Teaching an Old Bottling Line How Not to Suck (Air)

A CASE STUDY IN IMPROVING QUALITY PARAMETERS ON A 20 YEAR OLD BOTTLING LINE USING DO AND TPO MEASUREMENTS

Background

- Pelican Brewing began bottling in 1997
- Initial QA program for bottled beer - packaged air tests using Zahm & Nagel equipment
- Advice from outside experts for packaged air standards:
  - Initial Q/A standard of 0.7 ml of air in the headspace of 22 ounce bottles (1997)
  - This standard gradually changed over time
  - By 2012 the process average standard was halved to 0.35 ml air per headspace.

Packaging Equipment

- Tabletop Little Prince 1997-2004
- 4 head Meheen 2004-2014

Acquisition of small rotary filling line - Early nineties Prospero line

MEB Labeler

GAI 9 Head Rinser

Other pieces …

Conveyor

Infeed table

Installed in our Tillamook Brewery

CIMEC line

Filler/Crowner

Introducing dissolved oxygen testing to Pelican Brewing

- Dissolved oxygen meter - part of the capital plan for our Tillamook brewery
- During construction of our Tillamook brewery, one of the first investments was an Orbisphere 3100 dissolved oxygen meter.
- Final months of full scale operation at the Pacific City brewery, establish dissolved oxygen reference points:
  - Post fermentation
  - Post filter
  - Bright tank

What are good numbers for dissolved oxygen?

- Information about good DO specifications was difficult to find
- We had a new piece of equipment but little information about targets for DO or TPO (total packaged oxygen) that would give good flavor stability for 90-120 days
- Many of the colleagues we contacted were still using packaged air standards, even ones who owned DO meters

DO testing of packaged beer

DO vs TPO

- DO is the amount of oxygen dissolved in your beer, measured in ppb
- TPO is a calculated value which accounts for the measured DO level, and standardizes it across different package sizes.
- Relative oxygen levels for different size packages can be compared directly using TPO values

Quote from Chaz Benedict:

- "TPO is a ***normalized*** value that can be used to compare the ***relative oxygen content*** of any package size, but with the ***results expressed as a one liter package***."

Industry standards

- There appears to be a very wide range of standards and practices for measuring DO in packaged beer
- We settled on 100 ppb or lower as our target for TPO values
- 500 ppb should be achievable with just about any packaging line and represents a minimum standard

Turning DO measurements into TPO values

- Once a raw DO number is recorded, TPO can be calculated
- We use a spreadsheet provided by the manufacturer
- Inputs values include
  - Raw DO measurement
  - Fill level and corresponding headspace volume
  - Temperature

Procedures

- Pull sample from line as it exits fill head
- Note & record fill head # and fill level
  - Fill level will also determine headspace volume
- 5 minutes in mechanical shaker
- Pierce bottle and push through meter until measured DO stabilizes – about 2 minutes at Pelican
- Record DO & temperature

Wrist action shaker

TPO Calculator

	O2 in Headspace of Equilibrated Packages						
>	Temperature	*10*	°C		T	283.15	°K
>	Concentration	*0.051*	mg/l		Water vapor pressure	12.30892029	Water vapor pressure
>	Volume Liquid	370	ml		R	0.08310	Liter * bar / (K * mol)
>	Volume Headspace	20	ml			0.005125628	
						0.0001	
	temp degrees F	*53.2*			Water density	0.999701336	Water density
					Henry's Law coefficient	32945.9956	Henry's Law coefficient
	O2 absoulte					53.8963683	
	O2 in liquid	0.019	mg		Partial Pressure O2	0.0010	bar
	O2 in Headspace	0.026	mg		n	8.084E-07	mol
	Total O2	0.045	mg		M	32	g/mol
					m	0.0259	mg O2 in Headspace
	O2 relative						
	O2 in liquid	0.051	mg/l				
	O2 in Headspace	0.070	mg/l				
	Total O2	0.121	mg/l				

Four Variables

- Concentration: DO measurement
- Temperature in Celsius (a Fahrenheit conversion is easy to add)
- Volume of liquid in ml
- Volume of headspace in ml

Getting Started – Our experience

- First runs on our rebuilt CIMEC line showed good packaged air measurements but dreadful DO and TPO numbers
  - Good cap on foam but allowing a lot of DO into the beer in other places
  - Packaged air of 0.25-0.35 ml
- DO out of range: greater than 2000 ppb
- Ran both packaged air and DO/TPO in parallel – very little correlation
- DO/TPO is a much more sensitive test

Gradual Improvement

- Took a month to meet our minimum threshold of 500 ppb TPO.
- For our 12 oz bottle and typical fill levels, this equated to a raw DO of about 200 ppb
- 3-4 months later, average performance was about half that
  - Raw DO measurements of around 100
  - TPO between 200-250 ppb

Current Standards - CIMEC

- Normal values are 45-60 ppb raw DO
  - anything above 65-70 ppb is cause for concern and troubleshooting/retesting.
- With typical fill levels and temperatures, this equates to TPO of 107-142 ppb
- Pretty close to our long term goal: at or below 100 ppb
  - a vast improvement from where we began
- Our threshold for troubleshooting of 65-70 ppb roughly corresponds with TPO values of 155-170

Shelf life

- TPO vs storage conditions
  - Anything over 150 ppb noticeable on a hoppy beer within 3 weeks of warm storage (65-70 F)
  - Anything over 200 ppb noticeable on our Kiwanda Cream Ale after 3 weeks warm storage
  - Storage times under refrigeration extend to 4 months before in house triangle testing determines a statistical difference

Practical measures to limit DO pick-up on your packaging line

- Simple and obvious:
  - Triclover gaskets – don't use the damaged ones
  - Don't use clamps that bottom out
  - Don't use hoses with loose ends
  - Don't use hoses with damaged liners
  - Make sure the vacuum pump works properly!
  - Extend length of vacuum cycle to get a more complete purge
  - Be sure to cap on tight foam!
  - Pump seals and/or diaphragms in good shape

Double Pre-Evacuation

- Many of the older machines can be converted from single to double pre-evacuation
- On a simple machine with cam stops for filler valve settings, additional stops can be added for a second pre-evacuation
- We used trial and error to position these setpoints and their timing

Locally made UHMW cam stops, turning single pre-evac into double pre-evac

Phase two DO limiting

- Button valves are a frequent source of DO pickup on older bottling lines
  - Double O-ring construction originally
  - Our practice is to add a third O-ring on the outboard seal groove to maintain seal within the taper as the button valve is depressed
  - Weekly maintenance item
  - Vacuum, leveler and snift button valves all get triple o-rings

Button valves – double up the o-rings

Phase 2 continued

- Main filling valve
  - Pull valves every 100,000 bottles and inspect/replace all seals/o-rings (for us, every 3 weeks at current pace)
  - Shut-off seal (umbrella seal) needs to be exactly to specification
    - Will swell and expand over time and cleaning cycles
    - Results in slower beer flow and inconsistent filling due to variable diameters
  - Next seal in the valve is the one which counter-pressurizes the bottle itself
    - Susceptible to denting, creasing, etc which allows leakage of CO_2 and inconsistent fills and foam performance

Counter-pressure and leveler seals

Filler Valve

- Original design used a single o-ring
- Retrofitted with additional internal o-rings behind each bushing
  - Gives the valve 3 seal points instead of one
  - Needs tear-down/inspection every 6 months
  - Ensure replacement before oxygen or cleanability issues develop
  - Single o-ring setup required quarterly teardowns with reduced DO performance and cleanability overall

Front sleeve of filler valve

Back sleeve of filler valve

Phase three DO control

- Tower seals replaced every 6 months or 800,000 bottles
  - Primary purpose is to isolate the following line sets:
    - Beer supply to filling bowl
    - CO_2 supply to bowl headspace
    - CO_2 supply to leveler function
    - Keep vacuum away from everything else
  - These are large rotating seals, crucial to overall operation of the machine and the DO of your packaged beer

Phase three, cont.

- Lift cylinders
  - Grease before every run
  - We've altered the design of the lift cylinder on our machine
    - Machines from this era often changed lift cylinder design on a monthly or even weekly basis in ongoing attempts to build reliable machines
    - On an older machine such as ours, lift cylinders are frequently not available or have already been retrofitted
      - You are kind of on your own to get this component working well
      - Utilize your local machine shop! Become friends.
      - Find a Harley dealer. Stainless exhaust pipe for a Harley fits our lift cylinders perfectly

Lift cylinders continued

- Our machine tends to develop wear points that score the lift cylinders
  - Loss of compressed air and excessive air consumption
  - Irregular, uneven lifting
  - Inconsistent pressure on neck seals
  - Excessive wear on neck seals due to greater and uneven pressure
  - All resulting in intermittent and uneven DO pickup across the fill valves – not predictable

Operating parameters

- Common advice for operating fillers of this design and vintage is a bowl headspace pressure of 25-35 psi and run speed of 25 bpm
- Our experience is that we get much better results at 18 psi
  - We can't quite explain why this is the case, but 12 months of operating results has shown it to be true for our machine
  - We run at about 31-32 bottles per minute with 8 fill heads
  - Not too bad for an old machine …

Operating parameters, cont.

- CO_2 purge/sparge before bottle enters fill valve for filling cycle
  - Even after 2 vacuums, there is slight residual atmosphere remaining in the bottle which eventually ends up in the headspace of the filler bowl
  - Pre-sparging with CO_2 helps with this
  - Reduces the accumulated oxygen content in the bowl headspace

Operating parameters

- Vent bowl headspace through separate valve on top of bowl
- Continuously flush bowl headspace with new CO_2 to keep oxygen level low
- Maintain continuous pressure levels
  - Downside it costs extra CO_2 but offset by dramatically improved packaged beer quality over duration of packaging run
  - Without doing this we see raw DO levels increase by 100 ppb over the course of a 5 hour packaging run

Conclusion

- Take care of the basic issues
  - Use good clamps, gaskets, hoses, etc
- Maintenance is key
  - Internal seals & o-rings
- Experiment with retrofitting based on operational experience
- Experiment with operating parameters: run speed, bowl pressure, bowl venting, etc
- Invest in a DO meter and use it for every packaging run
  - Results from DO testing and TPO calculations will guide maintenance intervals, efficacy of retrofits/redesign work and different operating parameters