Applications Note

Alcohol by volume (AbV) Measurements using the TMR 33-37 Refractometer

The amount of alcohol in beer, expressed either as “ORIGINAL GRAVITY” (OG) or PERCENT ALCOHOL BY VOLUME (AbV), is fundamentally determined by distillation, however, distillation is a lengthy, time-consuming procedure. Measurement of the REFRACTIVE INDEX (RI) and DENSITY of beer provides a rapid method of routinely measuring OG or alcohol %.

An evaluation of the TMR 33-37 has found that the system provides an accuracy (to 95% confidence) of ± 0.02 to 0.03% AbV compared to the accepted standard of ± 0.07% AbV obtained with distillation methods.

The equations relating RI and density to OG or alcohol % are derived empirically, and the details of the best equations to use will depend on the type of beer being measure. However all the empirical equations are basically of the same form:

OG or alcohol % = a constant x RI - a constant x density - a constant

To standardise and simplify the equations, refractive index is normally expressed in “ZEISS” units. We will call the RI of the sample in Zeiss units “ZS”. The density term used, called “PRESENT GRAVITY” (PG) is

PG = 1000 x (SG - 1)	where	SG = specific gravity of sample
	and	SG = density of sample divided by density of water (0.9982)

(all terms being determined at 20°C)

Expressed in mathematical terms, the TMR 33-37 (when connected to a Paar density meter) use the following equations to calculate alcohol % and OG:

Alcohol percent by volume =	(A x ZS) - (B x PG) - C	eq.1
OG - 1000 =	(D x ZS) - (E x PG) - F	eq.2

where A, B, C, D, E and F are all constants,

ZS = refractive index of sample in Zeiss units,

and PG = present gravity of sample.

The user can program his own constants into the TMR 33-37. Up to 10 sets of the constants A, B, C, D, E and F representing 10 different types of beers may be programmed at any one time. Programming or changing of the constants is password protected operation. With the optional Windows operated software program, up to 300 sets of constants can be established.

Different breweries may have expressed with own equations for OG and alcohol % using different names for the terms and slightly different formats. For example, the RI of water sometimes appears as a separate term, but the RI of water at 20°C is a known constant (14.45 Zeiss units) * and can therefore be incorporated in the constants of the equations given here. Before entering constants in the TMR, the user must express the equation in the form of equations 1 and 2 shown above.

EXAMPLE 1

The Institute of Brewing in London recommend the use of the following equation (3) for OG. The equation, quoting the Institute of Brewing "is derived from a wide range of UK beers. It may be possible for individual breweries to derive an equation of greater accuracy, for their own use, where the range of materials and processes is more limited".

Eq.3

Original gravity in excess degrees = 3.24 - 1.644 PG + 2.597 (SR-WR)

Where SR = RI value for beer, Zeiss instrument scale reading

WR = RI value for water

PG = present gravity = 1000 x (SG-1)

We need the equation in the form :

OG - 1000 = D x ZS - E x PG - F

"Original gravity in excess degrees" = OG - 1000, SR = ZS, WR = 14.45

Therefore OG - 1000 = 2.597 x ZS - 1.644 x PG - 34.29

Making the constants to be entered :

D = 2.497

E = 1.644

F = 34.29

A typical beer might have a refractive index value of : ZS = 32.0

and a specific gravity of 1.0090 ie. PG = 9.0

giving OG - 1000 = 34 or OG - 1034

A change of 0.1 Zeiss units in the RI of the sample will lead to a change of 0.26 in the derived OG. A change of 0.0001 (1 in the 4th) in the measured specific gravity, ie. 0.1 in PG will leave to a change of 0.16 in the deduced OG.

EXAMPLE 2

A typical % alcohol formula might be :

Alcohol % by volume (AbV) = 0.3576 ZS - 0.3417 PG - 5.10

For our "typical beer with ZS - 32.0 and SG = 1.0090 (PG - 9.0), this would give :

% AbV of : 3.26%

A change of 0.1 Zeiss units in the value of ZS changes the % alcohol by 0.035.

A change of 0.0001 in the measured SG (0.1 in PG) changed the % alcohol by 0.035

The TMR 33-37, when in the alcohol scale mode, displays (and outputs to the printer or other data collection device) the following:

- Refractive Index in Zeiss units
- Specific Gravity
- Original Gravity
- Alcohol % by volume
- Sample Temperature in degrees C, Date and Time

The Zeiss reading measured by the TMR is displayed to 2 decimal places. The accuracy of the TMR 33-37 is ±0.05 Zeiss units.

Regardless of what the DMA is set to display, the TMR 33-37 will take the density measured by the DMA, divide by the density of water at 20°C (0.99820) to obtain the specific gravity of the sample, and display the specific gravity to 5 decimal places. (The significance of the 4th or 5th decimals will depend on the DMA in use).

The equations discussed in detail earlier are used to compute the Original Gravity (which is displayed to one decimal place) and the percent Alcohol by Volume (which is displayed to 2 decimal places).

The sample temperature as measured by the TMR is also displayed and output.

A copy of an actual printout from a TMR 33-37 is reproduced below :

BEER TEST	
Zeiss	47.85 @ 20.4 C
Specific Gravity	1.02725 @ 20.03 C
Original gravity	1045.2
Alcohol % by volume	2.70
Time 12.11 Date 08.12.98	

*The Zeiss value for water given in the standard accepted tables is 14.45, but it is common practice in the brewing industry to round this to 14.5 or even 15.0. As the Zeiss scale is linear, it does not matter which water value is provided that the same value is used CONSISTENTLY when setting the instrument and deriving the empirical alcohol equations.