumption. When a given quantity of alcohol is taken within 30 min., blood-alcohol level rises much more rapidly and higher (broken curve) than when approximately the same quantity is consumed at 30-min. intervals over a 4-hr. period (solid curve). In this study the 163 grams of ethyl alcohol (2.15 grams/kg of body weight) was diluted to 20 per cent by volume with water.

menting action of enzymes derived from yeasts on various carbohydrates, such as those in grapes, barley, grain, potatoes, or molasses.

In addition to alcohol and water, all spirits contain small and variable amounts of other volatile substances known as congeners. These substances may be derived from the grain or fruit from which the beverage is made or may be formed during fermentation. The different types and amounts of congeners account for the differences between the various liquors. Thus brandy owes its characteristic flavor to the volatile constituents (other than alcohol) of wine; true whisky, to those present after fermentation of grain; and rum, to those found in fermented molasses.

Even the most highly purified alcohol contains these substances in minute amounts (0.01 to 0.5%), and they are not eliminated by aging. They consist chiefly of higher alcohols (fusel oil), aldehydes, acids, ketones, and numerous other substances, many of which are not yet identified.

These substances are not in themselves toxic in the concentrations indicated, but apparently act by slowing down the rate at which alcohol is disposed of by the body. They possibly influence liver function and exercise their profound physiological action in amounts that are as small as those of certain vitamins and hormonal substances. Thus the effect of a given drink depends directly on the concentration of ethyl alcohol in the body and is influenced indirectly by the nature and amount of congeners.

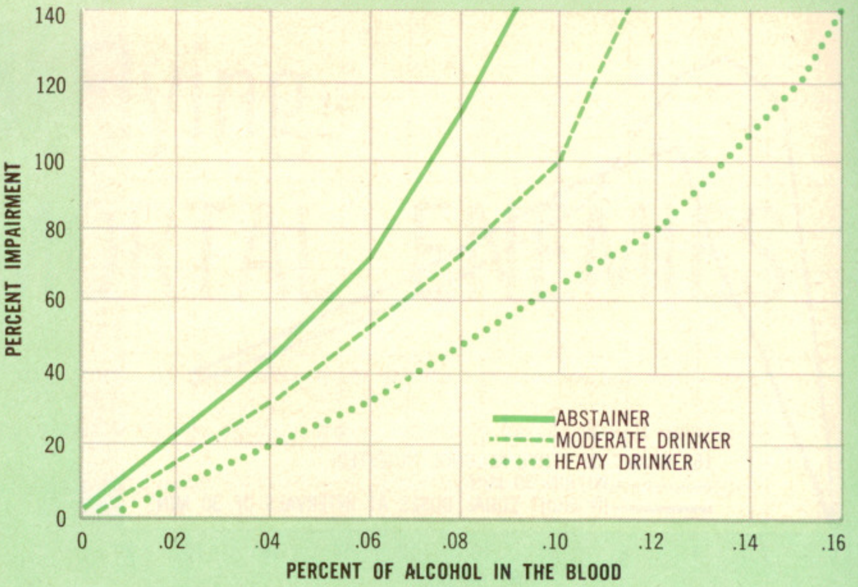
Most foods after entering the stomach undergo a series of chemical processes known as digestion before they can be absorbed into the blood stream. Alcohol, on the other hand, is rapidly absorbed without requiring digestion. It is freely soluble in the fluids and tissues, and it is absorbed by the membranes lining the various structures of the body.

Alcohol appears in the blood within a few minutes after it is ingested, especially if taken on an empty stomach, and shortly thereafter in the organs and tissues. Absorption can be explained on the basis of the physical laws of diffusion. Variations in the rate of absorption are caused by the concentration of alcohol in the drink, the emptying time of the stomach, and the blood flow in the stomach.

About one-fourth of the alcohol ingested is absorbed directly from the stomach and the remainder, from the small intestine. The concentration of alcohol in the blood rises rapidly during the initial period of absorption. It reaches a peak in about half to two hours and then slowly declines as the rate of elimination becomes greater than that of absorption.

Chart A shows the concentration of alcohol in the blood after drinking a total of 163 grams of ethyl alcohol (1) during 30 minutes and (2) divided into eight drinks at 30-minute intervals over a four-hour period. Each drink corresponds to about 61 cubic centimeters of whisky, or the equivalent of a highball. Relative to the 18 to 24 hour abstinence rule before flying, it should be noted that considerable quantities of alcohol remain in the blood for 16 hours following ingestion.

CHART C
STANDING STEADINESS



The relationship between per cent of alcohol in the blood and impairment of performance. The charts demonstrate the marked impairment in standing steadiness (c) and in the flicker test (d)

Several factors influence the concentration of alcohol in the blood and the rate of absorption:

1. The total amount of alcohol in a drink has a direct relationship to the concentration in the blood;

2. The dilution of a drink directly influences the rate of absorption;

3. The presence of food, especially such fatty substances as cream, milk, butter, or vegetable oils, retards the rate of absorption;

4. The alcohol in brewed beverages, such as beer, is absorbed more slowly than distilled liquor because carbohydrates and other material in beer act like food to slow the process;

5. By drinking slowly and allowing time between drinks, an opportunity is given for the body to dispose of some of the alcohol before more is added, and the concentration of alcohol in the blood does not rise so high as with rapid drinking (see Chart A).

Individuals vary considerably in the rapidity with which alcohol is absorbed from their gastrointestinal tracts. One factor may be the degree of habituation to alcohol. In some instances, habitual drinkers have been found to absorb alcohol more slowly than neophytes. The ability of the habitual drinker to tolerate larger amounts of alcohol, however, is attributed chiefly to an alteration in his response to given levels of this substance in the blood rather than to slower absorption.

Several experiments have found that, although a given amount of alcohol produces approximately the same blood-alcohol level in habitual drinkers as in abstainers, the symptoms and effects on various tests are less in the former. This indicates that higher concentration of alcohol in the blood is necessary to produce symptoms of intoxication in habitual drinkers, but the reasons for this are unknown (see Chart C).

After alcohol is absorbed, it is distributed throughout all the tissues and fluids of the body. It tends to reach its highest concentration in those parts of the body which have the richest supply of blood vessels and the highest content of water. Fatty tissues take up alcohol slowly but release it more slowly. The concentration of alcohol in the fluid that surrounds the brain and spinal

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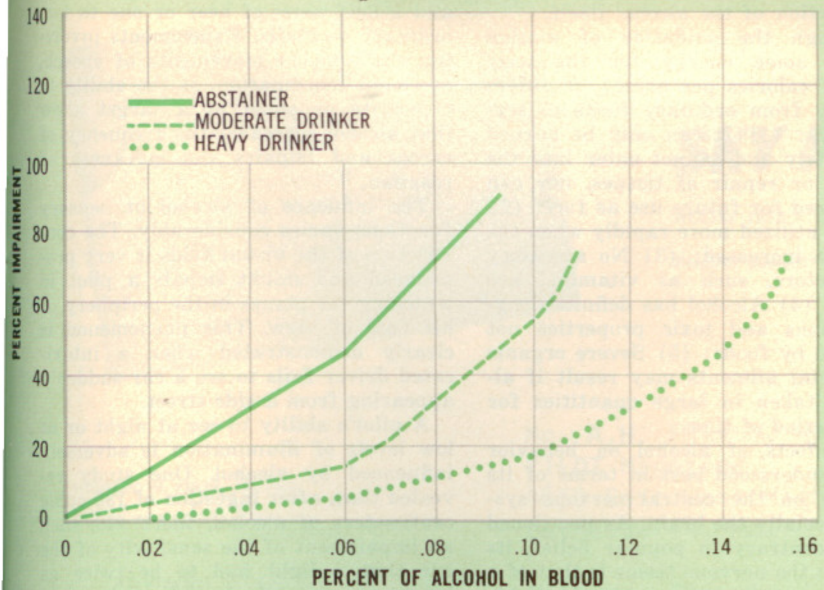
CHART D

FLICKER TEST



at higher concentrations of blood alcohol. Note the marked influence of tolerance to alcohol on the degree of impairment at any given blood-alcohol level.

cord rises more slowly than that in the blood but remains elevated for a longer time.

In general, however, the concentration of alcohol in the blood is a fairly reliable index of that in the brain. The relationship between the concentration of alcohol in the blood and in the brain is shown in Chart B. In appraising alcoholic intoxication, the urine, saliva, or breath may be used as well as the blood.

A large proportion of alcohol, usually more than 90% is oxidized in the body, with the initial stages occurring in the liver. Only a small fraction, less than 5%, is eliminated unchanged by way of the kidneys, lungs, and skin.

A man of average weight can burn about one-third fluid ounces of pure alcohol per hour. The rate of oxidation appears to be fairly constant regardless of the amount present in the body, and very few factors have been shown to influence this rate appreciably. There is a slight variation in the rate from one individual to another, but tolerance to alcohol is not believed to be caused by an increased ability to burn it. The congeners have some influence on the rate of oxidation.

Neither exercise nor any other procedure commonly employed to attempt to ameliorate intoxication is effective in causing the alcohol to burn more rapidly. Drinking black coffee, for example, serves to stimulate the brain, which has been depressed by the alcohol, and thus tends to counteract its effects. The inhalation of excess quantities of oxygen and carbon dioxide tends to increase the rate of elimination or oxidation, as is the case when insulin is injected.

Although many believe that alcohol has a stimulating effect, the exact opposite is true. Studies of the electrical potentials of nervous impulses have shown that the apparently stimulating action is caused by a paralysis of the inhibitory centers and not by action on the central nervous system directly. Possibly the initial feeling of stimulation is an attempt of the body to overcompensate for the effects on the central nervous system. This response is similar to that observed in initial exposures to high altitude and various drugs.

The influence of alcohol on other parts of the body appears to be much less prominent and significant. There is a temporary increase in pulse rate, blood pressure, and depth of breathing. These variables gradually return to normal unless additional amounts of alcohol are taken. The small blood vessels in the skin become dilated, resulting in an increased blood flow to the skin. This produces a feeling of warmth but leads to the loss of heat by radiation from the body and reduction in body temperature. Therefore, alcohol should not be taken during exposure to cold environments.

Respiration is not affected significantly but is depressed if large amounts are consumed. The contractions of the stomach are inhibited rather than increased, and the secretions of the salivary glands and the stomach are stimulated. The amount of hydrochloric acid in the gastric secretions is markedly elevated, accounting for the harmful effects of alcohol on ulcers. The digestive enzymes are not increased; their function is actually impaired. The flow of urine is increased, not only because of the large amount of fluid ordinarily taken with the alcohol but also because of the action of the alcohol itself.

Although the oxidation of alcohol provides some energy for the body (about 7 calories per gram), it differs markedly from ordinary foods in several ways: (1) It can only be burned immediately and cannot enter into the building or repair of tissues, nor can it be stored for future use as fuel; (2) It is not utilized more rapidly when the supply is increased; (3) No accessory food factors, such as vitamins, are present; (4) Alcohol has definite drug-like actions and toxic properties not possessed by foods; (5) Severe organic and mental ailments may result if alcohol is taken in large quantities for a long period of time.

The effects of alcohol on behavior can be understood best in terms of its influence on the central nervous system, especially the brain. As mentioned earlier, contrary to popular belief, its action on the nervous tissue is that of a depressant rather than a stimulant. After taking alcohol, a great majority of subjects manifest poorer performance in muscular functions.

Most persons are aware of these facts and take it not to improve their efficiency but to obtain relaxation, to feel "differently," or to gain confidence and relief from anxiety. The apparently stimulating response to alcohol comes primarily from exciting influences in the environment and a general sense of festivity common to most social drinking. In the absence of such influences, moods of elation may change rapidly to indifference, drowsiness, or depression.

Although the various stages of intoxication do not fall into precise patterns of behavior, certain generalizations can be outlined. The first symptom is a dulling of ones' critical judgment and sense of responsibility. Emotions and instinctive impulses are freed from their habitual control. Intellectual functions, related to the more complex and highly developed functions of the brain (cerebral cortex), are progressively impaired. As larger amounts of alcohol are taken, skilled reactions are disturbed, motor control is poor, speech becomes slurred, and sensory perceptions are influenced adversely. Finally, there is a loss of insight into the extent of one's impairment and at times a complete lapse of memory for recent events. The effects are insidious, and errors of judgment are sometimes unnoticed by the person experiencing them.

The impairment of motor functions is attributed not to the direct effect of alcohol on the muscles but rather to their nervous control. Muscular reflexes, such as the knee jerk and the protective eyelid reflex, show a decrease in speed and strength after only about one ounce of alcohol. Also small quantities increase the amount of body sway markedly in tests involving standing steadiness (see Chart D). Movements of the eye while reading or fixating on an object show significant variations in efficiency, averaging only 21% of the normal efficiency after one and a half pints of beer or one to two ordinary cocktails. Experiments involving the complex movements of speech, eye-hand coordination, or the ability to typewrite or shoot at a target show that alcohol increases the frequency of errors and impairs the quickness of reaction.

The influence of alcohol on sensory functions varies considerably. The constriction of the visual fields is very pronounced and might impair a pilot in watching for planes in the periphery of his field of view. This phenomenon is clearly demonstrated when a intoxicated driver fails to see a car suddenly appearing from a side street.

A pilot's ability to see at night or at low levels of illumination is adversely influenced by alcohol. One study revealed that, after ingestion of 180 cubic centimeters of alcohol, there was such an impairment of the sensitivity of the eye that a light had to be twice as bright as originally in order to be seen.

Another study, using a test of flicker frequency, indicated that a greater amount of light was needed for resolution of flicker as the blood alcohol concentration increased. This test is a sensitive measure of the effects of oxygen lack, fatigue, and other depressing stimuli. The sense of touch is also impaired fairly easily; hearing, however, appears to be very resistant to both alcohol and hypoxia.

Alcohol has a pronounced effect on mental performance, such as memory, judgment, and reasoning. Although the magnitude of the effect varies from person to person, its direction is never reversed. The primary effect seems to be that attention and connection are rendered less flexible for receiving new stimuli. In one experiment, telegraph operators receiving coded messages were found to be 22% less efficient after the ingestion of two bottles of beer and 56 to 72% after three to four bottles.

In tests of free association, alcohol diminishes the relevance of responses, and there are usually more nonsensical reactions. In studies of immediate memory for meaningful words nonsense syllables the percentage of impairment was found to vary 10 to 45% after drinking one to four ounces of whisky.

Committees, after extensive investigations, have selected critical levels of blood alcohol that roughly divide drinking drivers into three groups (see Chart E). For the average person weighing 150 pounds, the first stage (0.05% alcohol) would be reached after two ounces of whisky or two bottles of beer; and the second stage (0.15% alcohol) after six or seven ounces of whisky or six or seven bottles of beer.

If a driver is involved in an accident and his blood-alcohol level is between 0.05 and 0.15%, the finding is considered relevant to prosecution, especially if the usual symptoms are present. If the blood-alcohol level is above 0.15% this is considered as prima-facie evidence that the driver's behavior is significantly influenced by drinking.

Obviously a pilot who is under the in-

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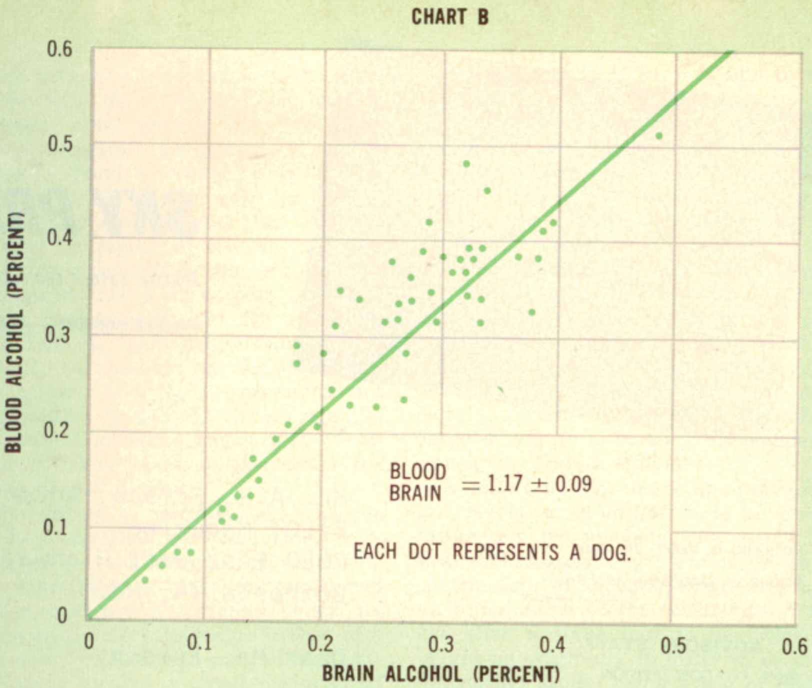

Correlation between the concentration of alcohol in the brain and in the blood. These results were obtained from experiments on 53 dogs who were given alcohol in amounts ranging from 0.5 to 6.0 grams/kg of body weight. Samples were obtained ½ to 12 hrs. later.

(Continued from page 72)

fluence of alcohol would be at a great disadvantage in remembering to check his instruments, in making complicated decisions, or in carrying out many other duties while flying. In aviation, there is not only the influence of alcohol alone to be considered but also the way in which altitude may accentuate these reactions.

Alcohol exercises its primary physiological action by depressing oxidation in the cells. This impairment is believed to occur not because alcohol interferes with the transport of oxygen to the tissues but because the tissue cells are poisoned in such a manner that they cannot use the oxygen properly. These effects on the tissue cells are similar to those resulting from various other narcotics which inhibit the oxidation of such substances as glucose, lactic acid, and pyruvic acid, important in carbohydrate metabolism in the brain tissue.

This interpretation explains (1) the striking effects of alcohol on the nervous system and (2) why alcohol and oxygen-want produce more serious effects on the nervous tissue and consequently on behavior if both are experienced simultaneously. Thus if an airman ascends to even a moderate altitude with alcohol in his blood, he would be especially vulnerable to the effects. For example, the alcohol in two or three cocktails would have the physiological action of four or five drinks at altitudes of approximately 10,000 to 12,000 feet.

The similarity in behavior of a person suffering from oxygen-want and one under the influence of alcohol is very striking. In both instances, memory, insight, and ability to concentrate, are markedly influenced. In fact, the psychological reactions of a person under the influence of alcohol resemble those of persons influenced by oxygen-want in low-pressure chambers and on mountain expeditions to high altitude. The most serious danger is the gradual and unwitting failure of sane judgment.

Tests were conducted during a high-altitude expedition concerning the combined effects of alcohol and oxygen-want. Alcoholic drinks of approximately one gram per kilogram body weight were ingested at 12,200 feet and 17,500 feet, and the tests were later repeated at sea level. Samples of venous blood were obtained for the determination of alcohol in the blood at half-hour intervals; psychological tests were given to observe any changes in sensory and mental function. The concentration of alcohol in the blood rose more rapidly and reached a higher level in the mountains than at sea level. The relative impairment in the psychological tests was also greater in the mountains than at sea level after the ingestion of alcohol.

Further studies of the relationship between alcoholic intoxication and oxygen-want have been made by observing the extent to which intoxication can be counteracted by inhaling excess concentrations of oxygen and carbon dioxide. Subjects were tested in a chamber after ingesting three-fourths to one and one-fourth grams of ethyl alcohol per kilogram of body weight, diluted to a total volume of about 250 cubic centimeters. Samples of venous blood were drawn for blood-alcohol and lactic acid determinations during various tests in which (1) the air in the chamber was normal and (2) the oxygen was increased 50% and the carbon dioxide from 0.2 to 5%.

Alterations in behavior were studied by a series of six psychological tests. In 18 of the 23 subjects, those who were exposed to the increased oxygen and carbon dioxide had significantly lower blood-alcohol and lactic acid values than those in the control series breathing air. Also, most of the subjects felt better, and their scores on tests were significantly improved.

Oxygen therapy has been used with some success in the treatment of acute alcoholic intoxication. For example, in a study of 100 patients, a marked improvement was noted following the inhalation by mask of approximately 60% oxygen for 20 minutes every hour for six hours. Although the mechanisms by which the improvement takes place are not understood, these experiments offer additional evidence that (1) alcohol produces some impairment in the chain of oxidative processes in the nervous tissue and (2) an airman not only lowers his ceiling but places himself in an unusually hazardous position by drinking alcohol before flight.

The general conclusions to be drawn from this discussion of the effects of alcohol on flying efficiency are as follows:

1. Most individuals have reduced efficiency in motor coordination, skill, memory, and other psychological functions after drinking moderate amounts of alcohol. With larger quantities, the effects were very marked. It is only reasonable, therefore, that pilots should refrain from the use of alcohol either before going on duty or while in flight.
2. A regulation stating that a pilot should abstain from drinking 18 hours before flight duty is desirable in view of the after effects of alcohol on memory and judgment as well as the length of time that traces of alcohol may be found in the blood and spinal fluid.
3. Airmen should be informed that the effects of alcohol are similar to those of oxygen-want and that the combined effects on the brain and nervous system are significant at altitudes even as low as 8,000 to 10,000 feet.
4. In studies of problem cases among airline flight personnel, excessive drinking was often found to be related to personal or social maladjustment or to apprehension about flying. When such individuals are discovered by the operating or medical departments of an airline, they should be suspended from flight duty until the basic cause for drinking has been eliminated.

In the final analysis, a choice must be made between excessive drinking and flying because the two are incompatible in the interests of safety and the flying public. ●