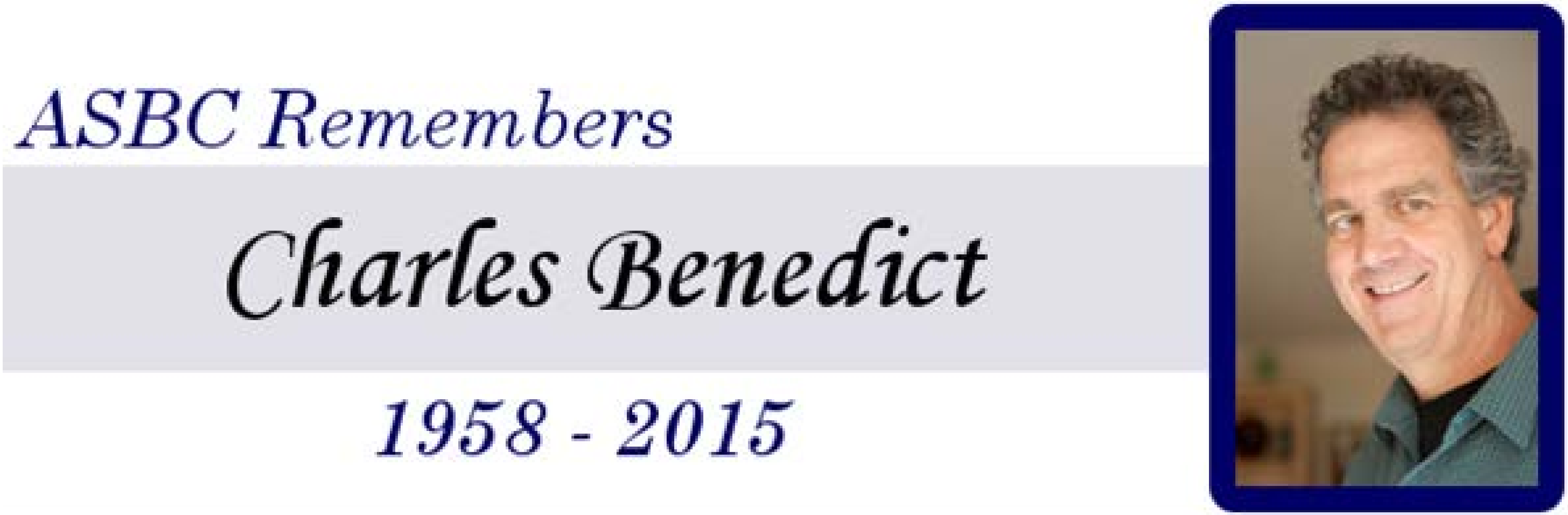
The Science Behind Packaging Quality

June 2015

In Memorandum



Introductions

- Lauren Torres – Bell's Brewery

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- Scott Brendecke – Ball Corporation

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- John Engel – MillerCoors LLC

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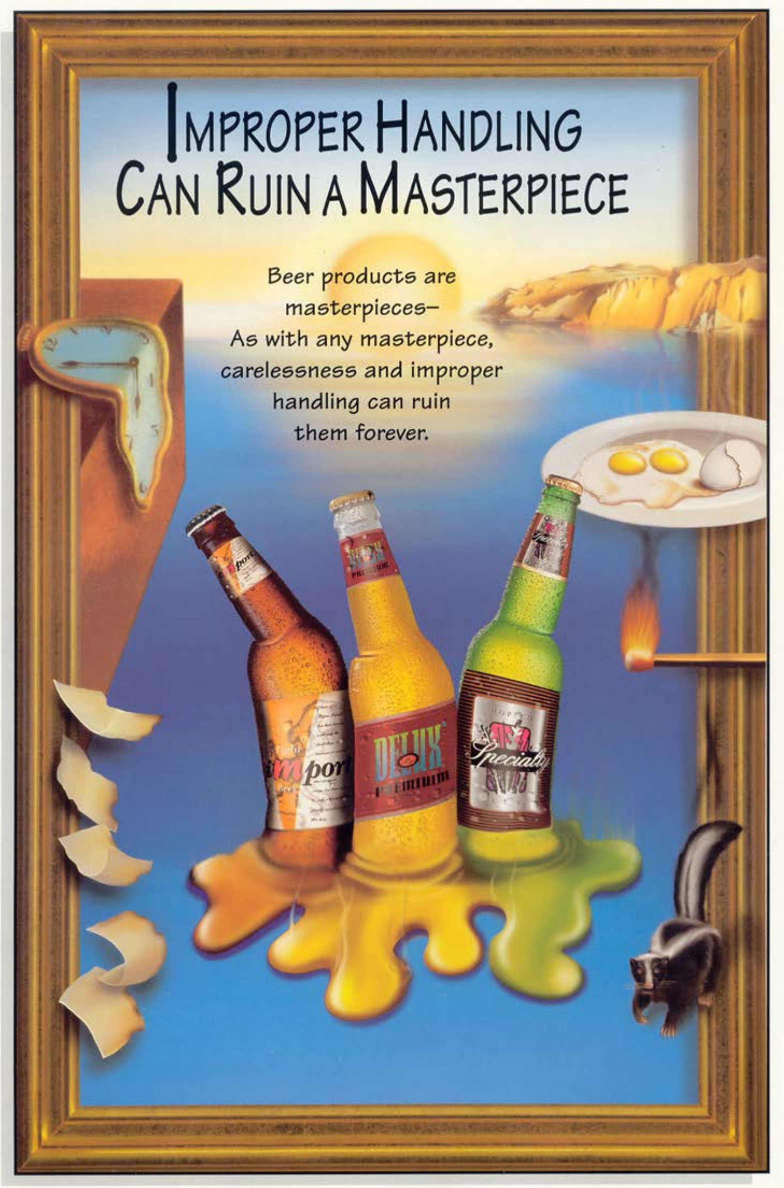
Workshop Agenda

- Setting the stage...
- Can Quality, Impacts to Flavor and Freshness...
- Dissolved Oxygen in packaged beer...
- Operational considerations of Bottle and Can filling...
- Trouble shooting / Q&A

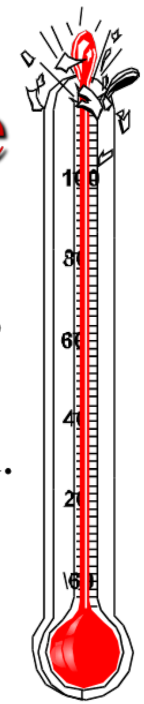
Setting the Stage

- How do you ruin beer?
- What are the "Enemies of Beer Flavor and Freshness"?



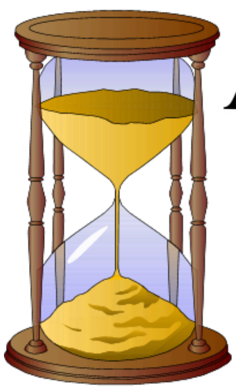
Enemies of Beer Flavor & Freshness

Light causes a "skunky" aroma and sulphury taste.
(includes fluorescent light)



Temperature

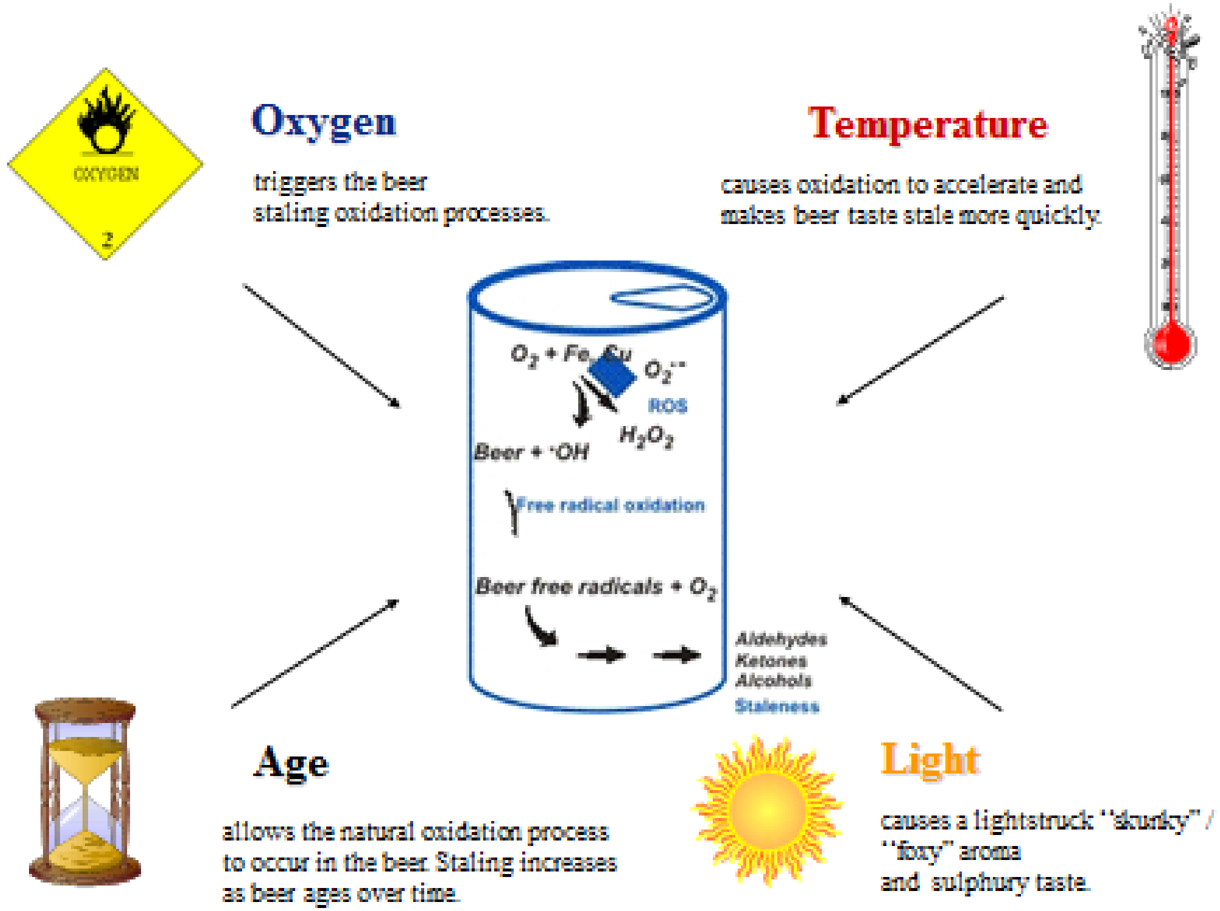
causes oxidation to accelerate and makes beer taste old more quickly than it should.



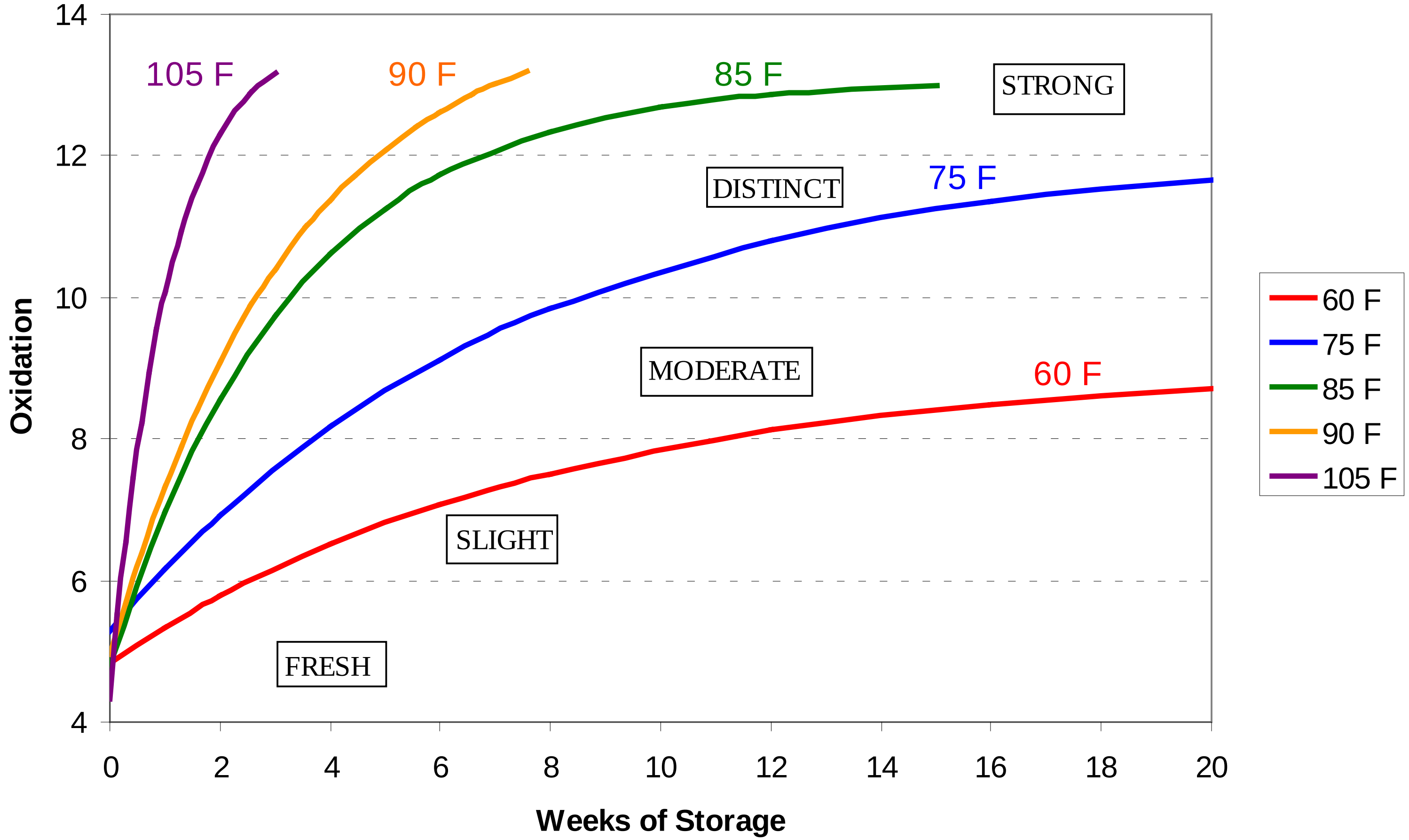
Age

allows the natural oxidation process to occur in the beer. Oxidation increases as beer ages.

The Science of Beer Freshness

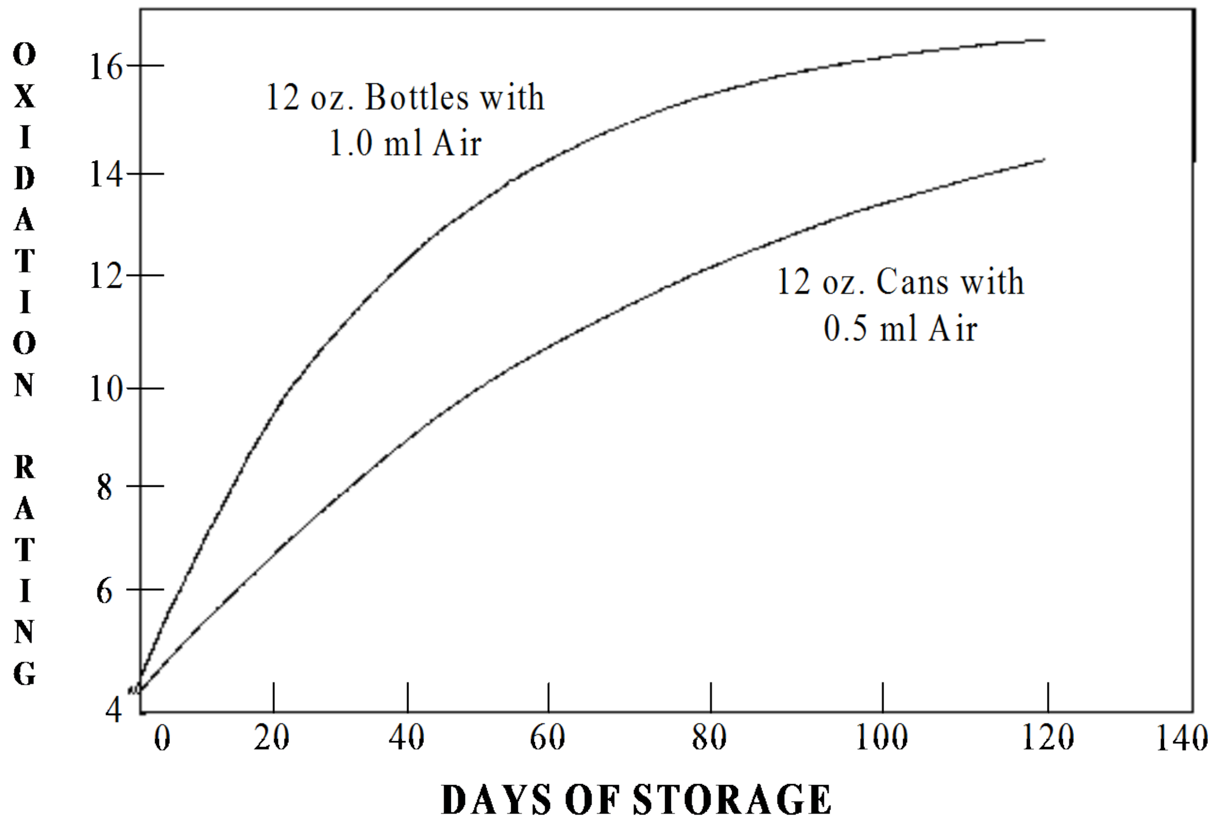


Oxidation Rate is Greatly Influenced by Temperature



Effect of Package Air on Oxidation

Beer Stored at 75°F



Effect of Packaging Materials

- **Scalping: Adsorption of beer flavors**
  - Bottle crown liners
  - Improperly cured can lining materials

- **Off-flavors in Bottled Beer from Crown Lining Materials**
  - Linoleic acid in epoxylated soybean oil used as a heat stabilizer in making PVC crown liners
  - Contaminants in natural oils and waxes used to reduce torques for twist-off crowns

- **Off-flavors in Canned Beer from Packaging Materials**
  - Organic solvents from poorly cured cans
  - Lubricant additives used in can making
  - Lid seal compositions and poorly cured linings
  - Unsaturated aldehydes (nonenal) in exterior can decoration, released during curing and condensed on inner surface

Can Quality, Impacts to Flavor and Freshness

Scott Brendecke

Receiving palletized cans at the Brewery

Proper handling of can pallets begins when the truck backs up to the dock

- Check for proper trailer packing
- Note any damage to cans
- Check trailer for off-aromas
- Describe and collect off-aroma samples for testing

Example aromas and possible chemical source

Aroma	Possible chemical compounds
Citrus	d-limonene, Ethyl butanoate, Octyl acetate
Rose	Geranyl acetate, Geraniol, Nerol
Woody	Linalool, 1-Hexanol, α-Ionone, Myrcene, Nerolidol
Fishy	Trimethylamine, Pyridine
Grassy	Hexanal, cis-3-Hexen-1-ol,
Coconut	δ-Nonalactone

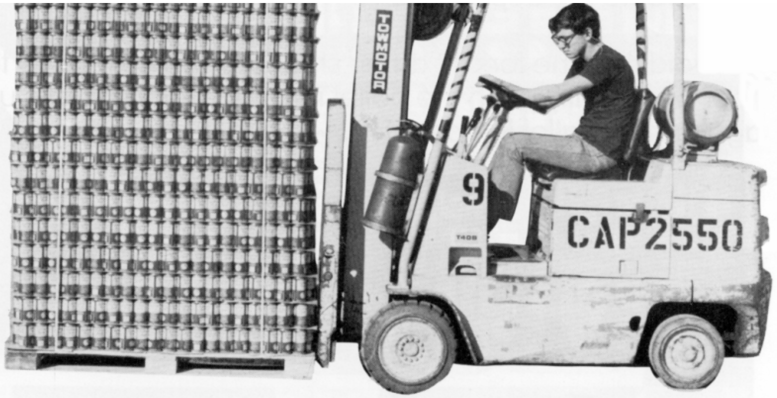
Moving pallets out of trailer

- Remove by hand when possible
- Using a pallet hook make moving pallets easier
- Moving with a forklift can damage cans

Moving cans to storage

- Don’t tilt pallet back when moving

- Keep pallet vertical
- Maintain space between pallet and front of forklift



RIGHT

Pallets with cans storage area

- Easily accessible
- Inside, not exposed to weather
- Oldest cans used first
- More than 1 year old checked before use

The storage area

- Storage area should be clean
- No sources of heat or humidity nearby
- Minimize wood or paper nearby (trans-2-nonenal)
- No items nearby with strong aromas

Depalletizing cans

- Area near the depalletizer for person to inspect cans
- Mirrored surface above cans for inspection
- Dented cans removed and sent to be recycled

Final Thought

Garbage in = Garbage out

One marginal can could ruin several good cans at the double seamer

Acknowledgments

Oskar Blues Brewing, Longmont Colorado

Ball Corporation, North American Metal Beverage division

The Science of Packaging Quality: The DO Edition

Lauren Torres

Bell's Brewery Inc.

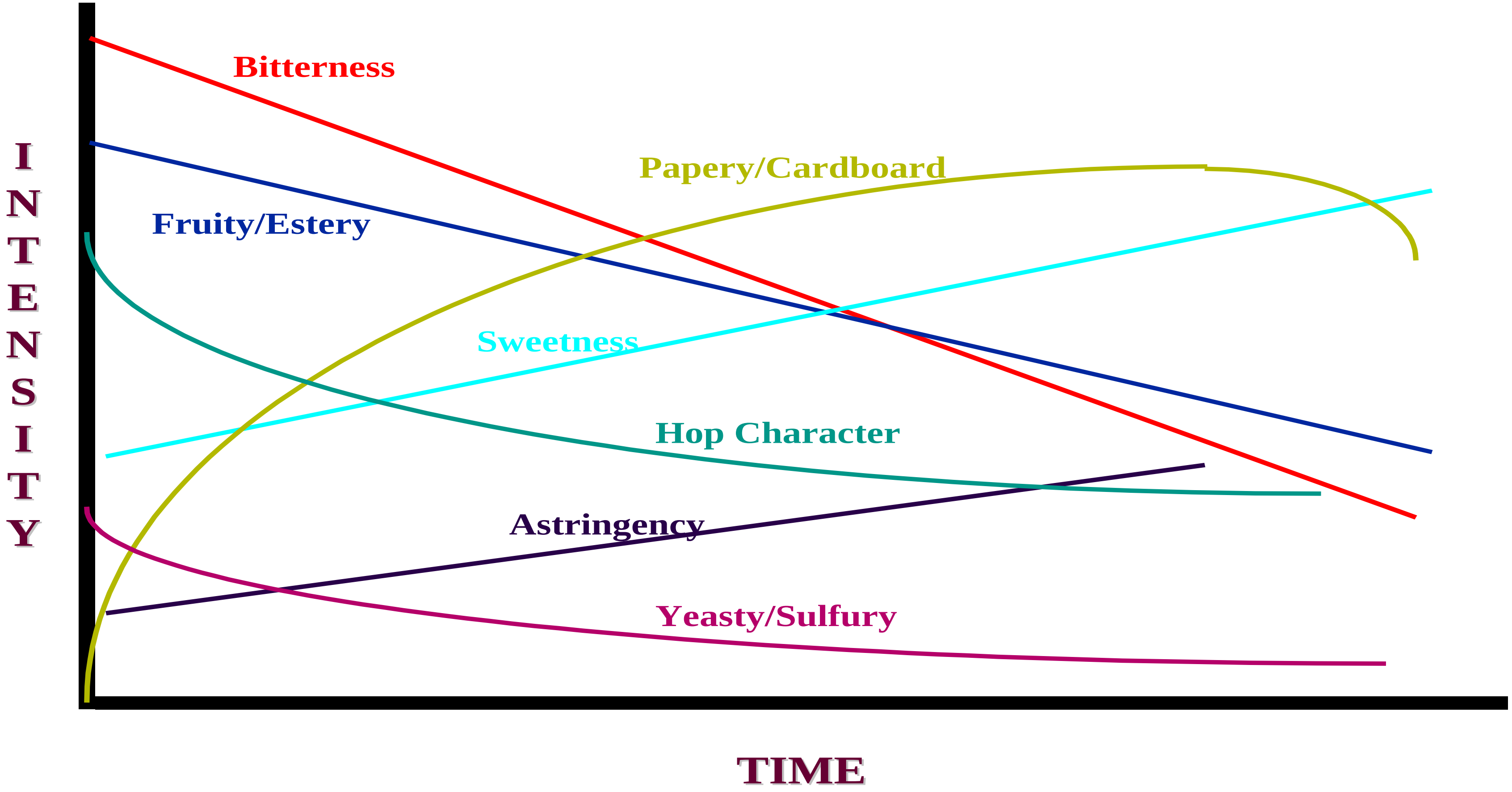
Galesburg, MI

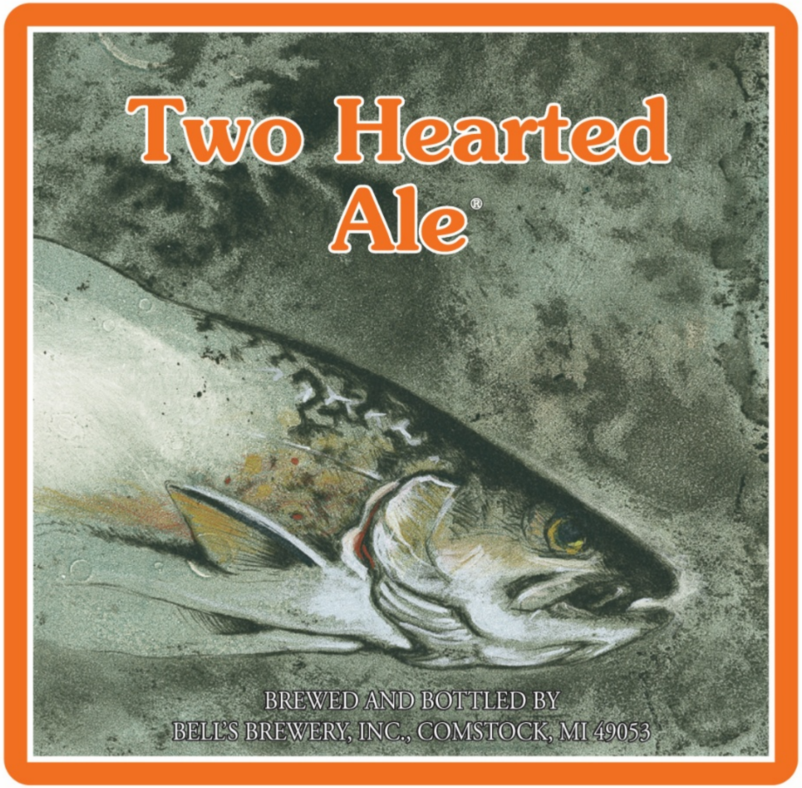
Goals of the session

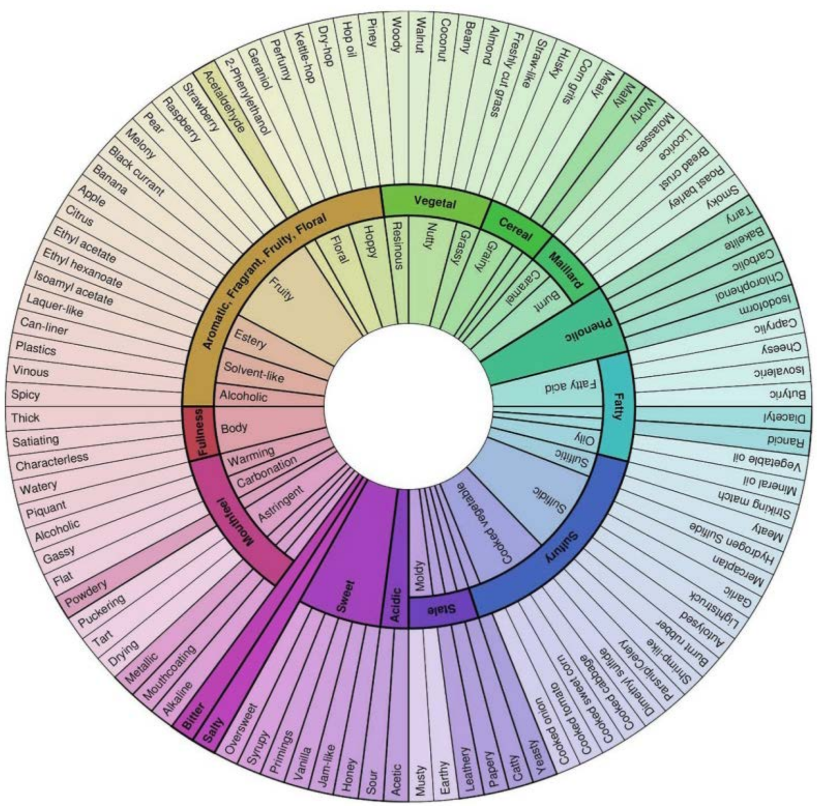
- Why do we care about O_2 in beer?
- How can O_2 be measured?
- What can be learned from these measurements?

- What is DO?
  - The amount of gaseous O_2 dissolved in a liquid
- Why should anyone care about DO?
  - It’s all about the flavor!

Fresh Beer → Stale Beer



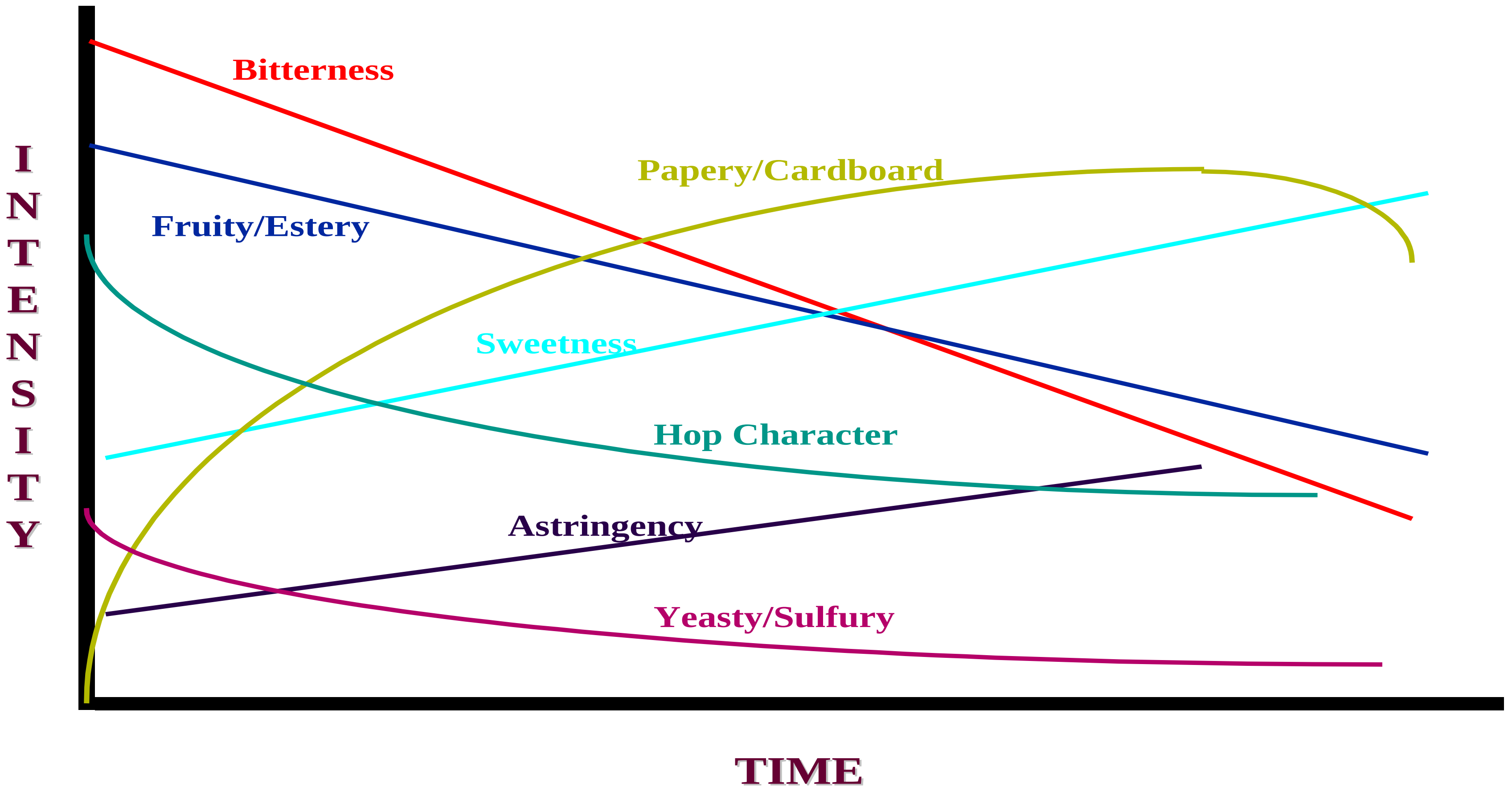




Descriptors: piney, resin, citrus, grapefruit

What happens to the unseamed package samples on the line when the filler stops?

Fresh Beer → Stale Beer



To calculate TPO you need:

- An equilibrated sample
- The ability to measure DO
- Temperature of sample
- Liquid Volume
- Headspace volume

$$m\,(t)\,(mg/l) = X\left[\frac{32 \cdot 1000 \cdot HS\,(4{,}15 \cdot 10^{-7}T^2 + 2 \cdot 10^{-4}T - 0{,}0701)}{0{,}082 \cdot T \cdot 1{,}0332 \cdot 100} + 1\right]$$

C. Vilachá and K. Uhlig

How has Bell's measured DO?

Zahm and Nagel Air Testing

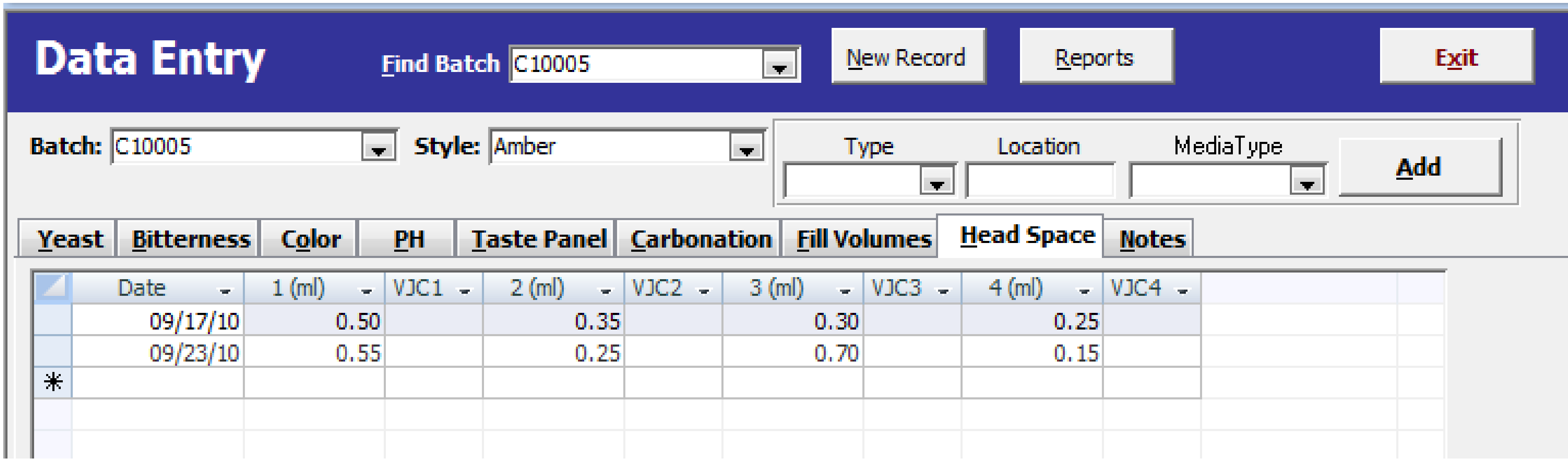
Pros

- Cheap ~$1500
- Better than nothing
- Different packages
- Can see a historical problem

Cons

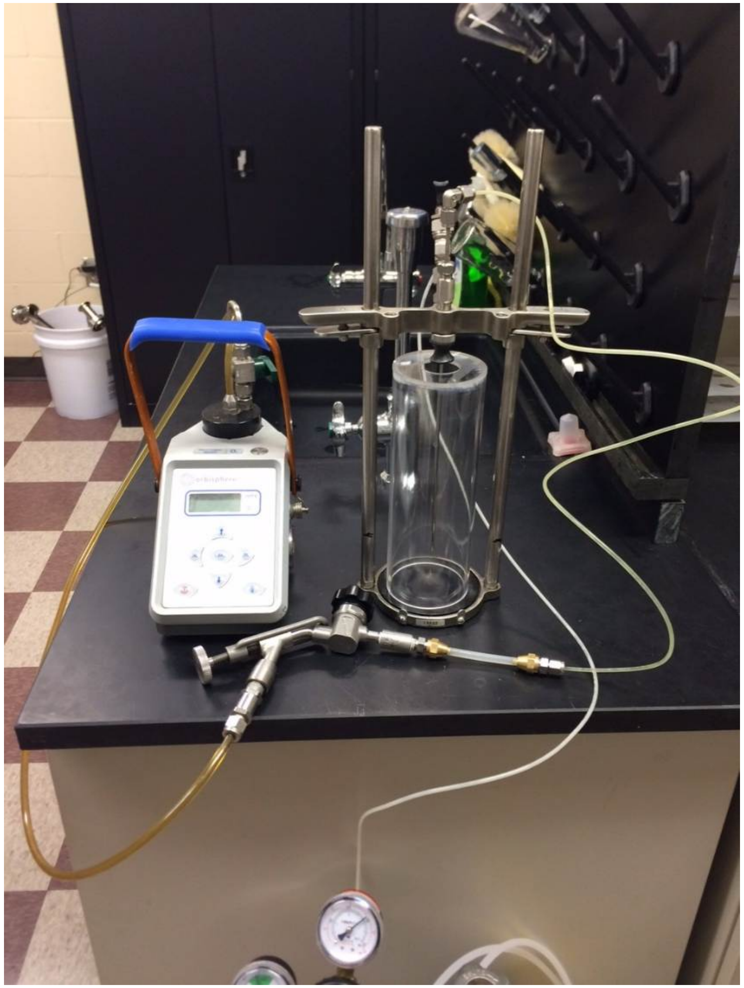
- Limited number of samples
- Corrosive chemical
- Repetitive movement injuries
- Retroactive results
- Bad for morale
- Assumptions
  - All air is removed
  - Gas measure is in the normal air proportions.

What did we do with the data?



“The goal is to have headspace air volumes of 0.5mL or lower. If the four bottle average is greater than 0.5mL, the warning limit has been exceeded and the Lab and Packaging Managers should be notified. An average of higher than 1.0 mL exceeds the action limit: the Production Manager, Packaging Manager, and the Shipping/Receiving department must be notified immediately.”

Membrane Zahmisphere

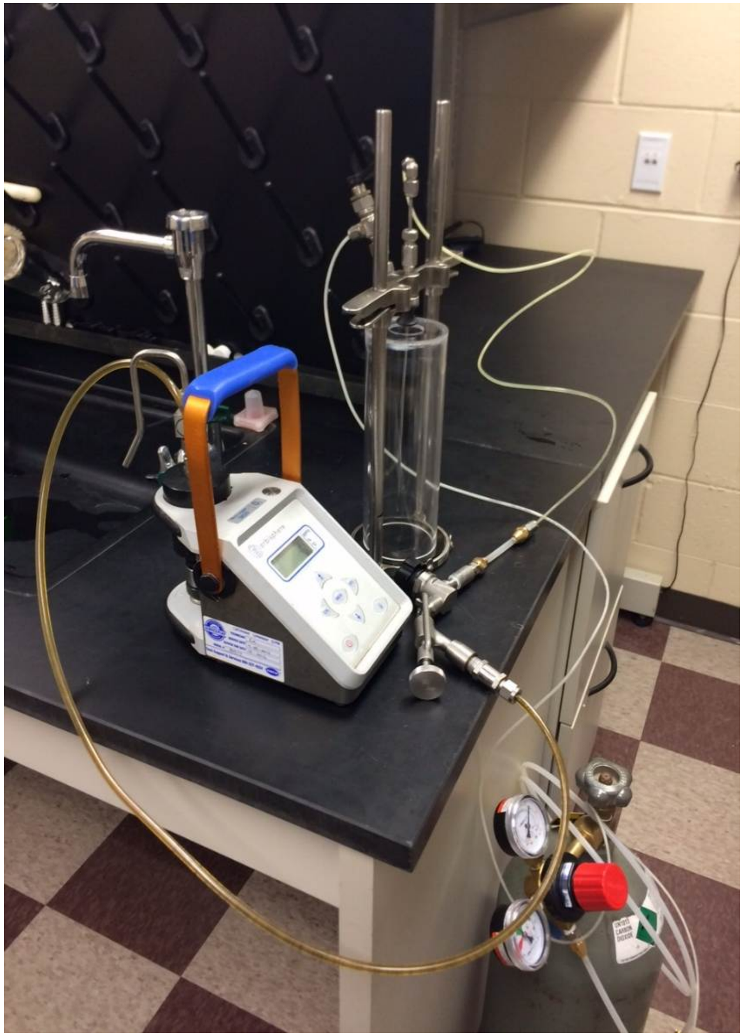


Pros

- Can calculate TPO
- Can run unlimited samples
- Real time readings
- Low to high range (~0-20ppm)
- Multipurpose
- Data logging
- HS vs DO measurements
- Can use + and – controls
- Different packages


OBERON
2015

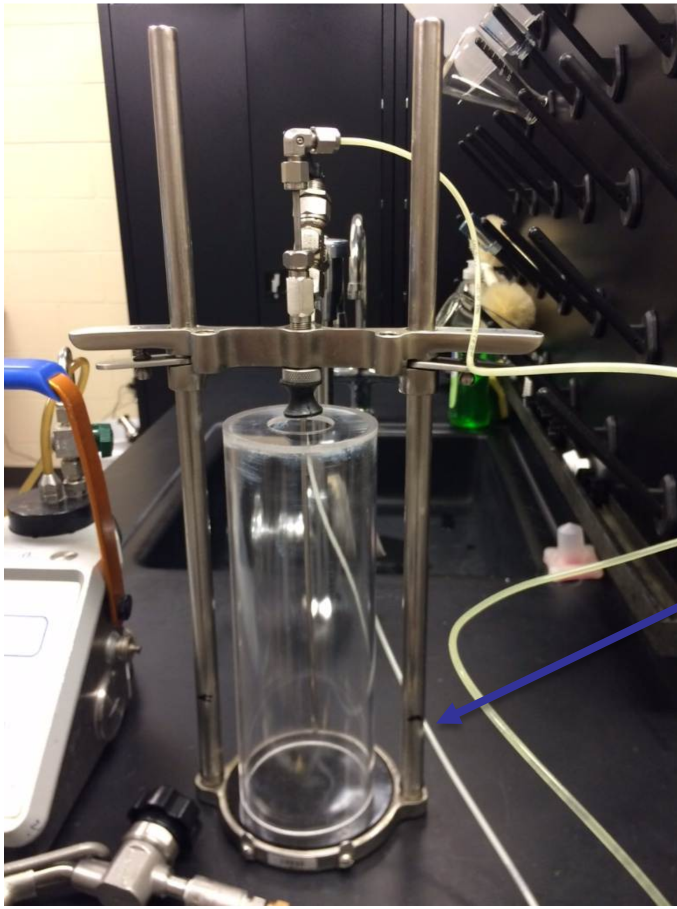
Membrane Zahmisphere



Cons

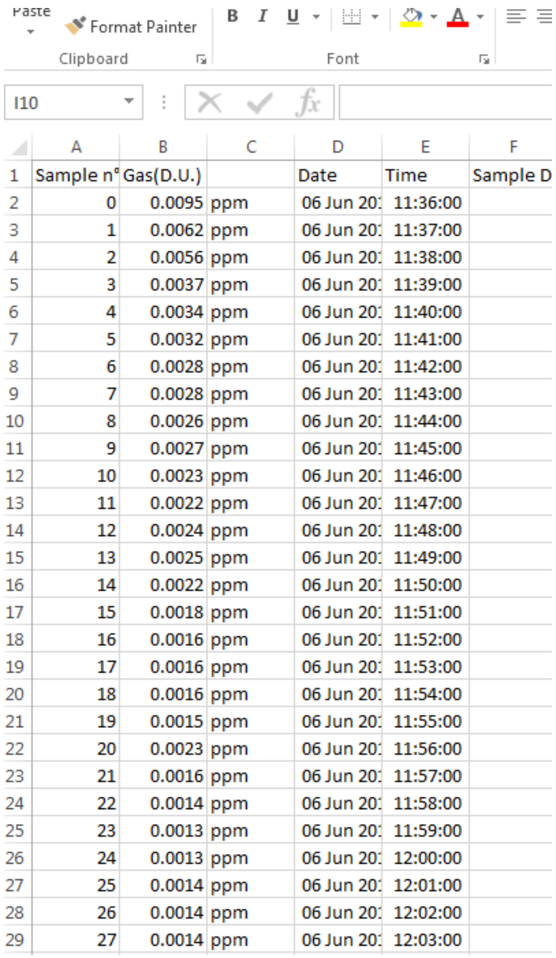
- Need to blank
- Fails low
- More complicated calibration
- Repetitive motion
- TPO with Z factor
- No temperature
- Clogging
- No HS vs DO measurements
- Cost $10,600 (membrane) + Piercer $1000 + N2 cylinder ($55)
- Safety
- Flow based reading

How did we use this?

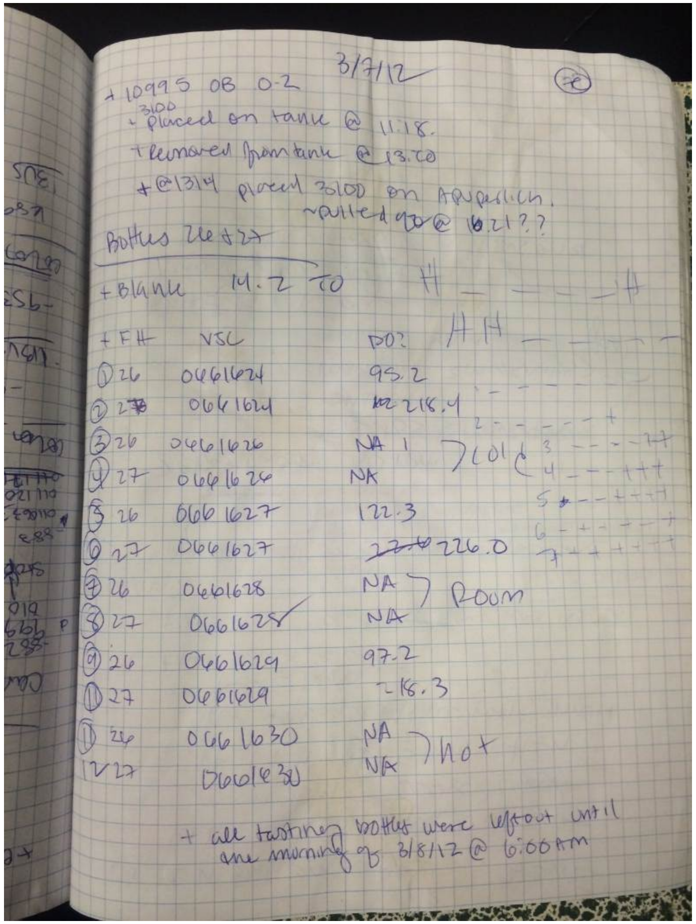


- Pierce
- Drop dip tube
- Turn on gas
- Open flow on DO meter ~150mL/min
- Read DO at

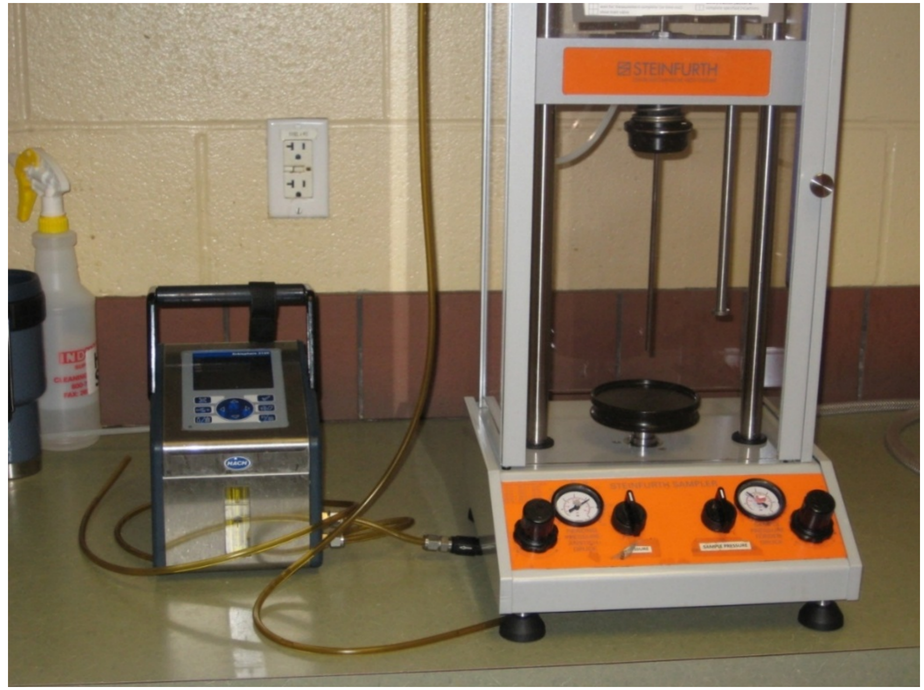
What does the data look like



	A	B	C	D	E	F
1	Sample n°	Gas(D.U.)		Date	Time	Sample D
2	0	0.0095	ppm	06 Jun 20	11:36:00	
3	1	0.0062	ppm	06 Jun 20	11:37:00	
4	2	0.0056	ppm	06 Jun 20	11:38:00	
5	3	0.0037	ppm	06 Jun 20	11:39:00	
6	4	0.0034	ppm	06 Jun 20	11:40:00	
7	5	0.0032	ppm	06 Jun 20	11:41:00	
8	6	0.0028	ppm	06 Jun 20	11:42:00	
9	7	0.0028	ppm	06 Jun 20	11:43:00	
10	8	0.0026	ppm	06 Jun 20	11:44:00	
11	9	0.0027	ppm	06 Jun 20	11:45:00	
12	10	0.0023	ppm	06 Jun 20	11:46:00	
13	11	0.0022	ppm	06 Jun 20	11:47:00	
14	12	0.0024	ppm	06 Jun 20	11:48:00	
15	13	0.0025	ppm	06 Jun 20	11:49:00	
16	14	0.0022	ppm	06 Jun 20	11:50:00	
17	15	0.0018	ppm	06 Jun 20	11:51:00	
18	16	0.0016	ppm	06 Jun 20	11:52:00	
19	17	0.0016	ppm	06 Jun 20	11:53:00	
20	18	0.0016	ppm	06 Jun 20	11:54:00	
21	19	0.0015	ppm	06 Jun 20	11:55:00	
22	20	0.0023	ppm	06 Jun 20	11:56:00	
23	21	0.0016	ppm	06 Jun 20	11:57:00	
24	22	0.0014	ppm	06 Jun 20	11:58:00	
25	23	0.0013	ppm	06 Jun 20	11:59:00	
26	24	0.0013	ppm	06 Jun 20	12:00:00	
27	25	0.0014	ppm	06 Jun 20	12:01:00	
28	26	0.0014	ppm	06 Jun 20	12:02:00	
29	27	0.0014	ppm	06 Jun 20	12:03:00	



Chemiluminescent Package Testing



Pros

- No blanking
- Fast
- Great software
- Fails high
- Easy calibration
- Multi-use
- HS vs DO measurements
- Easy operating
- Low maintenance
- No repetitive movement injury
- Very precise low DO range
- Lots of data memory
- Different packages
- Short analysis time
- Can use + and – controls

Chemiluminescent Package Testing

Cons

- Clogging
- Still need to calculate TPO
- Cannot see perfect distinction between HS and DO
- One will soon not be enough
- $12,000 (3100) + $ 6800 (Piercer) + $ 55 (N2) + $ 2500 (small shaker) $ 5645 (large shaker)

What did the raw data look like?

Date	Time	User ID	User name	Meas. con	Product lo	Product na	Liquid nar	Temperat	Temp. uni	Barom. pr	Barom. pr	Common (	Channel t	Concentra	Conc. unit	Meas. offs	Meas. offs	Partial pre	Part. pres	Channel e
10/31/2013	13:37:33	0	Default	0	Default	Default	Beer	12.4	°C	0.984	bar	2	O2	58.4	ppb	0	ppb	1.14	mbar	0
10/31/2013	13:39:49	0	Default	0	Default	Default	Beer	11.6	°C	0.984	bar	4	O2	57	ppb	0	ppb	1.095	mbar	0
10/31/2013	13:42:13	0	Default	0	Default	Default	Beer	10.8	°C	0.983	bar	2	O2	31.2	ppb	0	ppb	0.589	mbar	0
10/31/2013	13:44:30	0	Default	0	Default	Default	Beer	10.9	°C	0.984	bar	4	O2	36.2	ppb	0	ppb	0.684	mbar	0
10/31/2013	13:46:05	0	Default	0	Default	Default	Beer	11.4	°C	0.983	bar	4	O2	41.9	ppb	0	ppb	0.803	mbar	0
10/31/2013	13:48:55	0	Default	0	Default	Default	Beer	11.9	°C	0.983	bar	4	O2	46.6	ppb	0	ppb	0.901	mbar	0
10/31/2013	13:52:30	0	Default	0	Default	Default	Beer	12.6	°C	0.983	bar	4	O2	46.4	ppb	0	ppb	0.91	mbar	0
10/31/2013	16:32:54	0	Default	0	Default	Default	Beer	8.3	°C	0.978	bar	10	O2	74.8	ppb	0	ppb	1.334	mbar	0
10/31/2013	16:35:44	0	Default	0	Default	Default	Beer	8	°C	0.978	bar	4	O2	70.1	ppb	0	ppb	1.239	mbar	0
10/31/2013	16:37:59	0	Default	0	Default	Default	Beer	7.6	°C	0.977	bar	4	O2	56.5	ppb	0	ppb	0.992	mbar	0
10/31/2013	16:40:20	0	Default	0	Default	Default	Beer	8.1	°C	0.978	bar	4	O2	104.9	ppb	0	ppb	1.861	mbar	0
10/31/2013	16:42:25	0	Default	0	Default	Default	Beer	8.5	°C	0.978	bar	4	O2	85.6	ppb	0	ppb	1.533	mbar	0
10/31/2013	16:44:20	0	Default	0	Default	Default	Beer	8.6	°C	0.978	bar	4	O2	62.3	ppb	0	ppb	1.118	mbar	0
10/31/2013	16:52:46	0	Default	0	Default	Default	Beer	9.1	°C	0.978	bar	4	O2	86.4	ppb	0	ppb	1.568	mbar	0
10/31/2013	16:54:01	0	Default	0	Default	Default	Beer	8.7	°C	0.978	bar	4	O2	103	ppb	0	ppb	1.855	mbar	0
10/31/2013	16:56:26	0	Default	0	Default	Default	Beer	8.7	°C	0.978	bar	4	O2	67.6	ppb	0	ppb	1.216	mbar	0

What did the TPO calculation look like?

tank	Volume	HS volume	VJC	shaking (time	temp from 3100	d02	dO2 in ppm	10^-7	10^-4	K	HLCK	numerator	demoninator	fraction +1	TPO (ppm)	**TPO (ppb)**
K4	355	23	2951025	5	10	120.3	0.1203	1E-07	0.0001	283	0.0197	4091.9392	2397.6439	2.7067	0.3256	**325.6**
K4	355	23	2951025	5	10	149.9	0.1499	1E-07	0.0001	283	0.0197	4091.9392	2397.6439	2.7067	0.4057	**405.7**
K4	357	21	2951025	5	10	104.5	0.1045	1E-07	0.0001	283	0.0197	3715.1878	2397.6439	2.5495	0.2664	**266.4**
N3	355	23	3041625	5	8.5	104.9	0.1049	1E-07	0.0001	281.5	0.0191	3956.8881	2384.9356	2.6591	0.2789	**278.9**
N3	355	23	3041626	5	8.8	85.6	0.0856	1E-07	0.0001	281.8	0.0192	3983.8674	2387.4772	2.6687	0.2284	**228.4**
N3	355	23	3041627	5	9.1	62.3	0.0623	1E-07	0.0001	282.1	0.0193	4010.8621	2390.0189	2.6782	0.1669	**166.9**
N3	355	23	3041641	5	9.1	86.3	0.0863	1E-07	0.0001	282.1	0.0193	4010.8621	2390.0189	2.6782	0.2311	**231.1**
N3	355	23	3041641	5	8.6	103	0.103	1E-07	0.0001	281.6	0.0191	3965.8795	2385.7828	2.6623	0.2742	**274.2**
N3	355	23	3041641	5	8.7	67.6	0.0676	1E-07	0.0001	281.7	0.0192	3974.8726	2386.6300	2.6655	0.1802	**180.2**
E1	355	23	3041329	5	12	41.9	0.0419	1E-07	0.0001	285	0.0206	4272.6096	2414.5884	2.7695	0.1160	**116.0**
E1	355	23	3041329	5	12.3	46.6	0.0466	1E-07	0.0001	285.3	0.0207	4299.7695	2417.1301	2.7789	0.1295	**129.5**
E1	355	23	3041329	5	12.6	46.4	0.0464	1E-07	0.0001	285.6	0.0209	4326.9449	2419.6717	2.7882	0.1294	**129.4**
N4	355	23	3110848	5	8.7	91.7	0.0917	1E-07	0.0001	281.7	0.0192	3974.8726	2386.6300	2.6655	0.2444	**244.4**
N4	355	23	3110848	5	9	144	0.144	1E-07	0.0001	282	0.0193	4001.8621	2389.1717	2.6750	0.3852	**385.2**
N4	355	23	3110848	5	9.4	100.5	0.1005	1E-07	0.0001	282.4	0.0195	4037.8723	2392.5606	2.6877	0.2701	**270.1**
P1	355	23	3231342	5	8.3	72.3	0.0723	1E-07	0.0001	281.3	0.0190	3938.9106	2383.2411	2.6528	0.1918	**191.8**
P1	355	23	3231343	5	8.5	86.4	0.0864	1E-07	0.0001	281.5	0.0191	3956.8881	2384.9356	2.6591	0.2297	**229.7**
P1	355	23	3131343	5	8.7	77.5	0.0775	1E-07	0.0001	281.7	0.0192	3974.8726	2386.6300	2.6655	0.2066	**206.6**
P1	355	23	3231354	5	8.8	58.1	0.0581	1E-07	0.0001	281.8	0.0192	3983.8674	2387.4772	2.6687	0.1550	**155.0**
P1	355	23	3231354	5	8.8	53.6	0.0536	1E-07	0.0001	281.8	0.0192	3983.8674	2387.4772	2.6687	0.1430	**143.0**
P1	355	23	3231354	5	9	57	0.057	1E-07	0.0001	282	0.0193	4001.8621	2389.1717	2.6750	0.1525	**152.5**
O1	355	23	3291222	5	7.9	119.5	0.1195	1E-07	0.0001	280.9	0.0188	3902.9761	2379.8522	2.6400	0.3155	**315.5**
O1	355	23	3291222	5	8	138.7	0.1387	1E-07	0.0001	281	0.0189	3911.9571	2380.6994	2.6432	0.3666	**366.6**
O1	355	23	3291223	5	8.3	114.8	0.1148	1E-07	0.0001	281.3	0.0190	3938.9106	2383.2411	2.6528	0.3045	**304.5**

What did the TPO calculation look like?

O2 in Headspace of Equilibrated Packages						
Temperature	*7.9*	°C		T	281.05	°K
Concentration	*0.0671*	mg/l		Water vapor pressure	10.67766179	Water vapor pressure
Volume Liquid	355	ml		R	0.08310	Liter * bar / (K * mol)
Volume Headspace	23	ml			0.006743719	
					0.0001	
				Water density	0.999852525	Water density
				Henry's Law coefficient	31379.73586	Henry's Law coefficient
O2 absoulte					56.59506067	
O2 in liquid	0.024	mg		Partial Pressure O2	0.0012	bar
O2 in Headspace	0.038	mg		n	1.173E-06	mol
Total O2	0.061	mg		M	32	g/mol
				m	0.0376	mg O2 in Headspace
O2 relative						
O2 in liquid	0.067	mg/l				
O2 in Headspace	0.106	mg/l				
Total O2	0.173	mg/l				

Total Package Analyzer

Pros

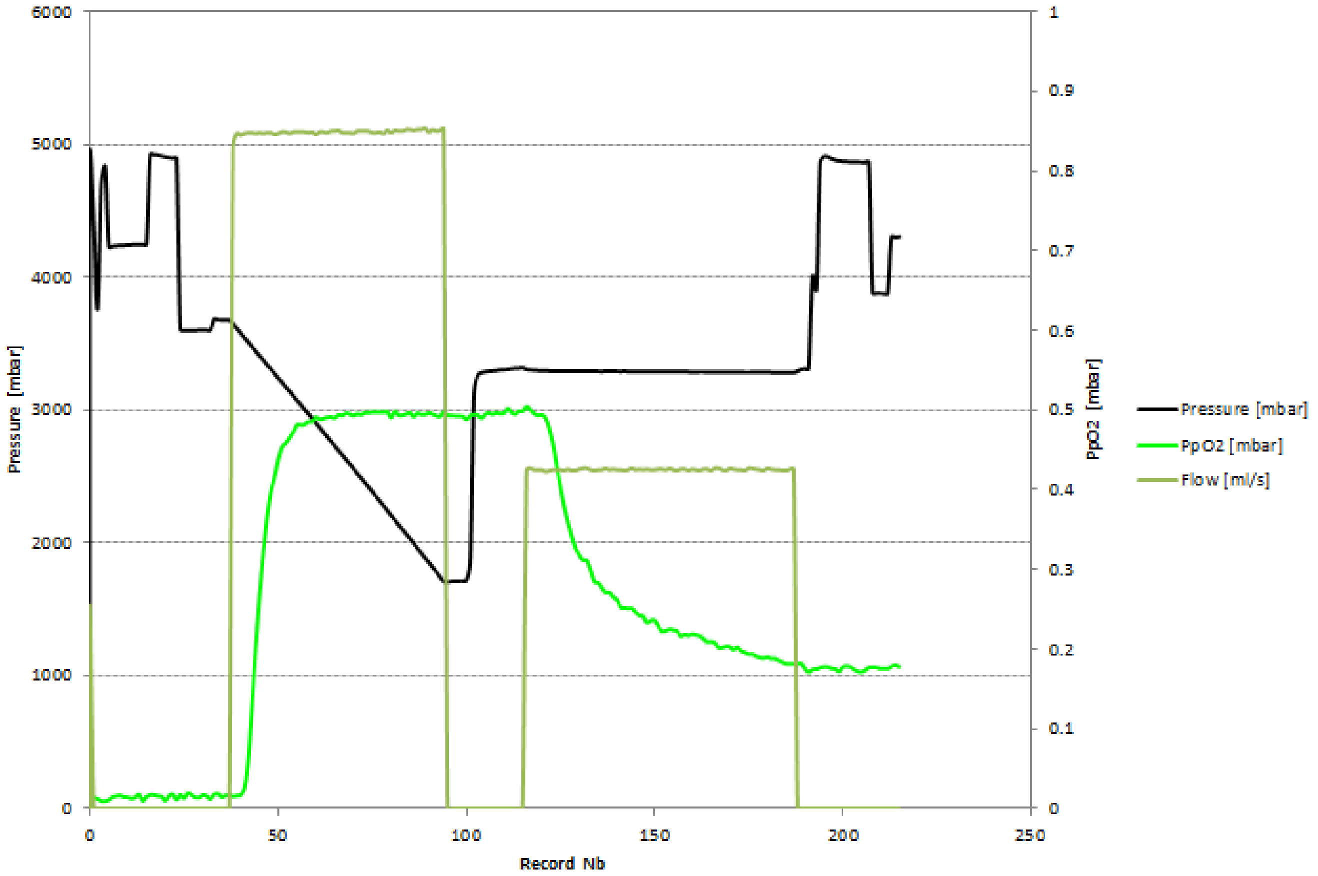
- No repetitive movement injury
- No clogging
- Measures headspace and liquid volumes
- Measures TPO (DO + HS O2)
- Measures CO2 purity, true CO2 and P/T CO2
- Lots of data
- Different package types
- Real time data
- Membrane technology
- Filler trouble shooting
- Can use + and – controls
- Safety

Total Package Analyzer

Cons

- $~60,000
- Loud
- Not multipurpose
- Longer measurement time
- More maintenance required

What does the data look like?



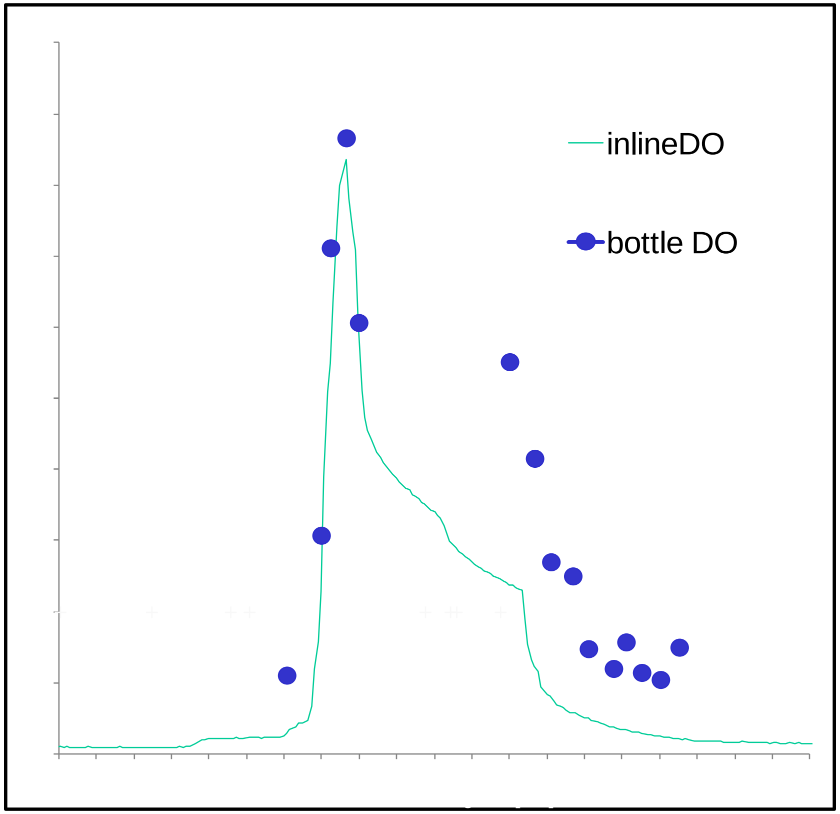
What have we learned from these different types of technology?

Air Testing

- We had a high DO problem three days ago in one part of the run
- Lauren needs to go the doctor
- Intentional sampling is important here
- Overall its better than nothing

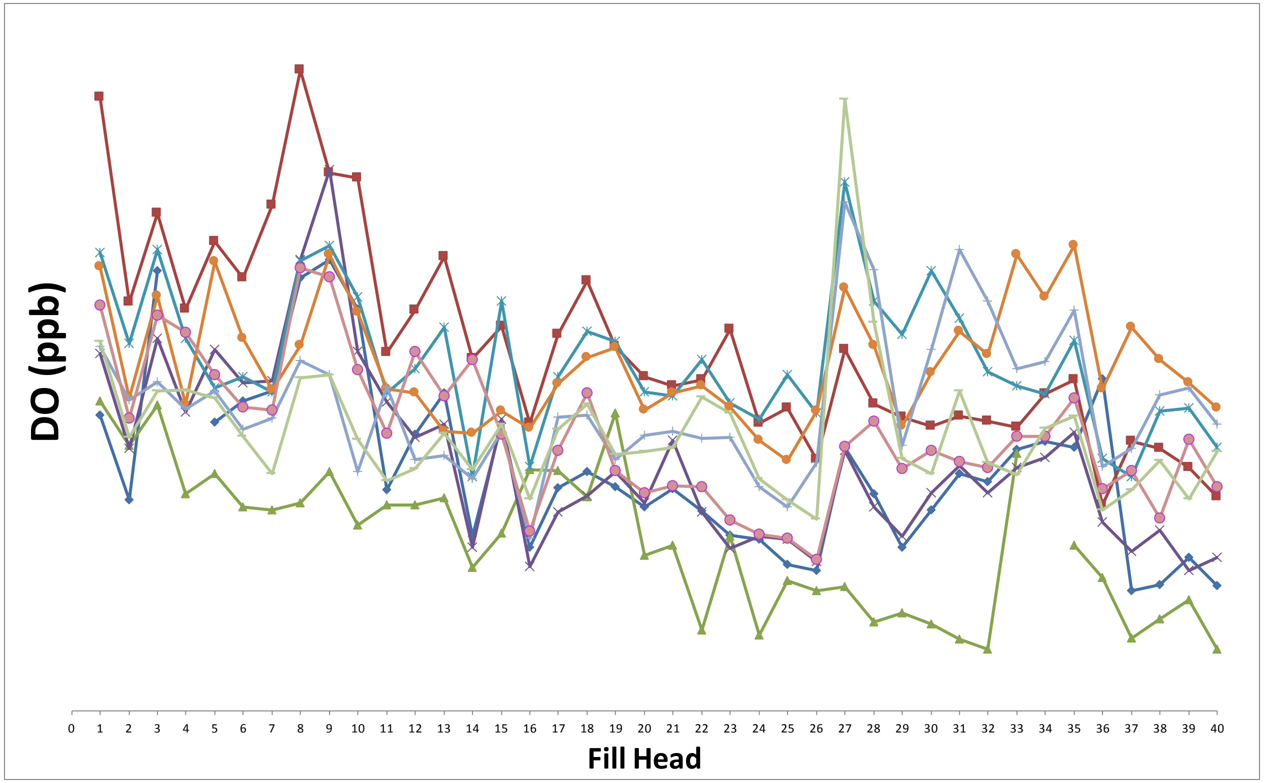
Portable DO meters coupled with some sort of piercer

- Inline DO matters

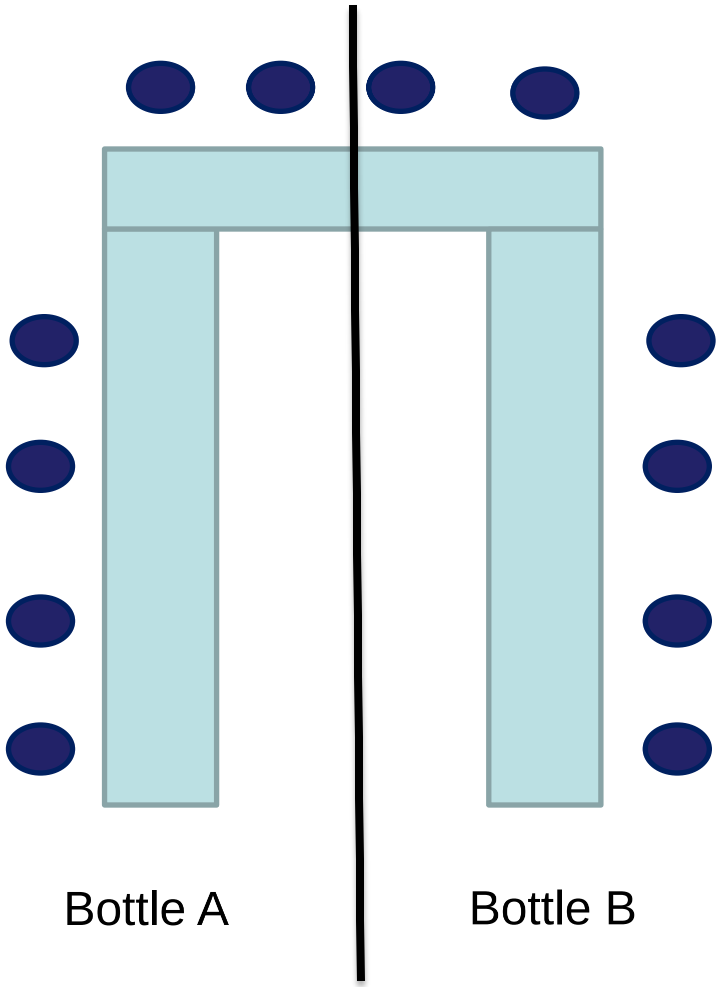


Portable DO meters coupled with some sort of piercer

- First look into valve to valve variation

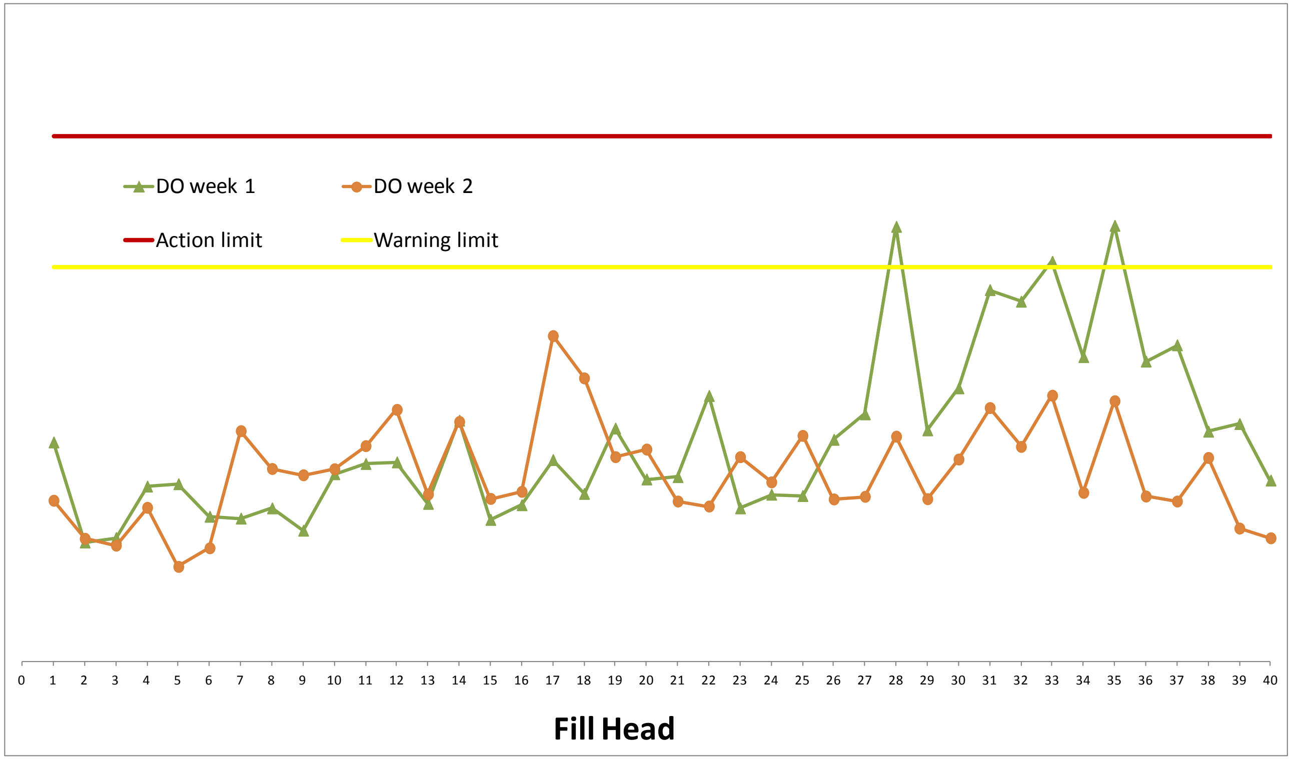


Bottle to bottle variation story



Portable DO meters coupled with some sort of piercer

- Maintenance can make fill valves perform better

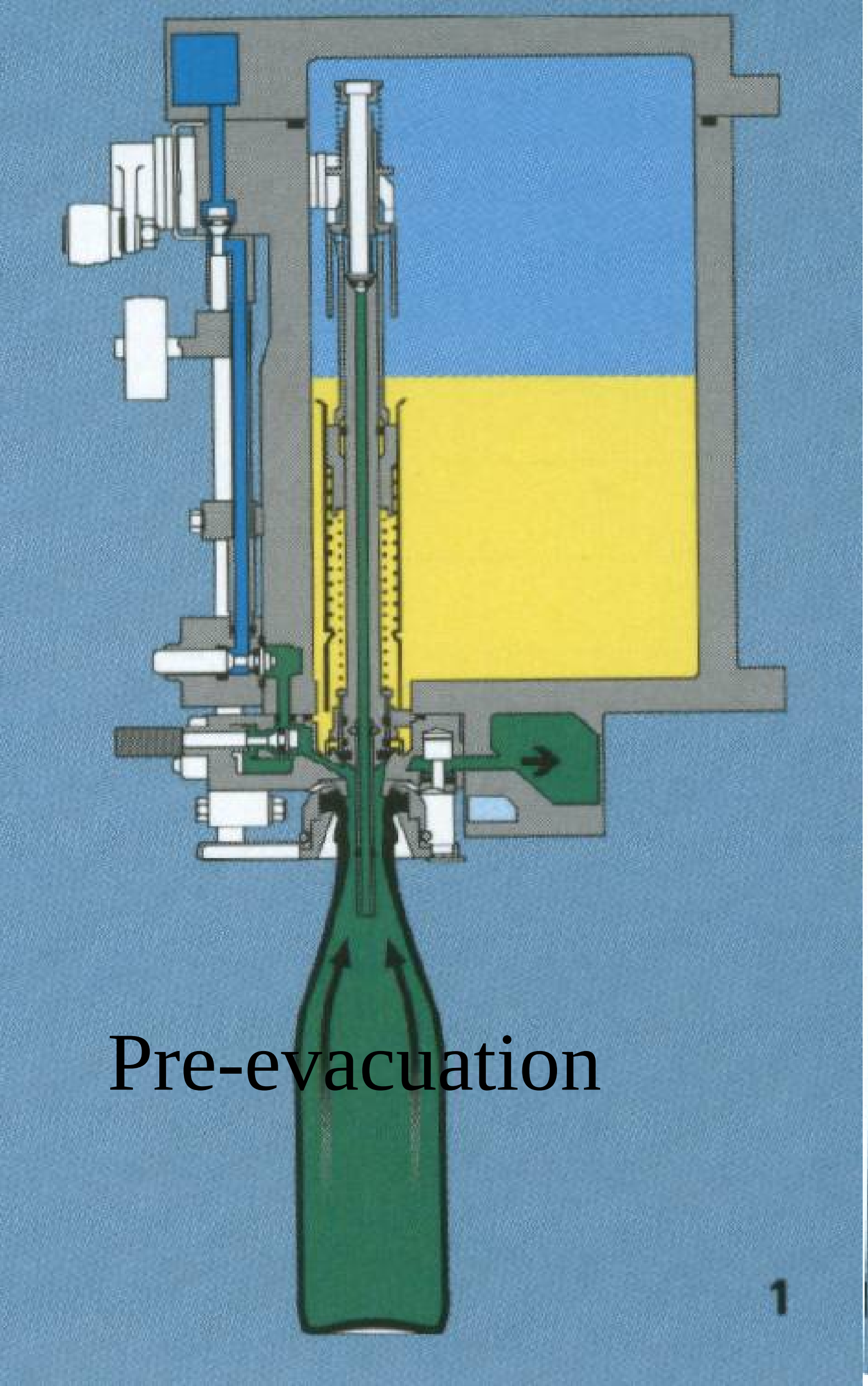


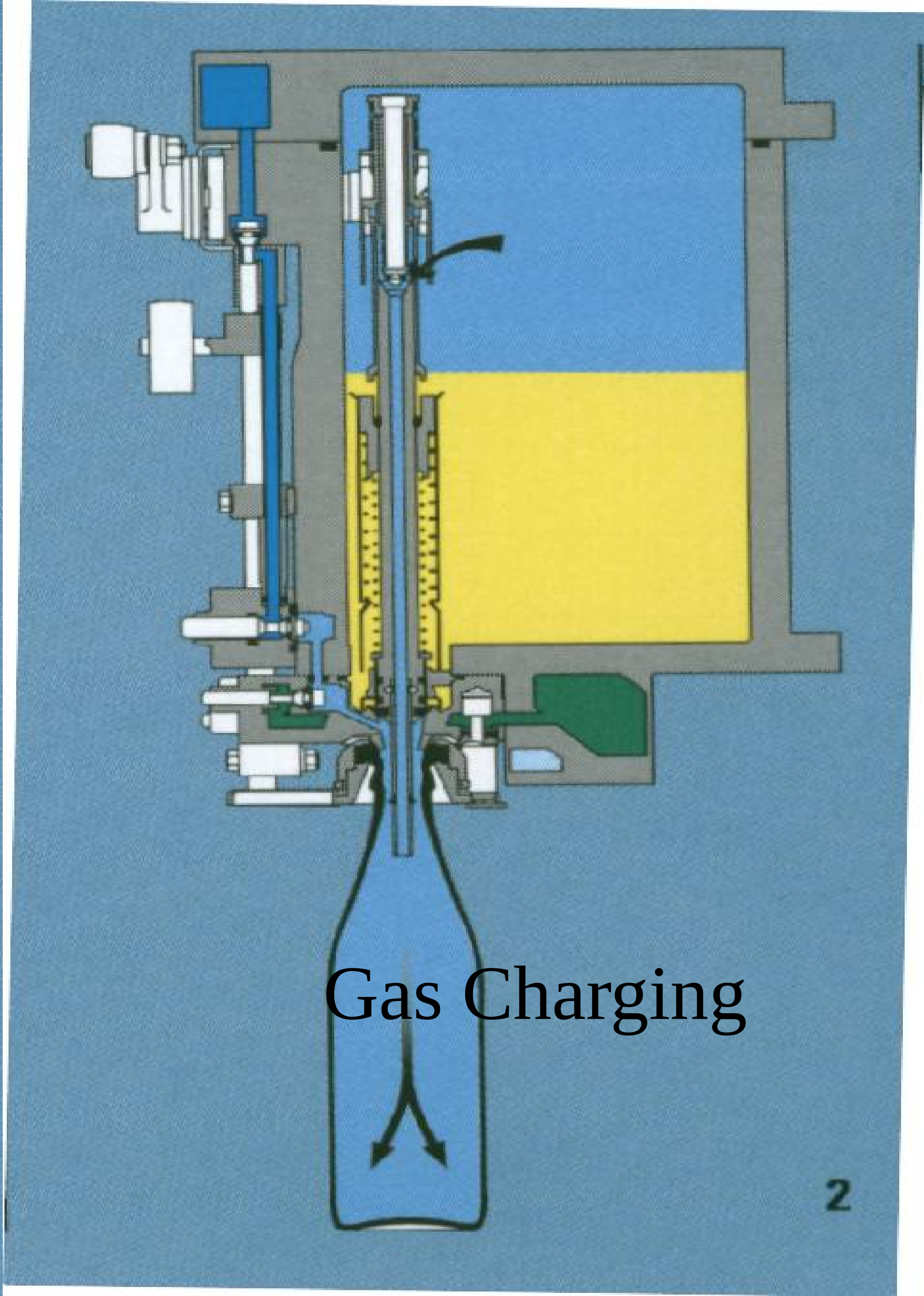
Portable DO meters coupled with some sort of piercer

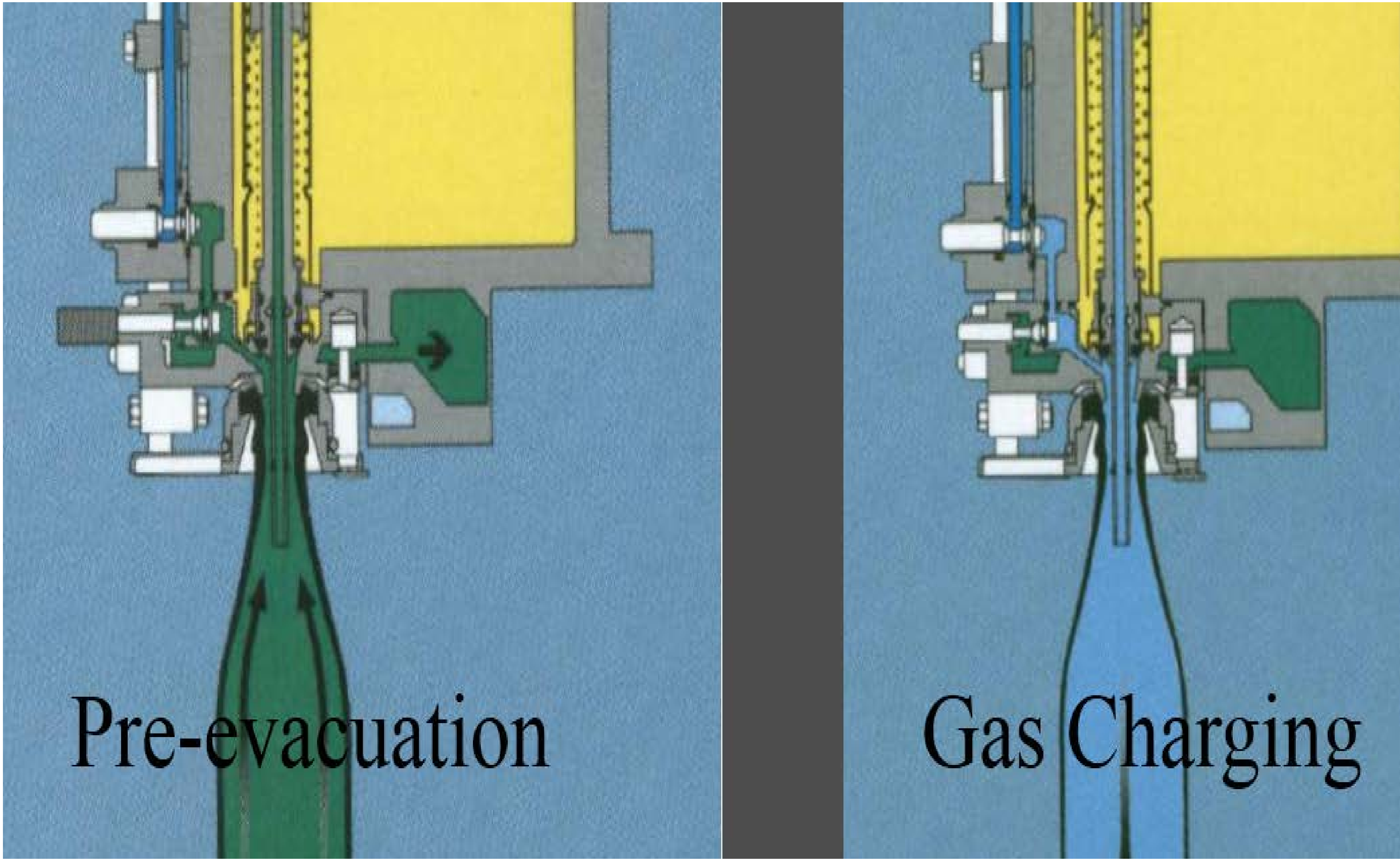
- If running 40 samples in a row, temperature matters, this may be yeast specific

Portable DO meters coupled with some sort of piercer

- Worn down CAM in filler
  - $75 to replace


Pre-evacuation
1

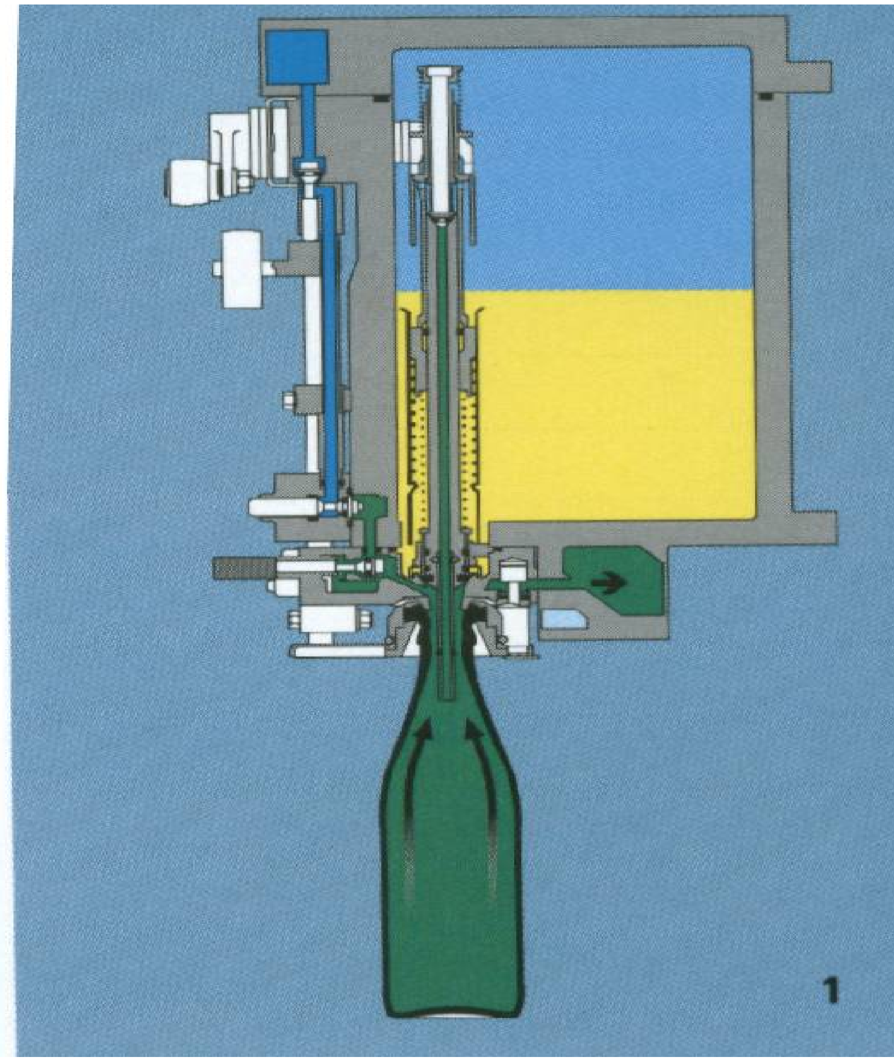

Gas Charging
2


Pre-evacuation
Gas Charging


New CAM
Old CAM

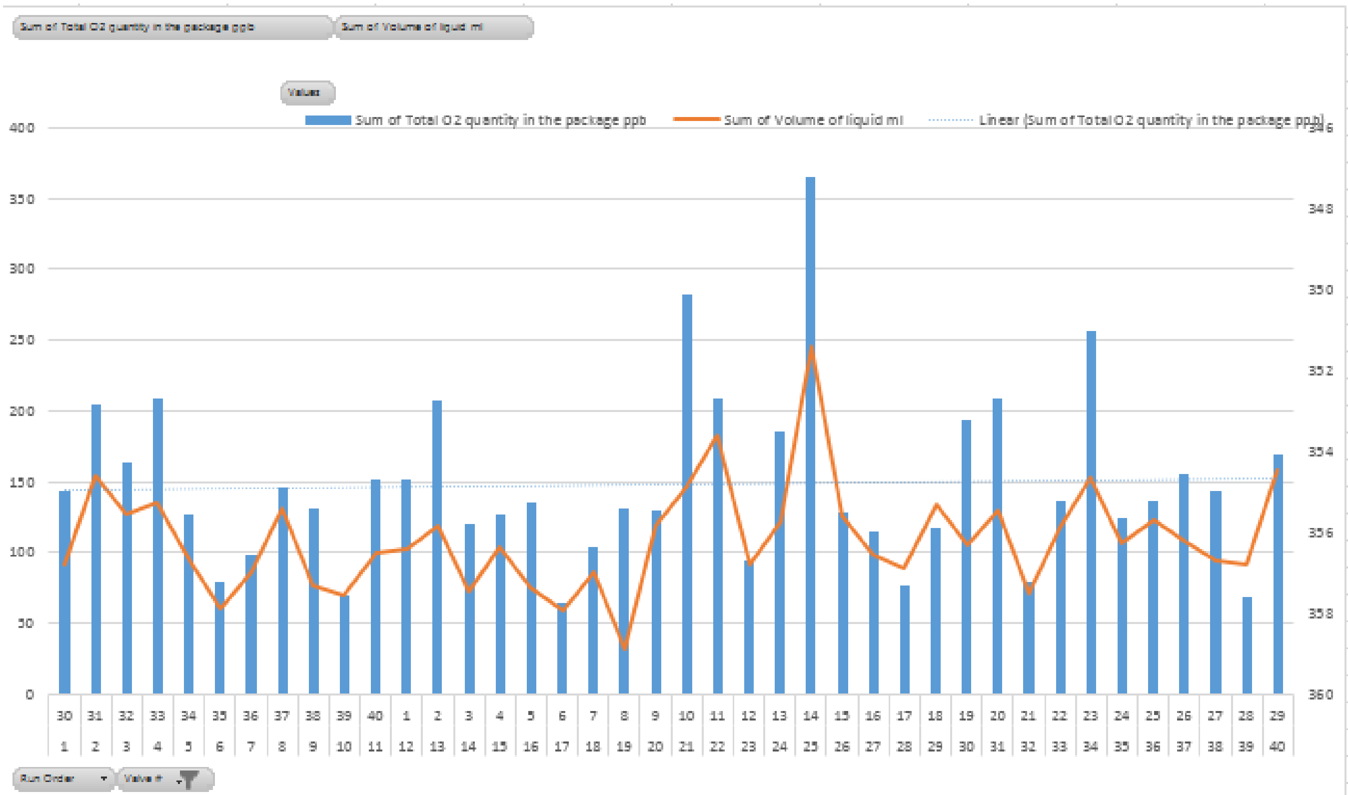
Portable DO meters coupled with some sort of piercer

- In trying to further reduce DO we created valve problems



Total Package Analyzer

- Fill volume correlation with TPO



Total Package Analyzer

- Shaking decreases TPO measurements significantly, because of robust yeast
- Low pressure in packages

Instruments we used

- Zahm and Nagel Series 5000 New Style Air Tester
- Hach Orbisphere 3650
- Hach Orbisphere 3100
- Steinfurth Sampler (semiautomatic)
- Eberback Benchtop Reciprocal Shaker
- Hach 6110

Acknowledgements

- Chaz Benedict
- Dr. Luke Chadwick
- Derek Stepanski
- Kevin Sudderth
- Rebecca Newman
- Bell’s Brewery Inc.
- ASBC

Thank you!

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Questions?

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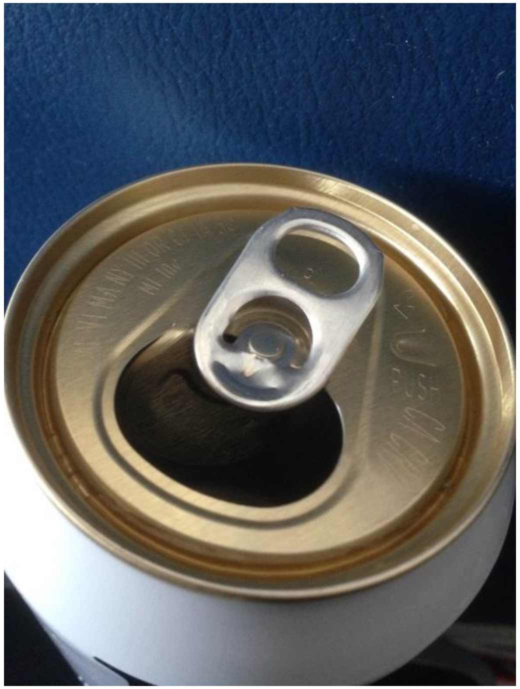
Operational Considerations Bottle Filling and Can Filling

John Engel

Operational Considerations of Bottle and Can filling...



Total Oxygen = Headspace (pO2) + Dissolved (dO2)

Operational Considerations of Bottle and Can filling...

Bottle Filling

- Crowns/Closures – O2 Ingress
- Vacuum Evacuation – need to minimize residual rinse water
- Jetting
- Crowner / Capper
- Filler Speeds (generally slower)
- Total Package Oxygen
  - Bottles more difficult to evacuate
  - Generally more dissolved O2

Can Filling

- Ends - Hermetic Seal with no O2 ingress
- Vacuum Evacuation
- Undercover gassing
- Rail Gassing
- Bubble Breakers
- Seamer and Seaming
- Filler Speeds (generally faster)
- Total Packaging Oxygen
  - More headspace O2
  - Easier to evacuate empty can
  - Harder to get gas out of headspace

TPO - Liquid & Headspace Effects

(Shaken Packages Only)

Liquid Vol. (oz.)	HS Volume (mL)	DO_2 (ppb)	HS O_2 (ppb)	TPO (ppb)
12	24	30	61	91
16	24	30	46	76
24	30	30	38	68
32	52	30	50	80
40	65	30	50	80

TPO - Cans vs. Bottles

- Cans contain more Headspace O_2:
  - It is easier to evacuate the empty can, but harder to get all of the gas out of the headspace
- Bottles contain more Dissolved O_2:
  - It is more difficult to evacuate the bottle – even with multiple pre-evacuation cycles

Note: Different package fillers and containers have different TPO characteristics...

Ideas for TPO Improvement

Develop specific criteria for every filler

Determine upper and lower control information for check diluent samples

- Use the information to check the diluent samples

Develop log books to monitor analyzer maintenance

Control chart each analyzer to determine instrument validity

Troubleshooting / Q&A

Troubleshooting Off-notes

Watch outs in the manufacturing of containers and closures are aldehydes that cause staling notes in beer include:

- Hexanol
- Octanol
- Octenal
- Nonanal

Storage of Containers is critical

- Musty (2,4,6 Trichloroanisol)
- Inky (Black Magic Marker - Bromophenol)

How to Troubleshoot TPO

1. Determine the TPO
2. Confirm that the TPO value is valid:
   - Check to see if a 2/3 to 1/3 HS:dO_2 relationship in a shaken sample is present & the CO_2 value is reasonable
3. Check the incoming beer DO to confirm spec
4. Measure the unshaken dO_2
5. TPO - unshaken dO_2 = HS O_2
6. Compare the shaken vs. unshaken dO_2
   - If the shaken dO_2 decreases compared to unshaken dO_2 – O_2 is coming from the liquid
   - If the shaken dO_2 increases compared to unshaken dO_2 – the O_2 is coming from the HS

Questions