HOW TO USE

THE

ALCO-CALCULATOR

A Manual to Provide
Understanding of the Principles
on which
This Educational Tool
is
Based

INTRODUCTION

The idea for a slide rule device to make simple estimates of the concentration of alcohol circulating in an individual's blood after consumption of various beverages was first put into practice by Dr. Leon A. Greenberg of the Rutgers University Center of Alcohol Studies in 1971. The present copyrighted ALCO-CALCULATOR, although the same in principle as the original, makes certain simplifying revisions, and extends its use to females.

PHYSIOLOGICAL BASIS

1. Distribution of Alcohol in the Body.

Ethyl alcohol, the important physiologically active compound present in fermented and distilled alcoholic beverages, is soluble in all proportions in water. After consuming beer, wine or distilled spirits, the ethyl alcohol in these beverages is absorbed into the blood stream and carried to all the tissues where it is thus distributed throughout the water of the body. In effect, the water of the body dilutes the alcohol and the resulting blood alcohol concentration (BAC) becomes essentially uniform in the water of the tissues.

The results produced by the ALCO-CALCULATOR are based on the assumption that the percentage of the body weight that is water is 58.0% in males and 47.4% in females, and that in both sexes the percentage of water in the blood is 80.65%. The first set of values (58.0% and 47.4%) are the *average* values for adult males and females; these values can vary substantially (±10%) from the average, depending on age, weight and height in males, and weight and height in females; to have used these modifying factors would have introduced unnecessary complexity into this device without any compensatory gain for the user. The percentage of water in the blood is less variable (±1%).

The manner in which these values for body water are used in the ALCO-CALCULATOR is illustrated by the following example:

A male weighing 150 pounds has an equivalent weight of 68.04 kilograms, which, multiplied by 58.0%, indicates a water volume of 39.46 liters in his body.

Two ounces of an 80 proof beverage contains 18.665 grams of ethyl alcohol (see Table 1); diluted by the 39.46 liters of water, the alcohol concentration is 0.0473 grams of alcohol per 100 milliliters of water, or 0.0473%. Since the blood is only 80.65% water (that is, each 100 milliliters of blood contains 80.65 milliliters of water), 100 milliliters of blood contains 0.0381 (0.0473 × 0.8065) grams of alcohol, or 0.0381%.

TABLE I

Beverage	Alcohol (grams)
Regular beer (4.75%)	13.299
Light beer (3.80%)	10.638
12% wine	2.800
20% wine	4.666
60 proof spirits	6.999
80 proof spirits	9.333
100 proof spirits	11.665

The amounts of alcohol in these beverages are contained in either 12 ounces of regular and light beer or in 1 ounce of the other beverages. All percentages are alcohol by volume, and those used for regular and light beers are the averages for a large number of American beers.

Example: On the ALCO-CALCULATOR, after inserting the slide into the case with male side up, align 2 on Scale B with Oz. 80 proof spirits on Scale A, and read above 150 lbs. on Scale D the answer of 0.0381%, i.e., 0.038%. If the female side of the slide is used, it will be noted that Scale B is positioned to reflect the lower percentage of body water in females; drinking the same amount of alcohol will result in a higher concentration of alcohol: for a 150 lb. female the concentration in the blood would be 0.047%.

Note: If beers, wines or spirits contain percentages of alcohol by volume that differ from those used on Scale A, two courses are open to the user: (i) choose the value on Scale A closest to the actual value and then adjust the reading found on Scale C proportionately; if a European Beer, for example, contains 6.5% alcohol, multiply the reading of Scale C by the factor 6.5/4.75 if the regular beer marking of Scale A was employed, or by 6.5/3.8 if the light beer marking was used; if 11% alcohol by volume wine was drunk, multiply by 11/12, if the 12% wine marking of Scale A was used, etc.; (ii) alternatively, one may interpolate between, or outside, the markings on Scale A, placing the designated amount of beverage (Scale B) at the appropriate place on Scale A (note, however, that the spacing is not linearly related to the percent alcohol by volume).

The relation between the concentration of alcohol in the water compartment of the body and that in blood applies to all tissues: for example, plasma (blood without its red cells) contains 94% water; hence, in the previous example, the concentration of alcohol in the plasma would have been 0.0473% × 0.94 = 0.0445%, higher than that in the whole blood. Knowledge of the water content of specific tissues (e.g., brain, liver, kidney, urine) provides an estimate of their expected alcohol concentration when the concentration in one tissue is known. Thus, from the alcohol concentration of the blood may be estimated the alcohol concentration of the plasma; in the example above, plasma concentration = 0.0381 × 94.0/80.65 or 0.0445%.

2. Elimination of Alcohol from the Body.

From the moment ethyl alcohol enters the circulation, it begins to disappear from the body. Its elimination occurs through one major and several minor channels: at least 90% disappears because of metabolism in the liver (where alcohol is oxidized to carbon dioxide and water); the remaining 10% is lost as unchanged ethyl alcohol mainly by excretion into the urine and by exhalation from the lungs, with more minor amounts lost via sweat and saliva. In total, the amount lost, *on the average*, is reflected as a decrease of 0.015% per hour in the BAC. This decrease is equivalent to the amount of alcohol contained in 0.8 ounces of 80 proof spirits for a 150 lb. male, or 2/3 of 0.8 ounces in a 100 lb. male. [This value cannot be obtained directly from the ALCO-CALCULATOR because Scale C does not extend below 0.02%. But align .03 (Scale C) with 150 (Scale D) and note that 1.6 (Scale B) is now aligned with Oz. 80 proof spirits (Scale A). Since double the concentration was used (0.015 × 2 = 0.03%), the answer is 1.6/2 = 0.8 ounces of 80 proof spirits.]

It was stressed that the loss of alcohol *averages* 0.015% blood alcohol per hour. Reports in the scientific literature attest to the fact that this rate is variable, depending on whether the drinker is in the fasted or fed state, and on a variety of other factors too numerous (and unnecessary) to enumerate here. The range of rates of elimination reported is wide, from 0.007% to 0.04% per hour. But the overwhelming bulk of the observations cluster closely about 0.015% per hour.

The decline of the BAC is relatively constant over any one period (at an average of 0.015% per hour), but when the concentration in the blood falls to about 0.02% the rate decreases, becoming proportional to the concentration: the lower the concentration, the slower the rate of elimination (see Figure 1).

Examination of Scales E and F reveals that every hourly division on Scale E equals a difference of 0.015% BAC on Scale F.

3. Absorption of Alcohol.

The legend of Scale C is MAXIMUM PERCENT BLOOD ALCOHOL (BAC). If the alcohol in the beverage drunk is consumed in a single gulp, and leaves the stomach and enters the blood stream and is distributed throughout all the tissues of the body instantaneously, then the concentration found in the blood would be the amount found on Scale C. This state of affairs does not occur! The processes listed take time. Even if a particular beverage is introduced rapidly into the stomach (e.g., 1 ounce of whiskey gulped in less than 5 seconds), depending on the individual, and the volume and composition of the stomach contents, the time for alcohol to empty from the stomach into the intestines can vary from 5 minutes to several hours. (Only trivial amounts of alcohol are absorbed directly into the blood stream from the stomach.) On the average, it can be assumed that the *peak* concentration of alcohol is reached in 30 to 120 minutes after termination of beverage consumption. The *peak* concentration is not the *maximum* possible concentration. Figure 1 illustrates the difference.

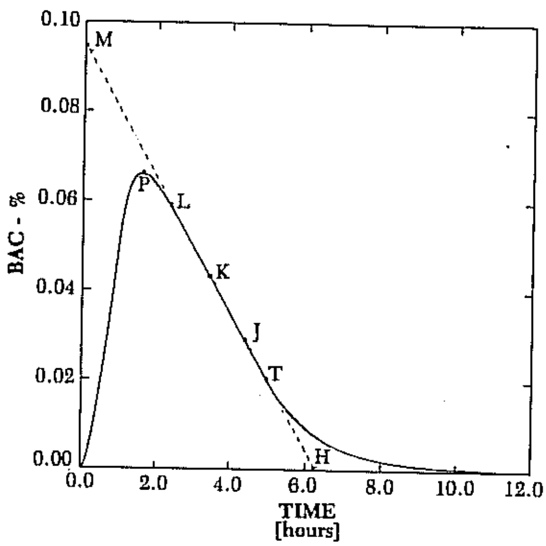

Figure 1. BAC time course after uniform ingestion of 4.8 ounces of 80 proof spirits by a 150 lb. male over 1 hour. M%: maximum possible percent BAC; P% peak BAC; T%: BAC below which decline is curvilinear; H: hours at which BAC would become zero if rate of elimination were linear throughout; J%, K%, L%: BAC at various times after peak BAC.

At some point after stopping drinking, the BAC reaches a peak (P%) and then declines; when it reaches concentration T% (at or below 0.02%), the decline becomes curvilinear. If the linear portion of Figure 1 is extended back to the beginning of drinking, that is, to time zero, it intercepts the BAC at point M%, the maximum percent blood alcohol of Scale B. Extended in the other direction, it intercepts the time axis at some point H hours. Dividing the BAC represented by M% by H hours gives, on the average, 0.015% per hour.

It is the time at which point P% is reached that is variable, and it is possible to visualize a situation where the beverage is drunk uniformly over time H and results in the situation depicted in Figure 2. The elimination of alcohol by the liver and other avenues has almost kept pace with the amount of alcohol being consumed. The slight elevation of the BAC is less than the concentration T%; the consequent lesser(<<.015%/hour) rate of elimination allows the increase of the BAC shown. In short, a 150 lb. male ingesting 0.8 ounces of 80 proof spirits uniformly during each hour would, over 6 hours, for example, show the BACs of Figure 2, which are quite different than the curve of Figure 1 where 4.8 ounces of the same beverage might have been drunk uniformly over 1 hour, rather than uniformly over 6 hours ($0.8 \times 6 = 4.8$ ounces).

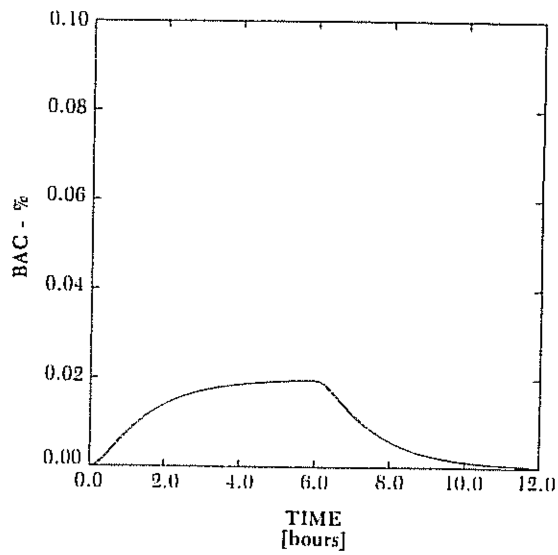

Figure 2. BAC time course after uniform ingestion of 4.8 ounces of 80 proof spirits by a 150 lb. male over 6-hour period.

4. Extrapolation of the BAC.

The last instruction on the ALCO-CALCULATOR (ESTIMATION OF BAC *BEFORE* AND *AFTER* THAT ALREADY ESTIMATED) attempts to answer two related questions: Given the BAC at a particular time, what would the BAC have been at some time before? And at some time after? If at the later time, the BAC (see Figure 1) would be lower by 0.015% per hour, from K% to J%, while at some time prior, it would be higher by 0.015% per hour, from K% to L%. It is important to emphasize, however, that at any time before the peak these considerations cannot apply; the calculation assumes that drinking stopped some time before this estimation of the BAC.

The colored sections of Scale F, designated sober, decreasing sobriety and intoxicated, reflect the recommendations of the National Safety Council and the American Medical Association, and are incorporated into the laws on driving of most states. These assessments presume sobriety at BACs below 0.05% and driving under the influence at BACs above 0.10%; additional considerations apply at BACs between these concentrations.

PROBLEMS

1. A 135 lb. male drinks 4 12 oz. bottles of regular beer between 6:00 P.M. and 8:00 P.M. What is his BAC at 10:30 P.M.? At 11:30 P.M.?

2. A 150 lb. female drinks 12 ounces of 12% wine and 3 bottles of light beer from 5:00 P.M. to 8:00 P.M. What is her BAC at 10:30 P.M.? At 12:30 A.M.?

3. A 180 lb. male is found to have a BAC of 0.16% at 2:00 A.M., following an accident at 12:30 A.M. He asserts that he had only 2 12 oz. bottles of regular beer and 1 oz. of 60 proof brandy from 8:00 P.M. to 11:00 P.M. How many beers did he drink? What was his BAC at the time of the accident? If he had drunk 80 proof whiskey, how many ounces would he have consumed? What would his BAC have been at 3:00 A.M.? When would his BAC have declined to 0.10%? At 2:00 A.M., how many grams of alcohol were circulating in his body (use Table 1)?

ANSWERS

1a. 0.053% 1b. 0.038%
2a. 0.081% 2b. 0.051%
3a. 10.5 3b. 0.183%
3c. 15.7 oz. 3d. 0.145%
3e. 6:00 AM 3f. 93.95 g