(2)

USAFSAM-SR-89-3

ALCOHOL - ACUTE EFFECTS IN AIRCREW

AD-A226 015

Edward A. Brook, Major, Canadian AF
Carl G. Simpson, Major, USAF, MC

June 1990

Final Report for Period July 1988 - June 1989

Approved for public release; distribution is unlimited.

USAF SCHOOL OF AEROSPACE MEDICINE
Human Systems Division (AFSC)
Brooks Air Force Base, TX 78235-5301

NOTICES

This final report was submitted by personnel of the Aerospace Medicine Branch, Education Division, USAF School of Aerospace Medicine, Human Systems Division, AFSC, Brooks Air Force Base, Texas, under job order SUPT-XX-ED.

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder or any person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

CARL G. SIMPSON, Major, USAF, MC
Project Scientist

John A Bishop

JOHN A. BISHOP, Colonel, USAF, MC
Supervisor

George Schwender MD

GEORGE E. SCHWENDER, Colonel, USAF, MC, CFS
Commander

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704 0188

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

3. DISTRIBUTION/AVAILABILITY OF REPORT
Approved for public release; distribution is unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
USAFSAM-SR-89-3

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
USAF School of Aerospace Medicine

6b. OFFICE SYMBOL (If applicable)
USAFSAM/EDK

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS (City, State, and ZIP Code)
Human Systems Division (AFSC)
Brooks Air Force Base, TX 78235-5301

7b. ADDRESS (City, State, and ZIP Code)

8a. NAME OF FUNDING/SPONSORING ORGANIZATION
USAF School of Aerospace Medicine

8b. OFFICE SYMBOL (If applicable)
USAFSAM/EDK

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State, and ZIP Code)
Human Systems Division (AFSC)
Brooks Air Force Base, TX 78235-5301

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
81130F	ED93	56	X1

11. TITLE (Include Security Classification)
Alcohol-Acute Effects In Aviation

12. PERSONAL AUTHOR(S)
Brook, Edward A.; Simpson, Carl

13a. TYPE OF REPORT
Final

13b. TIME COVERED
FROM 88/07 TO 89/06

14. DATE OF REPORT (Year, Month, Day)
1990, June

15. PAGE COUNT
74

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
05	08	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Ethanol; ethyl alcohol; psychoactive drug; depression; congeners; post alcohol impairment

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This Flying Safety Topic Kit emphasizes the acute effects of alcohol on performance and aviation. In particular, it discusses the available preparations, absorption, metabolism, physiology, and pharmacology of alcohol. More recent data on altitude, nystagmus, and hangovers are included. Although designed for a flight surgeon to present to aircrew, it could also be presented to a general audience with minimal alterations.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
Allen J. Parmet, Lt Col, USAF, MC, SFS

22b. TELEPHONE (Include Area Code)
(512) 536-2844

22c. OFFICE SYMBOL
USAFSAM/EDK

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

TABLE OF CONTENTS

List of Figures

Notice to Users

This Flying Safety Topic Kit emphasizes the acute effects of alcohol on performance and on aviation, in particular. More recent data on altitude, nystagmus, and hangover are included. Although designed for presentation to aircrew by a flight surgeon, it could also be presented to a general audience with minimal alteration.

The kit is organized into two parts. Part I (pages 1-25) has all the background material, complete with references, which the lecturer should be familiar with before giving the presentation. Part II (pages 26-46) consists of 20 slides and the accompanying narration. This narration conveys the main points from the background material in a more informal manner. The text is only one suggestion, however, and adjustments could be made to suit a particular audience and your personal style. Please feel free to modify this kit and, if you have any suggestions for improvements that would increase its effectiveness, forward them to the USAF School of Aerospace Medicine (USAFSAM/EDK), Brooks AFB, TX 78235-5301.

ALCOHOL - ACUTE EFFECTS IN AIRCREW

Introduction

Ethanol or ethyl alcohol is a ubiquitous, psychoactive drug. Because of its ready availability, easy manufacture, and long tradition of use, it has been tolerated in our society more than any other pharmacologically active chemical. It is a depressant that exerts its effects mainly on the central nervous system. The depression it causes is general, nonselective, and (except at lethal dosages) reversible. It differs from other drugs in that it is used primarily for social and recreational purposes rather than for its medicinal effects.

In our society almost all adults drink at least occasionally and half the male population will have temporary alcohol-induced problems during their lifetime (1). An estimated 10% of men and 3 - 5% of women will become alcoholics. Even light drinking interacts with prescribed medications and causes problems from mild - severe intoxication to hangover. This report will concentrate on the acute effects of ethanol and the adverse influence it has on the healthy flying population operating in an unforgiving environment.

Alcohol and Flying

Aircrew are certainly not all teetotallers or abstainers. A survey of British airline pilots revealed that 98.7% drank alcohol. The average consumption was four drinks four times per week (2). Figures for military aviators would likely be at least equal.

Unfortunately interactions of alcohol and aircrew have not always stopped at the airport ramp. A study of fatal general aviation accidents in 1963 found that in 35% (n=158) of them, aircrew tested positive for blood or tissue alcohol in postmortem examinations (3). Between 1968 - 1971 Blood Alcohol Concentrations (BACs) above 40 mg% were noted in 11.5% of pilots killed in general aviation accidents; consequently, the 8 hour "bottle to throttle" FAA rule was enacted in 1970. Since then, after an initial drop, the proportion peaked at 11.2% in 1974, averaged 8.6% from 1974 - 1978, and dropped to 5.7% in 1979 and 6.5% for 1980 - 1981 (Fig. 1).

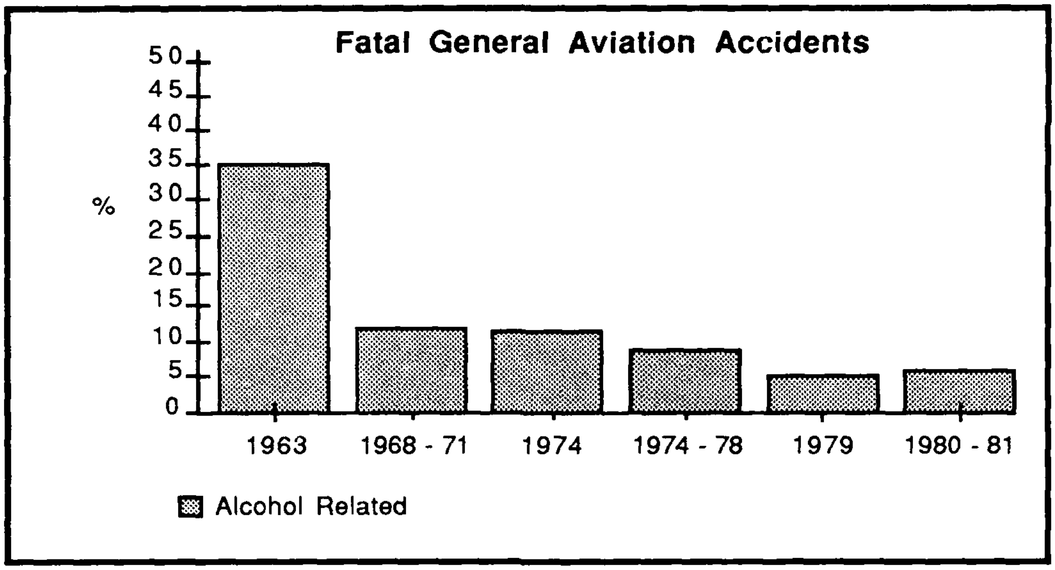


Figure 1. Alcohol-related general aviation accidents.

An important factor to consider when interpreting these statistics is that bacterial postmortem production of alcohol can reach 50 - 100 mg/100 g of tissue, thus making it difficult to determine pilot premortem BACs especially if a history of alcohol intake is unavailable (3). It's now thought that a large number of the presumed intoxicated aircrew victims prior to 1965 may be due to inadequate laboratory methods or to putrefaction. Ideally blood samples are obtained from the limbs in a fluoride tube and then refrigerated until analysis. If many different alcohols, other than ethanol, are present or if there are discrepancies between the levels from blood and from tissues, then postmortem fermentation is likely (4).

Air accidents attributed to alcohol use are much more common in general aviation than in commercial carriers. One dramatic exception, however, was a Japan Air Lines DC8 crash at Anchorage in 1977 with no survivors. The pilot had a BAC of 210 mg% (5) -- two to three times the legal limit for driving (depending on jurisdiction). There were also three civil airliner crashes in the 1980 - 1982 period in which the influence of alcohol on the aircrew was officially reported.

History

The use of alcohol dates as far back as the earliest recorded history. The first fermentation of fruits or grain probably occurred by chance. Soon thereafter, wine and beer were being produced at will, and ethanol became part of the culture. It was used not only as a beverage to accompany meals but for social, medicinal, and religious purposes as well. There is evidence of viticulture on ancient Egyptian papyri and tablets (6). Winemaking was introduced to the Mediterranean region by the Greeks, and then the Romans spread it through Western Europe. Indeed, Italy remains the premier country in the world today for both wine production and consumption (Fig. 3).

International Symbols

A	Austria	GB	UK	PE	Peru
AUS	Australia	GR	Greece	PL	Poland
B	Belgium	H	Hungary	R	Rumania
BG	Bulgaria	I	Italy	RA	Argentina
BR	Brazil	IL	Israel	RCH	Chile
CDN	Canada	IS	Iceland	S	Sweden
CH	Switzerland	J	Japan	SF	Finland
CS	Czechoslovakia	L	Luxemburg	SU	USSR
CY	Cyprus	M	Malta	TN	Tunisia
D	West Germany	MA	Morocco	TR	Turkey
DDR	East Germany	MEX	Mexico	U	Uruguay
DK	Denmark	N	Norway	USA	USA
E	Spain	NL	Netherlands	YU	Yugoslavia
EIR	Eire	NZ	New Zealand	YV	Venezuela
F	France	P	Portugal	ZA	South Africa

Figure 2. Country codes used in graphs.

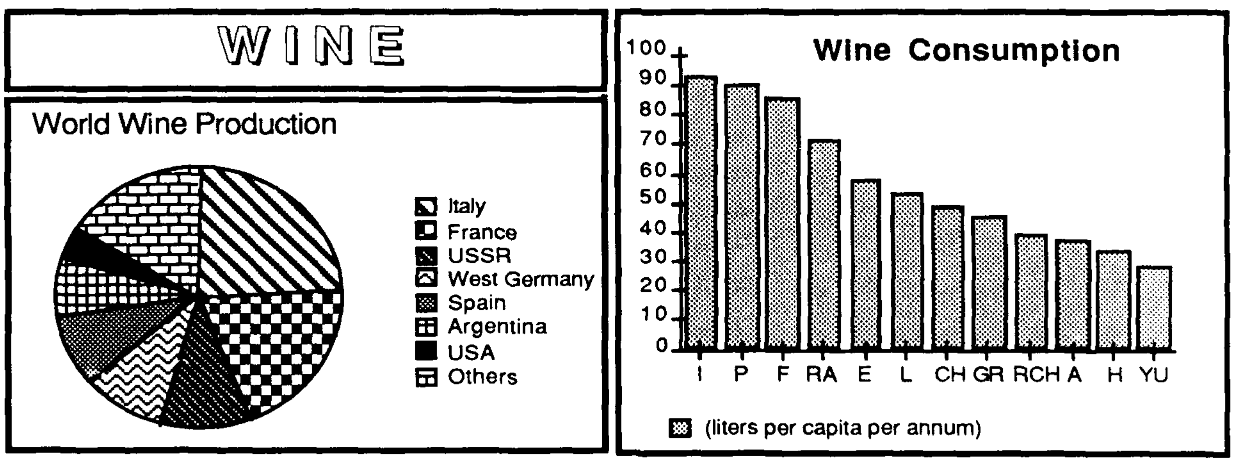


Figure 3. World wine production and consumption.

Distillation originated in the Middle or Far East and was exported to southwestern Europe by the Arabs during the early Middle Ages (7). The word "alcohol" is from the Arabic *al khol,* which referred to a cosmetic eye shadow that was a by-product of distillation. Since the use of alcohol was banned by Islam, except for medicinal or scientific purposes, the art of distilling spirits was passed on by western monks and alchemists. Alcohol was referred to as the "water of life"; *eau de vie* in French, *aqua vitae* in Italian, and *usquebaugh* in Gælic from which we derive the name "whiskey". In the Elizabethan era the physiological effects were alluded to by Porter in *Hamlet*, who noted alcohol provoked only "nose-painting, sleep and urine" (8). Today almost every country has an alcoholic beverage industry of some type (Fig. 4).

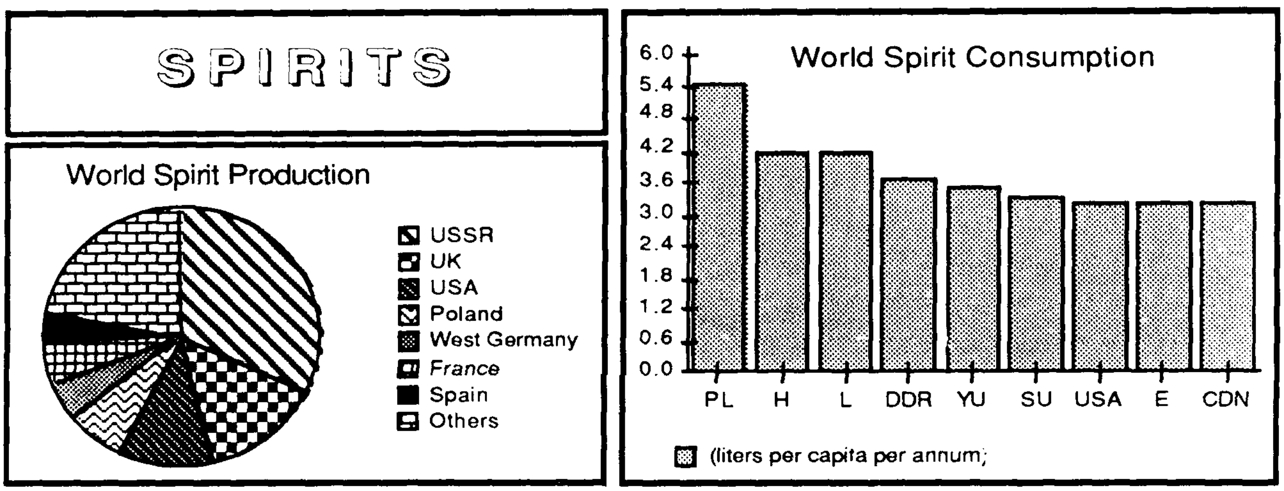


Figure 4. World spirit production and consumption.

The USA leads in production of beer (almost 180 million hl (hectoliters)), but ranks thirteenth in consumption - still, that works out to 82 liters for each man, woman and child (9) (Fig. 5). American liquor distillation is third worldwide (3,036 hl), while consumption ranks eighth at 3.2 liters per capita (7). Although in wine production the U.S. is seventh (14.7 million hl), as a wine drinking nation it is not in the top thirty (6). So in this country, beer is still the alcoholic drink of choice. The domestic taste in spirits mainly favors whiskey -- bourbon, American, Canadian, Irish, and Scotch, followed by vodka and rum (10). In the past few years sales of wine coolers with 2 - 7% alcohol have soared to 636 million liters (a $1.6 billion business) (11). The adverse economic impact of alcohol must also be remembered, however. In 1971 the cost of alcoholism to U.S. industry was estimated as $10 billion a year and the overall cost of ethanol abuse $25 billion (2).

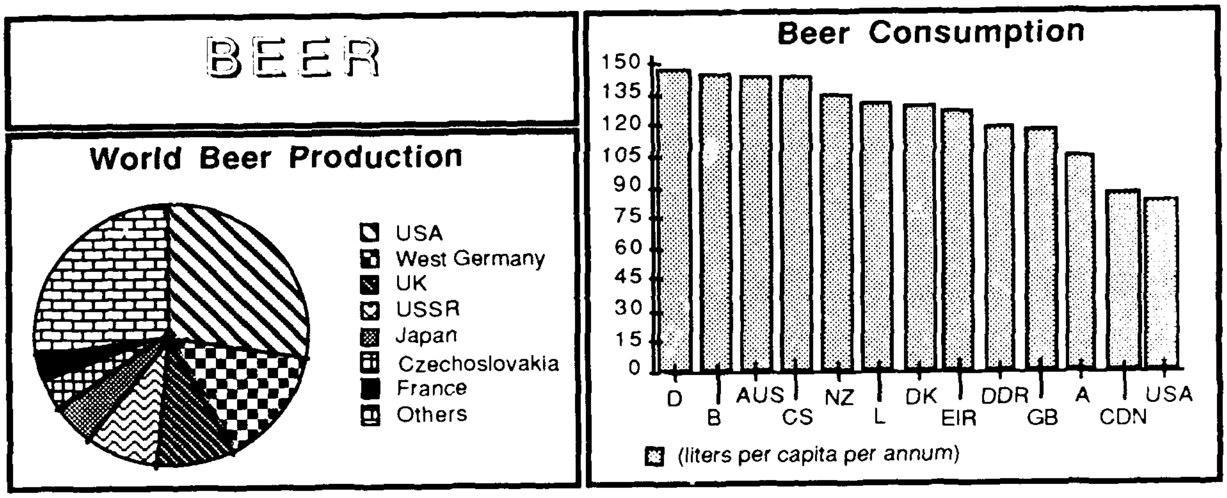


Figure 5. World beer production and consumption.

Chemistry

Ethyl alcohol or ethanol is a two-carbon, weakly charged, aliphatic molecule with the chemical formula CH_3CH_2OH (Fig. 6). Metabolically each gram of alcohol provides 7.1 kcal without any nutrients (1). The density of ethanol varies with temperature, but the standard specific gravity is 0.7930 (at 15.56°C).

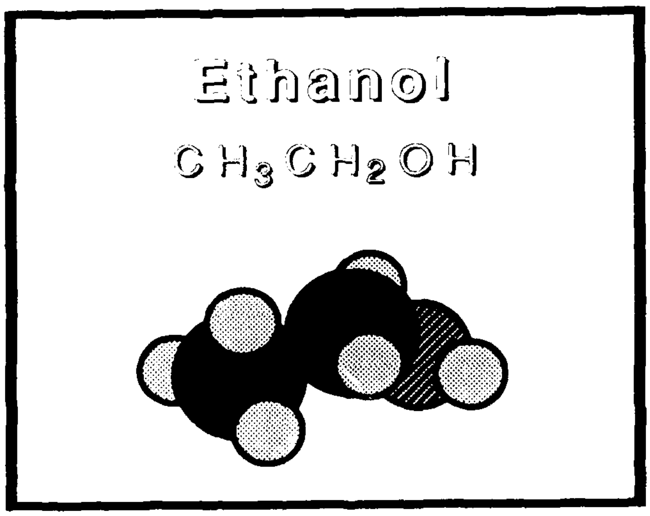


Figure 6. Ethanol chemical structure.

Fermentation is the chemical process by which sugar is changed into alcohol and carbon dioxide brought about by microorganisms such as yeasts (and even by bacteria postmortem which can lead to false estimates of tissue levels). In winemaking, the yeast is present naturally on the grape skins and once these are broken, sugar (which comprises about 30% of the pulp) can be fermented. If undisturbed, the sugars (mainly glucose and fructose) would be completely converted to alcohol creating a dry wine with about 15% ethanol by volume (6) (Fig. 7). This process is often halted either by adding sulphur or alcohol (to reach the 15% level) both of which are toxic to the yeast; or alternatively by separating out the yeast and passing the wine through a fine filter.

Spirits are made from the distillation of a fermented mash or base liquid. The source of the sugar may be natural, as with sugar cane or fruit, or it may come from the starch of potatoes or grain which have been malted to form sugar. Some examples of final products and their fermentation sources are: brandy or cognac (grape mash /wine), gin and vodka (grain/ potato), rum (sugar cane/molasses), tequila (agave cactus), and Calvados (apples) (7). The whiskeys are generally distilled from malted grains with the following combinations: Scotch (malted barley), Irish (barley, oats, corn, rye and wheat), Bourbon (corn mash), and Canadian (rye mash).

Beer is formed from the fermentation of a malted grain mash (generally barley). The mash is brewed at a high temperature with a mixture of water, yeast, and hops (used as a flavoring agent). The two basic classes of beer are the bottom-fermented *lagers* (including Pilseners) and the ales which are top-fermented ( ). Following fermentation, beer may be filtered and pasteurized to ensure a longer shelf-life allowing distribution farther than an unpasteurized draught would allow.

Preparations

Wines

Wines may vary considerably in their alcohol content. A dry white Moselle (1% sugar) has 10% ethanol by volume, while a red Bordeaux (0.2% sugar) has 12% ethanol. Port (only 70% water compared to the 87 - 89% for unfortified wines) has brandy added to it, resulting in a sweet (10% sugar) wine with 20% ethanol by volume (6). The potential alcoholic content of a wine (if all sugar is fermented out) is related to the original sugar content of the grape or "must-weight," and to the specific gravity (Fig. 7).

Wine

Specific Gravity	% Potential Alcohol
1.065	8.1
1.070	8.8
1.075	9.4
1.080	10.0
1.085	10.6
1.090	11.3
1.095	11.9
1.100	12.5
1.105	13.1
1.110	13.8
1.115	14.4
1.120	15.0

Figure 7. Potential alcohol concentration of wine.

SPIRITS

Gay Lussac (% by volume)	American Proof	British Proof
10	20	17.50
20	40	35.00
30	60	52.50
40	80	70.00
45	90	78.75
50	100	87.50
57	114	100.00
60	120	105.00
70	140	122.50
80	160	140.00
90	180	157.50
100	200	175.00

Figure 8. Proof systems for the alcoholic content of spirits.

Spirits

There are three main systems to measure the alcoholic content of spirits. The French or Guy Lussac (GL) method simply expresses it as a percentage of alcohol by volume. This is the system that the European common market has adopted as standard. The American proof system is equivalent to twice the GL system; thus 100% ethanol (which incidentally is impossible to distill from water) would be 200 proof. The British proof system is the most complicated, and is based on an archaic determination of what was called "proven spirit". This involved burning a mixture of gunpowder and the beverage in question to test whether it was over or under proof. Mathematically the British measure is equivalent to $^4/_7$ of the GL value; it is now being used less commonly worldwide (7). A comparison of the different measurement systems is given in Figure 8.

Beer

As with spirits, there are many conflicting and confusing systems to measure the alcoholic content of beers. Alcohol by volume is the simplest with alcohol by weight giving a slightly smaller figure (because ethanol is lighter than water). Some scales are based on the density of the beverage and termed "Plato" or "Balling" degrees. The strongest beer is from Kulmbach, in Bavaria,West Germany, with an alcohol content by volume of 13.2%. Other European beer from Germany, Belgium and Britain may run up to 10%. The average Pilsener worldwide is probably about 5% by volume (4 - 4.5% by weight) with an original specific gravity of 1.050 (6). In the USA regular beer is usually 5 - 6% alcohol by weight, but in several states it is limited by law to 3.2%.

Congeners

Congeners are impurities and by-products of distillation or fermentation which are present in beverages and impart to them distinctive odors and tastes. It is the congeners which distinguish a brandy from a whiskey, or a rum from a vodka. Distillers carefully control their amounts to achieve the desired balance. Some high congener content products such as whiskey or cognac are aged in wood to moderate their effects. Congeners found in spirits which partly contribute to the adverse effects of hangover include: low-molecular weight alcohols (e.g., methanol and butanol), aldehydes, esters, histamine, phenols, tannins, iron, lead, and cobalt. The concentrations of selected congeners in various alcoholic beverages are displayed in Figure 9.

Concentrations of frequent Congeners in Alcoholic Beverages (mg/dl)

Congeners	Vodka	Gin	Scotch	Cognac	Bourbon
Acetaldehyde	0.35	0.30	2.70	5.00	1.70
Ethyl formate	0.40	0.36	1.30	3.30	2.70
Ethyl acetate	0.00	0.05	28.20	45.00	82.50
Methanol	0.40	2.10	3.00	12.50	2.60
n-Propanol	0.00	0.05	12.80	14.00	11.00
i-Butanol	1.10	1.05	21.00	33.50	25.00
i-Amyl alcohol	0.40	0.00	26.00	98.00	120.00
Total	2.65	3.91	95.00	211.30	245.50

Figure 9. Congener concentrations in various spirits.

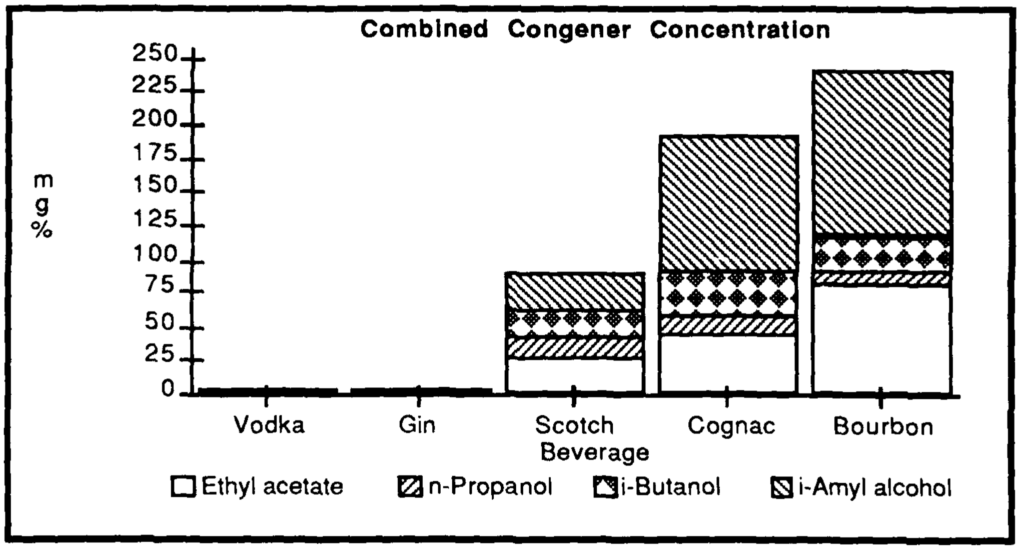


Figure 10. Selected combined congener concentrations.

Pharmacology

Absorption

Blood alcohol concentrations (BAC) are expressed clinically in milligrams of ethanol per deciliter (mg/dl or mg%). For legal impairment the level is often measured in grams per deciliter and expressed as a percentage. Thus 80 mg/dl or 80 mg% becomes 0.08 % (0.08 g/dl). I will use the mg% units in this paper.

Alcohol is rapidly and completely absorbed from the gastrointestinal tract. There is no need for dissolution; as it is already liquid, and its fat-soluble nature enhances its passage through the mucosa. When vaporized, it can be absorbed directly through the lungs. Because of its rapid action after ingestion, it is unnecessary to inject alcohol intravenously (i.e., for therapeutic treatment). Indeed this would be dangerous because of its respiratory depressant effect. Deaths have occurred after rapid pulmonary absorption in some cases (12).

On an empty stomach about 20% of a dose of alcohol is absorbed in the stomach and the remaining 80% is absorbed more rapidly and completely through the upper intestine. Minimal amounts are absorbed from the mucosa of the mouth and pharynx (1). A full stomach will delay absorption, resulting in a lower BAC over a longer period. A meal may reduce the subsequent maximum BAC by up to 50% (2). Food in the stomach slows absorption both by diluting the alcohol concentration and covering some of the villous surface, as well as prolonging the emptying time into the duodenum. The amount of fluid in which the alcohol is dissolved will also influence the speed of absorption. Concentrated spirits are taken up more rapidly than relatively dilute beer. The optimal concentration for absorption is 20% by volume (1). Congeners also reduce uptake. When diluted to equal ethanol concentrations, red wine is absorbed faster than either liquor (gin > whiskey) or beer (2). Sugars in fortified beverages slow down absorption while the carbon dioxide present in champagne, sparkling wine, and drinks mixed with soft drinks increases it.

Distribution

As a small molecule soluble in both water and fat, alcohol is well distributed among bodily fluids and tissues including the central nervous system (CNS). Small amounts are excreted unchanged by the kidneys and the lungs; however, this amounts to only a small percentage (5%). The Breathalyzer uses this principle by multiplying the alcohol concentration in expired air by a factor of 1000 to estimate the BAC with legal accuracy. Since alcohol is fat soluble as well as water soluble, it may diffuse into the fat and muscle tissue of the body. Given the same dose a lean individual will end up with higher BACs than a muscular mesomorph or an obese endomorph.

Given that there is approximately 20 g of alcohol in 12 oz of 5% beer or in a 1.5 oz shot of 80 proof liquor, the approximate peak BACs for persons of various weights can be estimated as in the table in Figure 11.

Weight (lbs)	Number of Drinks (of 10 ml pure ethanol/hr)					
	1	2	3	4	5	6
150	24	48	72	96	120	144
160	23	45	68	90	113	135
170	21	42	64	85	106	127
180	20	40	60	80	100	120
190	19	38	57	76	95	114
200	18	36	54	72	90	108
210	17	34	51	69	86	103
220	16	33	49	65	82	98
230	16	31	47	63	78	94
240	15	30	45	60	75	90
250	14	29	43	58	72	86

Figure 11. Estimated blood alcohol concentrations in mg% ethanol.

Metabolism

Almost all (95%) of an ingested dose of alcohol is metabolized, mainly in the liver, before excretion. The final breakdown products are carbon dioxide and water. There are no minerals or vitamins in alcohol; hence, apart from calories, there is no nutritional value. While the rate of metabolism of most substances in the liver is proportional to their serum concentration, alcohol metabolism is not dose-dependent. Its rate of breakdown is linear with respect to time; the average adult rate is about 10 ml of pure alcohol (1 oz of 66 proof liquor or 10 oz of beer) per hour. Thus, if consumption proceeds faster than this rate, the BAC will rise, resulting in impairment. Once a person has ceased drinking, the BAC will fall by at least 10 mg% per hour (13) in males (the 99% confidence limits in one experiment were 10.13 - 24.55 mg%/hr). There are some interpersonal differences in rates as well as intrapersonal differences due to circadian rhythm.

The first and clinically most important chemical step in the breakdown of alcohol is the production of acetaldehyde via the enzyme alcohol dehydrogenase. Disulfiram or Antabuse works by inhibiting aldehyde dehydrogenase, the next enzyme in the sequence, which converts acetaldehyde to acetone (1). The resulting buildup of acetaldehyde causes symptoms in Antabuse-like reactions. After chronic ethanol usage other metabolizing enzymes (of the microsomal ethanol-oxidizing system) may be induced, leading to tolerance and faster metabolism in the alcoholic. Cross-tolerance for other drugs sharing these enzyme pathways (such as barbiturates) also develops. There are no safe, practical, methods, however, of accelerating metabolism in the nondependent individual.

Physiological Effects

Alcohol works as a general, nonselective CNS depressant. The initial, apparent stimulating action on behavior that is often seen is due to the depression of inhibitory centers within the brain. At low doses the brain stem may be depressed, but not the cortex which is released from lower inhibitory control. There will be mild euphoria, loss of discrimination, fine movement, memory, and concentration as well as impairment of thought, organization and motor processes (12). This lessening of inhibitions and euphoria is also seen with low doses of other sedative-hypnotic drugs. At higher doses or rising BACs, excitatory synapses are also depressed and the sequence of drowsiness, sleep, general anesthesia, coma, and death may follow. Early behavioral changes are seen as low as 20-30 mg%. The legal limit (for driving) is typically set at 80 - 100 mg% and doubling this often leads to narcosis or coma. Fatal doses can be as low as 300 - 400 mg% although there is one case report of a survivor discharging herself from a hospital two days following a measured BAC of 1,510 mg%(14). Alcohol, either alone or in combination, is probably responsible for more overdose deaths than any other agent (1).

Ethanol alters EEG activity by increasing slow-wave sleep and reducing REM sleep early in the night sometimes followed by a later REM rebound with intense, vivid dreams or nightmares (1). Even a few drinks reduces sleep latency (the time between lying down and falling asleep). This fragmentation of sleep patterns may cause a deficiency in deep sleep. Both alcohol and caffeine have been effective in animals to reset circadian rhythms, but only at high doses. The presence of side effects in humans precludes their utility for this purpose in transmeridian flights (15).

Like other sedatives, alcohol acts as an anticonvulsant. Withdrawal may be followed by hyperexcitability, however, with seizures peaking at 8 - 12 hours after the last dose. The sedative effects of ethanol may interact additively with other hypnotics and tranquilizers,resulting in greater impairment from low doses than would be expected from the BACs alone. There is also an anti-oxytocic effect; alcohol was formerly prescribed intravenously for premature labor.

Alcohol acts as a vasodilator in the skin and extremities. This causes the blood vessels in the skin to expand and appear closer to the skin's surface. It produces flushing and a feeling of warmth. In a cold environment, however, the rapid heat loss this causes is counter-productive. The only place for low doses in the treatment of minor cold injuries is during recovery within a warm environment when there is no further risk of low temperature exposure.

Hepatic synthesis of fat and deposition in the liver is increased by alcohol. Unless this process is continued chronically, leading to cirrhosis, it is reversible and liver function is not compromised. There is no evidence that acute intoxication or moderate use over long periods will cause liver damage. The diuretic effects of alcohol are partly due to osmotic diuresis and partly a direct inhibition of anti-diuretic hormone (ADH). The obvious danger of this well-known effect is the dehydration resulting from an episode of imbibition.

While the loss of inhibition noted with low doses of ethanol may cause some lack of restraint, it is not an aphrodisiac. In fact, the opposite effect may occur as reflex control of blood vessels and erectile tissue is lost, and impotence results. As Porter remarked in Macbeth,"it provokes the desire, but it takes away from the performance" (8).

Detrimental Effects in Aviation

Effect of low levels of alcohol

In low doses ethanol can impair discrimination, as well as visual and audio perception. Tracking performance is impaired; distance judgment is degraded; and visual acuity is decreased (16). It interferes with both short and long-term memory and disrupts decision-making, judgment, and hand-eye coordination. Reaction times are increased (2). One of the most disturbing features is the inability of imbibers to recognize their own performance decrements. These effects, including lack of insight by drinkers, have been likened to the insidious effects of hypoxia. Until recently alcohol and lack of oxygen were assumed to be synergistic. There is also diurnal variability. Performance testing has confirmed the perception that equal doses of ethanol are more efficacious at 2300 than at 0700 or 1100 (15).

Relationships have been noted in industry and transportation between BAC and accidents. There are significantly more industrial accidents in workers with BACs of 30 mg%. In U.S. road transport those with (legal) BACs of 80 mg% had double the accident rate of sober operators. For those with BACs of 150 mg% the risk factor was 10 and for 200 mg% 20 times (2). British studies have revealed that a third of drivers who die in road accidents are legally impaired (17).

In flying experiments conducted in 1973, experienced and inexperienced pilots with various BACs (40, 80, and 120 mg%) performed ILS approaches in a Cessna 172 (13). Each of the 16 pilots performed two simulated night IFR flights including four ILS approaches to minimums and two missed approaches. The number of major errors increased for each group during the 32 flights made at each BAC (Fig. 12). It was necessary for the safety pilot to take control once at 40 mg%, three times at 80 mg%, and in half the flights made at 120 mg%, leading to proposals for a regulation mandating not only implied consent to draw blood in non-fatal mishaps but also a maximum permissible BAC of 40 mg% for aircrew (3).

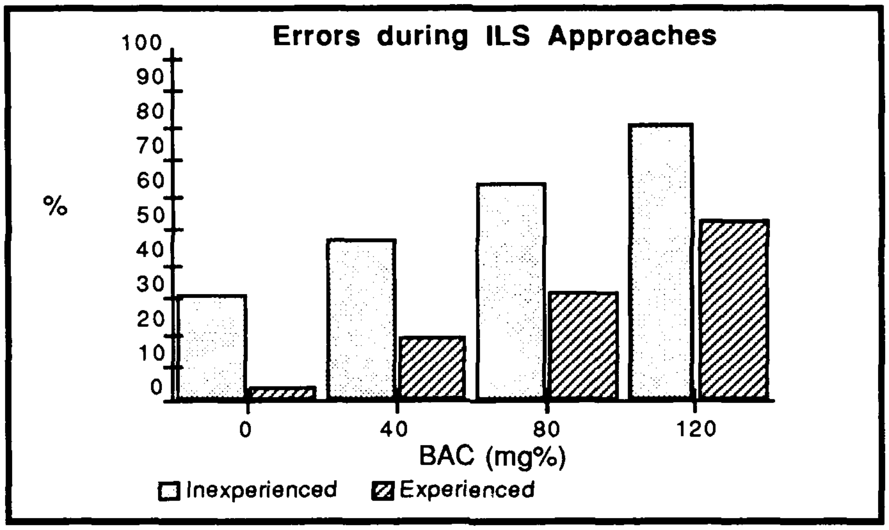


Figure 12. Errors flying instrument landing approaches by experienced and inexperienced pilots.

During the next year, performances in a Link GAT-1 flight simulator were measured with and without varying doses of alcohol. The purpose of the experiment was to calibrate the technique so that it could be used to evaluate the safety of drugs and toxins in aviation use. During the initial experiment significant decrements were found, even at low doses, and they increased in direct proportion to quantity of alcohol consumed. The doses were 0.3, 0.6, and 0.9 g/kg body weight which produced BACs of 25, 55, and 85 mg% respectively -- BACs within legal driving limits in most jurisdictions (18).

Another simulator study was reported in 1986 after the FAA had set 40 mg% as the arbitrary level of impairment in aviation (19). The subjects received either an ethanol dose to reach that level or they received a placebo. They were tasked to maintain straight and level flight while scanning for silhouette targets. Later unusual attitudes were simulated which required the subjects to initiate a recovery. While there were some impairments of control and scanning, the most dramatic results were the pilots' performances when faced with the unusual attitudes. They took longer to respond and were often confused. Rather than being overcontrolled many control inputs were inadequate; in several instances the simulators crashed.

Alcohol reduces the tolerance to positive acceleration ($+G_z$); i.e., moderate doses reduced it by up to 0.4 G. The severity of decreased cardiovascular tolerance for a given G "load" is worsened by alcohol (4).

Alcohol and Hypoxia

It has long been conventional wisdom that altitude and alcohol positively interact. It was thought that, for example, "two or three cocktails at 8,000 ft cabin altitude are equal to four or five at sea level." Recent experiments, however, have put this to the test.

Using the Multiple Task Performance Battery (MTPB), Collins (20) compared results using alcohol and a placebo (a few drops of rum extract floated on ice cubes) at both ground level (1300 ft) and simulated altitude (12,500 ft). Contrary to the popular belief he found no synergism between intoxication and hypoxia (both ground and altitude peak BACs were around 77 - 78 mg%). As expected alcohol, and to a lesser extent hypoxia, impaired performance, but in combination the effect was simply additive.

Later Collins replicated these results with two groups of men aged 30 - 39 and 60 - 69 years old (21). Again he found that alcohol impaired performance (more in the older group), but this time there was no decrement noted due to altitude, either alone or in combination. The BACs themselves were not affected by the hypoxia.

AIH - Alcohol-induced hypoglycemia

An ethanol load in a fasting healthy individual is likely to produce a transient hypoglycemia within 6 - 36 hours due to a reduction of gluconeogenesis (1). This condition would exist long after alcohol was no longer detectable in the blood; it is exacerbated by poor diet or by any pancreatic or liver disease. Although this condition is not rare, it is seldom reported, either in survivors or in fatalities, because of the rapid postmortem changes in serum glucose. At least one mishap, however, was attributed to this condition. A witness had seen the pilot collapse over the controls shortly before a crash, and the blood sample that was quickly obtained after death revealed an ethanol level of 98 mg% (not enough to cause unconsciousness by itself) but with a blood glucose level of only 20 mg% (22).

PAN - positional alcohol nystagmus

Many studies have been done to investigate the effect of alcohol on the vestibular system and its influence on eye movements and spatial orientation.

Vestibular impairment by alcohol-induced nystagmus was first noted in 1842 (23). Over a century later, in 1954, the two phases of positional alcohol nystagmus (PAN) were identified. PAN I appears about 30 minutes after drinking a single dose of alcohol and lasts about 3 - 4 hours (Fig. 13). The fast component of nystagmus is in the same direction as the dependent side of the head. PAN II appears in the opposite direction 5 - 6 hours after alcohol ingestion (regardless of the dose). It lasts for 5 - 10 hours -- perhaps long after the BAC has returned to zero.

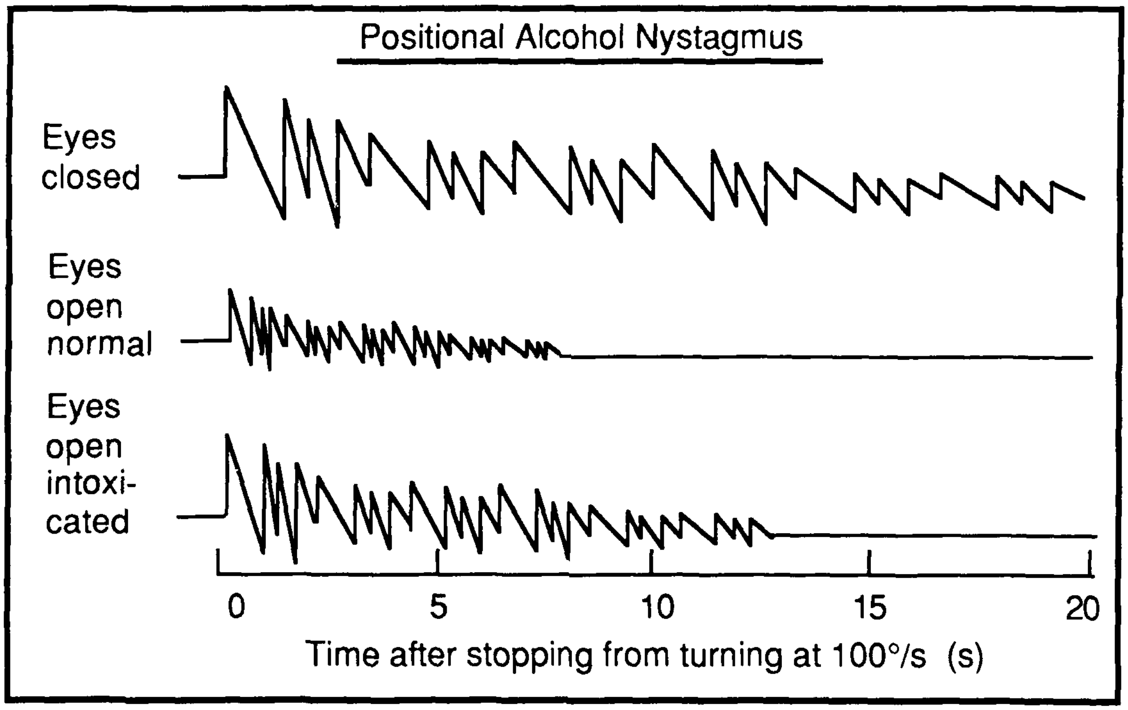


Figure 13. Positional alcohol nystagmus I.

Ryback examined 14 volunteers (both pilots and non-flyers) with electronystagmography for positional and Coriolis nystagmus at intervals of 10 and 34 hours post alcohol ingestion (vodka or bourbon). The Coriolis nystagmic response, starting at 7 hours post ingestion, was accentuated and prolonged and the usual habituation to repeated stimulation did not occur even after 34 hours (in the bourbon drinkers). He concluded that ethanol had a detrimental effect on the vestibular system, even 36 hours after ingestion, especially if the beverage was high in congeners.

Baloh in 1979 reported that, at levels of 50 mg% and higher, ethanol impairs reaction time, smooth pursuit velocity, and saccades (high velocity jumps used to bring a target in the periphery into focus) (24). Now Katoh has indicated that this effect on saccadic velocity appears acutely and persists for at least 3 hours (25).

Recent research by Money shows that BAC levels of 50 mg% impair the ability to fixate visually and perform tracking tasks while receiving vestibular stimulation (4,26). Performance is also worse with hypoxia. Visual disorientation can persist at least 6 hours after BACs have returned to zero.

PAI - post alcohol impairment

Post Alcohol Impairment (PAI), or commonly termed "hangover," is a common phenomenon experienced by most users of alcohol on occasion after excessive drinking. The symptoms are variable and include nausea, vomiting, anorexia, heartburn, thirst, diaphoretics, tremors, headache, dizziness, fatigue, irritability, anxiety, and mental depression. After a significant drinking session, higher mental and reflex functions may be negatively affected for at least 48 - 72 hours (23). In contrast to intoxication, PAI may occur when the BAC has decreased to 0 mg% (but normally only after it had peaked previously at an intoxicated level).

Vitamin deficiencies and dehydration (a common problem in this condition) are no longer thought to cause this condition. The occurrence of PAI probably depends on a combination of factors including ethanol concentration (proof), volume, peak BAC, and the presence of congeners. It was shown that, with peak BACs of 125 mg%, two thirds of bourbon (high congener) drinkers experienced hangovers versus less than half of the vodka drinkers; the bourbon groups' symptoms were also more severe. This effect of congeners, however, only appears to be present after large quantities of alcohol are consumed and high BACs are reached (27).

There have been mixed results regarding performance decrements following ethanol ingestion because in some studies inadequate peak BACs were reached and in others measurements were made before BACs had returned to zero. For example, Collins, using the MTPB, demonstrated definite impairment from acute intoxication. On the "morning after" there was variance due to circadian effects, but no significant change from congeners or hangover. He did not find any decrease in visual tracking 8 hours following alcohol intake with a mean peak BAC of 93 mg% (28), and he had the same negative results for visual reaction times.

Recent Scandinavian research, however, found a 20% reduction of driving skills when the BAC had been 0 mg% for at least 3 hours following a prior peak of 147 mg% (29). In their hungover condition, the subjects were unable to tell if they were fit to drive. Since the main determinant of flying fitness is often the aircrew's subjective determination of their own status, this lack of insight has significant implications for aerospace safety.

In a Navy study published in 1986, the flight simulator performance of ten P3-C Orion pilots was tested 14 hours after achieving a BAC of 100 mg%. Noting that previous inconclusive studies had not required complex tasks, these researchers created scenarios that stressed the execution of unusual emergency procedures. The two flights that each subject flew included loss of two engines after takeoff (on the same side) with an ILS approach back to the runway. Pilot performances were worse under hangover conditions in almost all measures (5). The authors concluded that alcohol had impeded the ability to process information especially in non-routine tasks when attention had to be divided between conflicting priorities. A further concern was the pilot's lack of awareness of their impaired condition -- as with the drivers in the previous study.

Wise compared completion of a pre-flight checklist in "non-drinking" subjects who had drunk a quantity of alcohol sufficient to achieve a BAC of 100 mg%. Their performance at 30 minutes and at 14 hours post-ingestion was measured (30). The preset errors which the subjects were expected to check and correct included: gear handles "UP," speed brakes in the extended position, flaps set at 50%, tip tanks "SELECTED" (allowing the normal action to turn the selector to "OFF"), parking brakes "OFF," and an altimeter misset by 1000 feet. Fourteen hours after drinking, 68% of the subjects missed at least one error compared to only 10% when sober. In fact, the results were similar to the intoxicated condition (when, not surprisingly 89% erred) in spite of the simple checklist which, if followed, would have eliminated all the errors (Fig. 14). Not anticipating the fault conditions, the subjects ignored them and remained unaware of their oversights.

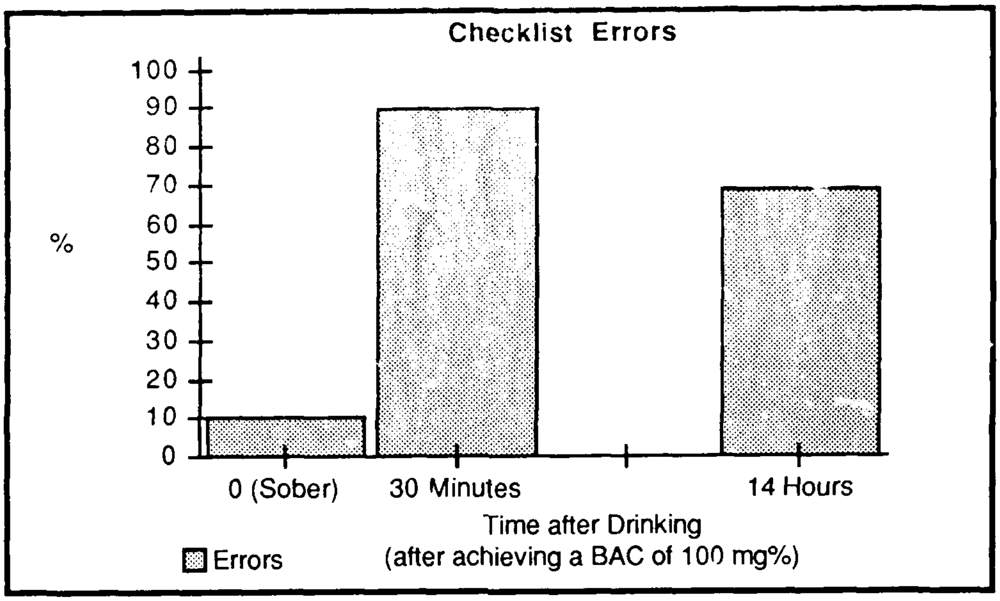


Figure 14. Errors in checklist procedures.

Attitudes and Misconceptions

In a 1978 survey, 50% of 835 general aviation pilots in Vermont viewed it safe to fly 4 hours after drinking alcohol (2,19). It was estimated that between a quarter to one-third of the respondents would consider it safe to fly when a post imbibition BAC was still in excess of 15 mg%. Of course, this percentage roughly parallels the 20% of general aviation pilots killed in mishaps during that time with the same BAC levels. Another survey using a national sample of pilots was analyzed from the perspective of the respondents' use of alcohol and flying experience (19). It was found that pilots were more cautious about flying than driving. While heavy drinkers were more lenient towards drinking and driving, all were less tolerant about drinking and then flying. Although, from their responses, it would seem that few would attempt flying while legally impaired, some of them believed it was possible to pilot an aircraft with a BAC between 0 and 40 mg%. Many more would drive with BACs between 40 and 100 mg% (Fig. 15).

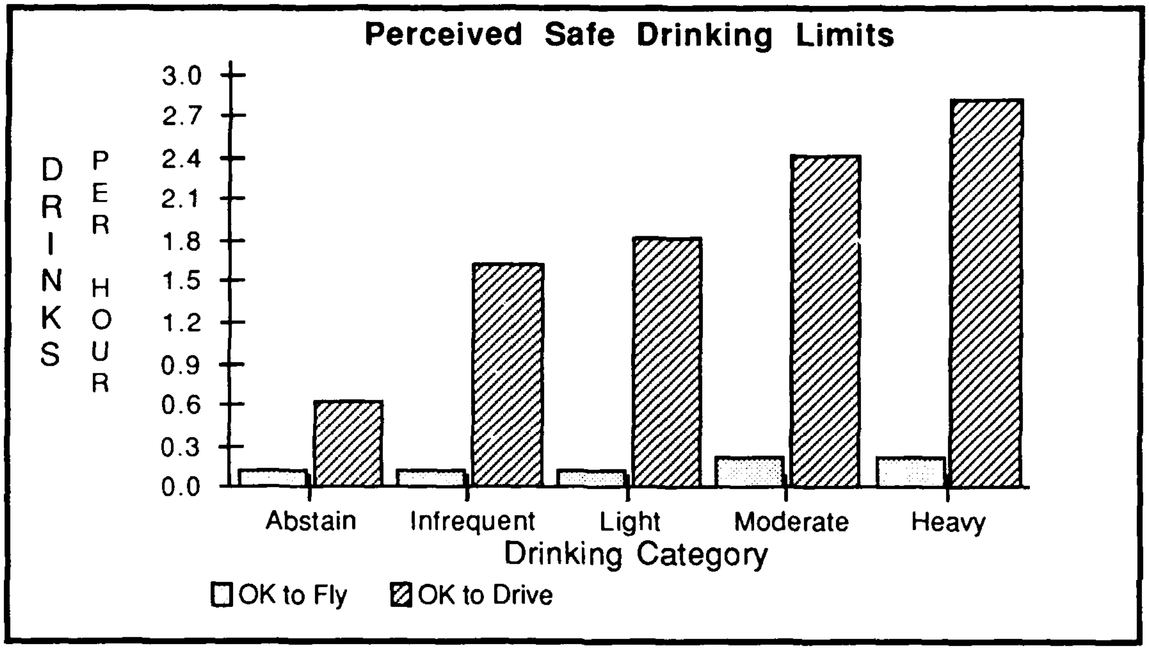


Figure 15. Perceived safe drinking limits by pilots for flying and driving.

Summary — Aeromedical Policy

Alcohol is a difficult matter to discuss, first because most people have strong feelings about it one way or the other, and second because there are so many variables that it is difficult to predict with certainty the effects of a certain amount of alcohol on an individual.

Most people are now familiar with the legal limits and sanctions for driving while intoxicated (DWI). To compare driving to flying may help to understand the extreme conservatism necessary in the latter environment. Vehicles in motion do not have as many degrees of freedom as aircraft. Drivers control left and right (yaw) movement only, while pilots rotate their airplanes around the pitch and roll axes as well. In addition, they control their craft in a coordinated combination of all three motions while being subjected to resultant G "forces" several times that of gravity. The speed of automobiles is legally limited to 55 - 65 mph while jets normally cruise at ten times this speed. Aviators have to simultaneously navigate, communicate, and monitor complex aircraft systems while their vision is restricted by a small field of view and possibly obscured by inclement weather. Most important, drivers, if they are lost, fatigued, or spill their coffee, can simply pull over and stop and rectify the situation, or rest. Solo pilots do not have that option. Therefore, the saying that "flying is as easy as driving a car" is simply not true -- an aircraft is much more complicated and controlling it is much more demanding.

Another factor to remember when considering the USAF mission is that alcohol consumption generally rises in a combat zone (3). Unit discipline is the strongest weapon to prevent excessive drinking and flying sorties while hungover. In emergency conditions the effects of alcohol and hangover are most pronounced. This situation is more likely to develop when pilots scheduled to fly particularly stressful or dangerous missions drink to control their anxiety. The subsequent combination of hangover and a nonroutine or emergency procedure may have a tragic conclusion.

Society does seem to be changing with regard to its market trends for alcohol products. Where the trendsetters in California drank cocktails 20 years ago, white wine 10 years ago, and coolers 5 years ago, it is now fashionable to consume only fruit juice or bottled water (10). Perhaps soon more neo-prohibitionists will have succeeded in having booze labeled with warnings about "fetal alcohol syndrome" and other health hazards just as cigarettes now are. These warnings are now posted by law in all establishments in California that sell alcoholic drinks.

Since 1985, FAA regulations (Part 91.11) have set a prohibited BAC level of 40 mg% and required the implied consent of aircrew to provide the results of any test that may indicate ethanol levels in the blood (31). Many also feel that the 8 hour bottle to throttle rule is too simple and inadequate to prevent aircrew flying while impaired by intoxication or hangover. Making rules will not by themselves change human conduct, however. It is the responsibility of everyone in aviation to be aware of the acute effects of alcohol and adjust their own patterns of behavior to ensure safe flying.

References

1. Schuckit MA. Alcoholism and drug dependency in Harrison's Principles of Internal Medicine, pp. 2106-2111. 11th Ed, Braunwald E *et al*. Eds. 1987.

2. Hawkins FH. Human factors in flight. Hants, England: Gower Technical Press, 1987.

3. Dehart RL Ed. Fundamentals of aerospace medicine. Philadelphia: Lea & Febiger, 1985.

4. Ernsting J, King P Eds. Aviation Medicine, 2nd Ed. Boston: Butterworths & Co Ltd, 1988.

5. Yesavage JA, Leirer VO. Hangover effects on aircraft pilots 14 hours after alcohol ingestion: a preliminary report. Am J Psych 143(12): 1546-1550 (1986).

6. Johnson H. The world atlas of wine. London: Mitchell Beazley Pub, 1985.

7. Lord T. The World Guide to Spirits. pp. 6-27, 1979.

8. Shakespeare W. Macbeth. Act II, Scene 3.

9. Jackson M. The world guide to beer. Philadelphia: Running Press, 1977.

10. Editor. Cheers through the tears. The Economist Apr 16: 77-78 (1988).

11. Editor. American boozers cool it. The Economist Aug 29: 64 (1987).

12. Julien RM. A primer of drug action. pp. 66-75. San Francisco: W.H. Freeman, 1975.

13. Billings CE, Wick RL, *et al.* Effects of ethyl alcohol on pilot performance. Aerospace Med 44(4): 379-382 (1973).

14. McWhirter ND Ed. Guiness book of world records. Toronto: Bantam Books, 1984.

15. Coleman RM. Wide awake at 3:00 a.m.; By choice or by chance? New York: W.H. Freeman, 1986.

16. Green R. A guide to booze in "Human Factors: Just for You" Liang S Ed. (reprinted from Flying Safety) Dec: 16-19 (1984).

17. Editor. One round too many. The Economist Sep 13: 55 (1986).

18. Henry PH, Flueck JA,*et al.* Assessment of performance in a Link GAT-1 flight simulator at three alcohol dose levels. Aerospace Med 45(1): 33-34 (1974).

19. Ross OE, Mundt JC. Effects of blood alcohol level on pilot performance, pp. 1182-1186. Proceedings of the Human Factors Society, 30th Annual Meeting, 1986.

20. Collins WE, Mertens HW, et al. Some effects of alcohol and simulated altitude on complex performance scores and Breathalyzer readings. Aviat Space Environ Med 58: 328-332 (1987).

21. Collins WE, Mertens HW. Age, alcohol, and simulated altitude: Effects on performance and Breathalyzer scores. Aviat Space Environ Med 59: 1026-1033 (1988).

22. Gibbons HL. Alcohol, aviation and safety revisited: A historical review and a suggestion. Aviat Space Environ Med 59: 657-660 (1988).

23. Ryback RS, Dowd PJ. After effects of various alcoholic beverages on positional nystagmus and coriolis acceleration. Aerospace Med 41(4): 429-435 (1970).

24. Baloh RW, Sharma S, *et al.* Effect of alcohol and marijuana on eye movements. Aviat Space Environ Med 50(1): 18-23 (1979).

25. Katoh Z. Slowing effects of alcohol on voluntary eye movements. Aviat Space Environ Med 59: 606-610 (1988).

26. Money KE, Landolt JP. Unusual toxicological property of alcohol: The density effect on the organ of balance, pp. 51-58, in "Conference Proceedings of the Aerospace Medical Panel Symposium held at London on 4 October 1983," 1984.

27. Hill RJ, Schroeder DJ, Collins WE. Vestibular response to angular accelerations and to coriolis stimulation following alcohol ingestion. Aerospace Med 43(5): 525-532 (1972).

28. Collins WE, Chiles WD. Laboratory performance during acute alcohol intoxication and hangover. Hum Factors 22: 445-462 (1980).

29. Franck DH. 'If you drink don't drive' motto now applies to hangovers as well. JAMA 250(13): 1657-1658 (1983).

30. Wise LM. Residual effects of alcohol on aircrew performance. Aerospace Safety Sep: 16-19 (1980).

31. Anonymous. You're the flight surgeon. Aviat Space Environ Med 57: 808 (1986).

Bibliography

1. Dellinger JA, Taylor HL. Measuring the effects of neurotoxicants on flight simulator performance. Aviat Space Environ Med 56(3): 254-257 (1985).

2. Dellinger JA, Taylor HL, Richardson BC. Comparison of the effects of atropine sulfate and ethanol on performance. Aviat Space Environ Med 57: 1185-1188 (1986).

3. Dowd PJ, Wolfe JW, Cramer RL. Aftereffects of alcohol on the perception and control of pitch attitude during centripetal acceleration. Aerospace Med 44(8): 928-930 (1973).

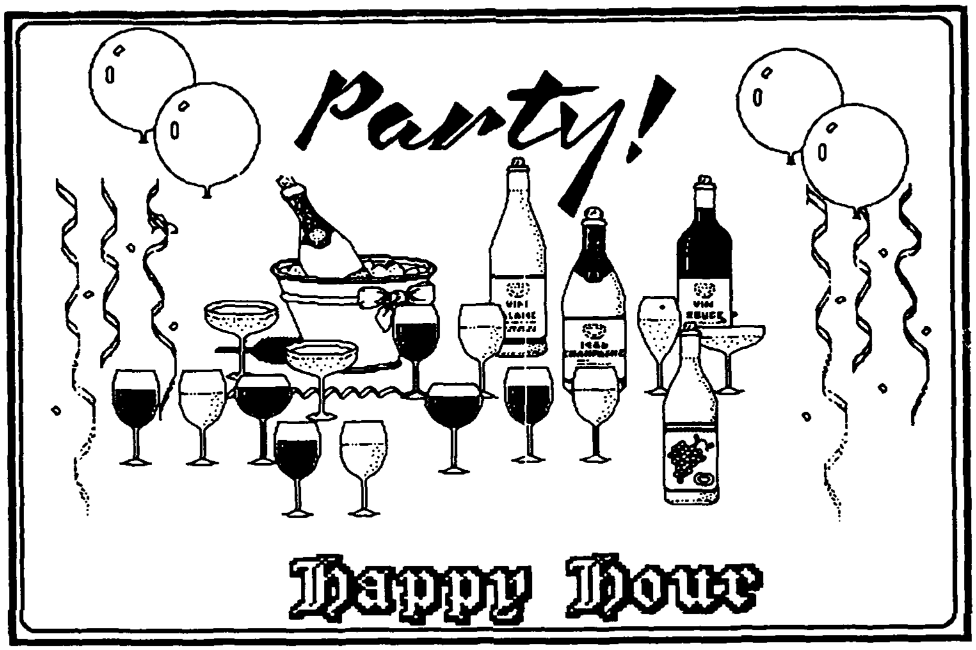
4. Jones WB. Alcohol consumption by pilots (letter). Ann Emerg Med 14(3): 278 (1985).

5. Murphree HB, Greenberg LA, Carroll RB. Neuropharmacological effects of substances other than ethanol in alcoholic beverages. Fed Proc 26(5): 1468-1473 (1967).

6. Ross LE, Ross SM. Pilot's attitudes toward alcohol use and flying. Aviat Space Environ Med 59(10): 913-919 (1988).

Alcohol - Acute Effects in Aircrew (Part II)

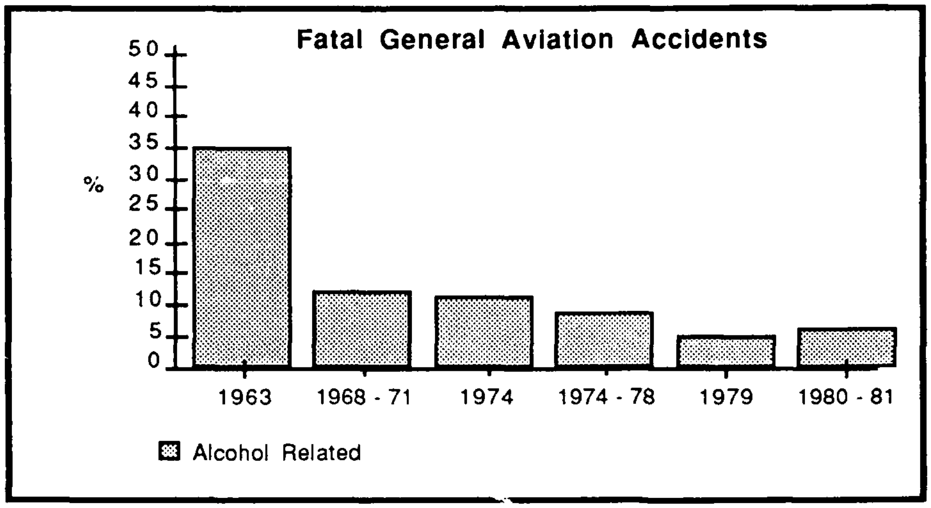
Slide 1



Ethanol or ethyl alcohol is a drug that is used in most societies and found almost everywhere. Because it is easily made and has a long tradition of use it has been accepted more widely than any other medicinal substance. It it is used mainly for social and recreational purposes rather than for its pharmaceutical effects.

In the U.S.A. almost all adults drink at least occasionally, and half of us will have some type of alcohol problem during our lifetime. On average 10% of men and 3 - 5% of women will become alcoholics. Even light drinking causes problems ranging from mild - severe intoxication to hangover. This briefing will concentrate on the immediate effects of alcohol and the adverse influence it can have in the flying environment.

Slide 2

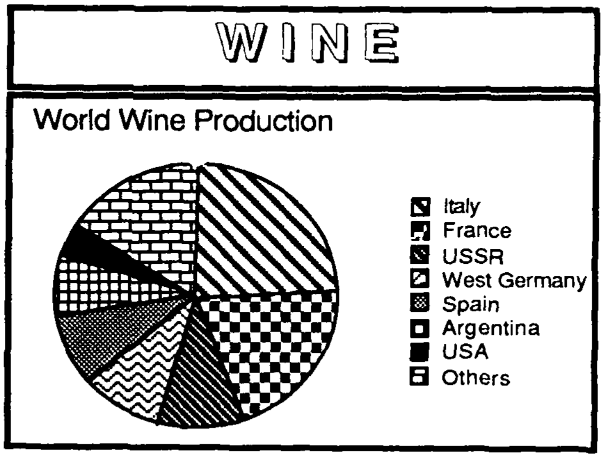


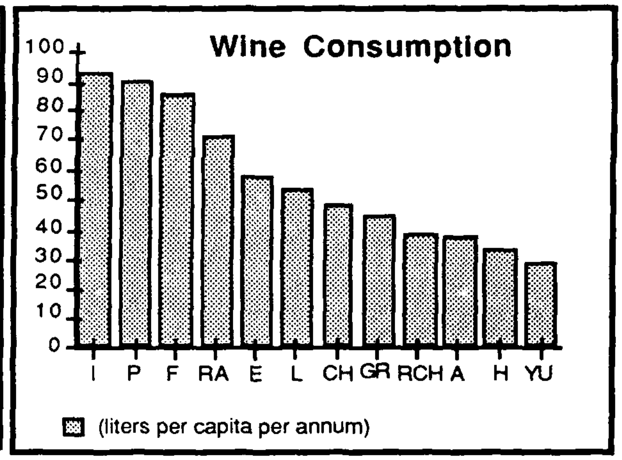
Aircrew are certainly not all teetotallers or abstainers. A survey of British airline pilots revealed that 98.7% drank alcohol. The average consumption was four drinks four times per week. Figures for military aviators would likely be at least equal.

Unfortunately the effects of alcohol on aircrew have not always stopped at the airport ramp. In 1963, 35% of fatal general aviation accidents were positive for blood or tissue alcohol. After the FAA 8 hour "bottle to throttle" rule was enacted in 1970 there was an initial drop in the percentage; the proportion peaked at 11.2% in 1974, averaged 8.6% from 1974 - 78, and dropped to 5.7% in 1979 and to 6.5% during 1980 - 81.

Air accidents attributed to alcohol use are much less common in commercial carriers. One dramatic exception, however, was a Japan Air Lines cargo DC8 which crashed at Anchorage in 1977 without survivors. The pilot was found to have a BAC of 210 mg% -- almost three times the legal limit for driving. There were also three civil airliner crashes in the 1980 - 82 period in which the influence of alcohol on the aircrew was officially reported.

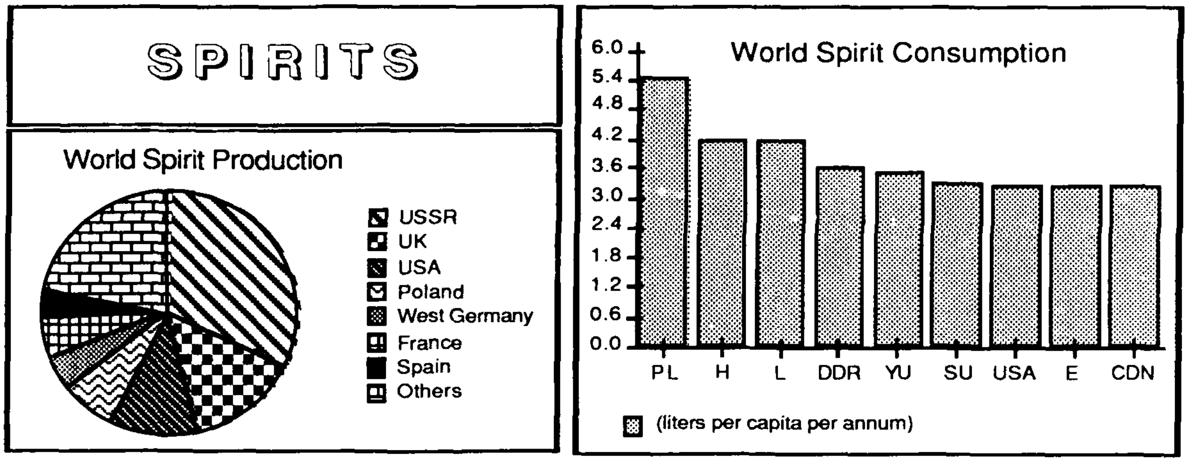
Slide 3





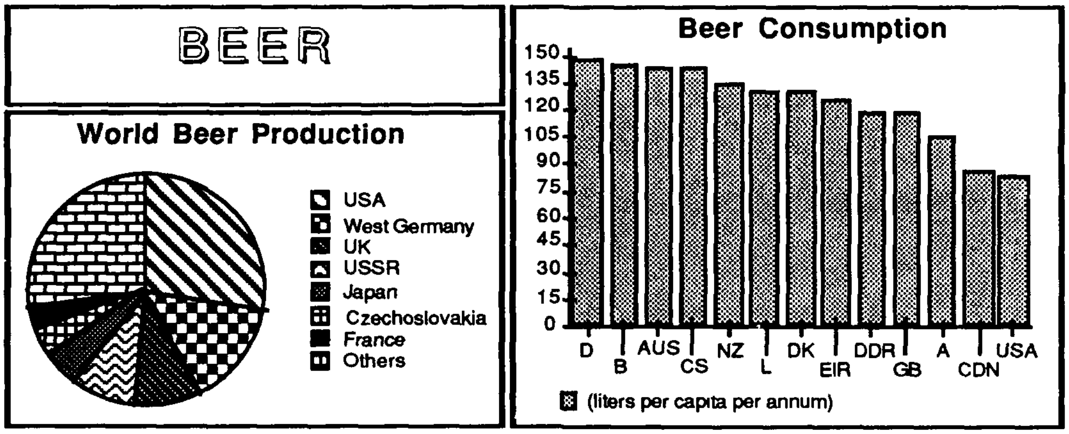
The use of alcohol dates back as far as recorded history. Winemaking was introduced to the Mediterranean region by the Greeks, and then the Romans spread it through Western Europe. Italy is still the number one country in the world for both wine production and drinking. Although the U.S. is seventh in wine production, there aren't enough wine consumers to make it into the top thirty of wine drinking nations.

Slide 4



Distillation originated in the Middle East and was exported to Europe by the Arabs during the Middle Ages. The word "alcohol" is actually from the Arabic. Since its use of alcohol was banned by Islam, the art of distilling spirits was passed on by western monks and alchemists. Alcohol was referred to as the "water of life"; or *eau de vie* in French, and *usquebaugh* in Gælic, from which we derive the name "whiskey." In the Elizabethan era the physiological effects were known to Shakespeare, who in *Hamlet* noted that alcohol provoked only "nose-painting, sleep and urine." Today almost every country has an alcoholic beverage industry of some type. American liquor distillation is third worldwide, while consumption ranks eighth at 3.2 liters per capita. We drink mainly whiskey: bourbon, American, Canadian, Irish, and Scotch, followed by vodka and rum.

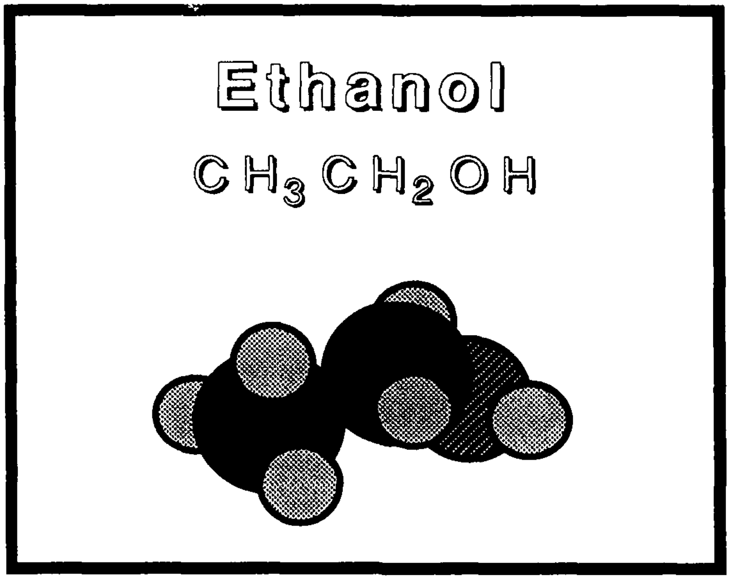
Slide 5



The USA leads in the production of beer but ranks only thirteenth in consumption -- still that works out to 82 liters for each man, woman, and child. So in this country it is still beer which is foremost. In the past few years sales of wine coolers with 2 - 7% alcohol have soared to become a billion dollar business.

The adverse economic impact of alcohol must also be remembered, however. In 1971 the cost of alcoholism to U.S. industry was estimated as $10 billion a year; the overall cost of ethanol abuse was $25 billion.

Slide 6



Ethyl alcohol or ethanol is a weakly polarized, relatively simple molecule. Each gram of alcohol provides 7.1 calories without any nutrients. The density of ethanol is less than that of water.

Sugar is changed into alcohol and carbon dioxide by fermentation which is brought about by yeasts and even by bacteria. In winemaking, the yeast is present naturally on the grape skins and, once these are broken, sugar in the pulp can be fermented.

Slide 7

Wine

Specific Gravity	% Potential Alcohol
1.065	8.1
1.070	8.8
1.075	9.4
1.080	10.0
1.085	10.6
1.090	11.3
1.095	11.9
1.100	12.5
1.105	13.1
1.110	13.8
1.115	14.4
1.120	15.0

SPIRITS

Gay Lussac (% by volume)	American Proof	British Proof
10	20	17.50
20	40	35.00
30	60	52.50
40	80	70.00
45	90	78.75
50	100	87.50
57	114	100.00
60	120	105.00
70	140	122.50
80	160	140.00
90	180	157.50
100	200	175.00

If undisturbed the sugars would be completely converted to alcohol creating a dry wine with about 15% ethanol by volume. Wines may vary considerably in their alcohol content. A dry, white Moselle has 10% ethanol, while a red Bordeaux about 12%. Port has brandy added to it resulting in a sweet wine with 20% ethanol. The potential alcoholic content of a wine (if all sugar is fermented out) is related to the original sugar content of the grape. The table on the left shows the potential alcoholic content of wines depending on how much sugar is fermented.

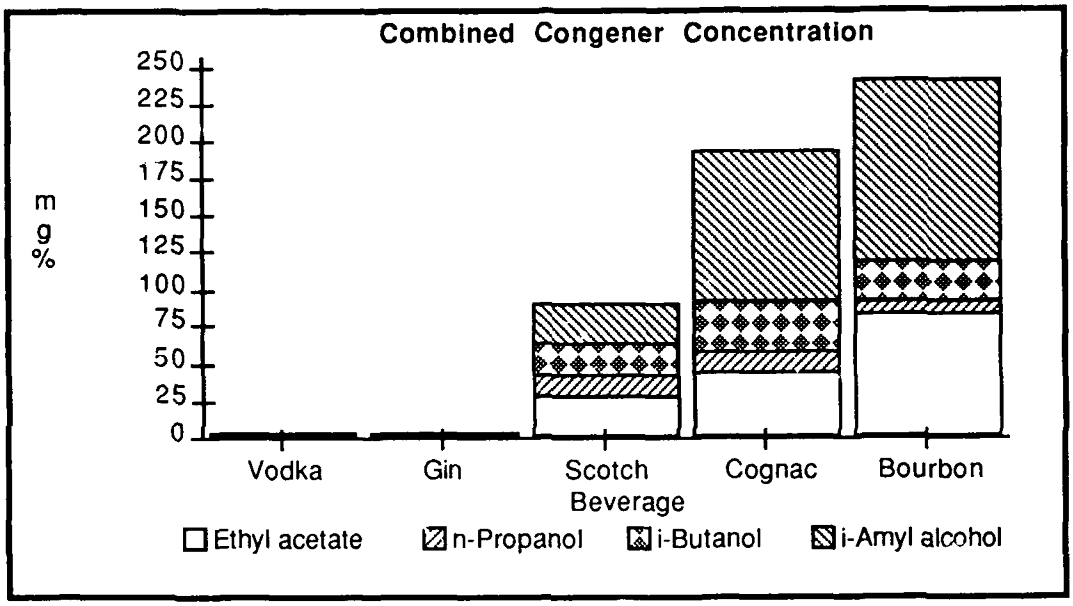
Spirits are made from the distillation of a fermented mash or base liquid. Some examples of final products and their sources are: brandy or cognac (grape mash /wine), gin and vodka (grain/ potato), rum (sugar cane/molasses), and tequila (agave cactus). The whiskeys are generally distilled from malted grains with the following combinations: Scotch (malted barley), Irish (barley, oats, corn, rye, and wheat), Bourbon (corn mash), and Canadian (rye mash). There are three systems to measure the alcoholic content of spirits. The simplest method expresses it as a percentage of alcohol by volume (Gay Lussac). The American proof system is equivalent to twice this, thus 100% ethanol would be 200 proof. The British measure is now being used less commonly. A comparison of the different measurement systems is seen in the right-hand table.

Slide 8

TYPICAL BEER STRENGTHS		
Beer	Origin	
Kulminator	Bavaria	13.2%
Strong beers	Germany	10.0%
Strong beers	Belgium	10.0%
Strong beers	England	10.0%
Strong beers	Worldwide	8.0%
Pilsener	Worldwide	5.0%
Ales	English	3.5%
Regular beer	U.S.A	3.2%

Beer is formed from a malted grain mash (generally barley). The mash is brewed at a high temperature with a mixture of water, yeast, and hops (used as a flavoring agent). The two basic classes of beer are the bottom-fermented *lagers* (including pilseners) and the ales which are top-fermented. Following fermentation, beer may be filtered and pasteurized to ensure longer shelf-life and further distribution. The strongest beer is from Kulmbach, in Bavaria, West Germany, with an alcohol content of 13.2%. Other European beer may run up to 10%. The average pilsener is about 5% by volume. In the USA regular beer is limited by law in many states to 3.2% alcohol by weight.

Slide 9



Congeners are impurities in beverages which impart to them distinctive odors and tastes. It is the congeners which let you distinguish a brandy from a whiskey, or a rum from a vodka. Some higher congener containing products such as whiskey or cognac are aged in wood to moderate their effects. Congeners found in spirits may contribute to the adverse effects of hangover. The concentrations of selected congeners in various alcoholic beverages are displayed in this slide.

Slide 10

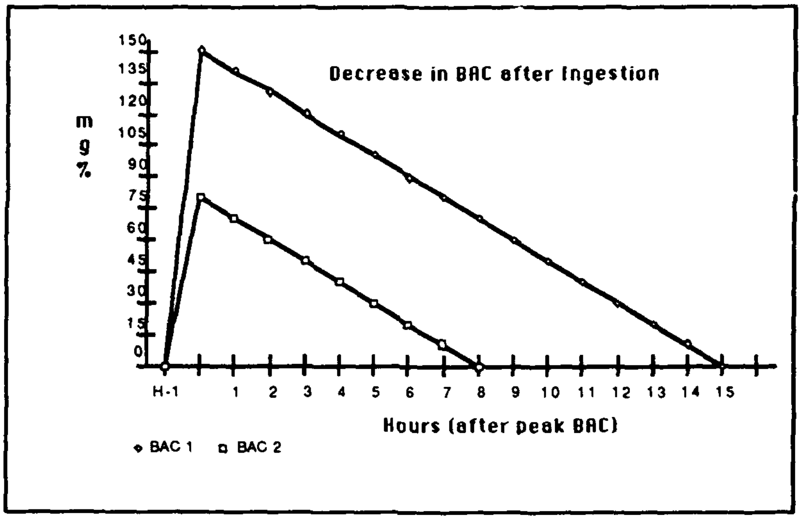
Weight (lbs)	Number of Drinks (of 10 ml pure ethanol/hr) 1	2	3	4	5	6
150	24	48	72	96	120	144
160	23	45	68	90	113	135
170	21	42	64	85	106	127
180	20	40	60	80	100	120
190	19	38	57	76	95	114
200	18	36	54	72	90	108
210	17	34	51	69	86	103
220	16	33	49	65	82	98
230	16	31	47	63	78	94
240	15	30	45	60	75	90
250	14	29	43	58	72	86

Blood alcohol concentrations (BAC) are expressed in milligrams of ethanol per deciliter; however, legal impairment is often measured in grams. Therefore, if you are impaired at 0.08 %, it is equal to 80 mg%. I will use the mg% units in this presentation.

Alcohol is rapidly and completely absorbed from your gastrointestinal tract. On an empty stomach about 20% of a dose of alcohol is absorbed in your stomach; the remaining 80% is absorbed through the upper intestine. A full stomach will delay absorption resulting in a lower BAC, but it lasts over a longer period. Concentrated liquors are taken up more rapidly than relatively dilute beer. When diluted to equal alcohol concentrations, red wine is absorbed faster than either liquor (gin > whiskey) or beer because of the congeners present. Sugars in fortified beverages slow down absorption while the carbon dioxide present in champagne, sparkling wine, and drinks mixed with soft drinks increase it.

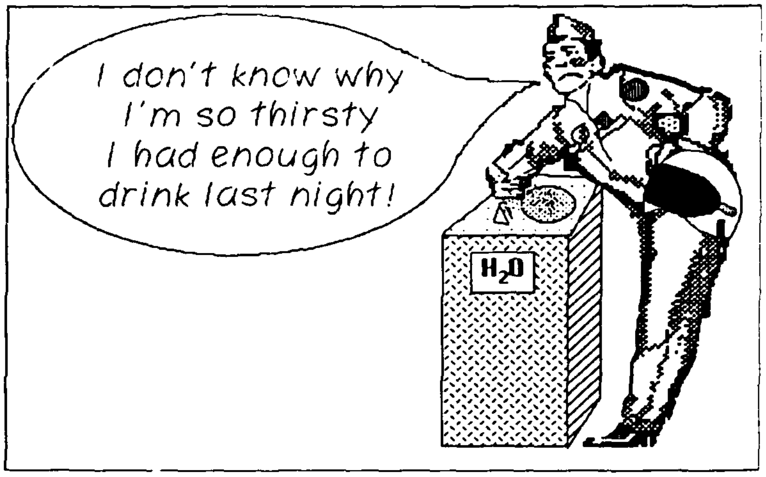
Since alcohol is fat soluble as well as water soluble, it may diffuse into the fat and muscle tissue of your body. Given the same dose, a lean individual will end up with higher BACs than a muscular body builder or an obese "fatso." There is the same amount of alcohol in 12 oz of beer as in a 1.5 oz shot of 80 proof liquor. The peak BAC you will get from a certain number of drinks can be seen in this table opposite your weight.

Slide 11



Almost all alcohol is metabolized in your liver. The final breakdown products are carbon dioxide and water. There are no minerals or vitamins in alcohol; hence, apart from calories, there is no nutritional value. Its rate of breakdown is constant -- about 10 ml of pure alcohol (1 oz of 66 proof liquor or 10 oz of beer) per hour. This means that if you drink faster than this you will be impaired. Once you cease drinking, the BAC will fall by 10 mg% per hour. As you can see, if you peaked at 150 mg%, it would take 15 hours to clear from your system; even at 75 mg% (legal to drive) the BAC would not reach zero until 8 hours; hangover effects would persist even longer.

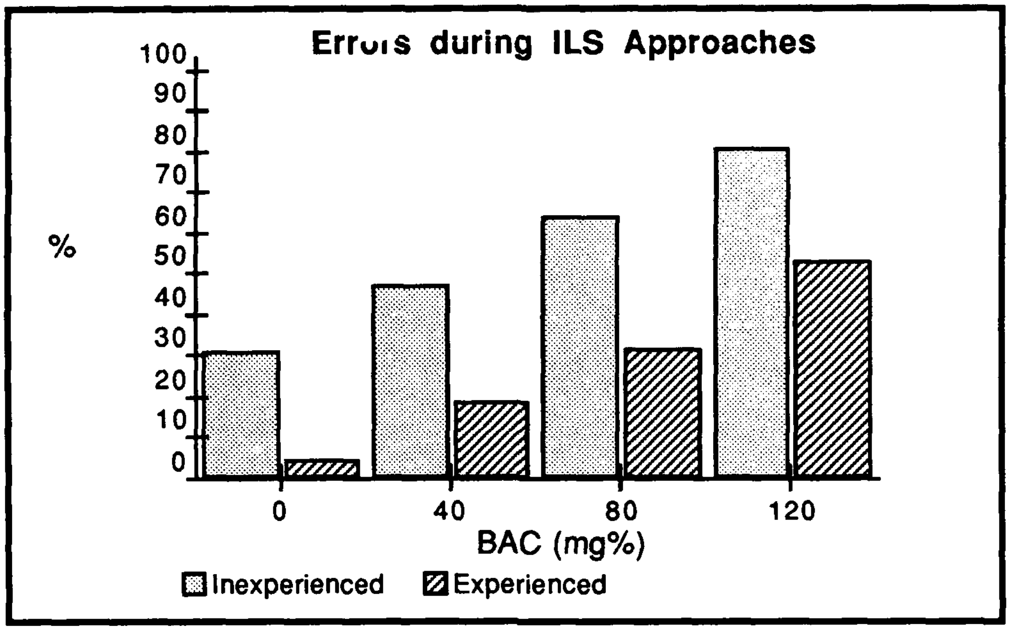
Slide 12



Alcohol works as a general CNS depressant. The initial high that you feel is caused by a loss of inhibition within the brain. At low doses you will have mild euphoria, loss of discrimination, fine movement, memory, and concentration as well as impairment of thought, organization, and motor processes. At higher doses or rising BACs the sequence of drowsiness, sleep, general anesthesia, coma, and death may follow. Early behavioral changes are seen as low as 20 - 30 mg%. The legal limit (for driving) is typically set at 80 - 100 mg%. A level of 300 - 400 mg% will usually kill you. Alcohol, either alone or in combination, is probably responsible for more overdose deaths than any other agent. Even a few drinks fragment your sleep patterns and cause a deficiency of deep sleep. Alcohol is also a diuretic. This means that it increases urine production, making you urinate more. The obvious danger of this well-known effect is dehydration.

Alcohol dilates blood vessels in the skin and extremities. It produces flushing and a feeling of warmth. Should you use it to treat frostbite? The only place for low doses in the treatment of minor cold injuries is during recovery within a warm environment and only when there is no further risk of low temperature exposure.

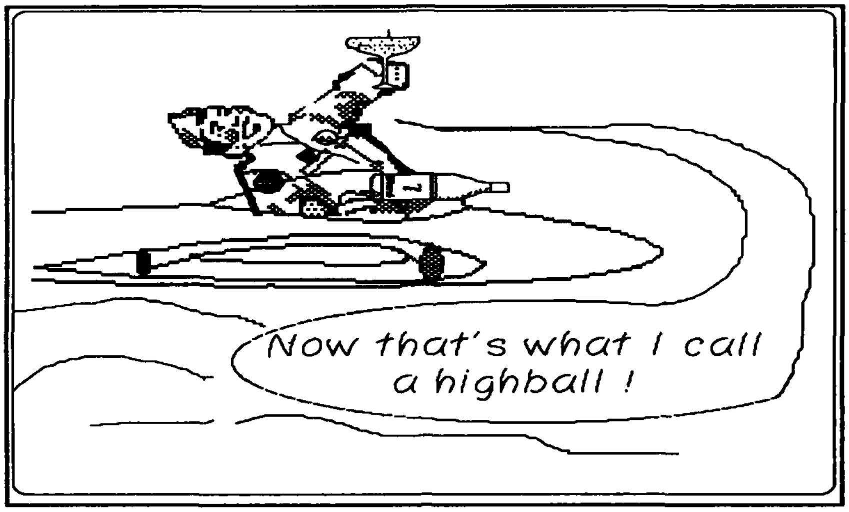
Slide 13



In low doses ethanol will impair your discrimination as well as your visual and audio perception. Tracking is impaired;distance judgment is degraded; and visual acuity is decreased. It disrupts your decision-making, judgment, and hand-eye coordination. You will react slower. One of the most disturbing features is the inability to recognize your problem.

Experiments were done with experienced and inexperienced pilots performing ILS approaches in a Cessna 172 while they had various BACs (40 mg%, 80 mg%, and 120 mg%). Each of the pilots performed two simulated night IFR flights including four ILS approaches to minimums and two missed approaches. The number of major errors increased during the 32 flights made at each BAC. It was necessary for the safety pilot to take control once at 40 mg%, three times at 80 mg%, and in half the flights made at 120 mg% !

Slide 14



Alcohol reduces our tolerance to positive acceleration (eyeballs down or $+G_Z$). A moderate dose reduces the threshold by up to 0.4 G and increases the severity of the symptoms for a given G "load."

It has long been thought that altitude and alcohol positively interact; for example, "two or three cocktails at 8,000 ft cabin altitude are equal to four or five at sea level." Recent experiments, however, have not found this relationship between intoxication and hypoxia. Alcohol impaired performance (more in an older age group), but there was no decrement noted due to altitude either alone or in combination. The BACs themselves were not affected by hypoxia.

Hypoglycemia or low blood sugar can easily result from alcohol ingestion. At least one mishap was attributed to this condition. A witness had seen the pilot collapse over the controls shortly before a crash; the blood sample that was quickly obtained after death revealed an ethanol level of 98 mg% (not enough to cause unconsciousness by itself), but the blood glucose level was far below the normal range.

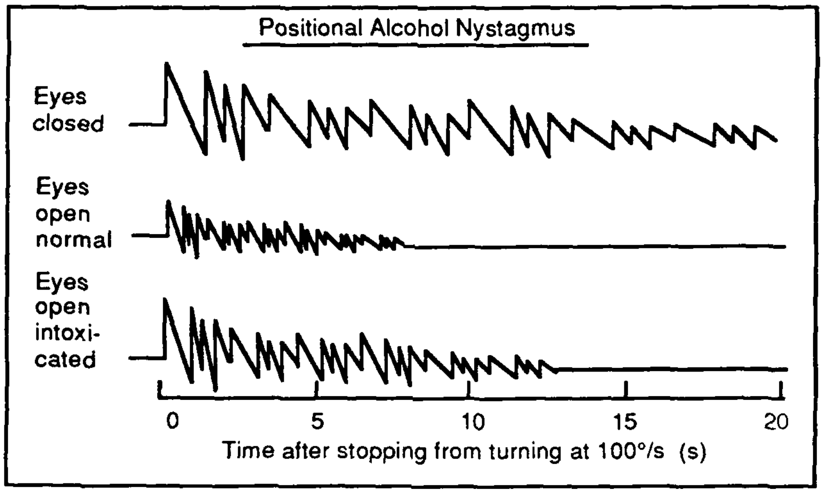
Slide 15

(Ear Diagram)

Some drinkers among you may have noticed that they have to wait for the bed to go past before they can jump on it and that things get even worse when they lie down. Drinking alcohol affects the middle ear's semicircular canals which are like angular accelerometers. Each canal is a fluid-filled tube with a watertight door across the end. The fluid (called perilymph) tries to stay in the same position because of its inertia, while the head rotates either on its own, or with external motion, such as during aircraft yaw, pitch, or roll corrections. The movement this system detects is passed to the brain where the information is integrated with the muscular control of eye movements allowing us to keep an object in focus on one part of the retina even while our head rotates. To demonstrate the effectiveness of this system, hold your finger at arm's length in front of you while you rapidly turn your head back and forth or nod up and down, keeping your gaze directed towards your finger. Now try the same thing while moving your finger instead. See how blurred it becomes! If you thought they were both equally blurred, perhaps we'd better test you on the Breathalyzer before you leave the lecture hall!

For this system to work, the fluid must not be affected by gravity, and the fluid within and without the system must have the same density. Alcohol in this system disturbs the gravity balance and causes upward displacement by its buoyancy compared with water, blood, and other biological fluids. The balance organ falsely interprets this as head motion and moves the eyes in the opposite direction to fix the visual gaze. Because there was no actual head movement, however, the errant eye movement stimulates the false perception that the world is moving instead.

Slide 16



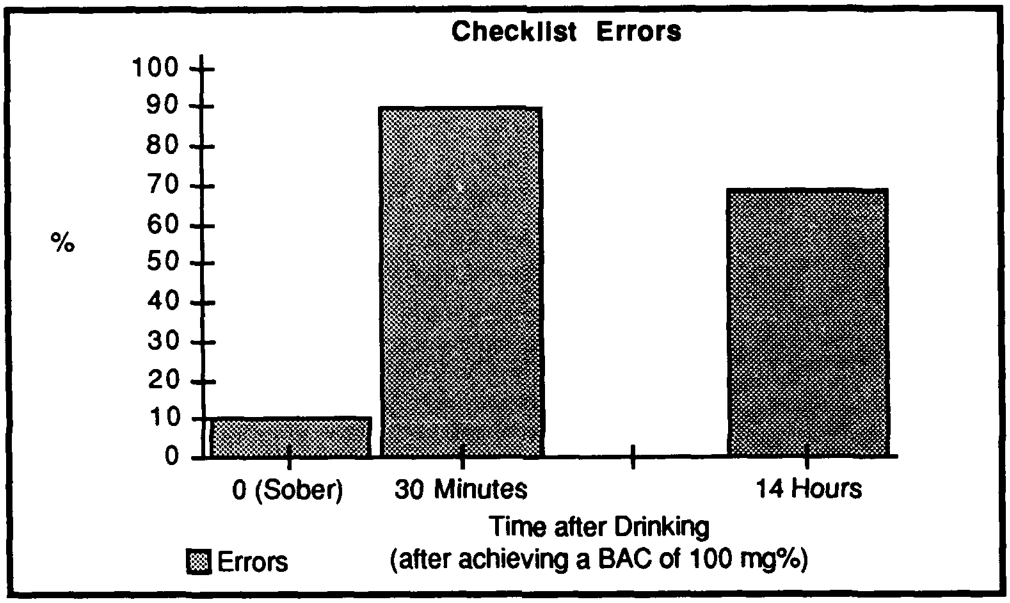
This effect is called positional alcohol nystagmus (Phase 1) or PAN 1 (nystagmus is the term for this eye movement). PAN 1 will occur while there is a buildup of alcohol in the blood, but before it is diffused into the perilymph. Due to the other direct effects of high BACs on the brain, the individual may not be aware of PAN 1. Then there is a phase where equilibrium exists between the BAC and ethanol in the perilymph, and positional alcohol nystagmus is not present. After BACs have fallen, even to zero, however, it takes a little longer to get rid of the alcohol in the perilymph. This imbalance causes PAN 2 with uncoordinated eye movements in the opposite direction. Unfortunately the effect of the density difference between alcohol and perilymph, and thus PAN, is accentuated with increased G. Consequently, this means that PAN and balance problems can be seen up to 2 days following moderate drinking (long after the BAC has returned to zero) if the person is exposed to 2 or 3 G! Some jokers have suggested that, since it is the lighter specific gravity of alcohol that causes this physical effect, the remedy could be to mix your drinks with a denser fluid such as heavy water. This would be expensive (it costs more than $60 an ounce), and would not avoid the sedative effect of alcohol.

Slide 17

Post Alcohol Impairment or "hangover" is a common experience that most of you have had on occasion after excessive drinking. The symptoms are variable and include nausea, vomiting, loss of appetite, heartburn, thirst, sweating, tremors, headache, dizziness, fatigue, irritability, anxiety, and mental depression. After a significant drinking session your brain may be negatively affected for at least 48 - 72 hours. In contrast to intoxication, hangover may occur when the BAC has decreased to 0 mg% (but normally only after it had peaked previously at an intoxicated level). More bourbon (high congener) drinkers experienced hangover than vodka drinkers in one experiment, and the bourbon groups' symptoms were also more severe. This effect of congeners, however, only appears to be present after large quantities of alcohol are consumed causing high BACs.

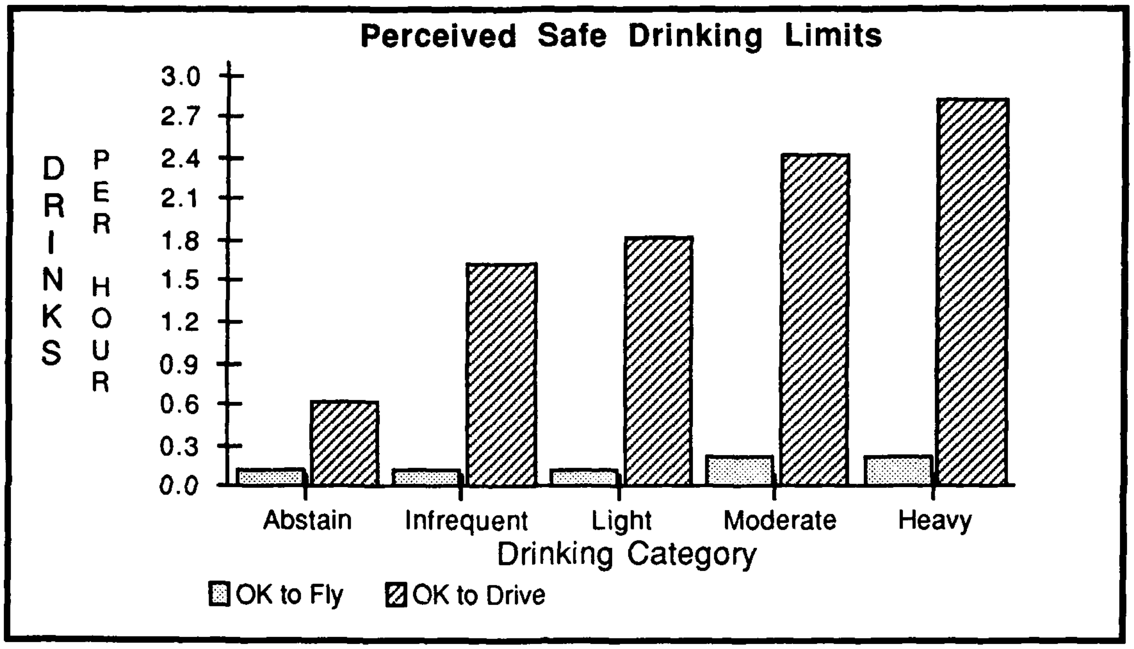
A Navy study of 10 P3-C Orion pilots tested flight simulator performance 14 hours after achieving a BAC of 100 mg%. The two flights that each subject flew included loss of two engines after takeoff (on the same side) with an ILS approach back to the runway. Pilot performances were worse under hangover conditions in almost all measures. Alcohol had impeded the ability to process information, especially in nonroutine tasks when attention had to be divided between conflicting priorities. A further concern was the lack of awareness of their impaired condition -- since your own judgment is often the determinant of whether you are fit to fly, this lack of insight has significant implications for flight safety.

Slide 18



Another study compared performance in the completion of pre-flight checklists by subjects who had not drunk alcohol with the performance of those who had drunk alcohol at 30 minutes and at 14 hours. The preset errors which the subjects were expected to check and correct included: gear handles “UP,” speed brakes in the extended position, flaps set at 50%, tip tanks “SELECTED” (allowing the normal action to turn the selector to “OFF”), parking brakes “OFF,” and an altimeter misset by 1000 feet. Fourteen hours after drinking, 68% of the subjects missed at least one error compared to only 10% when sober. In fact the results were similar to their intoxicated condition (when, not surprisingly 89% erred). This poor performance occurred in spite of of the simple checklist which, if followed, would have eliminated all errors. Not anticipating the fault conditions, the subjects ignored them, and remained unaware of their oversights.

Slide 19



A survey of pilots was analyzed according to the respondents' use of alcohol and flying experience. It was found that pilots were more cautious about flying than driving. While heavy drinkers were more tolerant towards drinking and driving, all were less tolerant about drinking and flying. Although, from their responses, it would seem that few would attempt flying while legally impaired, some of them believed it was possible to pilot an aircraft with a BAC between 0 and 40 mg%. Many more would drive with BACs between 40 and 100 mg%.

Slide 20

Points To Remember

- Always respect alcohol.
- Set a limit before you drink and stick to it.
- Buy a round of snacks rather than drinks.
- Drink slowly, never gulp.
- Don't succumb to "chugging" contests.
- Don't feel obligated to drink at functions.
- Never drink and drive.
- Never, never consider flying after drinking or when hungover.

Alcohol is a difficult matter to discuss, first because most of you have strong feelings about it one way or the other, and second because there are so many variables that it is difficult to predict with certainty the effects of a certain amount of alcohol.

Most of you are now familiar with the legal limits and sanctions for driving while impaired. To compare driving to flying may help to understand why you must be so much more careful than the general public. Cars do not have as many degrees of freedom as an aircraft. The driver controls left and right (yaw) movement only, while you can rotate your airplane around the pitch and roll axes as well. In addition you control, in a coordinated combination, all three motions while being subjected to a resultant G "force" several times that of gravity. The speed of an automobile is legally limited to 55 - 65 mph while you cruise at ten times this speed. You are simultaneously navigating, communicating, and monitoring complex aircraft systems while restricted by a narrow field of view that may be obscured by inclement weather. Most important, drivers, if they become lost, fatigued, or spill their coffee, can simply pull over and stop and rectify the situation, or rest. A solo pilot doesn't have that option.

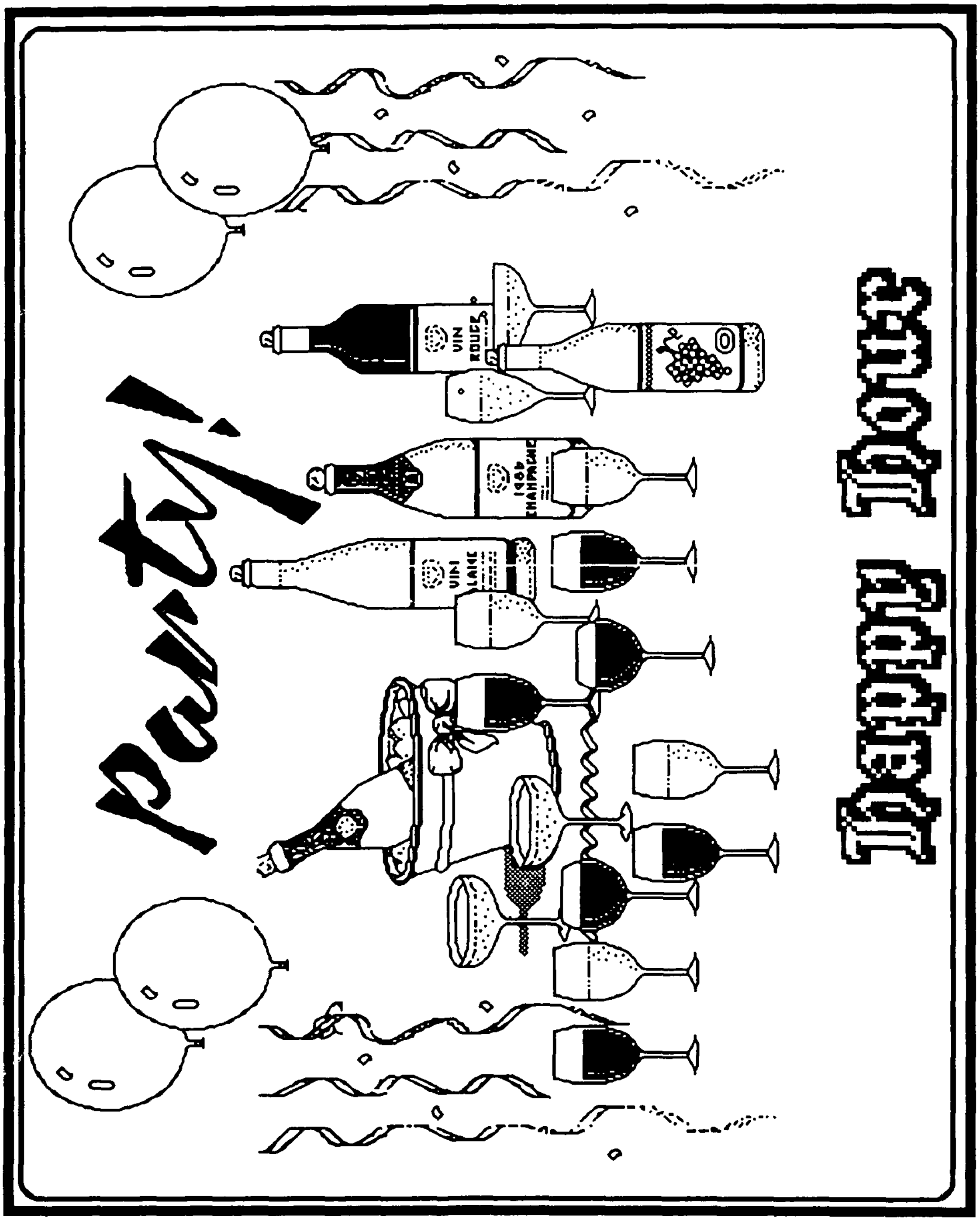
Another factor to remember is that in emergency conditions the effects of alcohol and hangover are most pronounced. This situation is more likely to develop when you're scheduled to fly particularly stressful or dangerous missions, and drink to control your anxiety. The combination of hangover and a non-routine or emergency procedure may make that your final mission.

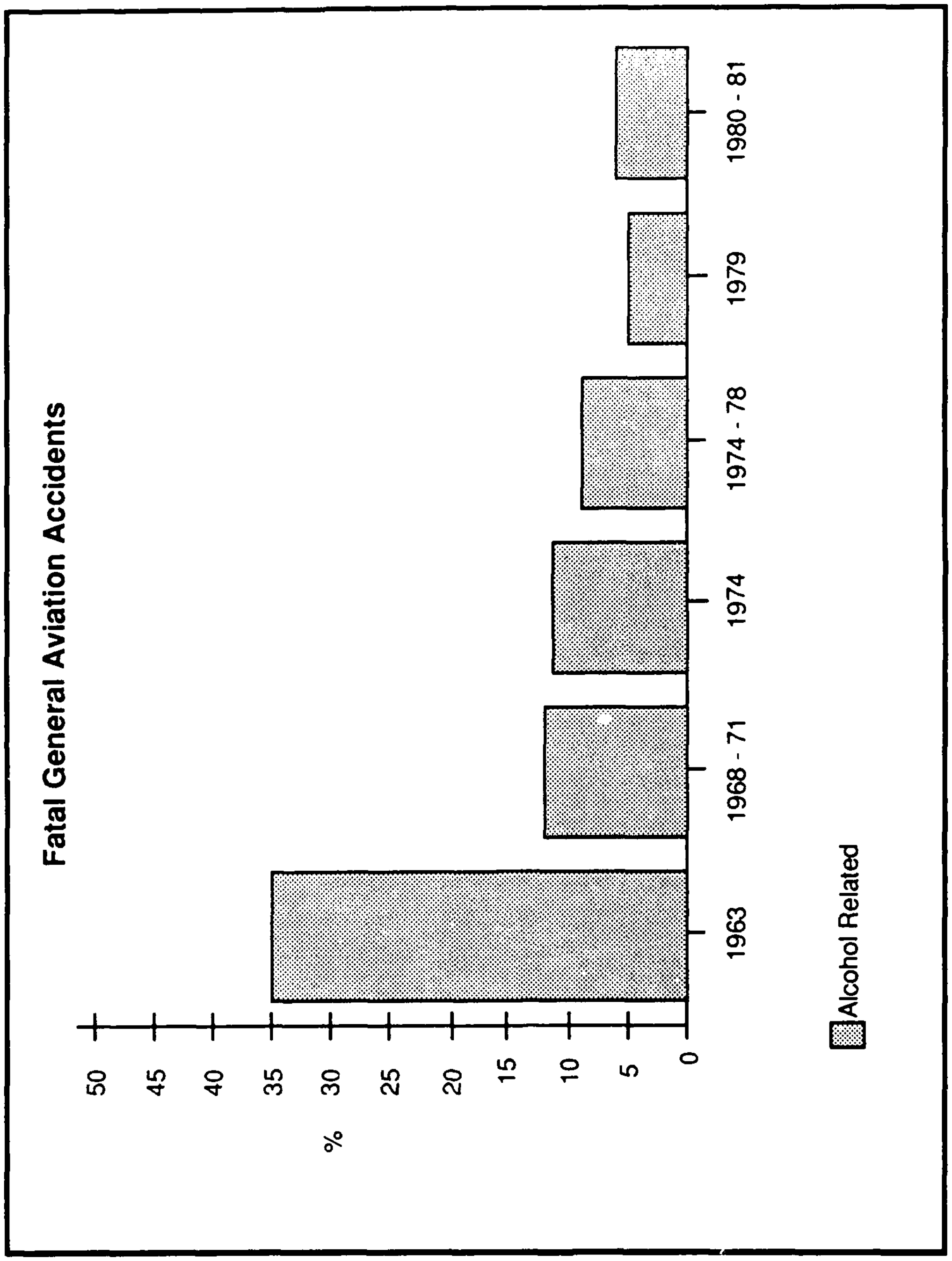
The "8 hour bottle to throttle" rule is too simple and inadequate to always prevent you from flying when impaired by intoxication or hangover. It is your responsibility to be aware of the acute effects of alcohol and adjust your own patterns of behavior to ensure safe flying.

ATTACHMENT I

PART III

VU-GRAPH MASTERS

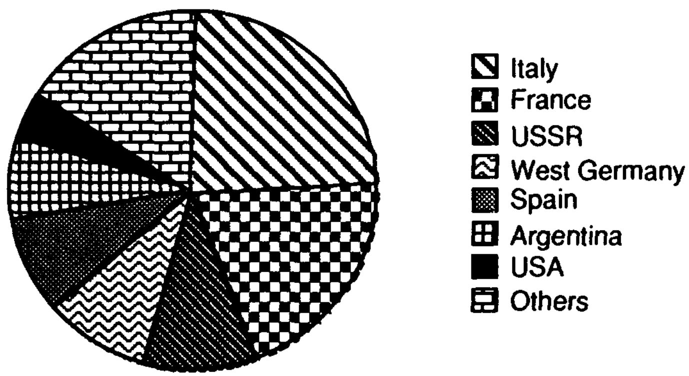

Party!
Happy Hour
VIN ROUGE
VIN BLANC
CHAMPAGNE

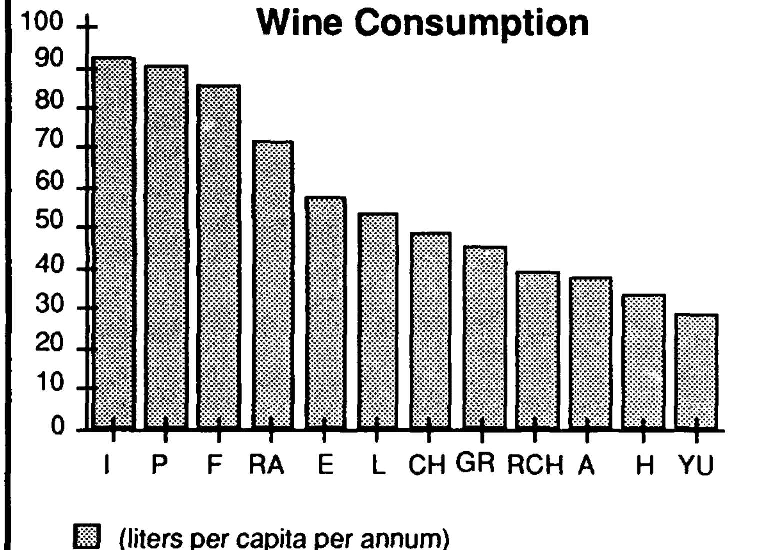


Fatal General Aviation Accidents
%
50
45
40
35
30
25
20
15
10
5
0
1963
1968 - 71
1974
1974 - 78
1979
1980 - 81
Alcohol Related

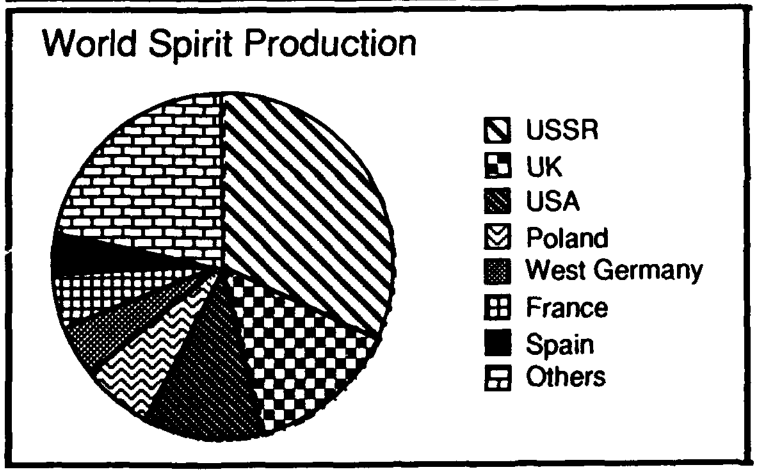
WINE

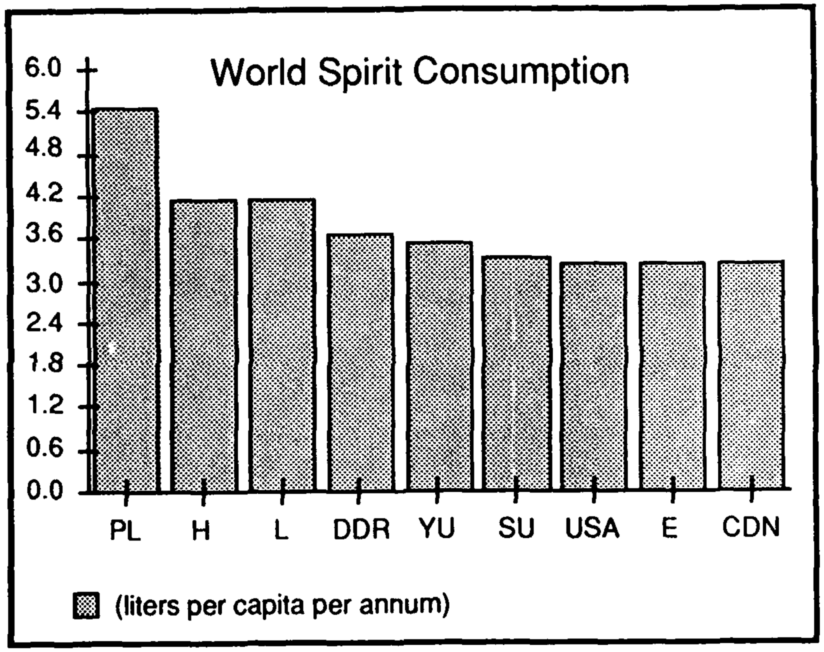
World Wine Production



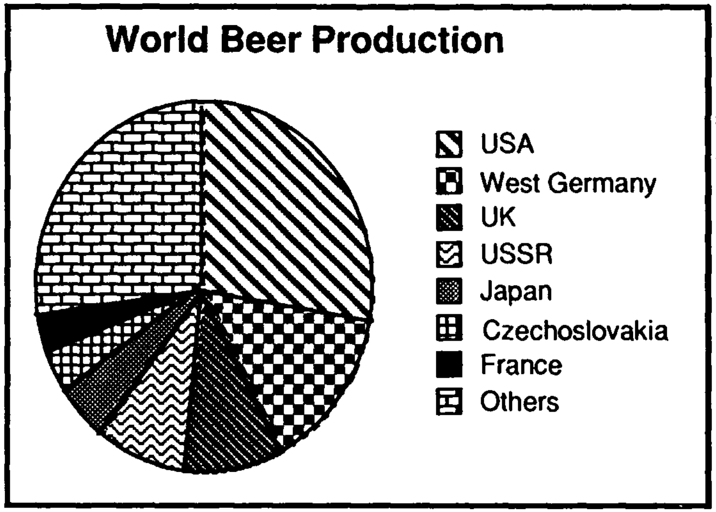


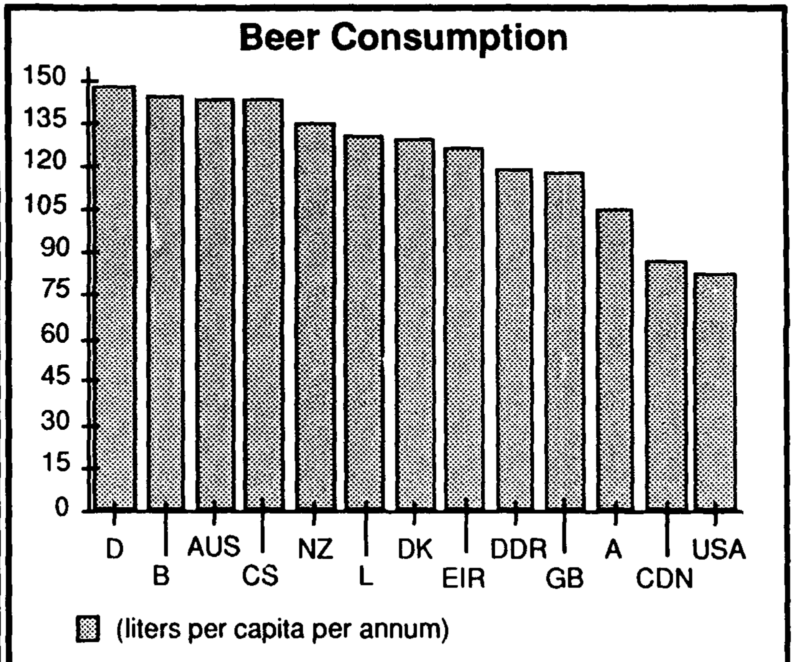
SPIRITS


World Spirit Production
USSR
UK
USA
Poland
West Germany
France
Spain
Others


World Spirit Consumption
6.0
5.4
4.8
4.2
3.6
3.0
2.4
1.8
1.2
0.6
0.0
PL
H
L
DDR
YU
SU
USA
E
CDN
(liters per capita per annum)

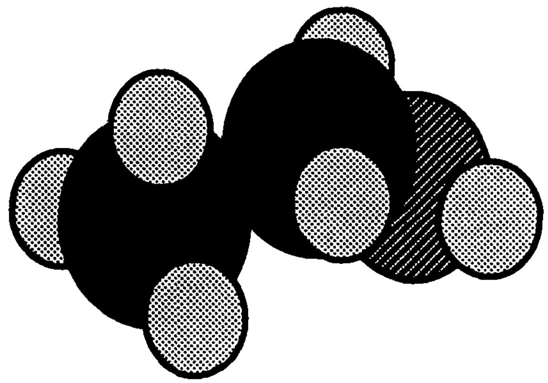
BEER


World Beer Production
USA
West Germany
UK
USSR
Japan
Czechoslovakia
France
Others


Beer Consumption
150
135
120
105
90
75
60
45
30
15
0
D
B
AUS
CS
NZ
L
DK
EIR
DDR
GB
A
CDN
USA
(liters per capita per annum)

Ethanol

CH_3CH_2OH



Wine

Specific Gravity	% Potential Alcohol
1.065	8.1
1.070	8.8
1.075	9.4
1.080	10.0
1.085	10.6
1.090	11.3
1.095	11.9
1.100	12.5
1.105	13.1
1.110	13.8
1.115	14.4
1.120	15.0

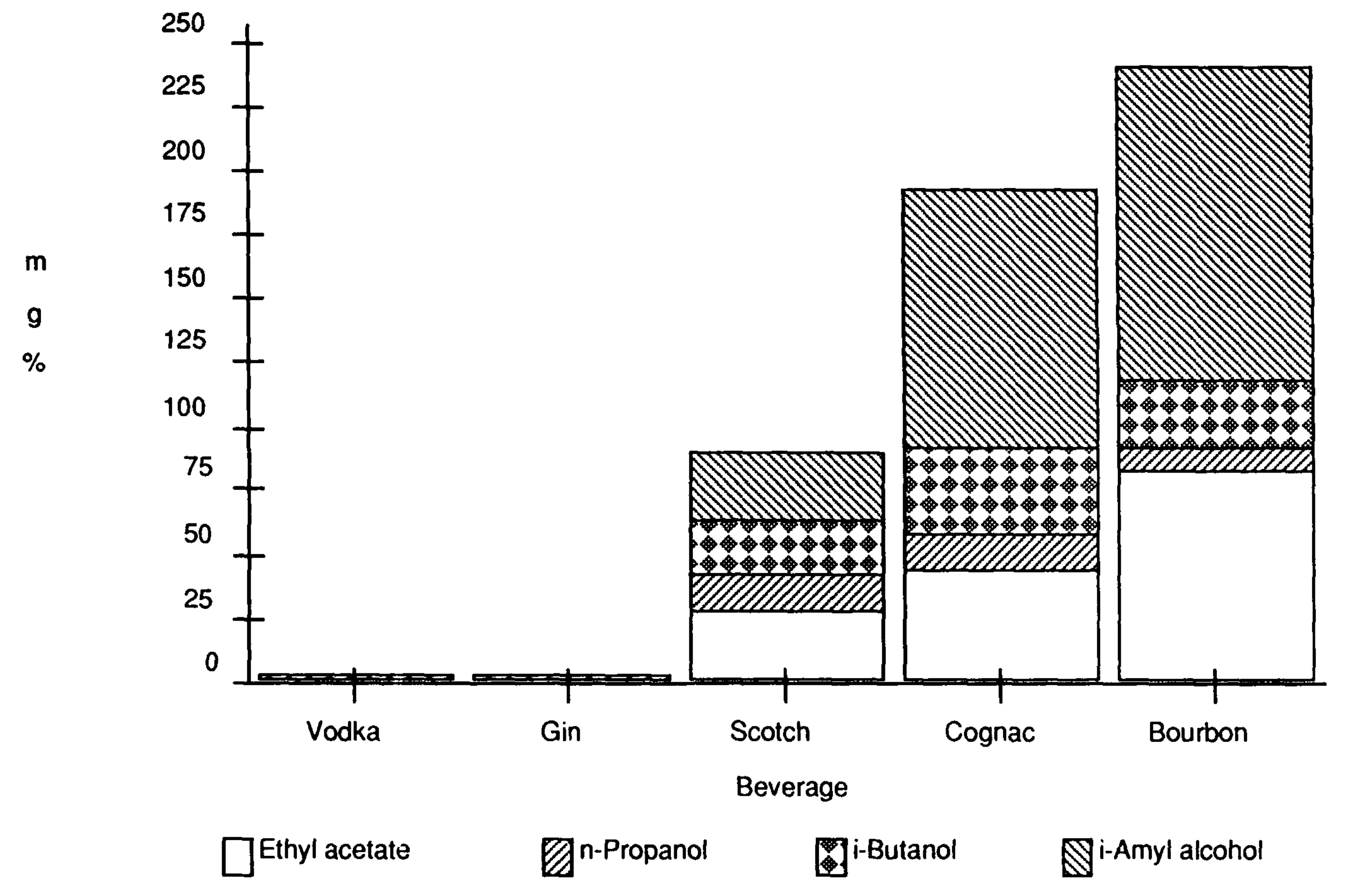
SPIRITS

Gay Lussac (% by volume)	American Proof	British Proof
10	20	17.50
20	40	35.00
30	60	52.50
40	80	70.00
45	90	78.75
50	100	87.50
57	114	100.00
60	120	105.00
70	140	122.50
80	160	140.00
90	180	157.50
100	200	175.00

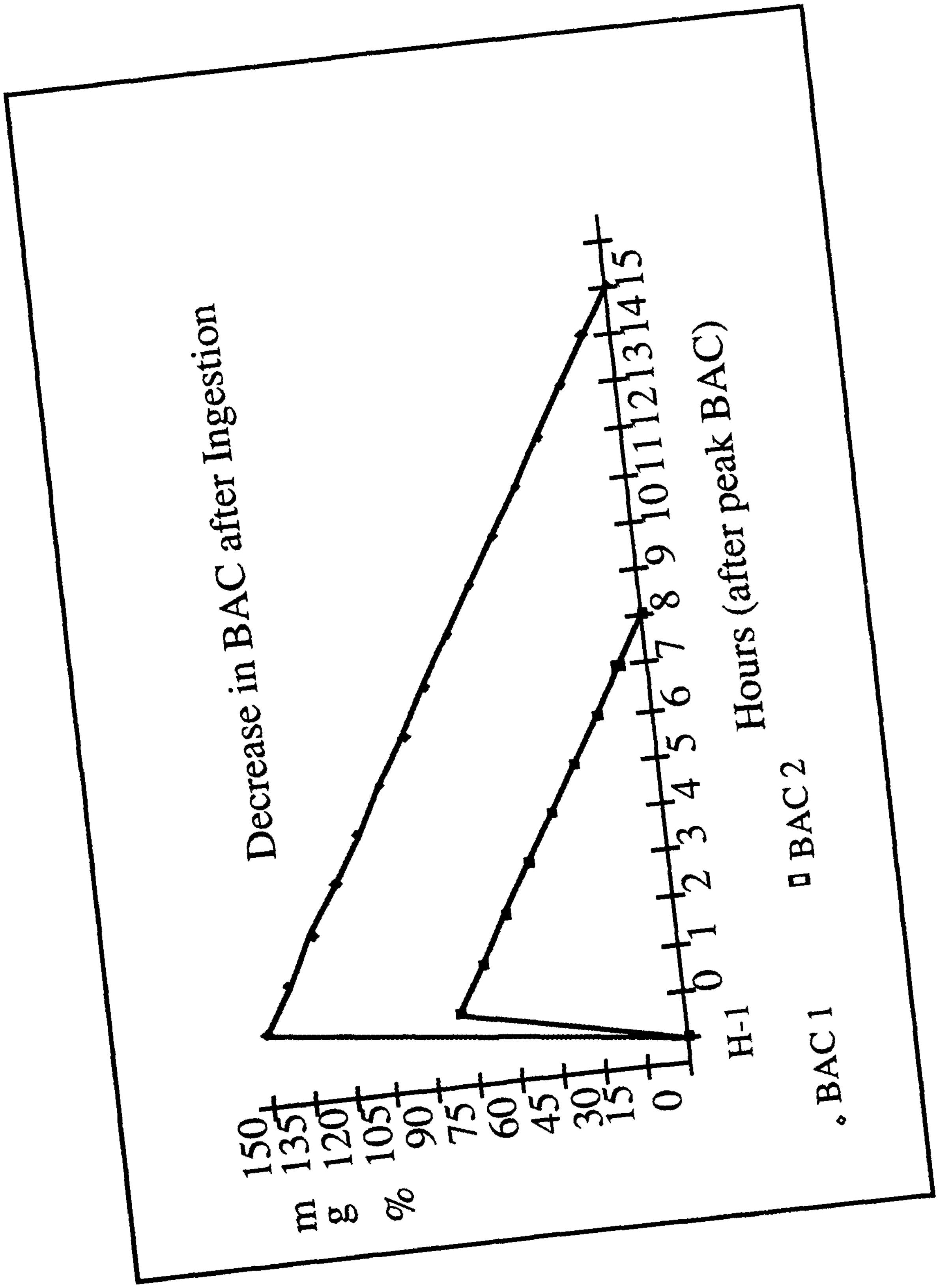
TYPICAL BEER STRENGTHS

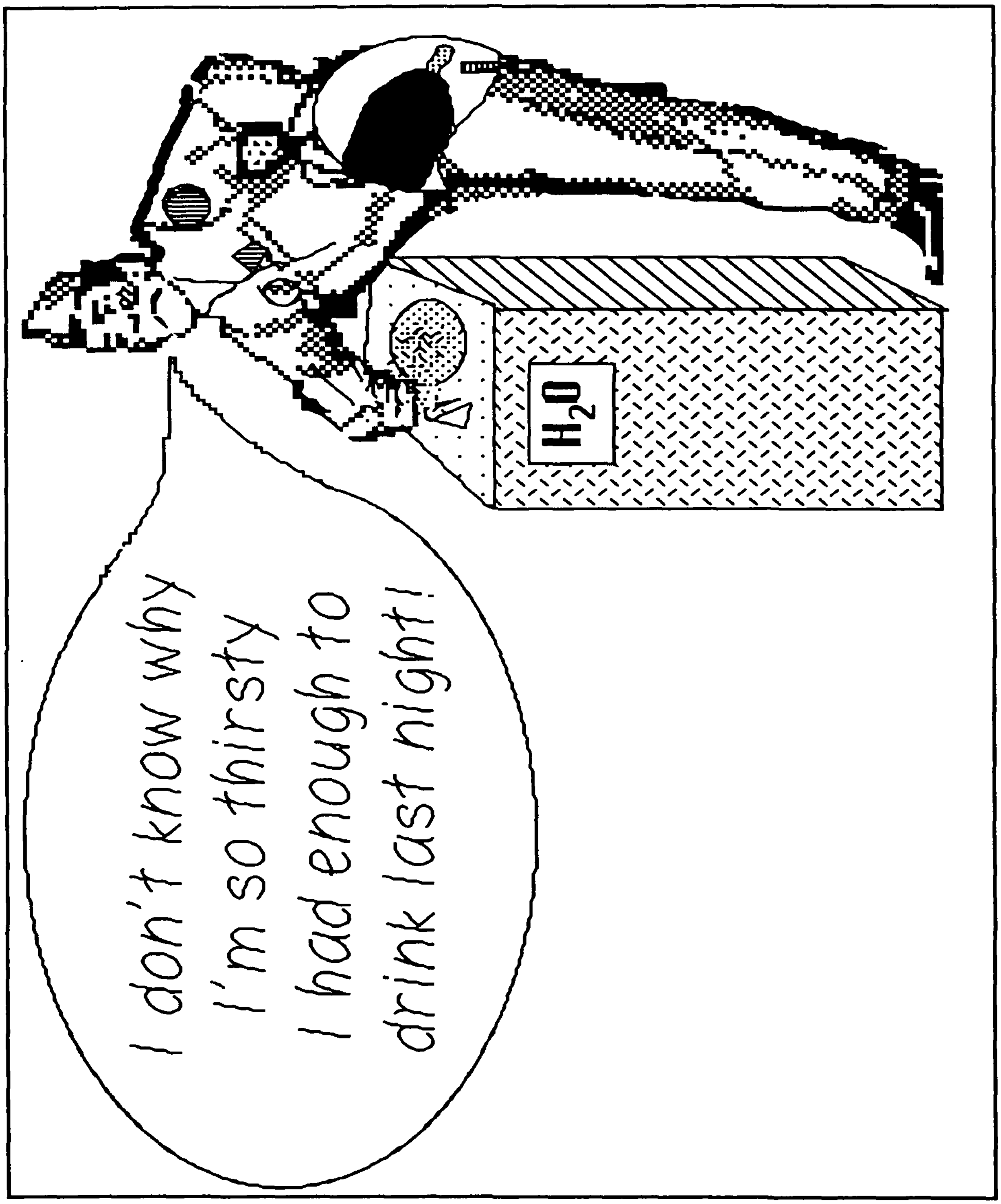
Beer	Origin	
Kulminator	Bavaria	13.2%
Strong beers	Germany	10.0%
Strong beers	Belgium	10.0%
Strong beers	England	10.0%
Strong beers	Worldwide	8.0%
Pilsener	Worldwide	5.0%
Ales	English	3.5%
Regular beer	U.S.A	3.2%

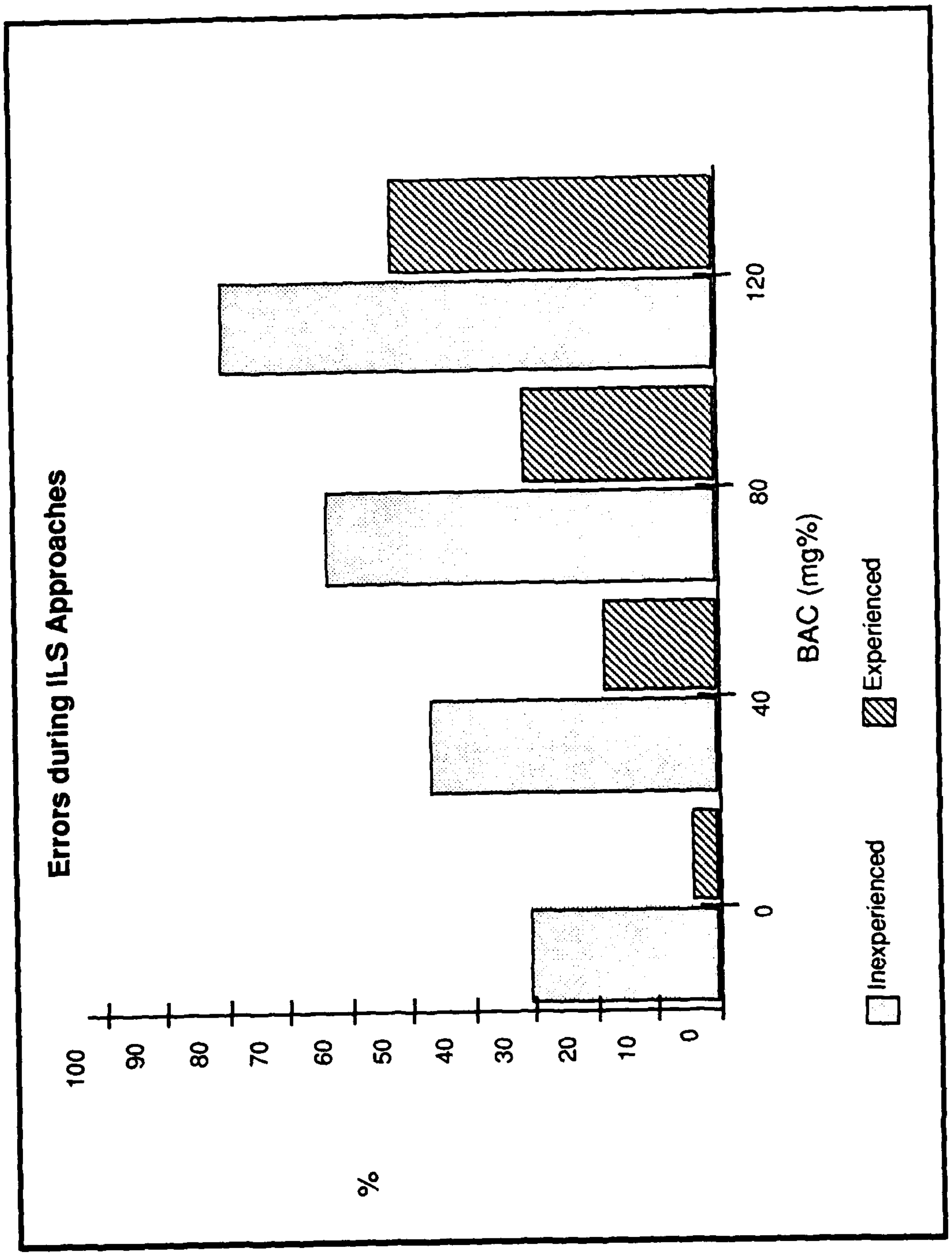
Combined Congener Concentration

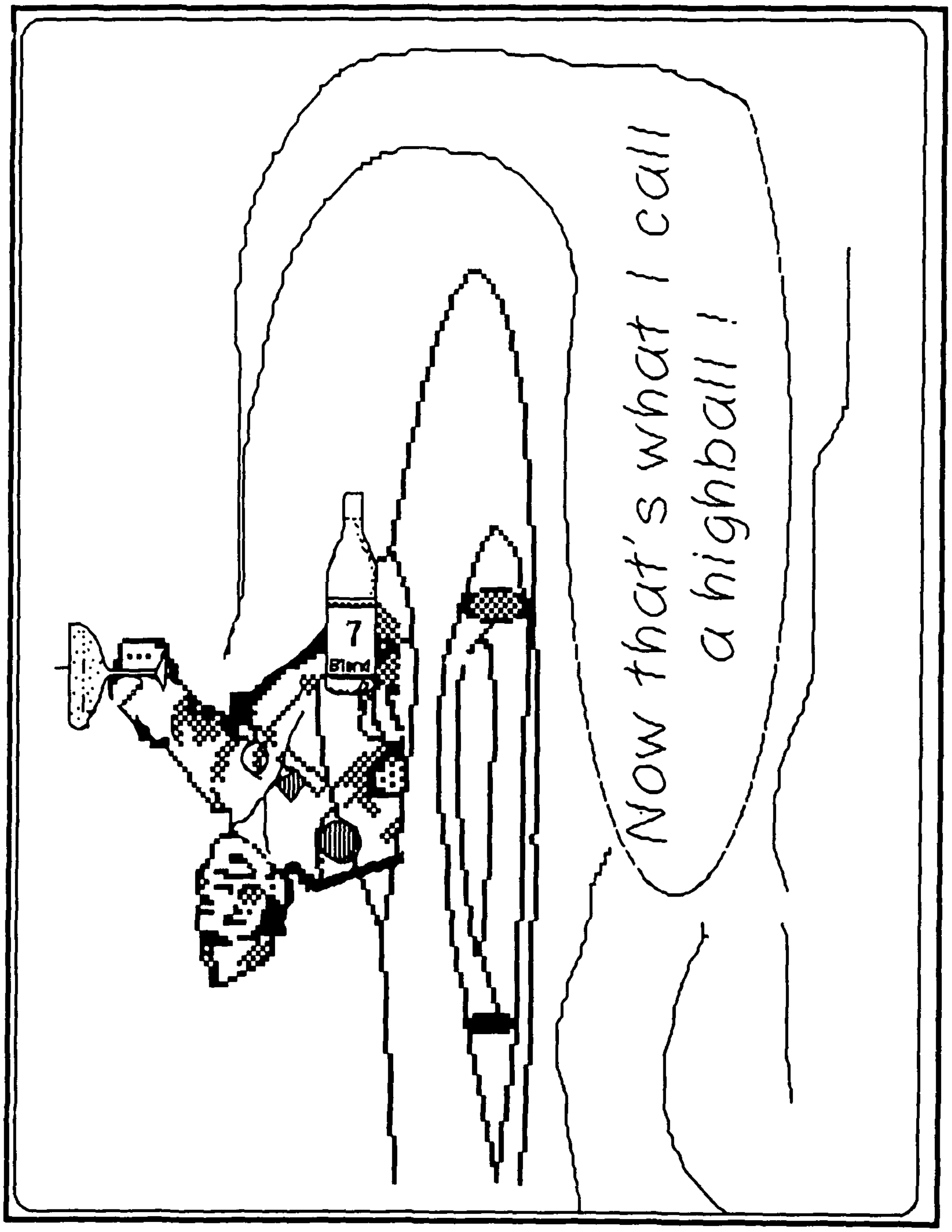


Weight (lbs)	Number of Drinks (of 10 ml pure ethanol/hr)					
	1 5	2	3	4		6
150	24	48	72	96	120	144
160	23	45	68	90	113	135
170	21	42	64	85	106	127
180	20	40	60	80	100	120
190	19	38	57	76	95	114
200	18	36	54	72	90	108
210	17	34	51	69	86	103
220	16	33	49	65	82	98
230	16	31	47	63	78	94
240	15	30	45	60	75	90
250	14	29	43	58	72	86

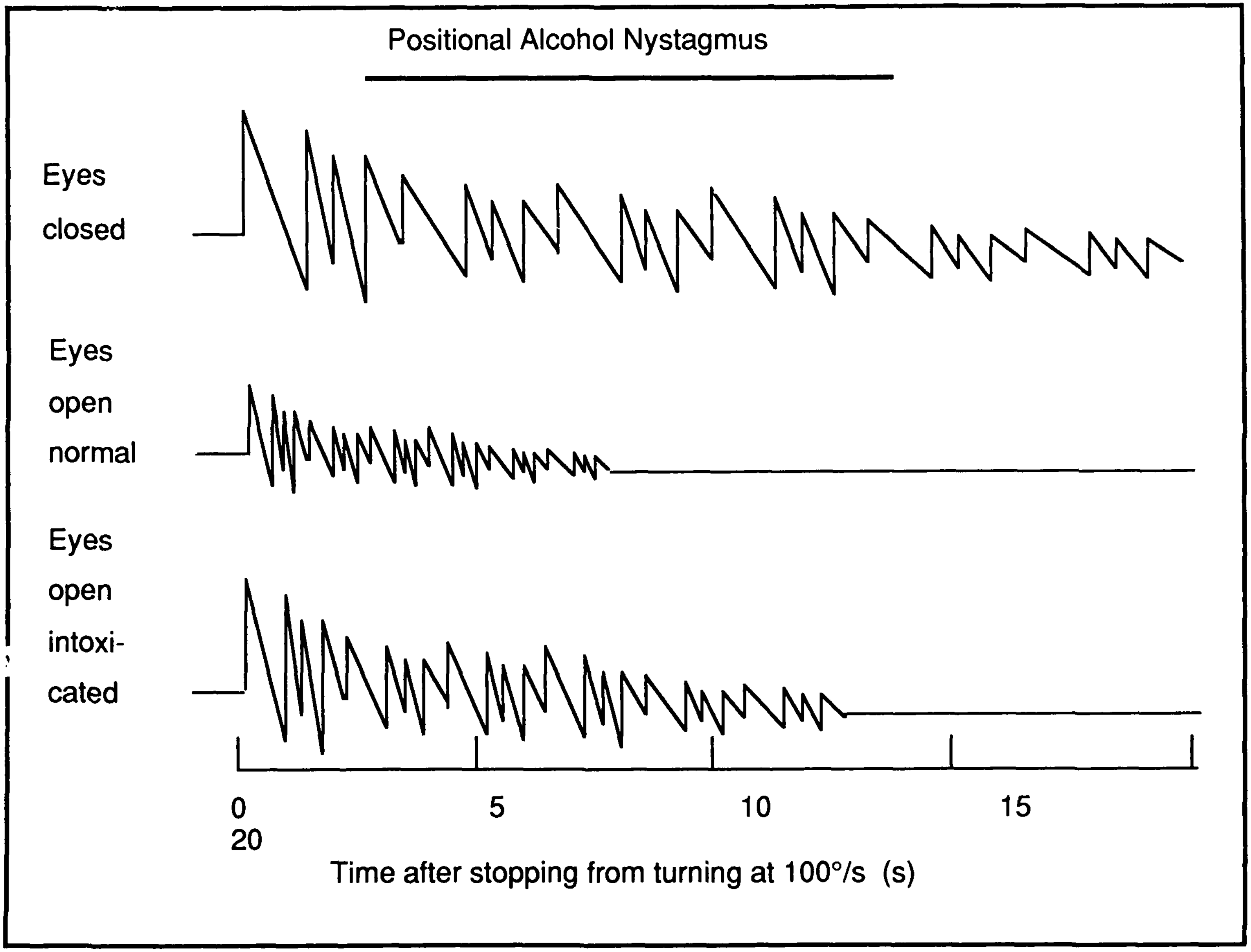

Decrease in BAC after Ingestion
mg%
150
135
120
105
90
75
60
45
30
15
0
H-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Hours (after peak BAC)
BAC 1
BAC 2

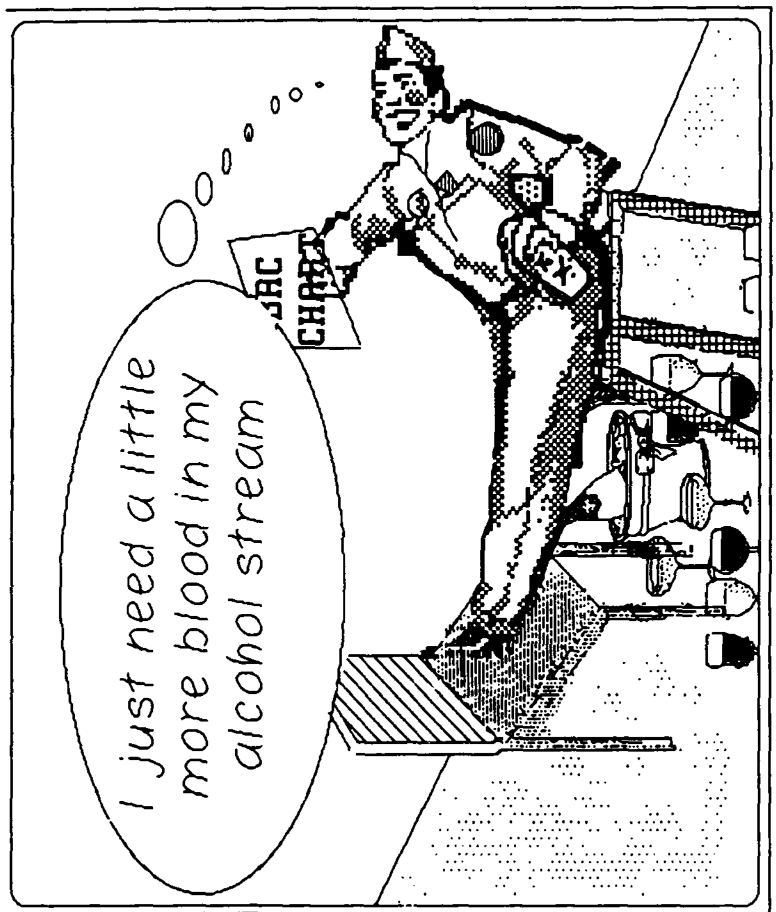

I don't know why
I'm so thirsty
I had enough to
drink last night!
H_2O

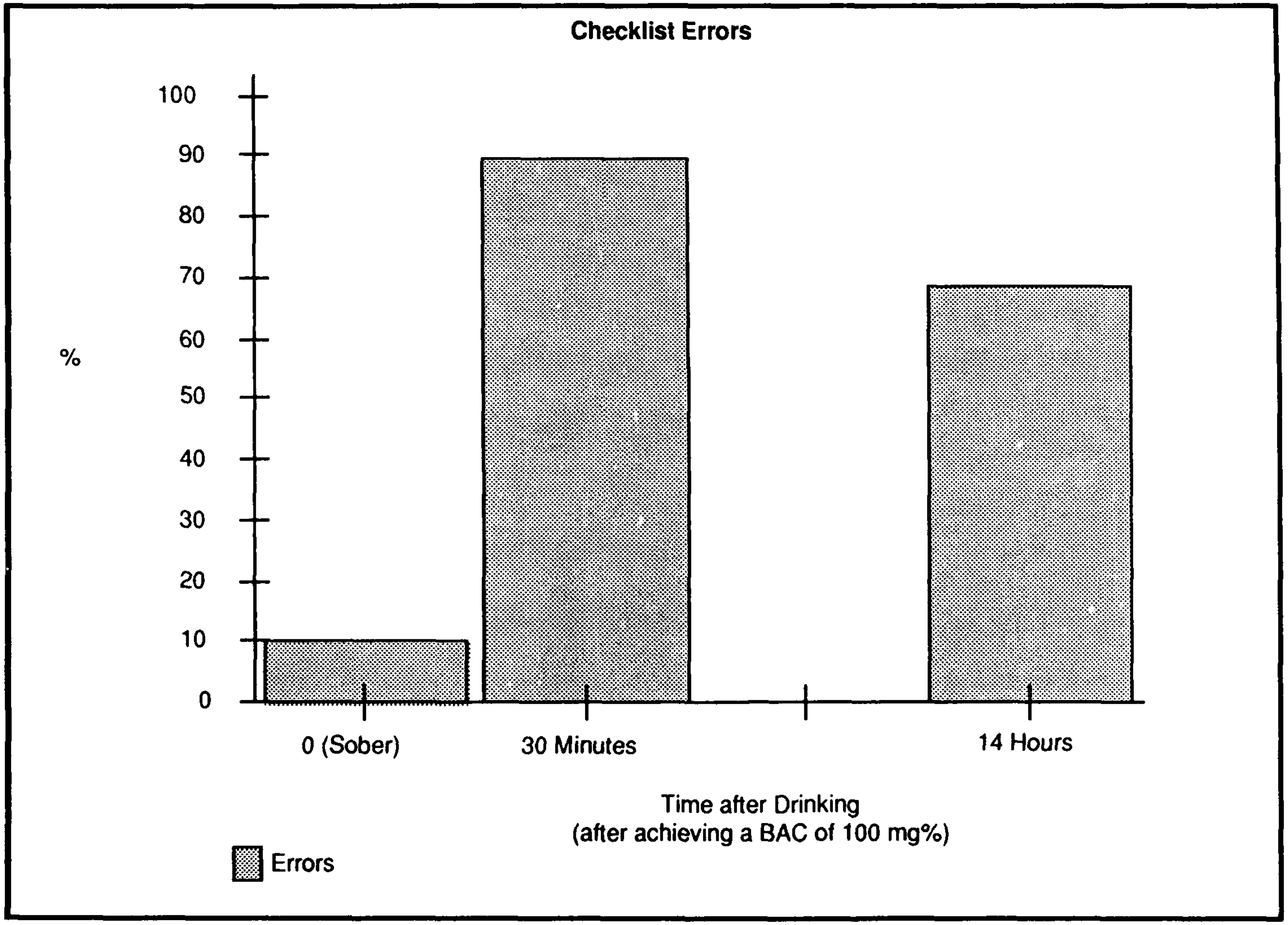

Errors during ILS Approaches
%
100
90
80
70
60
50
40
30
20
10
0
0
40
80
120
BAC (mg%)
Inexperienced
Experienced

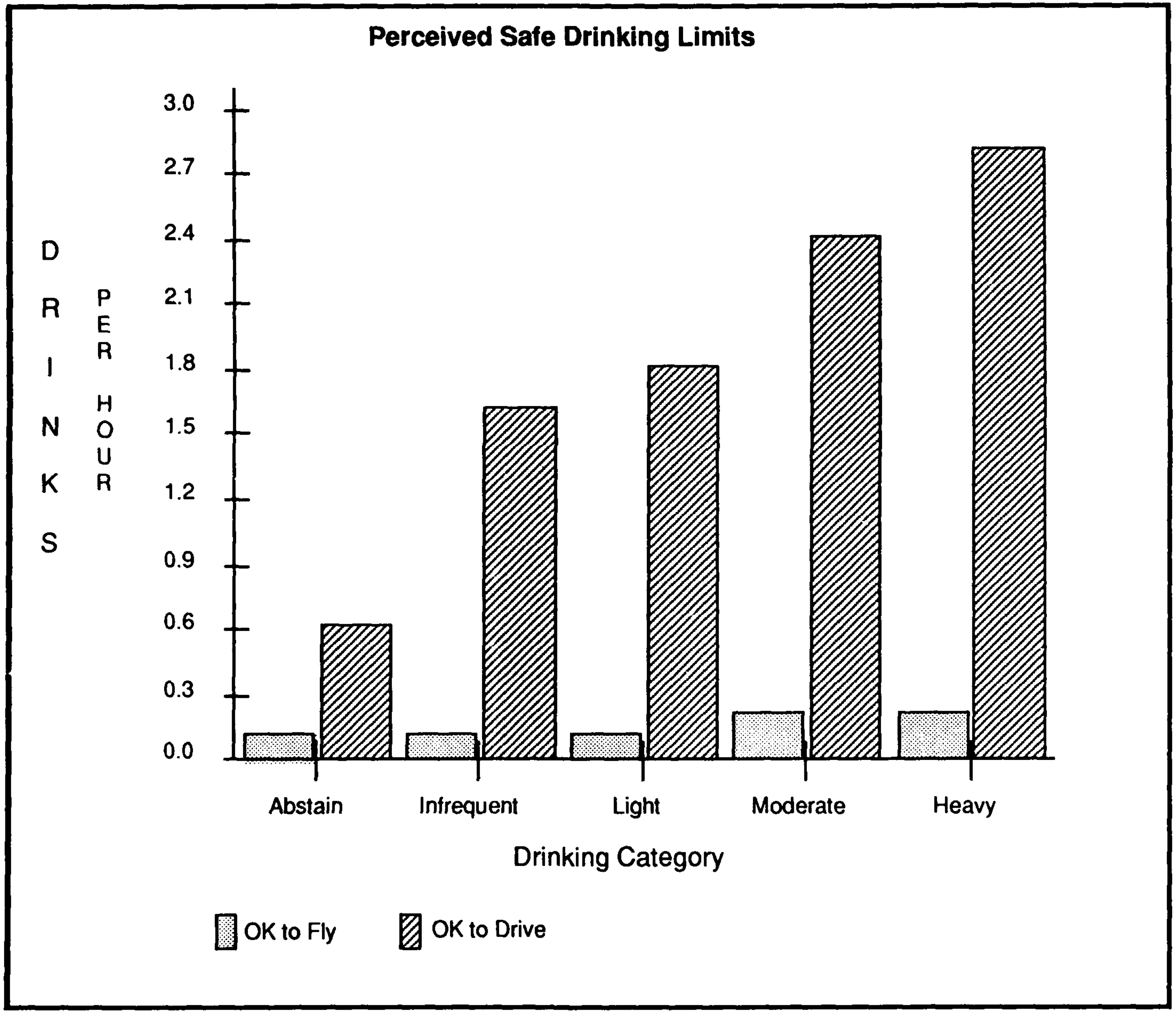

Now that's what I call
a highball !
7
Blend

(Ear Diagram)


Positional Alcohol Nystagmus
Eyes closed
Eyes open normal
Eyes open intoxi-cated
0
20
5
10
15
Time after stopping from turning at 100°/s (s)


I just need a little more blood in my alcohol stream


Checklist Errors
%
100
90
80
70
60
50
40
30
20
10
0
0 (Sober)
30 Minutes
14 Hours
Time after Drinking
(after achieving a BAC of 100 mg%)
Errors


Perceived Safe Drinking Limits
DRINKS PER HOUR
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
Abstain
Infrequent
Light
Moderate
Heavy
Drinking Category
OK to Fly
OK to Drive

Points To Remember

- Always respect alcohol.
- Set a limit before you drink and stick to it.
- Buy a round of snacks rather than drinks.
- Drink slowly, never gulp.
- Don't succumb to "chugging" contests.
- Don't feel obligated to drink at functions.
- Never drink and drive.
- Never, never consider flying after drinking or when hungover.

* U. S. GOVERNMENT PRINTING OFFICE: 1990--761-051/20088