Table 1: Some definitions and notes pertaining to measures of alcohol and extracts in spirits.

Alcoholic Strength: A measure of the amount of alcohol in the beverage. The alcohol content of a distilled spirit typically refers to the amount of ethyl alcohol (as opposed to higher or fusel alcohols). The analysis of the spirit for alcohol content is an important part of distilling laboratory work for quality assurance programs and for legal reporting purposes. Results, however, are subject to appreciable variation and under official methods the analyses are time consuming and expensive.
Distilland residuals is a term we use in our laboratory and might not be discussed in the same way by others. It refers to the solids – any matter left behind in the residual liquid portion of the distillation flask after all the alcohol and some water has been distilled-off. It represents the concentrated sugars, non-sugar carbohydrates, protein and minerals etc. from the spirit, wine or liqueur and needs to be reconstituted back with distilled water to the original or starting volume used for the distillation operation (usually and officially 100 mL) prior to extract determination.
Gravimetric and Volumetric Distillations: Distilled spirits often need to be measured following laboratory-scale distillation to obtain the alcohol from the spirit free of any solids or extract present. The latter left behind in what this author calls the distilland residuals (see above). Officially approved methods describe the process in detail, however it should be noted that other alcohols and volatiles do distill over and reactions take place in the heat of distillation that can affect the subsequent reading of alcohol; it is not as simple as expected that the final distillate is simply a binary mixture of ethanol and water. Though most alcohol vs. specific gravity tables were generated over a 100 years ago by careful distillations of alcohol and water blends; other than quite pure vodka or grain neutral spirits (of high purity!) most distilled spirits cannot be considered in the same way based on solids present from sugars, acids, flavorings, fruit pulp , creams etc. Yet tables, generated from specific gravity determinations of pure alcohol/water mixtures, were rapidly adopted by the alcohol beverage industry and have served well for over 100 years. Early on the density values and specific gravity values were obtained gravimetrically – the latter values using an instrument known as a pycnometer. Gravimetric distillations (based on weight) giving true alcohol by weight values for a sample of water and ethanol but requiring a correction for alcohol by volume. The density of pure ethanol being 0.7907 (grams/milliliter) meaning volume determination for the same weight of alcohol required a factor of 1.2647 (the inverse of 0.7907) to convert to volume. 100 grams of alcohol would exist in a physical volume of 126.47 mL. Volumetric distillations (starting typically with exactly 100 mL) would give a true alcohol by volume content (temperature dependent) but would require a compensating correction for weight. The issue today becomes one of accounting for the extract content in sugar rich or flavor rich spirits. The sample specific gravity includes the extracts present and alcohol values need to be corrected for the actual sample specific gravity (SG). A fact that seems largely to have been forgotten by the distilling industry (but not by the brewing industry). This fact perhaps due to the fact that traditionally spirits such as whisky, whiskey (Bourbon) rum and tequila and the classic white spirits (vodka, gin) contained little in the way of extracts; only a little possible derived from any wood aging or minor additions of sugar/citric acid (in vodka) for example. Such spirits carrying SG values significantly below 1.0000.
Sample Density or Gravity: The sample density or SG of a distilled spirit is that value measured directly in the spirit containing the alcohol, water, any sugars (protein) or additives (fats in cream-based liqueurs), etc. For brewers the measurements always include the alcohol and extract content of the beer and the latter being related to an expression of sugar content - grams of sugar per 100 grams of wort. [Equivalent to % weight/weight (w/w)]. In the brewing industry this is denoted as "degrees Plato" (°P) and to a first degree of approximation beer responds in the same way as the original solutions of sucrose and water used to derive the Plato scale. Distillers do not usually refer to extract content in their process operations as the usual product of distillation is a mixture of water and ethanol with some congeners added to the mix. With sugars added or flavorings, etc., there will be "extract content" to the spirit and this makes difficult the measurement of the true alcohol content. This is due to obscuration or the "masking" of alcohol by solids in the extract. Distillers need to be aware of this and current regulations and sometimes need to run a test on solids to perform a proof obscuration adjustment to the measured alcohol content. Distillers will measure an apparent alcohol content unless distilling the sample when high solids/extract containing beverages are involved. In cases with very low solids there will be no major issue measuring alcohol but for high extract samples the distiller will need to make some corrections to the evaluations of alcohol content to account for the higher than 1.0000 SG of the sample due to extracts. Sample densities and specific gravities can be inter-converted using equations described in the text.
Specific gravity (SG) or relative density: is an intensive property of a substance (be it solid or liquid) and is, historically, the ratio of the density of a substance at the temperature under consideration to the density of water at the temperature of its maximum density (4 °C). The actual density in theory – for the purposes of most discussions with respect to alcoholic beverages – is generally 20 °C/20 °C relative to water at unity though, elsewhere in the alcohol beverage world, it is typically expressed as at 20 °C/4 °C. The complexity of the temperature associations could not be presented in depth here - full details may be found in the literature (see the references). An SG value is numerically equal to the density in grams per milliliter (or Kg per liter) but is stated as a pure number (because the division by the water's own density value leads to a cancellation of the units), while density is stated as mass per unit volume. Water has a specific gravity of 1.0000 at 20°C. Base and derivative density values form mathematical grounding in many of the formulas used in alcohol and extract calculations. The density value 0.998201 will be seen in the literature as pertaining to the formulas and conversions of alcohol density, specific gravity, and alcohol by weight and volume and while understood within this article is also not covered in any depth here.
Apparent and Real Extract: Brewers measure changes in density as sugars are consumed during fermentation and converted into alcohol. Measurements are obscured (the true gravity is "hidden") by alcohol (of lower density than water, sugar solutions or beer) causing "buoyancy effects" with hydrometers for example. Thus false or apparent readings of gravity are made when instruments measure beer (containing water, sugars and alcohol); hence "apparent extract". For distillers the

same principles are in effect but the extract is from the addition of sugars, proteins and other solids materials from flavor additions, fruit etc. So in cases of high solids content the distiller needs to run laboratory scale distillations to separate the alcohol from the extract (solids) and to determine the alcohol SG in the distillate (largely the alcohol and water). The solids are left behind but can be determined by bringing the distillation pot residuals back up to the initial sample volume and measuring the extract-containing solution (with no alcohol present) to obtain the extract content. The real extract is a true(r) measure of remaining sugars - and proteins etc. - as determined in the absence of alcohol (removed via distillation or boiling). When distiller's measure a sample containing sugars this will be an "apparent" gravity and neither the true alcohol content or extract content can be directly determined. The true or real extract is expressed in grams per 100 grams of sample (a Plato value) and is needed to obtain correct calorie content of a spirit sample along with the alcohol by weight value.
Plato. A typical way to report extract in distilled spirits (sometimes referred to as degrees Brix which are closely similar though not 100% exactly correlated) as weight percent (e.g. 12 Plato is 12 grams/100 grams extract). Plato values may be obtained directly from hydrometers calibrated in degrees Plato, by means of specific gravity measurements as related to standard Plato (or extract) tables and (to varying degrees of approximation) by calculation – some equations seen in the text here. The Plato scale and tables are themselves approximations for complex physical-chemical reasons. Brewers and winemakers take this as an expression of the sugar content in units of grams of sugar per 100 grams of wort equivalent to % weight/weight (w/w). In the brewing industry this is denoted as "degrees Plato" (°P) and winemakers referring to it as "degrees Brix". Plato and SG values can be inter-converted using appropriate formulas (as discussed in the text) and this will prove important in working through the equations presented for determining distilling analytical parameters.
Tabarie: - A mathematical relationship that goes back 180 years – derived by a Mr. M. E. Tabarie. Tabarie noted the relationship between the SG's of the alcohol and of the real and apparent extracts for beer. $SG_{Alc} = SG_{Beer} - SG_{RE} + 1$ **or** $SG_{Beer} = SG_{RE} + SG_{Alc} - 1$ or $SG_{RE} = SG_{Beer} - SG_{Alc} + 1$ These rearranged equations work well if any two of the values are known with any degree of accuracy for "normal strength" beers. The details and history are complex and are reviewed elsewhere (see the special references section below). [These relationships begin to fail to deliver accurate values somewhere between 7.5 to 10% ABV and even brewers need to entertain some caution for high strength beers and a modified equation should ideally be employed up to 8% alcohol by weight (ca. 10 % ABV - see Nielsen and Aastrup, 2004). Official methods (AOAC) adopted by agencies such as the TTB include the "Tabarie equation" in varied "disguises" to calculate the extract content based of the sample SG and the alcohol SG but, as seen for brewers in the discussions above, the relationships don't work well for wine-strength or distilled strength beverages. A cogent but extensive mathematical approach to extend this to higher alcohol beverages has actually been covered recently (Hackbarth, 2009: 2011) but is not yet well known or perhaps used beyond the brewhouse chemist]. Potential limitations to the use of the Tabarie relationship are also discussed by Hackbarth (2009:2011). For distillers we recommend obtaining the "true real extract" content from distilland residuals (-defined above in this Table; the solids remaining in the distillation flask after bringing these back to 100 mL or other original volume used for the distillation itself). This value is obtained in the usual way as a Plato (Brix) value or as a density or specific gravity measurement using hydrometers, refractometers or a digital density meter, etc. Conversions from SG to Plato for calorie determinations then performed as described in the text.

References:

General References: (The article by Spedding, 2013 cites many references originally used to prepare the article relevant to brewers and their determinations of alcohol content and extract values and should provide more material for the reader wishing to go into more depth on this topic.).

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Website links:

http://www.ttb.gov/rulings/2004-1.pdf

http://www.ttb.gov/rulings/2013-2.pdf

Electronic Code of Federal Regulations (Alcohol): http://www.ecfr.gov/cgi-bin/text-idx?SID=147181b7b51c5332001195bd4967f4fe&tpl=/ecfrbrowse/Title27/27tab_02.tpl

Gauging Manual: http://www.ttb.gov/foia/gauging_manual_toc.shtml

Lab Methods for Distillers: http://www.ttb.gov/expo/presentations-black/s14-bw.pdf

Proof Obscuration: http://www.ttb.gov/foia/gauging_manual_toc.shtml#27:1.0.1.1.25.4.504.2

The Alcoholometric Tables may be found here: http://www.itecref.com/alcohol-tables.html (last accessed April, 2013) or www.oiml.org/publications/R/R022-e75.pdf. (last accessed May, 2013)

The Beverage Alcohol Manual (Spirits) http://www.ttb.gov/spirits/bam.shtml

Special Tabarie References: A formula of value to brewers and perhaps incorrectly adopted in wine and distilled spirits methods for estimating the extract content, but included in many instrumentation algorithms, is the Tabarie relationship which relates alcohol and sample SG numbers to solve for the extract SG. This only works well under limited conditions for typical strength domestic type beers and imposes some relatively "unknown" limits on specifications outlined in the text of this article. It was revaluated for extension to higher alcohol and high(er) extract containing alcoholic beverages recently (see the Hackbarth references below) and needs to be better understood by wine and distilling chemists going forward. As it is an important and misunderstood equation references are provided here for the interested reader to follow up on.

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