Annual meeting June 14-17, 2015
La Quinta, California

The Evolution of CO_2 Measurement

What does it bring breweries and what is the next step?

Frank Verkoelen, Pentair Haffmans

Week 25 -2015

Content:

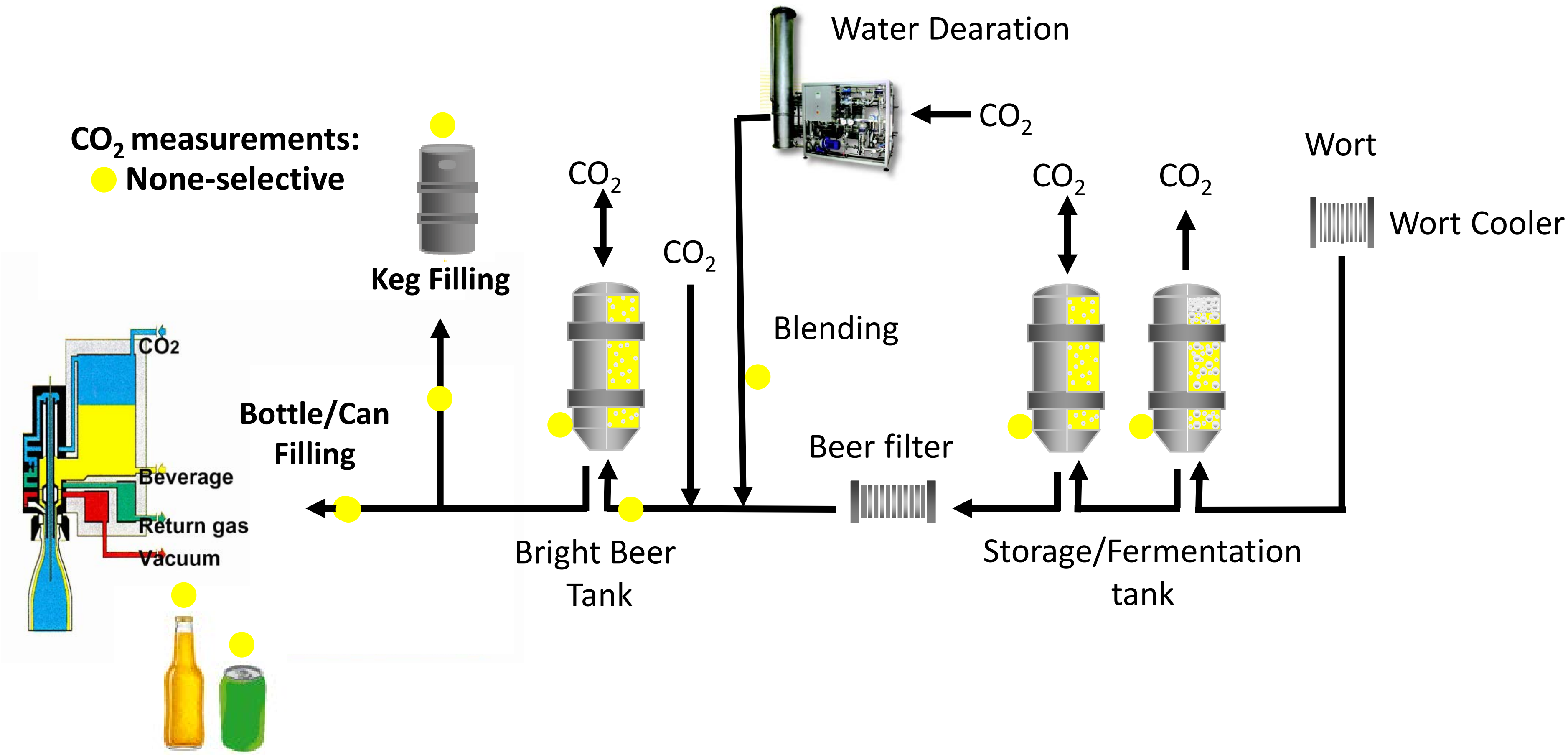
- Applications
- Setting the standard
- CO_2 measurement, General
- Influence factors
- CO_2 measurement of packages
- New technologies
- Calibration/Verfication
- Good practice

The Science of Beer

How does a brewery determine the optimum gas content for a new product development?

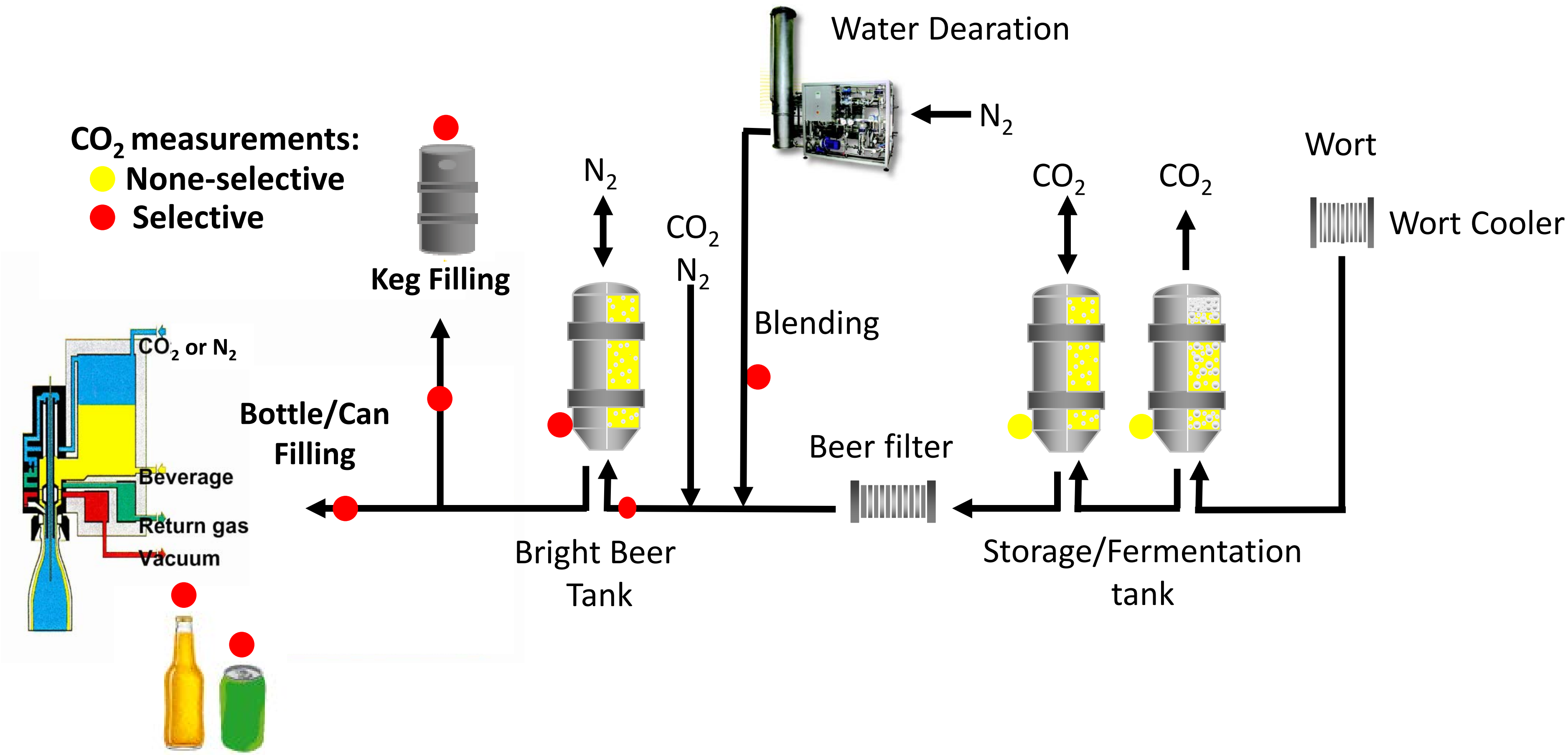
By Tasting (Tasting Panels)!

CO_2 MEASUREMENT, Typical Applications with CO_2



Medium used to transport beer, flush production lines and used as counter pressure on tanks is important in the choice of the CO_2 measurement.

CO_2 MEASUREMENT, Typical Applications with N_2



Medium used to transport beer, flush production lines and used as counter pressure on tanks is important in the choice of the CO_2 measurement.

CO_2 MEASUREMENT

CO_2 METHODOLOGY

Which standard CO_2 Measuring Methodology is followed?

ASBC Method of Analysis

or

Analytica-EBC?

Evolution of CO_2 MEASUREMENT

Evolution of CO_2 MEASUREMENT results in a wide range of CO_2 Measuring Methods

CO_2 measurement methods	ASBC Methods	EBC Methods
- Manometric (mechanical)		
- P&T	beer-13	9.28.3
- Multi-volume expansion	beer-13	9.28.5/6
- Membrane		
- Manometric (optical)		
- Adsorption		
- None invasive		
- Chemical/titrimetric		
- Blom & Lund		9.28.1
- Titration (Corning)		
- Special CO_2 detectors		
- Thermal conductivity		9.28.4
- Attenuated Total Refrection ATR		

The Science of Beer

CO_2 MEASUREMENT

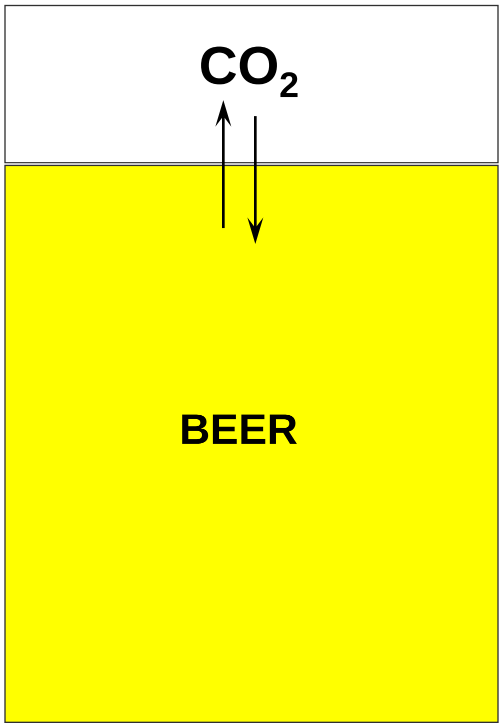
Estimated 90 % of CO_2 MEASUREMENT currently used in brewing industry:

Henry's Law

"The volume of gas dissolved in a liquid is proportional to the pressure of the gas above the liquid "

CO_2 MEASUREMENT

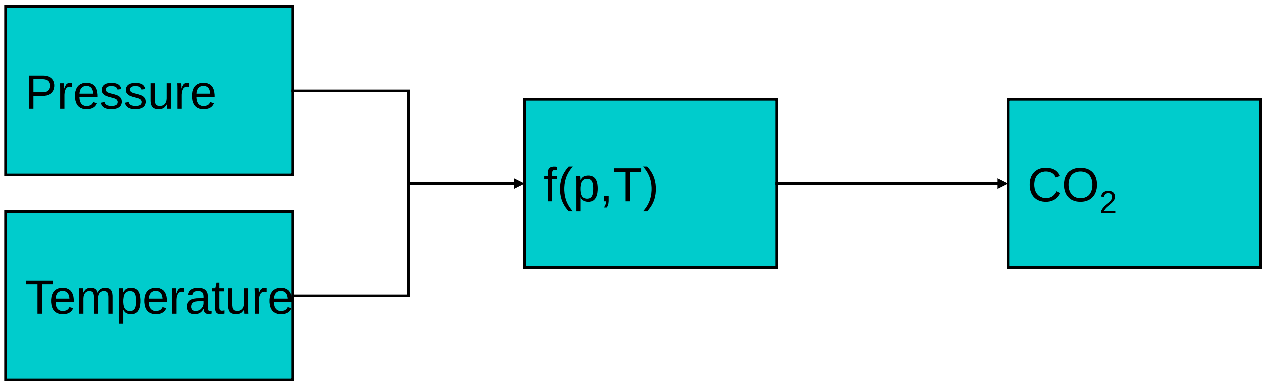
CO_2 MEASUREMENT BASED ON HENRY'S LAW



Henry: $CO2 = P * f(t)$

CO_2 MEASUREMENT

FUNCTIONAL DIAGRAM HENRISCH LAW



ASBC CO_2 CHART

SOLUBILITY OF CARBON DIOXIDE IN BEER PRESSURE—TEMPERATURE RELATIONSHIPS

Results Expressed as Volumes CO_2 (°C—760 mm) per Volume Beer

CONVERSION SCALE (sp gr beer, 1.01)

GAGE PRESSURE — POUNDS PER SQUARE INCH

°F	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
32	2.15	2.27	2.38	2.48	2.59	2.70	2.80	2.90	3.00	3.11	3.21									
33	2.10	2.23	2.33	2.43	2.53	2.63	2.74	2.84	2.96	3.06	3.15	3.25								
34	2.06	2.18	2.28	2.38	2.48	2.58	2.69	2.79	2.90	3.00	3.09	3.19								
35	2.02	2.14	2.24	2.34	2.43	2.52	2.63	2.73	2.83	2.93	3.02	3.12	3.22							
36	1.98	2.09	2.19	2.29	2.38	2.47	2.57	2.67	2.77	2.86	2.96	3.05	3.15	3.24						
37	1.94	2.04	2.14	2.24	2.33	2.42	2.52	2.62	2.71	2.80	2.90	3.00	3.09	3.18	3.27					
38	1.90	2.00	2.10	2.20	2.29	2.38	2.48	2.57	2.66	2.75	2.85	2.94	3.03	3.12	3.21					
39	1.86	1.96	2.06	2.15	2.25	2.34	2.43	2.52	2.61	2.70	2.80	2.89	2.98	3.07	3.16	3.25				
40	1.83	1.92	2.01	2.10	2.20	2.30	2.39	2.47	2.56	2.65	2.75	2.84	2.93	3.01	3.10	3.19	3.28			
41	1.79	1.88	1.97	2.06	2.16	2.25	2.34	2.43	2.52	2.60	2.70	2.79	2.88	2.96	3.05	3.14	3.23			
42	1.75	1.85	1.94	2.02	2.12	2.21	2.30	2.39	2.48	2.56	2.65	2.74	2.83	2.91	3.00	3.09	3.18	3.26		
43	1.72	1.81	1.90	1.99	2.08	2.17	2.26	2.34	2.43	2.52	2.61	2.69	2.78	2.86	2.96	3.04	3.13	3.21		
44	1.69	1.78	1.87	1.95	2.04	2.13	2.22	2.30	2.39	2.47	2.56	2.64	2.73	2.81	2.90	2.99	3.07	3.16	3.24	
45	1.66	1.75	1.84	1.91	2.00	2.08	2.17	2.26	2.34	2.42	2.51	2.60	2.69	2.77	2.86	2.94	3.02	3.11	3.19	
46	1.62	1.71	1.80	1.88	1.96	2.04	2.13	2.22	2.30	2.38	2.47	2.55	2.64	2.72	2.81	2.89	2.98	3.06	3.15	3.23
47	1.59	1.68	1.76	1.84	1.92	2.00	2.09	2.18	2.26	2.34	2.42	2.50	2.59	2.67	2.76	2.84	2.93	3.02	3.09	3.18
48	1.56	1.65	1.73	1.81	1.89	1.96	2.05	2.14	2.22	2.30	2.38	2.46	2.54	2.62	2.71	2.79	2.88	2.96	3.04	3.13
49	1.53	1.62	1.70	1.79	1.86	1.93	2.01	2.10	2.18	2.25	2.34	2.42	2.50	2.58	2.67	2.75	2.83	2.91	3.00	3.07
50	1.50	1.59	1.66	1.74	1.82	1.90	1.98	2.06	2.14	2.21	2.30	2.38	2.46	2.54	2.62	2.70	2.78	2.86	2.94	3.02
51		1.57	1.64	1.71	1.79	1.87	1.95	2.02	2.10	2.18	2.26	2.34	2.42	2.49	2.57	2.65	2.74	2.82	2.90	2.97
52		1.54	1.61	1.68	1.76	1.84	1.92	1.99	2.06	2.14	2.22	2.30	2.38	2.45	2.53	2.61	2.68	2.76	2.84	2.92
53		1.51	1.59	1.66	1.74	1.81	1.89	1.96	2.03	2.10	2.18	2.26	2.34	2.41	2.49	2.57	2.64	2.71	2.79	2.86
54			1.56	1.63	1.71	1.78	1.86	1.93	2.00	2.07	2.15	2.22	2.30	2.37	2.45	2.52	2.59	2.66	2.74	2.81
55			1.53	1.60	1.68	1.75	1.82	1.89	1.97	2.04	2.12	2.19	2.26	2.33	2.40	2.47	2.54	2.62	2.69	2.76
56			1.50	1.57	1.65	1.72	1.79	1.86	1.93	2.00	2.08	2.15	2.22	2.29	2.36	2.43	2.50	2.57	2.64	2.71
57				1.54	1.62	1.70	1.77	1.83	1.90	1.97	2.04	2.11	2.18	2.25	2.32	2.39	2.46	2.53	2.60	2.66
58				1.51	1.59	1.67	1.74	1.80	1.87	1.94	2.01	2.08	2.15	2.21	2.28	2.35	2.42	2.48	2.55	2.62
59					1.56	1.64	1.71	1.77	1.84	1.91	1.98	2.04	2.11	2.17	2.24	2.31	2.38	2.43	2.50	2.57
60					1.54	1.62	1.69	1.75	1.82	1.88	1.95	2.01	2.08	2.14	2.21	2.27	2.34	2.40	2.47	2.53
61					1.51	1.59	1.66	1.72	1.79	1.85	1.91	1.97	2.04	2.10	2.17	2.23	2.30	2.36	2.43	2.49
62						1.56	1.63	1.69	1.76	1.82	1.88	1.94	2.01	2.07	2.14	2.20	2.26	2.32	2.39	2.45
63						1.54	1.60	1.66	1.72	1.78	1.85	1.91	1.98	2.04	2.10	2.16	2.22	2.28	2.35	2.41
64						1.51	1.58	1.64	1.70	1.75	1.82	1.88	1.94	2.00	2.06	2.12	2.18	2.24	2.30	2.36
65							1.55	1.61	1.67	1.73	1.79	1.85	1.91	1.96	2.03	2.09	2.15	2.21	2.27	2.33
66							1.52	1.58	1.64	1.70	1.76	1.82	1.88	1.93	1.99	2.05	2.11	2.17	2.23	2.29
67							1.50	1.55	1.61	1.67	1.73	1.79	1.85	1.90	1.96	2.02	2.08	2.14	2.20	2.25
68								1.53	1.59	1.64	1.70	1.76	1.83	1.87	1.93	1.98	2.04	2.10	2.16	2.22
69								1.51	1.57	1.62	1.68	1.73	1.79	1.84	1.90	1.96	2.01	2.07	2.13	2.18
70									1.54	1.59	1.65	1.70	1.76	1.81	1.87	1.92	1.98	2.05	2.10	2.15
71									1.52	1.57	1.63	1.68	1.73	1.78	1.84	1.89	1.95	2.01	2.06	2.11
72										1.54	1.60	1.65	1.71	1.76	1.81	1.86	1.92	1.97	2.03	2.08
73										1.52	1.57	1.62	1.68	1.73	1.78	1.83	1.89	1.94	2.00	2.05
74										1.50	1.55	1.60	1.65	1.70	1.76	1.81	1.86	1.91	1.97	2.02
75											1.52	1.57	1.63	1.68	1.73	1.78	1.83	1.88	1.94	1.99
76											1.50	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95
77												1.53	1.57	1.62	1.67	1.72	1.77	1.82	1.87	1.92
78												1.50	1.55	1.60	1.65	1.70	1.75	1.79	1.84	1.89
79													1.53	1.58	1.63	1.67	1.72	1.77	1.82	1.87
80													1.50	1.55	1.60	1.65	1.70	1.74	1.79	1.84
81														1.53	1.58	1.63	1.68	1.72	1.77	1.82
82														1.52	1.56	1.60	1.65	1.70	1.75	1.79
83														1.50	1.54	1.58	1.63	1.68	1.73	1.77
84															1.52	1.56	1.61	1.65	1.70	1.74
85															1.50	1.54	1.58	1.62	1.67	1.71
86																1.52	1.56	1.60	1.65	1.69

°F	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
49	3.15																									
50	3.10	3.17																								
51	3.06	3.13	3.19																							
52	3.00	3.06	3.13	3.22																						
53	2.94	3.01	3.09	3.16																						
54	2.89	2.96	3.04	3.10	3.17																					
55	2.83	2.89	2.97	3.04	3.11	3.18																				
56	2.78	2.85	2.92	2.99	3.06	3.13	3.20																			
57	2.73	2.80	2.87	2.94	3.00	3.08	3.15	3.22																		
58	2.69	2.75	2.82	2.88	2.96	3.02	3.09	3.16																		
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60	2.60	2.66	2.73	2.79	2.86	2.92	2.99	3.05	3.11	3.18																
61	2.56	2.62	2.69	2.75	2.81	2.87	2.94	3.00	3.07	3.14	3.19															
62	2.52	2.58	2.64	2.70	2.77	2.83	2.90	2.96	3.02	3.08	3.14	3.20														
63	2.48	2.53	2.60	2.66	2.72	2.78	2.85	2.90	2.97	3.03	3.09	3.16														
64	2.43	2.49	2.55	2.61	2.68	2.74	2.80	2.86	2.92	2.98	3.04	3.10	3.17													
65	2.39	2.45	2.51	2.57	2.63	2.69	2.75	2.81	2.87	2.93	3.00	3.06	3.11	3.18												
66	2.35	2.41	2.47	2.53	2.59	2.65	2.71	2.76	2.82	2.88	2.94	3.00	3.06	3.12	3.18											
67	2.31	2.37	2.43	2.49	2.55	2.61	2.67	2.72	2.78	2.84	2.90	2.96	3.02	3.07	3.13	3.19										
68	2.28	2.33	2.39	2.44	2.50	2.56	2.62	2.67	2.73	2.78	2.85	2.90	2.96	3.02	3.07	3.13										
69	2.24	2.30	2.36	2.41	2.47	2.52	2.58	2.63	2.69	2.74	2.80	2.86	2.92	2.97	3.03	3.08	3.14									
70	2.21	2.26	2.31	2.36	2.42	2.48	2.54	2.59	2.65	2.70	2.76	2.81	2.87	2.92	2.98	3.03	3.09	3.14								
71	2.17	2.22	2.28	2.33	2.39	2.44	2.50	2.55	2.61	2.66	2.72	2.77	2.83	2.88	2.94	2.99	3.04	3.09	3.15							
72	2.14	2.19	2.24	2.29	2.35	2.40	2.46	2.51	2.57	2.62	2.67	2.72	2.78	2.83	2.89	2.94	3.00	3.05	3.10	3.15						
73	2.11	2.16	2.21	2.26	2.31	2.36	2.42	2.47	2.53	2.58	2.63	2.68	2.73	2.79	2.84	2.89	2.96	3.00	3.06	3.10	3.16					
74	2.07	2.12	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53	2.58	2.64	2.69	2.74	2.79	2.84	2.90	2.95	3.00	3.06	3.11	3.16				
75	2.04	2.09	2.14	2.19	2.24	2.29	2.35	2.40	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.86	2.91	2.96	3.01	3.06	3.11	3.16			
76	2.01	2.06	2.11	2.16	2.21	2.26	2.31	2.36	2.41	2.46	2.51	2.56	2.61	2.66	2.71	2.76	2.81	2.86	2.91	2.96	3.01	3.06	3.12	3.16		
77	1.97	2.02	2.07	2.12	2.17	2.22	2.27	2.32	2.37	2.42	2.47	2.52	2.57	2.62	2.67	2.72	2.77	2.82	2.87	2.92	2.97	3.02	3.07	3.12	3.17	3.22
78	1.94	1.99	2.04	2.09	2.14	2.18	2.23	2.28	2.34	2.38	2.43	2.48	2.53	2.58	2.63	2.67	2.72	2.78	2.83	2.88	2.93	2.97	3.02	3.07	3.12	3.16
79	1.92	1.96	2.01	2.06	2.11	2.16	2.21	2.25	2.30	2.35	2.40	2.45	2.50	2.54	2.59	2.64	2.69	2.74	2.79	2.83	2.88	2.93	2.98	3.03	3.08	3.12
80	1.89	1.93	1.98	2.03	2.08	2.13	2.18	2.22	2.27	2.32	2.37	2.41	2.46	2.50	2.55	2.60	2.65	2.70	2.75	2.79	2.84	2.89	2.94	2.98	3.03	3.07
81	1.87	1.91	1.96	2.00	2.05	2.10	2.15	2.20	2.25	2.29	2.34	2.38	2.43	2.48	2.53	2.57	2.62	2.66	2.71	2.76	2.81	2.85	2.90	2.94	2.99	3.04
82	1.84	1.89	1.94	1.98	2.03	2.07	2.12	2.16	2.21	2.26	2.31	2.36	2.40	2.44	2.49	2.54	2.59	2.63	2.68	2.72	2.77	2.82	2.86	2.90	2.95	3.00
83	1.82	1.86	1.91	1.95	2.00	2.04	2.09	2.13	2.18	2.22	2.27	2.32	2.37	2.41	2.46	2.50	2.55	2.59	2.64	2.68	2.73	2.78	2.82	2.87	2.91	2.96
84	1.79	1.83	1.88	1.92	1.97	2.02	2.06	2.10	2.15	2.19	2.24	2.28	2.33	2.37	2.42	2.46	2.51	2.56	2.60	2.64	2.69	2.74	2.78	2.82	2.87	2.91
85	1.76	1.80	1.85	1.89	1.94	1.98	2.03	2.07	2.12	2.16	2.21	2.25	2.29	2.33	2.38	2.43	2.47	2.51	2.56	2.60	2.65	2.69	2.74	2.78	2.82	2.87
86	1.74	1.78	1.83	1.87	1.91	1.95	2.00	2.04	2.09	2.13	2.18	2.22	2.26	2.30	2.35	2.39	2.43	2.48	2.53	2.57	2.61	2.65	2.69	2.73	2.78	2.83

CO_2 MEASUREMENT

CALCULATION OF CO_2 EQUILIBRIUM CONCENTRATION according to **ASBC**

$$CO_2\,[Vol] = 3.45778 - 7872.43*P*10^{-5} + 1513.53*T*10^{-4} + 7779.99*P^2*10^{-7} + 3963.09*T^2*10^{-7} - 1677.07*P*T*10^{-6} - 2791.5*P^3*10^{-9} + 4679.44*P^2*T*10^{-9} - 1424.25*P*T^2*10^{-8} + 116.914*P^2*T^2*10^{-9}$$

- CO_2 = CO_2 equilibrium concentration in Volume
- P = equilibrium pressure (partial) in psig
- T = temperature of the liquid in ^oF.

Note:

- Calculation based on beer with Specific Gravity (sp gr) of 1.01 kg/l
- Conversion from % by weight to volume: CO_2 [Vol] = 5.0607 x CO_2 [% by wt] x sp gr

The Science of Beer

CO_2 MEASUREMENT

CALCULATION OF CO_2 EQUILIBRIUM CONCENTRATION according to **EBC**

$$CO_2[\%m/m] = A \times \left(p[\text{barg}] + p_{atm}[\text{bara}]\right) \times e^{\left(C + \frac{D}{T[^\circ\text{C}]+273{,}15}\right)}$$

- CO_2 = CO_2 equilibrium concentration
- A = conversion factor/compensation factor
- p = equilibrium pressure (partial) in barg
- p_{atm} = atmospheric pressure in bara
- C = solubility-dependent factor (-10.74*)
- D = product- dependent factor (2617.25*)
- T = temperature of the liquid in ^{o}C.

* Calculation based on beer with an OG of 12 ^{o}Plato and apparent attenuation of 80 %

Conversion from % m/m to Volume: CO_2 [Vol] = 5.061 x CO_2 [% m/m] x S (specific gravity)

The Science of Beer

CO_2 MEASUREMENT

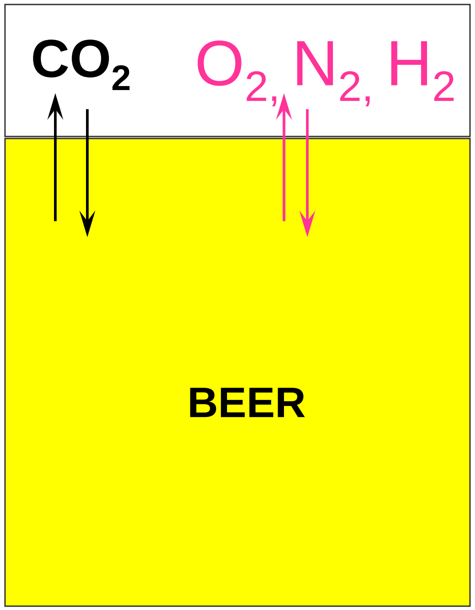
ERROR SOURCES MANOMETRIC CO_2 MEASUREMENTS

- Foreign gasses in the beverage
- Changes in the atmospheric pressure

  Note: Solved in most of the digital CO_2 meters by using a absolute pressure measurement
- Composition of the beverage

CO_2 MEASUREMENT, effect Foreign Gasses

CO_2 MEASUREMENT based on HENRY‘s and DALTON‘s LAW



Henry: $CO_2 = P * f(t)$

Dalton: $P = [P\ CO_2 + P\ O_2 + P\ H_2 + P\ N_2\ ]$

The Science of Beer

CO_2 MEASUREMENT, effect Foreign Gasses

SELECTIVE CO_2 MEASUREMENT OF PACKAGED BEER;
calculation of CO_2 equilibrium concentration compensated for headspace air:

By ASBC CO_2 chart:
Calculate correction for partial pressure of air in headspace to be subtracted from the measured gauge pressure

$$P_{corrected}[\mathrm{psig}] = \left(P[psig] + 14.7 - \frac{v_{air}}{v_{head\ space}} x14.7 \right)$$

By EBC:

$$CO_2[Vol] = A \times \left(p[\mathrm{barg}] + p_{atm}[\mathrm{bara}] - p_{atm} \times \frac{v_{air}}{v_{head\ space}}[\mathrm{bar}] \right) \times e^{\left(C + \frac{D}{T[°\mathrm{C}] + 273{,}15} \right)}$$

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CO_2 MEASUREMENT, Failures due to Foreign Gasses

Supposition 1: Effect of air

O_2 and N_2 dissolved are proportional to atmospheric conditions

O_2 content	simulated CO_2 content [Vol]				
ppm w/w	0^0C	5^0C	10^0C	15^0C	20^0C
0.10	0.02	0.02	0.02	0.02	0.02
1.00	0.21	0.20	0.19	0.18	0.16

Supposition 2: Effect of Nitrogen (N_2 or CO_2/N_2 mix-gas injection)

N_2 content	simulated CO_2 content [Vol]				
ppm w/w	0^0C	5^0C	10^0C	15^0C	20^0C
1	0.06	0.05	0.05	0.05	0.04
10	0.55	0.53	0.49	0.45	0.42

CO_2 MEASUREMENT, Failure due to Composition of Beverage

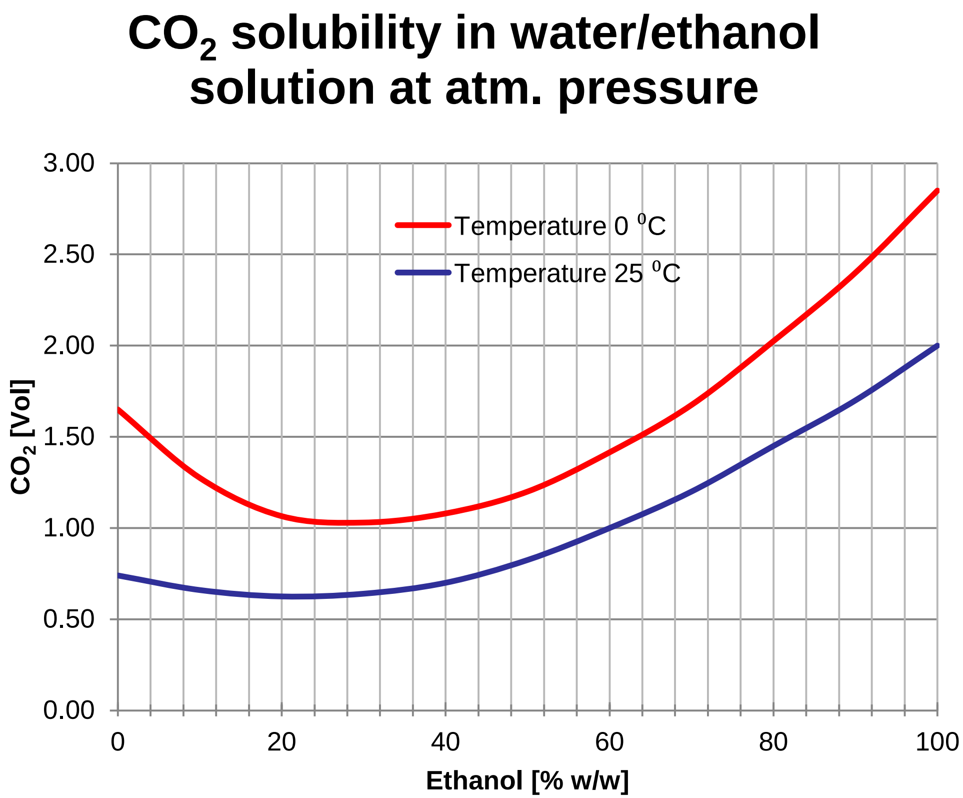
- CO_2 solubility in beer 12 °Plato is approximately 0,96 x CO_2 solubility in water
- CO_2 solubility in soft drink with 10 g/l sugar (=10 °Brix) is approximately 0,90 x CO_2 solubility in water
- As the extract content gets smaller the CO_2 solubility in beer approaches the solubility in water
- Rule of thumb: approximately 1% CO_2 solubility per 3 °Plato or 1 °Brix

Note: In practice the difference in CO_2 solubility will not be taken into account

CO_2 MEASUREMENT, Influence of Ethanol Content

Information in literature different opinions are found :

- Paukner: in a range of 4-6 % Ethanol the CO_2 solubility is comparable with water
- Haffmans:



Note: In practice the difference in CO_2 solubility will not be taken into account

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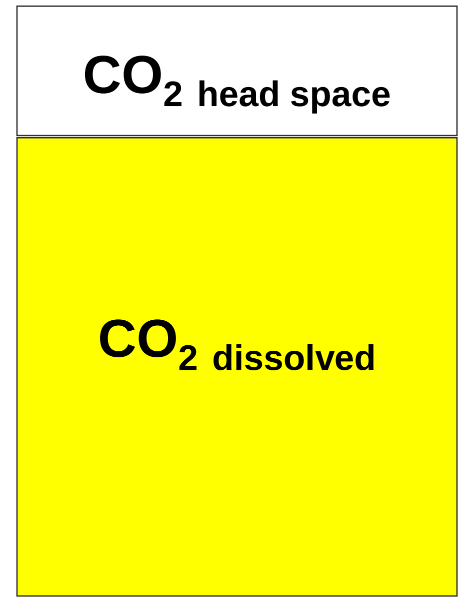
Methods of CO_2 MEASUREMENT, Effects of Failures

CO_2 measurement methods	ASBC Methods	EBC Methods	Selective	Gas/liquid	Remark
- Manometric (mechanical)					
- P&T	beer-13	9.28.3	X	gas	
- Multi-volume expansion	Beer-13	9.28.5/6	√	gas	Anton Paar
- Membrane			√	gas	Gas selective membrane, only in-line
- Manometric (optical)					
- Adsorption			√	gas	only in-line
- None invasive			√ /X	gas	only bottles (glass & PET), can measure CO_2 pressure and total pressure
- Chemical/titrimetric					
- Blom & Lund		9.28.1	√	liquid	
- Titration (Corning)			√	liquid	
- Special CO_2 detectors					
- Thermal Conductivity		9.28.4	√	gas	Orbisphere
- Attenuated Total Reflection ATR			√	liquid	only in-line

CO_2 MEASUREMENT of PACKAGES

CO_2 MEASUREMENT of PACKAGES, Temp. Effects

- CO_2 Measurement of Packaged beer (bottle, can and/or keg)
- $CO_{2\ total} = CO_{2\ head\ space} + CO_{2\ dissolved}$
- $CO_{2\ total}$ = constant and independent of temp.
- When temp. increases:
  $CO_{2\ head\ space}(\uparrow) + CO_{2\ dissolved}(\downarrow)$
- Example: packaged bottle
  $V_{liquid} = 300$ ml
  $V_{head\ space} = 15$ ml
  $CO_{2\ dissolved}$ at 10 ^oC= 2.65 Vol
  $CO_{2\ dissolved}$ at 20 ^oC= 2.61 Vol



CO_2 MEASUREMENT of PACKAGES, Temp. Effects (cont.)

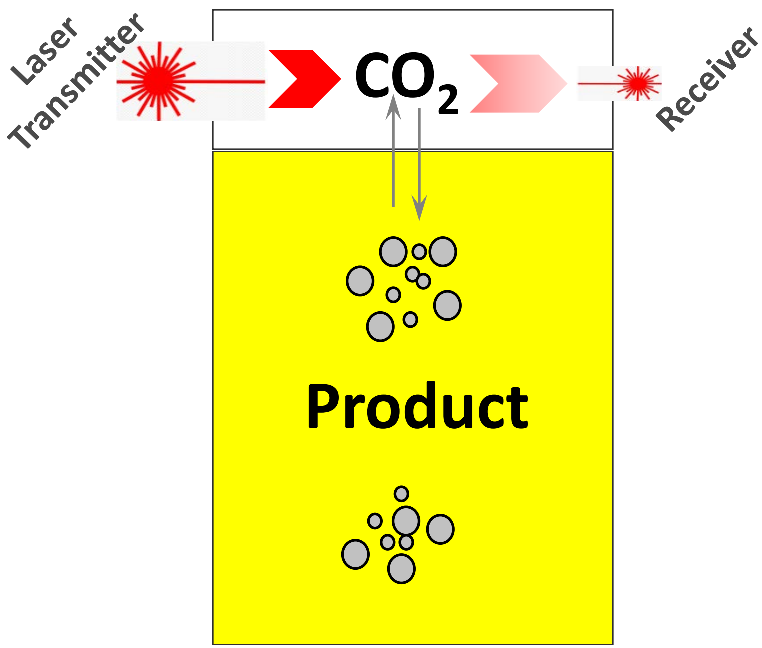
Possible solutions:

- Always measure the CO_2 concentration of packages on a standardized temp. for example 25 ^{o}C (according to ASBC method).
- Use an instrument that is able to measure the CO_2 concentration temperature independently: A “new” CO_2 quantity “CO_2 temp standard $CO_{2\ TS}$“ or “normalization temp.” was introduced.

CO_2 MEASUREMENT of PACKAGES, Non-Invasive

Next step in selective CO_2 MEASUREMENT of Packaged beer (bottles only)

NON-INVASIVE CO_2 Measurement



- Package remains unopened.
- Equilibrium pressure, Total pressure and temp. are measured without contacting the bottle.

Non-Invasive CO_2 Measurement, Video (real time)

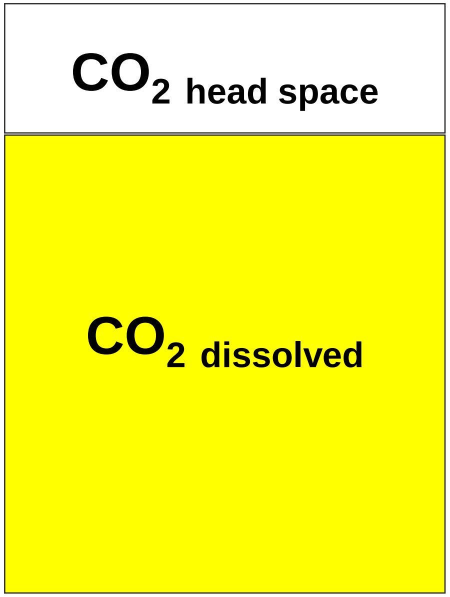
5-10 seconds for results !

CO_2 MEASUREMENT of PACKAGES, Next Step??

Next step in CO_2 Measurement of Packaged beer (bottle, can):

Analogue to TPO:

Measurement of TPCO= $CO_{2\ total}$ =$CO_{2\ head\ space}$ + $CO_{2\ dissolved}$???



- No attemporation: $CO_{2\ total}$ makes the CO_2 measurement of packages temp. independent.
- No equilibration of package, when measured separately (as performed in the Haffmans Automator)

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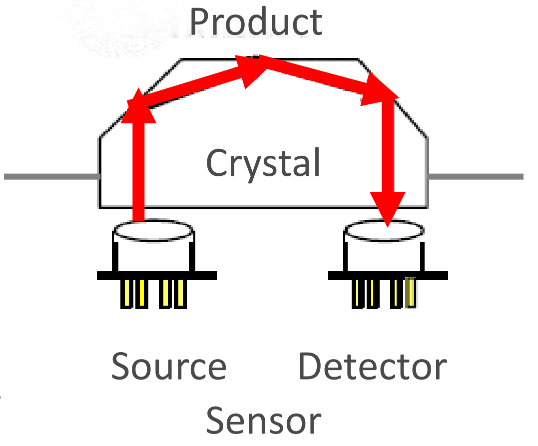
CO_2 MEASUREMENT, ATR-Method (in-line)

New in-line CO_2 measurement technology is ATR.

ATR Uses of infrared light (IR) and its Attenuated Total Reflectance (ATR).



Infrared beams are directed under an angle onto the optically crystal, make sapphire, that is installed at the probe's process connection and is in contact with the product.
The infrared light enters the liquid surface and through Absorption, it will attenuate and the reflected spectrum of this beam is measured.

ATR CO_2 measurement is:
- Selective
- Fast (short measurement interval) and
- Beverage composition has no influence

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CO_2 MEASUREMENT CALIBRATION

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CO_2 MEASUREMENTS, Calibration

Manometric (mechanical):

- Calibration of pressure and temperature (indirect).

Manometric (optical):

Adsorption:

Calibration (indirect)

- CO_2 Differences with lab result to be corrected.

None-invasive:

Calibration (indirect) of

- total pressure and partial CO2 pressure by using a certified gas (CO2 or CO2/N2 mixture) at different pressures.

Special detectors:

Thermal Conductivity:

Calibration (indirect) with

- Certified gas (one point or two point calibration)

ATR

- 7 fixed products stored (Beer, beverage, beverage diet, wine, mineral water, strong beer, MID) and one to create a customer specific product.
- Field calibration adjusting and aligning to trends in a repeated manner against lab result (use of offset or gain adjustment).

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CO_2 MEASUREMENTS, Verification

Trace CO_2:

- An installation that produces water with a known CO2 quantity based on pressure and temperature conditions.

High precision Calibration Kit

An accurate determined quantity of sodium Bicarbonate is combined with a ready-made diluted Citric acid solution to provide an accurate carbon dioxide concentration only to be used to calibrate/verify the thermal conductivity sensor.

CO_2 MEASUREMENT, Good Practice

1. Use **<u>one</u>** CO_2 calculation, without compensating for CO_2 solubility, or density for all beers and beverage types at all stages of the production.
   This avoids operators involved in CO_2 measurement needing to adjust CO_2 formula's for each product which can lead to mistakes.

2. At beverage development, determine preferred CO_2 content through taste panels.
   This CO_2 content is calculated based on the CO_2 calculation above.

3. Reproducibility of CO_2 measurement is relevant for proper CO_2 control, true CO_2 level not relevant;

4. Use selective CO_2 measurement when foreign gas contents do not allow proper quality control.

What do all these CO_2 methods bring brewing industry

New CO_2 meter/measuring method have different advantages;
Reduction of sample preparation/faster results
Choice needs to be fine tunes with product/application
Need for standardization

Issues:

Comparability of CO_2 measurement/methods
Calibration of special detectors (ATR and Thermal Conductivity) against master

THANK YOU FOR YOUR ATTENTION!

Frank Verkoelen