ESG Processes at Anheuser-Busch, Inc.

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ECHE430 / CHEM448 ; Module # 11

Design & Construction of Fermented Beverages

Chemical & Biomedical Engineering Department

Case Western Reserve University

Joseph Yurko, PE   May 27, 2025

ESG Processes at Anheuser-Busch, Inc.

Presentation Summary

- Introduction
- Environmental, Social & Governance Priorities
- Brewery Process Operations List
- Brewery Process Block Flow Diagram with 8 Sustainable Processes

1. CIP Recovery from Post Rinse water to be used as Pre-Rinse water for Vessel and Line Cleaning
2. Heat Recovery from Hot Vapor Vents for heating utility water
3. Spent Grains dried and sold as animal feed
4. 7-Effect Evaporator concentration of hops BCS to generate molasses for animal feed
5. Spent Hops & Yeast to Biological Energy Recovery System (BERS) to generate methane gas
6. Distillation of Waste Beer to generate Ethanol for industrial sales
7. CO2 collection from Alpha Fermentation for re-carbonization of O’Doul’s non-alcoholic beer
8. Spent Beechwood Chips (Beta Fermentation Process) shredded for use as landscape mulch
9. Recommendations

Joseph Yurko, P.E. Introduction

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- JAY Project Management, LLC
  - •President & CEO, 2 years
  - •Private Practice Consultant; AIChE Fellow & active member of AIChE Institute for Sustainability
  - •Project Management, Project Engineering, and Process Engineering; Promoting an H2 Economy
- Novo Nordisk a/s; Xellia Pharmaceuticals USA, LLC
  - •Lead Project Engineer, 5 years; Critical & Non-Critical utilities Subject Matter Expert for Audits
  - •Manufacturing of Lyophilized Sterile Injectables of Vancomycin at two factories
  - •Bedford, Ohio; 200 employees; FDA & EMA regulated & compliant facility
- Boehringer Ingelheim GmbH; Ben Venue Laboratories, Inc.
  - •Senior Project Engineer, 12 years; Critical & Non-Critical utilities Subject Matter Expert for Audits
  - •Energy Expert, BI Global Sustainable Use of Energy, Engineering & Technology Task Force: BI Cleveland Site, Multiple factory projects on energy and water conservation
  - •Manufacturing of Lyophilized Sterile Injectables of Chemotherapy agents at four factories
  - •LEED Silver Certified USGBC Research & Development center with non-GMP pilot plant
  - •Bedford, Ohio; 1100 employees; FDA, EMA, ANVISA, PMDA & TGA regulated & compliant facility
- AECOM, URS, Washington Group International, Morrison Knudsen Corp.
  - •Staff Process Design Engineer, 22 years
  - •Engineering, Design and Construction Company; Cleveland, Ohio; 1500 employees, ISO-9001
  - •Design Engineer, Construction Check-out Engineer, and Field Commissioning Engineer
  - •Anheuser Busch, Inc.: Brewing, Fermentation and Finishing Beer Subject Matter Expert

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Environmental, Social & Governance, or Planet, People & Profit

- **<u>Environmental</u>**: Company impact on nature & energy consumption
  - Good environmental practices
  - Energy efficiency
  - Transparency
  - Eco-friendly and energy performance technologies
  - Carbon footprint metrics followed
  - Sustainable materials in supply chain
  - Habitat protection and improvement
  - Strategies to reduce risk and cost
- **<u>Social</u>**: Impact of company on stakeholders (internal & external)
  - Safety & security at work
  - Improved health and occupational health
  - Organization structure, leadership, compensation
  - Community service, involvement, and development
  - Stakeholder identification and engagement
  - Human rights, labor practices, consumer issues and protection
  - Employee benefits, hiring and retention
  - Promoting diversity, equity and inclusion
- **<u>Governance</u>**: Company approach to leadership, demographics & controls
  - Employee benefits and compensation
  - Financial viability of organization (profitability)
  - Transparency and ethics
  - Executive compensation
  - Dissemination of new technologies
  - Good business practices, including procurement & supply chain
  - Relations between economic actors
  - Supporting local economies
  - Cost effective strategies
  - Risk reduction strategies

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Anheuser-Busch, Inc. Brewery History (Joe Y. Projects 1981-2002)

1. St. Louis Brewery, SLB, Missouri: Opened 1852, JY Engineering design projects
2. Newark Brewery, NEB, New Jersey: Opened 1951, JY EPC, Start-Up, Fermentation
3. Los Angeles Brewery, LAB, California: Opened 1954, JY Engineering design projects
4. Tampa Brewery, TAB, Florida (Closed): Opened 1959, JY EPC, Start-Up, O'Doul's
5. Houston Brewery, HOB, Texas: Opened 1966, JY EPC, Start-Up, Bud Dry
6. Columbus Brewery, COB, Ohio: Opened 1968, JY EPC, Start-Up, ERP PCS-7
7. Jacksonville Brewery, JAB, Florida: Opened 1969
8. Merrimack Brewery, MEB, New Hampshire: Opened 1970
9. Williamsburg Brewery, WAB, Virginia: Opened 1972, JY Engineering design projects
10. Fairfield Brewery, FAB, California: Opened 1976, JY Engineering design projects
11. Baldwinsville Brewery, BAB, New York: Opened 1983, JY Engineering design projects
12. Fort Collins Brewery, FCB, Colorado: Opened 1988, JY EPC, Start-Up, ERP PCS-7
    * Only A-B brewery with less than 20 brews per day, 5,000 ft. elevation boiling point is 203.F
13. Cartersville Brewery, CVB, Georgia: Opened 1993, JY EPC, Start-Up, Brewery
    A-B Brewery Total Installed Cost for items 12 & 13: $300MM each in 1990 USD approximately
    A-B Production: US 90 million barrels of beer annually (1 BBL = 31 Gal.)

A-B Revenue: US $15.588 billion (2018), 19,000+ Employees
A-B Parent Company: AB InBev (Belgian-Brazilian Co.), Acquired A-B on July 13, 2008 for $52 Billion USD
A-B Website: www.anheuser-busch.com * EPC = Engineer, Procure and Construct

Brewery Process Operation List

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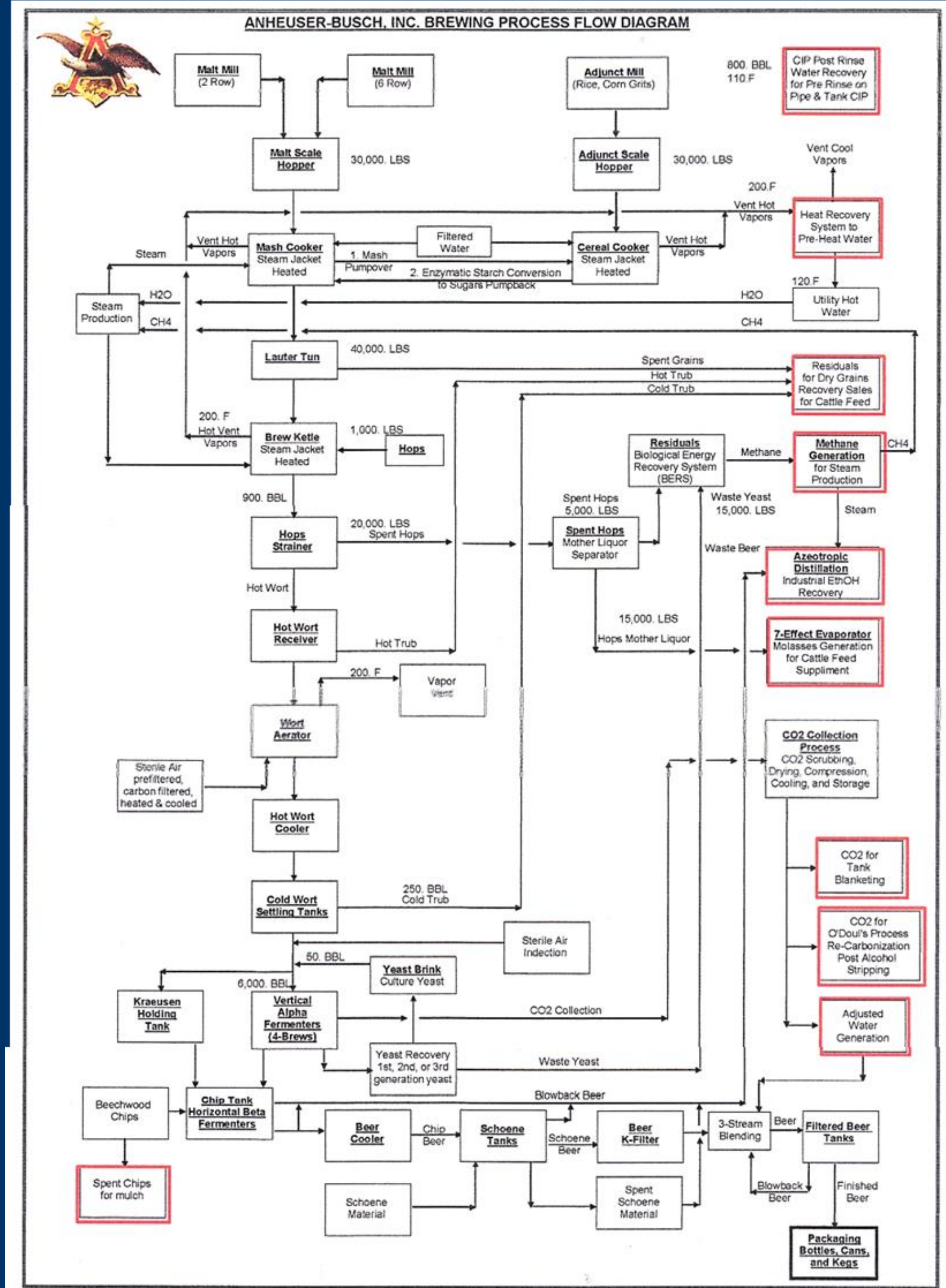
- **MALTING** Allows grain's enzyme digestive system to develop
- Barley
- Steeping
- Germination: Grain grows enzymes to covert starch to sugar for growth
- Kilning
    - **Barley Malt** (not generated at A-B Breweries)
- **BREWING WORT PRODUCTION** **Grains enzymes** convert starches to sugars
- Milling: Cereal Adjunct: Rice, highest starch content; Corn Grits grainier flavor; Corn Syrup sweeter
- Mashing: Add Water: 90% of Beer is water; Convert starches to sugars with enzymes (Amylase)
- Lautering: Add Water and strain solids
- Wort Boiling: Add Hops: Bitter flavor, Clarifying extract in resins, Preservatives
- Trub Separation: Settling and decanting from solids (coagulation of proteins, very bitter)
- Wort Cooling & Aeration: Counter current air stripping of aromatics and cooling of falling Wort
    - **Wort**
- **FERMENTATION** Converts sugars to alcohol and carbon dioxide
- Pitching: Add yeast during fermenter fill, and collect after Primary Fermentation for use again later
- Primary Fermentation: Alpha fermentation (5-7 days)
- Secondary Fermentation: Beta fermentation, Beechwood Aging Process with Krausened Beer (14 days)
    - **Beta Beer (Chip Beer)**
- **FINISHING** Clarifies beer and removes turbidity, balance flavor and density
- Chill Proofing: Schoene material settling and decanting beer
- Blending: Beer product with adjusted water and blow-back beer
- Filtration: Kieseldorf Filters (diatomaceous earth filters, bottles & cans) and sheet filters (kegs)
    - **Finished Beer**
- **PACKAGING** Beer is placed into bottles, cans, or kegs; labeling cartons and pallets for shipment
- Filling: Bottles, Cans & Kegs
- Pasteurization: Bottles & Cans
- Labels & Cartons: Bottles & Cans

Brewery Process Operation Block Flow Diagram

ESG Sustainable Processes:

(Reference # 3, pages 491-492)

1. Clean-in-Place (CIP) Post-Rinse recovered as Pre-Rinse for Vessel and Line CIP
2. Heat Recovery from Hot Vent Vapors to Pre-Heat utility water for process uses
3. Spent Grains dried for sales as animal feed
4. Biological Energy Recovery System (BERS) converts spent hops and waste yeast into methane for steam boiler combustion
5. Distillation of Waste Beer to generate ethanol for industrial use sales
6. 7-Effect evaporator conversion of Hops BCS, Brewer Condensed solubles, into molasses for sale as an animal feed nutrient supplement
7. CO2 collection from Alpha Fermentation for re-carbonization of O'Doul's non-alcoholic beer, tank blanketing, and generating Adjusted Water for 3-stream blending of Finished Beer.
8. Spent Beechwood Chips shredded for sales as landscape mulch



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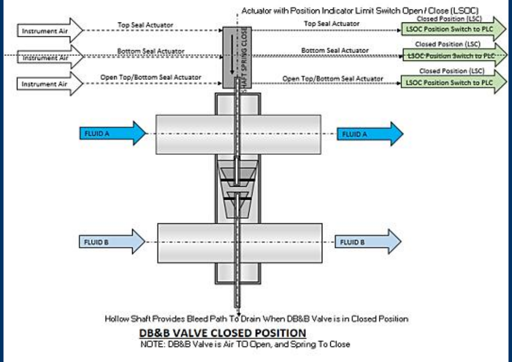
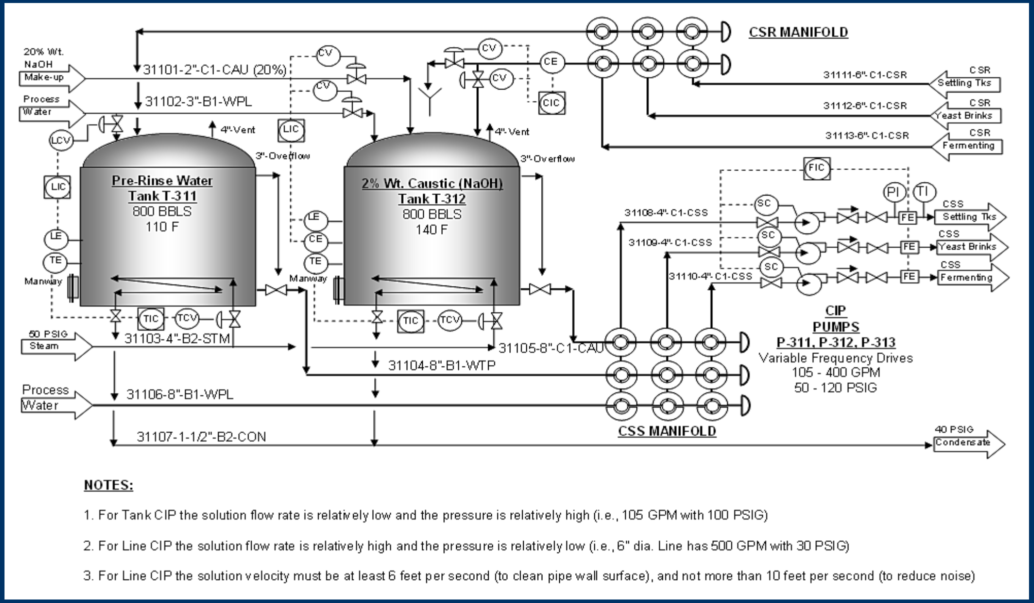
Clean-in-Place (CIP) Operations (Typical all Breweries)

(Reference # 2, Cleaning Technology, pages 1-16)

- Piping (Sch 5S, 304SS) Lines: low pressure (50 psig) & turbulent flow (6 fps min)
- Vessels (304SS): high pressure (105 psig) at 100 gpm per jet (Gama-Jet)
- First Rinse with hot water (110.F)
- Second Rinse with 2% hot caustic (140.F)
- Final Rinse with cold water (55.F)
- Recover Final Rinse for First Rinse in CIP Tank
- All CSS & CSR manifolds are with mixproof valves
    - Sanitary Double Block & Bleed (DBB) protection
    - Mixproof valves are efficient and compact





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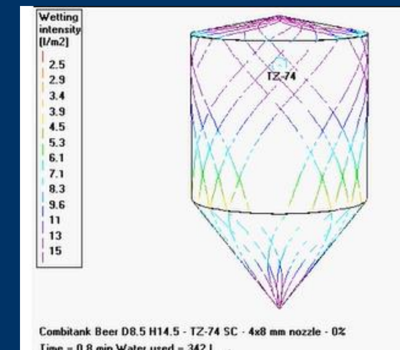
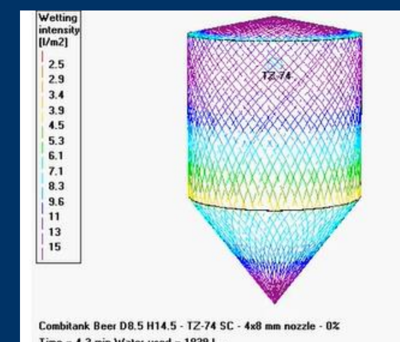
<u>Clean-in-Place (CIP) Operations</u> (Typical all Breweries)

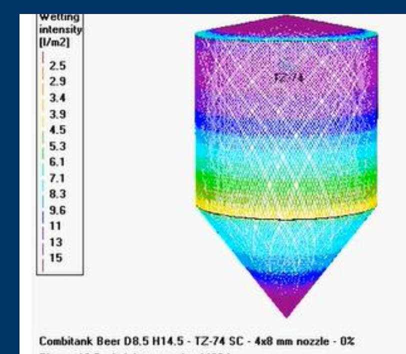
(Reference # 3, page 527)

Vessel CIP needs spray jet nozzles for Cleaning Solution Supply (CSS)

- Gama-Jet (Cloud Sellers) is primary spray jet nozzle used
- Provides 120 psi jet impingement at wall
- Full pattern needs 10-minute cycle
- Material of construction: 316SS
- Dynamic Nozzle CIP versus Static Spray Ball CIP saves 30% water during vessel cleaning
- ESG Impact
  - **Environmental:**
    - Each BBL Beer uses 50 BBL Water
    - Reclaim water saves 800 BBL H2O per CIP cycle or 80%
    - Energy savings is at 85% using water pressurized jets
    - Gama-Jet efficient water jet pattern CIP saves water volume
  - **Social**:
    - Safe efficient and reliable automation
    - People not in tanks eliminates confined space entry & fall protection
  - **Governance**:
    - Savings of Water, Chemicals & Energy
    - Automation reduces labor
    - Automation saves time
    - Increase in production potential







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<u>Columbus Brewhouse Operation Processes</u>:

- Mill Towers:
  - Two Mill Towers for North & South Brewhouse
  - Each has a Malt and Rice/Corn Grits Bin Receiver
  - Each has a Malt and Rice/Corn Grits Mill
- Mash Cooker:
  - Each Brewhouse has a Mash Cooker for a total of two
- Cereal Cooker:
  - Each Brewhouse has two Cereal Cookers, total of four
- Brewkettle:
  - Each Brewhouse has two Brewkettles for a total of four
- Hops Strainer or Lauter Tun:
  - Each Brewhouse has a Lauter Tun for a total of two
- Wort Aerator:
  - Each Brewhouse has a Wort Aerator for a total of two

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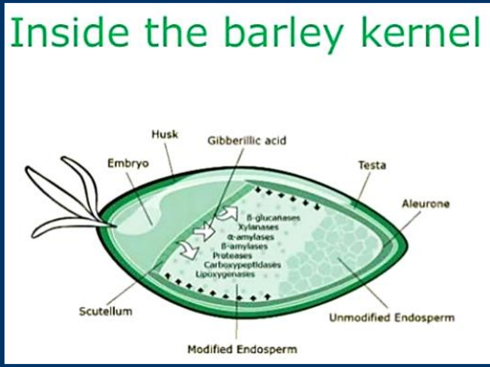
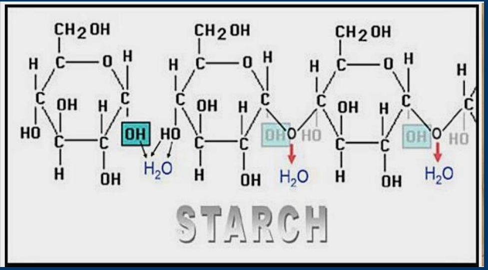
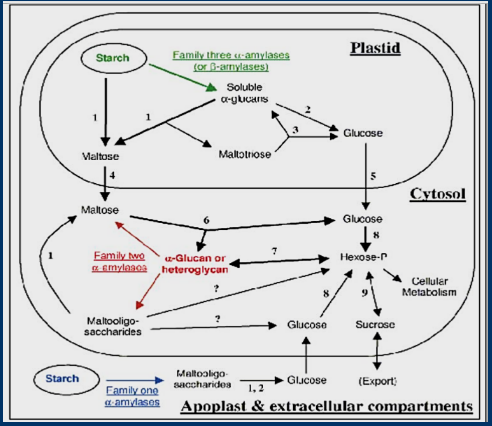
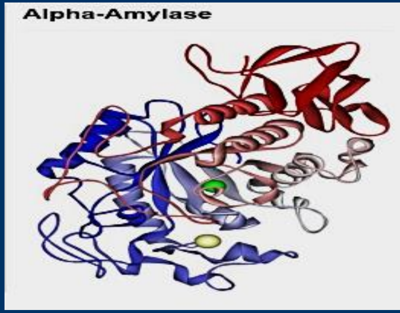
Columbus Brewhouse Operation Processes:

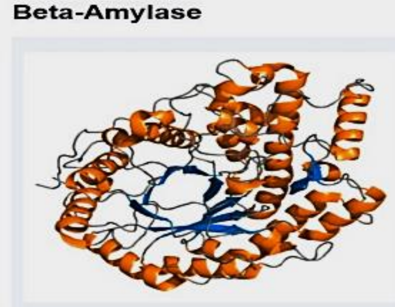
- Mill Tower: Grind grains for cookers
  - Mill barley kernels into components (like powder)
  - Recipe has **10k Lbs** barley & **15k Lbs** rice or corn grits
  - Makes a **900 BBL** brew, about $100k value at this point
- Mash & Cereal Cooker: Two Cooker Brewing
  - Activate enzymes to convert starch into sugar
- Lauter Tun: Strain husks from sweet wort for Brewkettle
  - Spent husks to animal feed & BCS to Evaporation
- Brewkettle: Heat Recovery from vent
  - Add hops to sweet wort for bitterness and preservative
- Hops Strainer:
  - Separate spent hop husks from sweet wort to BERS
- Wort Aerator:
  - Drive off undesirable aromatic flavors and cool wort











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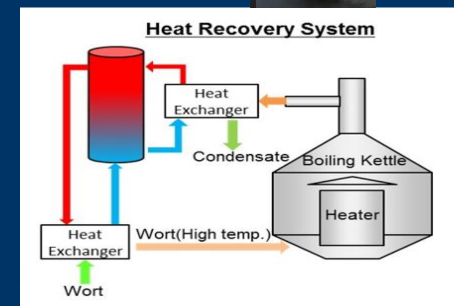
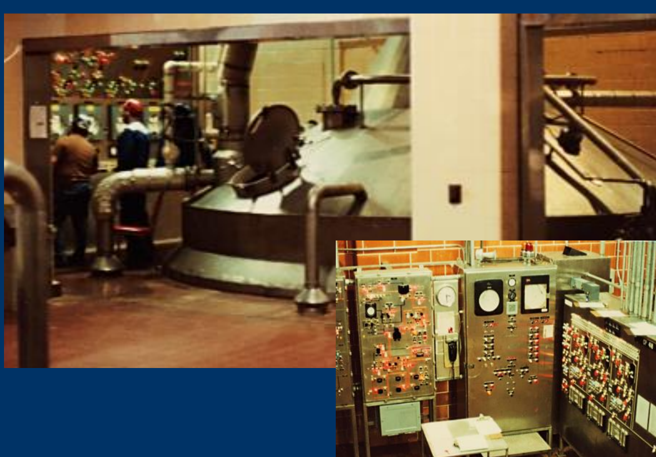
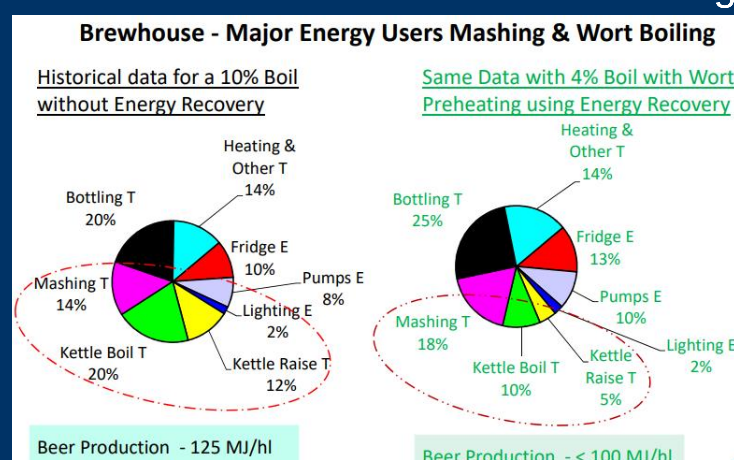


Heat Recovery from Hot Vapor Vents

Columbus Brewery Brewhouse Operation

- Heat exchange equipment located on upper floors or roof
- Hot vapors at 200.F vented from Brewkettles
- Hot vapors depart Brewhouse through vent at roof elevation
- Heat Exchangers above recover heat from vented vapors
- Cold water is heated to 110.F from vented Brewkettle vapors
- ESG Impact
    - **Environmental**: Hot water generated used as CIP Post Rinse water saving water heating, reducing fossil fuel loading
    - **Social**: Safer for operators at controls remote from hot vapor
    - **Governance**: Automation reduces labor & hot water heating





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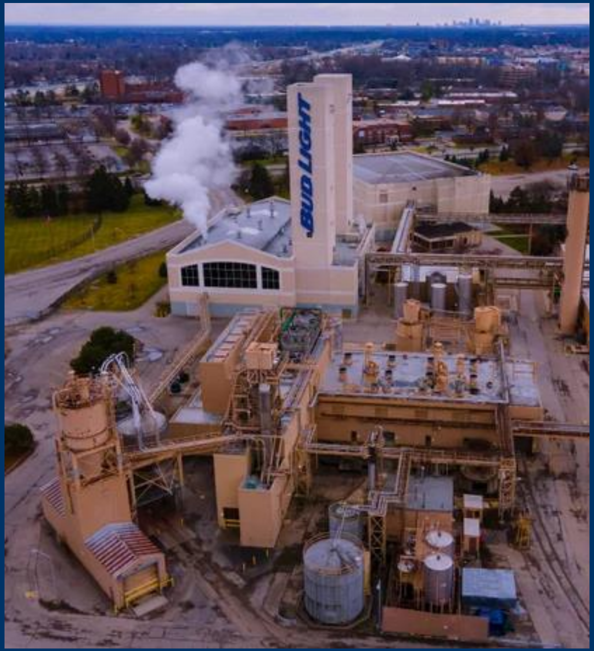
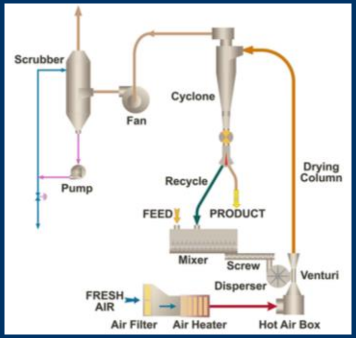
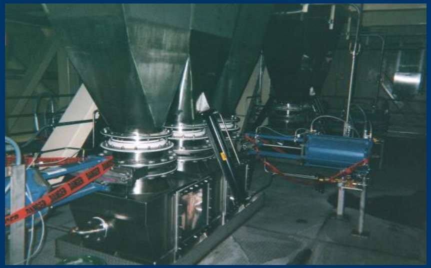
Columbus Spent Grains Dried for Animal Feed

(Reference # 4, pages 14 – 15)

- Lauter Tun grains separation from wort, a post mash cooker
- Grains collect into hopper with screw auger feed to a pneumatic transfer of grains to yard tank truck loading with a flash dryer
- Flash dryer uses a continuous air & product recirculatory system
- Yard tank drops grains into truck/enclosure for removal & sales
- ESG Impact
    - **Environmental**:
        - Waste stream has been eliminated
    - **Social**:
        - People safe with remote automated operation
    - **Governance**:
        - Automation saves time, utilities, labor, and fines
        - Adds a revenue stream with animal feed sales







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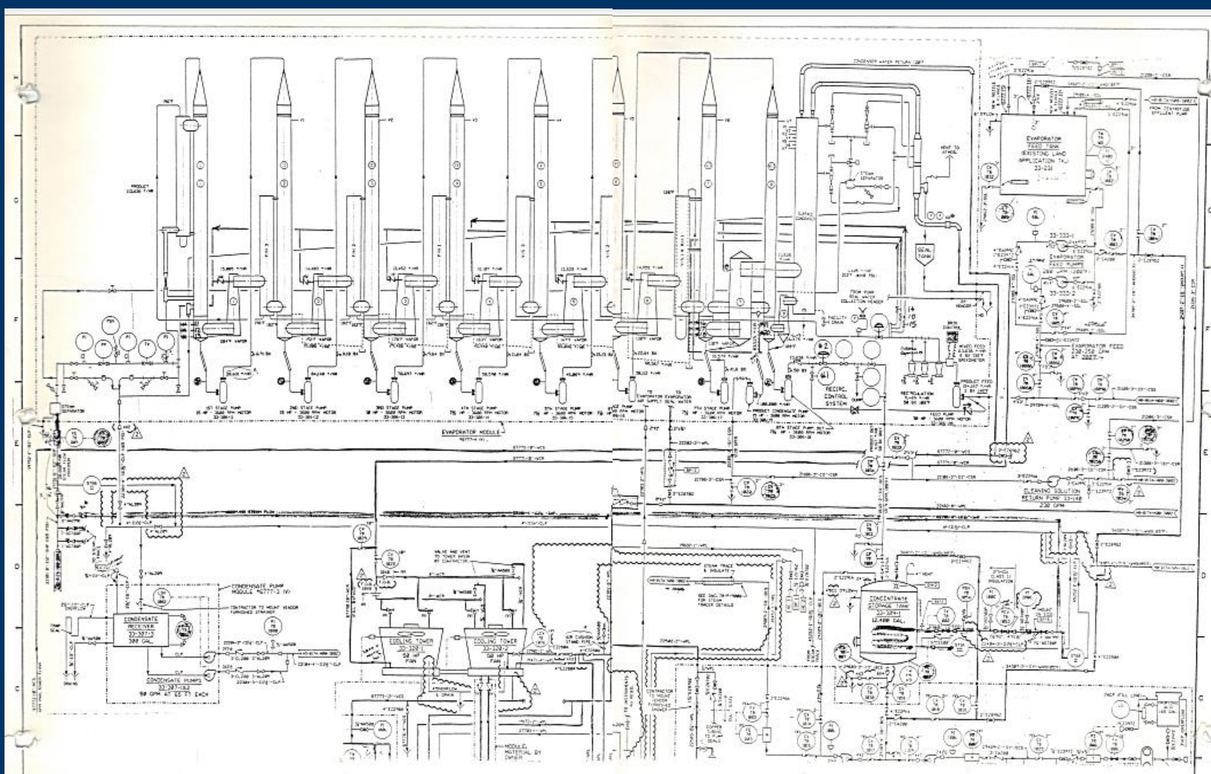
Houston 7-Effect Evaporator (JBT, T.A.S.T.E. Evaporator)

- Thermally Accelerated Short Term Evaporation
- Receives Hops Brewer Condensed Solubles (BCS)
- Removes water & concentrates BCS into Molasses
- Molasses sold as animal feed nutrient supplement



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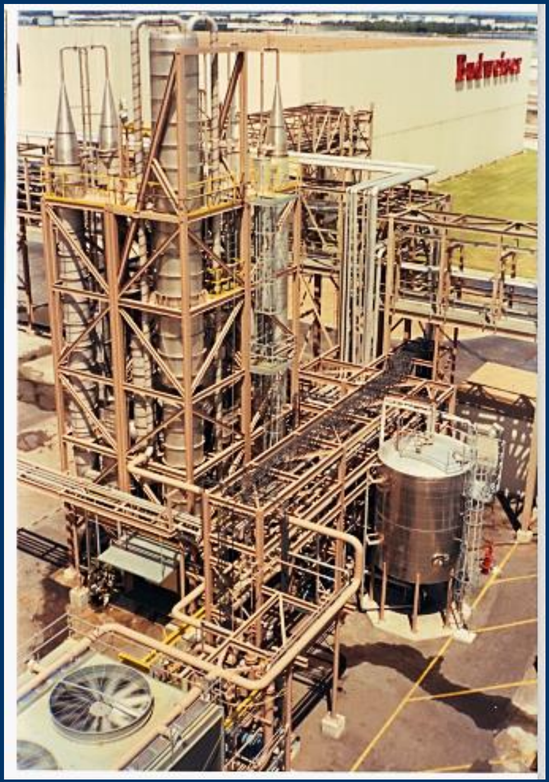
<u>Houston 7-Effect Evaporator</u> (JBT, T.A.S.T.E. Evaporator)

- BCS sent to TASTE evaporator to remove 50% of BCS daily fine
- Houston BCS Wastewater fines were about $6,000/day
- TASTE evaporator project cost is estimated at $2MM
- A-B project appropriations request was $2.2MM
- A-B engineering ROI project estimate was 12 months
- The ROI project estimate does not include the variable profits of by-product molasses sales
- ESG Impact
    - **Environmental**:
        - Waste stream removed from BOD treatment
    - **Social**:
        - People safe with remote automated operation
    - **Governance**:
        - Automation saves time, utilities, labor, and fines
        - Adds a revenue stream with molasses sales



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<u>Columbus & Cartersville Breweries</u>

Biological Energy Recovery System (BERS)

- Collects waste hops & yeast in digester tanks that converts wastes into methane gas with bacteria
- BERS Process at Columbus Brewery, Ohio
  - Bottom photo has BERS behind Brewery
  - Bottom photo has BERS in summer
- BERS Process at Cartersville Brewery, Georgia
  - Top photo has BERS in foreground & Brewery in background right corner
  - Bottom photo has BERS in background left corner & Brewery in foreground

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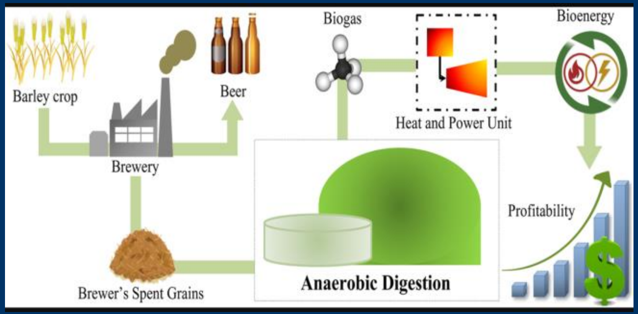
BERS Process Flow Diagram



Biological Energy Recovery System (BERS)

- Anaerobic Digestion of spent hop husks on site
- Produces methane biogas for combustion locally
- Combustion in boilers generates plant steam at brewery
- ESG Impact
    - **Environmental**:
        - Waste stream removed from Biological Oxygen Demand (BOD) treatment
    - **Social**:
        - People safe automated operation remotely
    - **Governance**:
        - Automation saves time, utilities, and labor

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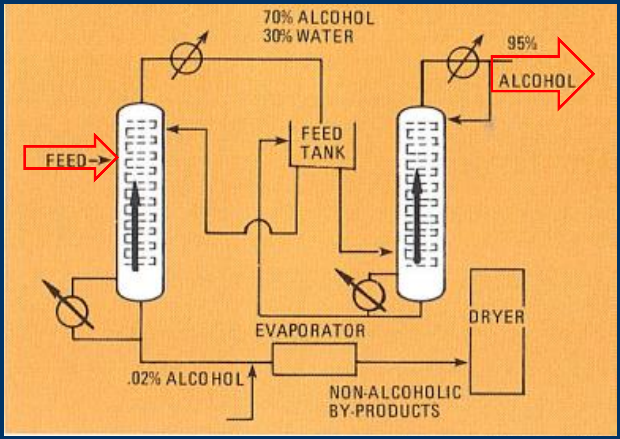
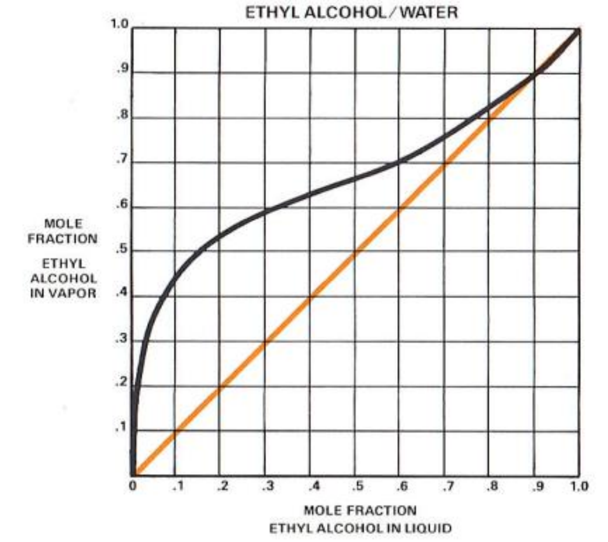
<u>Distillation of Waste Beer</u> (APV 2-Column Unit)

(Reference # 6, pages 32 – 37)

1. Brewery effluents contain ethyl alcohol in waste beer
2. Ethyl alcohol amounts from 2-4% v/v in plant effluent
3. Distillation of ethanol in waste beer effluent
4. Steam heated reboiler & Glycol chilled condenser
5. Feed contains water, ethanol, sludge and yeast
6. Reboiler bubbles more volatile ethanol up columns
7. Water, sludge and yeast drop down the column
8. Each SS sieve tray up the column enriches ethanol
9. The first column ethanol concentration is 70%
10. The second column ethanol concentration is 95%
11. Ethanol product flows are about 50 U.S. GPM
12. Still bottoms contain less than 0.02%v/v ethanol
13. Azeotrope at 95% ethanol in rectifying column top
14. Use the 95% ethanol concentration for sales
15. This 95% ethanol is suitable for an industrial solvent
16. Capitol equipment costs are about $500k USD (304SS)
17. Total installed costs are about $1MM USD
18. Operating costs are steam and weekly CIP





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Columbus (L) & Houston (R) Distillation of Waste Beer

(APV 2-Column distillation Unit)

- ESG Impact
  - **Environmental**:
    - Waste stream removed from BOD treatment
  - **Social**:
    - People safe automated operation remotely
  - **Governance**:
    - Automation saves time, utilities, and labor
    - Added revenue of a waste stream converted to a by-product

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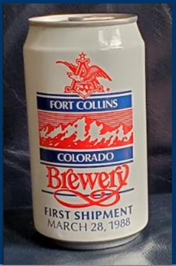

<u>Construction Site:</u>
<u>Fort Collins, Colorado</u>
<u>Subassembly Mobilization</u>

Railcar delivery of larger 304SS Fermenter domed tops and inverted cone bottoms with legs

Crane pick and set Fermenter components for site erection in place with the Clydesdale Horse Tractor Trailer returning home after a parade

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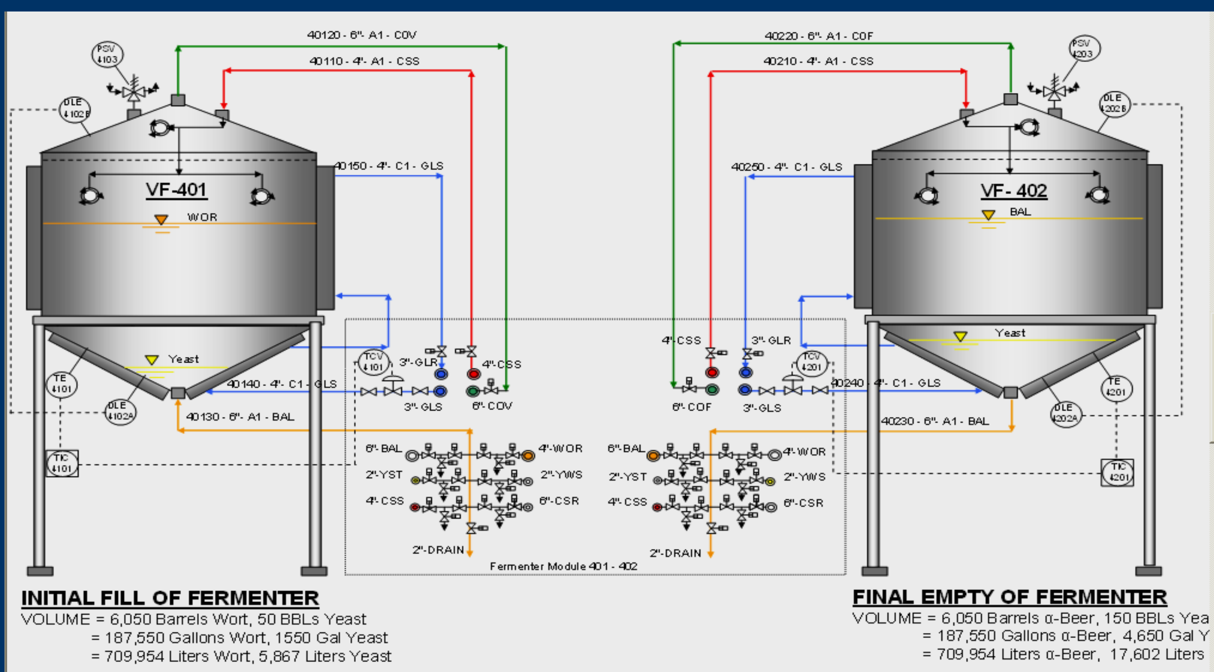
Alpha Fermentation Process

- Fermenter Equipment Model
- Process Flow Diagram
- Piping Modules
- Floor Level Inlet-Outlet Piping
- Fermenter Control Room New Design 2000s



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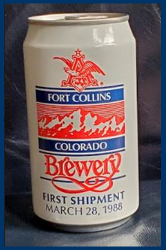
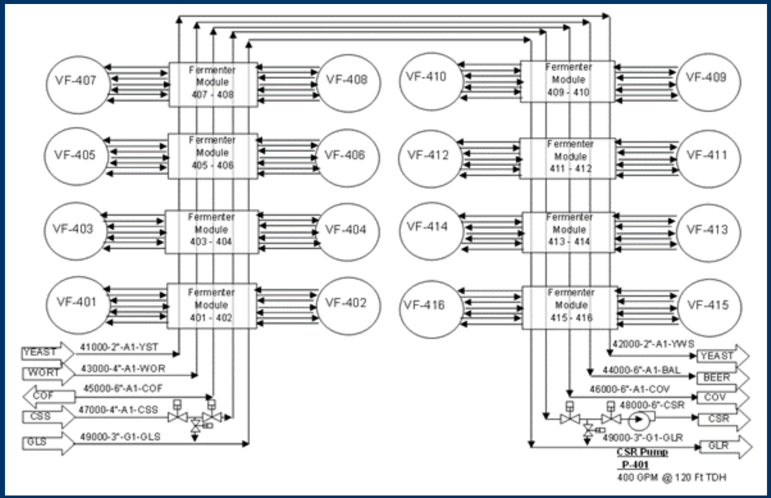


Alpha Fermentation Process

- Fort Collins Brewery Fermentation Cellar (16 fermenters @ 6,050 BBLs each)
- PSV for Pressure & Vacuum Relief (not visible on top cone)
- CSS lines (not visible on top cone)
- Manway
- 4” CO_2 Line
    - COV: Vent
    - COF: Collect
- Fermenter Top Cone
- Catwalk



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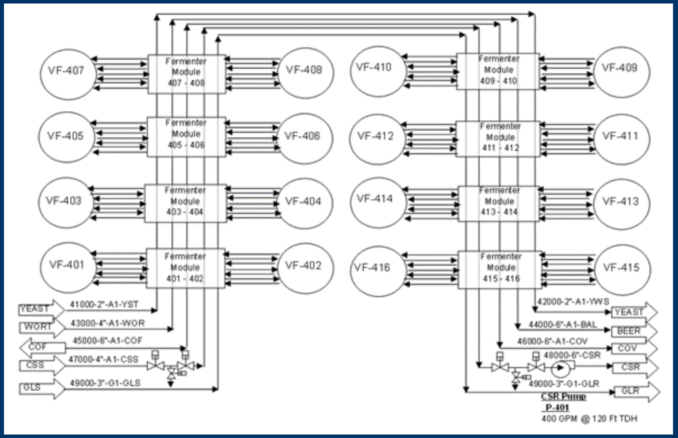
Primary Fermentation Process

Columbus Brewery Vertical fermenter (16 @ 6,050 BBL, 187,550 Gal. each)

- Top Cone, 30'dia
- Side Wall, 30'
- Cooling Jacket
- Staircase
- No mechanical agitation of batch all mixing by CO2 bubbles from yeast metabolism of glucose in Wort



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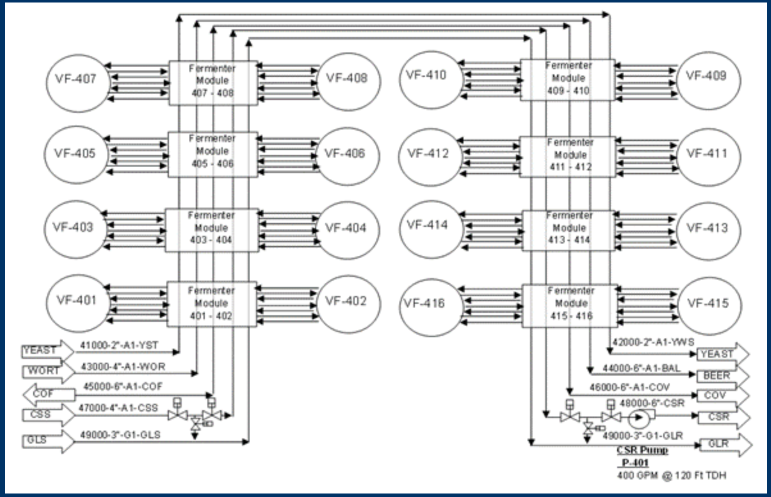
Alpha Fermentation

Columbus Brewery bottom of vertical fermenter (6,050 BBL, 187,550 Gal.)

- Bottom Cone
- Fill-Empty Nozzle
- Temperature Probe
- Fill-Empty Line 6” Piping



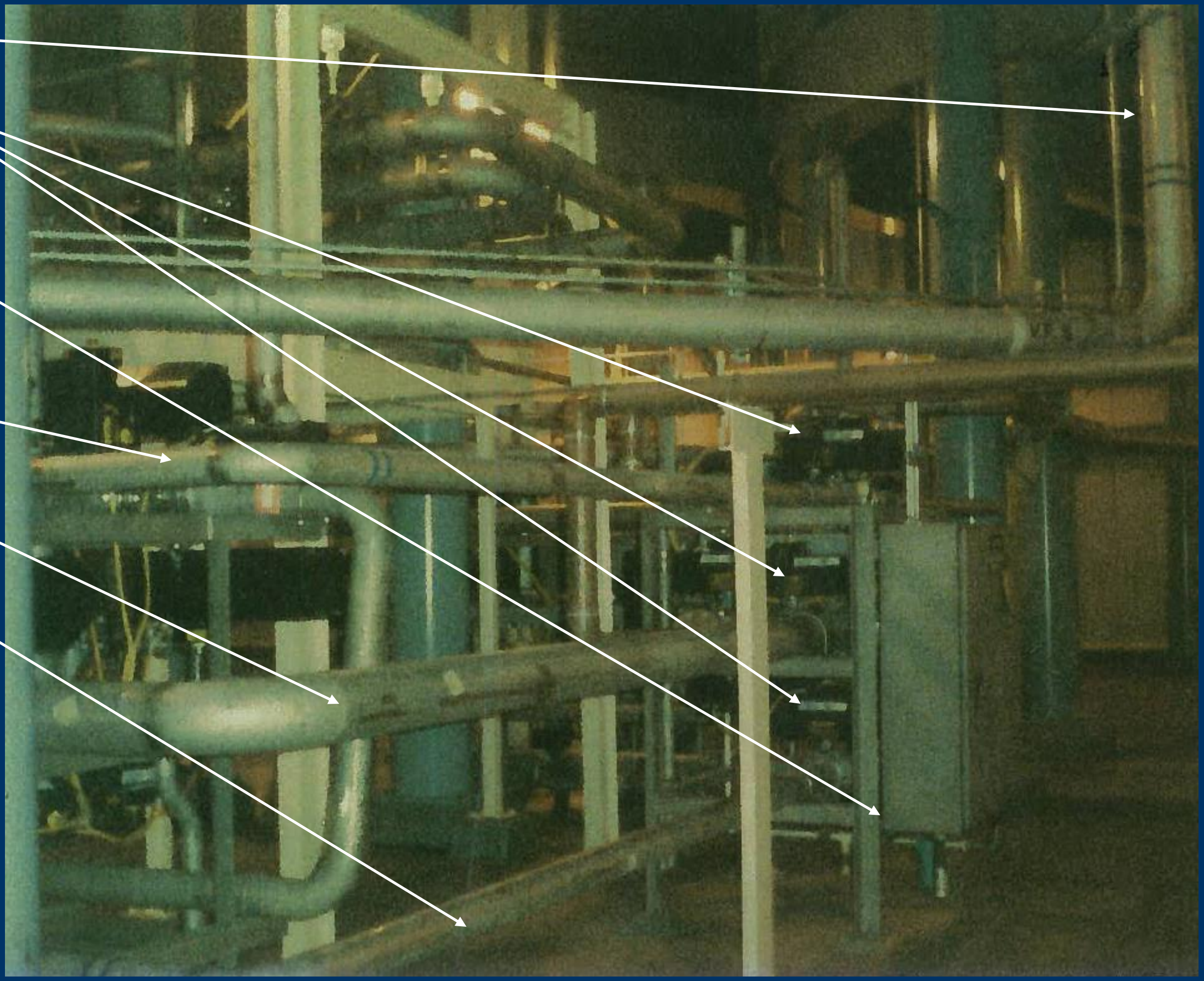
ESG Processes at Anheuser-Busch, Inc.

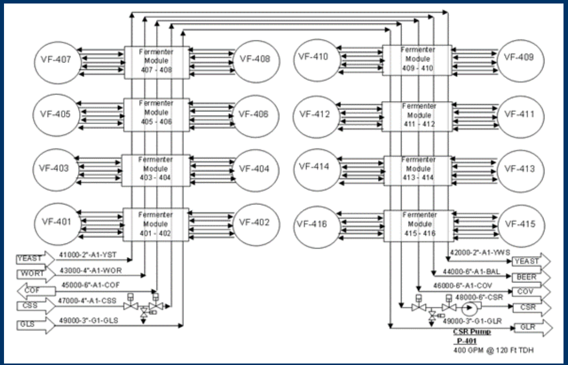
AB

Alpha Fermentation

Columbus Brewery bottom of vertical fermenter piping module

- Fill-Empty 6” Piping
- Automated Valves
  With LSOC position
- Solenoid Cabinet
- Piping Headers
  - 4” CSS
  - 4” Beer
  - 6” CSR
  - 4” CO2
    Not visible





ESG Processes at Anheuser-Busch, Inc.

AB

Columbus & Fort Collins Brewhouse and Fermentation Control Room

- Automation Upgrade
- Siemens PCS-7
  - ERP Monitoring
  - ERP Controlling
  - ERP Trending
- Historical Data
- Real Time Mods
- Electronic Signatures
- Audit Trail of Process Change Control
- SAP-ERP System
- Control Panels from 1990s and the 2000s

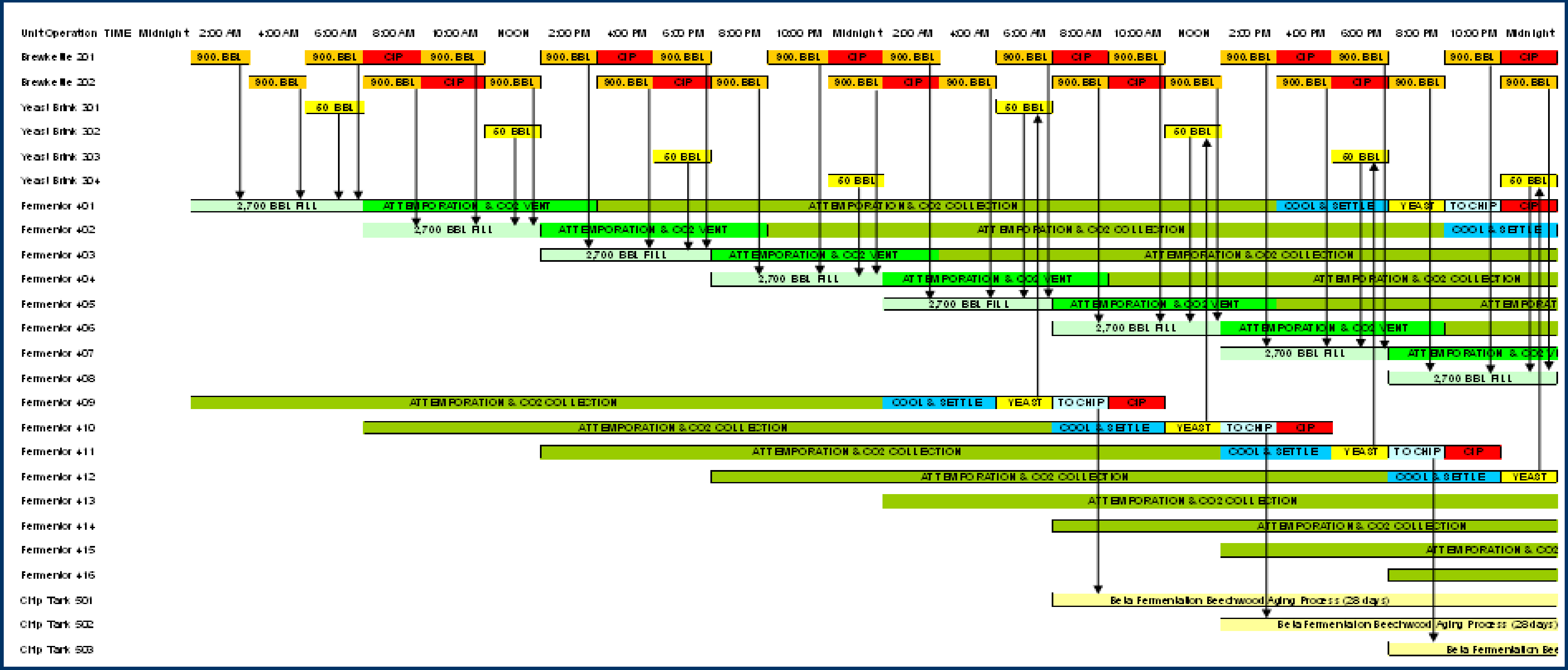
ESG Processes
at Anheuser-Busch, Inc.

AB

Brewing Operations Schedule With CIP:

Columbus Brewhouse Unit Operations Schedule, 20 Brews/day (900.BBL)

- Alpha Fermentation Operations 7 days, 16 Fermenters
- Beta Fermentation Operations 19 days, 120 Fermenters



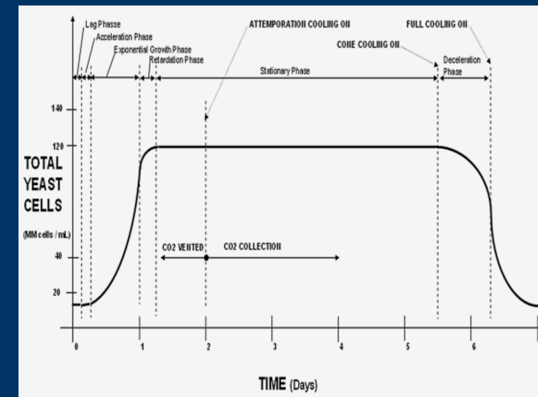
ESG Processes at Anheuser-Busch, Inc.

AB

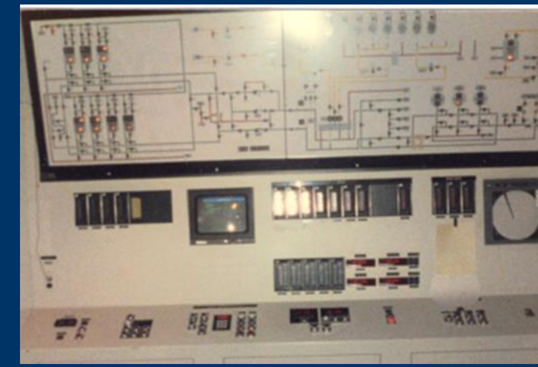
Alpha Fermentation Process

Columbus Brewery 16 Fermenter Schedule

- 7-day process of CO_2 generation
- First 2-Days Vent CO_2 (impure air mixture)
- Next 3.5 Days Collect CO_2 (most pure, 15 Ferm.)
- Old Fermentation Control Panels shown below are from the 1970-1980s

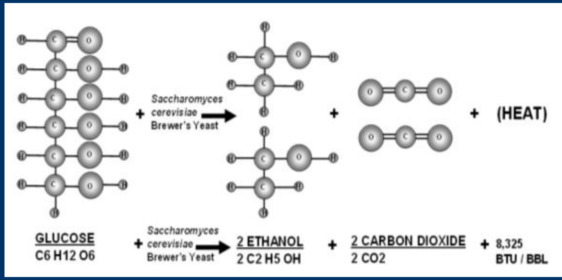


FERM	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20	Day 21	Day 22	Day 23	Day 24	Day 25
1	CIP	Fill	Ferm 1	Ferm 1	Ferm 1	Ferm 1	Ferm 1	Ferm 1	Cool	Yeast draw	Empty	CIP	Fill	Ferm 1	Ferm 1	Ferm 1	Ferm 1	Ferm 1	Ferm 1	Cool	Yeast draw	Empty	CIP	Fill	Ferm 1
2		CIP	Fill	Ferm 2	Ferm 2	Ferm 2	Ferm 2	Ferm 2	Ferm 2	Cool	Yeast draw	Empty	CIP	Fill	Ferm 2	Ferm 2	Ferm 2	Ferm 2	Ferm 2	Ferm 2	Cool	Yeast draw	Empty	CIP	Fill
3			CIP	Fill	Ferm 3	Ferm 3	Ferm 3	Ferm 3	Ferm 3	Ferm 3	Cool	Yeast draw	Empty	CIP	Fill	Ferm 3	Ferm 3	Ferm 3	Ferm 3	Ferm 3	Ferm 3	Cool	Yeast draw	Empty	CIP
4				CIP	Fill	Ferm 4	Ferm 4	Ferm 4	Ferm 4	Ferm 4	Ferm 4	Cool	Yeast draw	Empty	CIP	Fill	Ferm 4	Ferm 4	Ferm 4	Ferm 4	Ferm 4	Ferm 4	Cool	Yeast draw	Empty
5					CIP	Fill	Ferm 5	Ferm 5	Ferm 5	Ferm 5	Ferm 5	Ferm 5	Cool	Yeast draw	Empty	CIP	Fill	Ferm 5	Ferm 5	Ferm 5	Ferm 5	Ferm 5	Ferm 5	Cool	Yeast draw
6						CIP	Fill	Ferm 6	Ferm 6	Ferm 6	Ferm 6	Ferm 6	Ferm 6	Cool	Yeast draw	Empty	CIP	Fill	Ferm 6	Ferm 6	Ferm 6	Ferm 6	Ferm 6	Ferm 6	Cool
7							CIP	Fill	Ferm 7	Ferm 7	Ferm 7	Ferm 7	Ferm 7	Ferm 7	Cool	Yeast draw	Empty	CIP	Fill	Ferm 7	Ferm 7	Ferm 7	Ferm 7	Ferm 7	Ferm 7
8								CIP	Fill	Ferm 8	Ferm 8	Ferm 8	Ferm 8	Ferm 8	Ferm 8	Cool	Yeast draw	Empty	CIP	Fill	Ferm 8	Ferm 8	Ferm 8	Ferm 8	Ferm 8
9									CIP	Fill	Ferm 9	Ferm 9	Ferm 9	Ferm 9	Ferm 9	Ferm 9	Cool	Yeast draw	Empty	CIP	Fill	Ferm 9	Ferm 9	Ferm 9	Ferm 9
10										CIP	Fill	Ferm 10	Ferm 10	Ferm 10	Ferm 10	Ferm 10	Ferm 10	Cool	Yeast drain	Empty	CIP	Fill	Ferm 10	Ferm 10	Ferm 10
11											CIP	Fill	Ferm 11	Ferm 11	Ferm 11	Ferm 11	Ferm 11	Ferm 11	Cool	Yeast draw	Empty	CIP	Fill	Ferm 11	Ferm 11
12												CIP	Fill	Ferm 12	Ferm 12	Ferm 12	Ferm 12	Ferm 12	Ferm 12	Cool	Yeast draw	Empty	CIP	Fill	Ferm 12
13													CIP	Fill	Ferm 13	Ferm 13	Ferm 13	Ferm 13	Ferm 13	Ferm 13	Cool	Yeast draw	Empty	CIP	Fill
14														CIP	Fill	Ferm 14	Ferm 14	Ferm 14	Ferm 14	Ferm 14	Ferm 14	Cool	Yeast draw	Empty	CIP
15															CIP	Fill	Ferm 15	Ferm 15	Ferm 15	Ferm 15	Ferm 15	Ferm 15	Cool	Yeast draw	Empty
16	YEAST Making															CIP	Fill	Ferm 16	Ferm 16	Ferm 16	Ferm 16	Ferm 16	Ferm 16	Cool	Yeast draw
Fermenters Generating CO2															4	5	6	7	8	8	7	6	5	4	
Days of Week																	1	2	3	4	5	6	7		



ESG Processes at Anheuser-Busch, Inc.

AB



Alpha Fermentation Processes

<u>Columbus Reaction Kinetics & Material Balance</u>

(Reference # 3, Pages 480-481)

2 Lbs. Glucose + Yeast **-->** **0.511** Lbs Ethanol + **0.489** Lbs CO_2 + **0.322** BTUs + **12** Yeast

Saccharomyces cerevisiae   Saccharomyces cerevisiae

CO_2 Lbs collected per BBL of Wort Fermented = **0.4** (Lbs Extract / BBL)start – (Lbs Extract / /BBL)end, Note: 1 BBL = 31 Gallons

Use **0.4** factor and not **0.489** factor since it shows changes in specific gravity due to alcohol production and CO_2 dissolved in the Wort

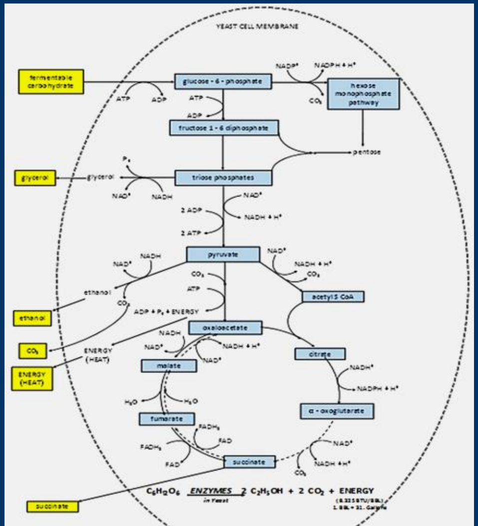
Start CO_2 Collection at Extract Balling = 13.4 ºB = 36.53 Lb Extract / BBL
End CO_2 Collection at Extract Balling = 4.4 ºB = 11.58 Lb Extract / BBL
Extract Fermented: (36.53 – 11.58) = **24.95** Lbs / BBL Total

CO_2 Produced = **0.4** (**24.95**) Lbs / BBL = **9.98** Lbs / BBL of CO_2

In 3.5 Days (or 84 Hrs): **9.98** Lbs / BBL / **84** Hrs = **0.12** Lbs / BBL / Hr of CO_2

For a single **6,050** BBL Fermenter the Maximum CO_2 Collection is from
15 Fermenters: **6,050** BBL (**0.12**) Lbs / BBL / Hr = **726** Lbs / Hr CO_2 Average

Average Maximum CO_2 Collection is: **726** Lbs / Hr CO_2 Av (**15**) Fermenters =
10,890 Lbs CO_2 / Hr Av = **1,829,520** Lbs CO_2 / Week = <u>**47,568** Tons CO_2 / Year</u>



Typical Saccharomyces cerevisiae Yeast Cell

For 12 Anheuser Busch Breweries with comparable production volumes as the above example we would have:
(**12**) Breweries (**47,568**) Tons CO_2 / Year = <u>**570,810** Tons CO_2 / Year</u>

ESG Processes at Anheuser-Busch, Inc.

AB

Columbus CO2 Collection: Alpha Fermentation PFD

(Carbon Collection and Storage, CCS)

(Reference # 3, pages 482 – 485)

1. CO2 Foam Trap: 12,000 Lb/Hr CO2 at 0.5 PSIG
2. CO2 Blowers: 12,000 Lb/Hr CO2
3. CO2 Booster Compressor: P = 3.5 – 5 PSIG
4. CO2 Scrubber Packed Columns: Removes keytones & amines
5. CO2 Carbon Filter Purifiers: Removes organic compounds
6. CO2 Compressor and Intercooler: P =250 PSIG, T =275-325 F
7. CO2 Gas Aftercooler: Removes most H2O, T = 40-45 F
8. CO2 Dryers: Removes balance of residual H2O
9. NH3 Compressor and Cooler: P = 250 PSIG
10. CO2 Gas Liquifier: Ammonia chilled, T = -8 to -10 F
11. CO2 Liquid Storage Vessel: 700,000 Lbs (81k Gal) CO2, 3-day storage
12. CO2 Liquid Evaporator: Steam heated CO2 evaporation

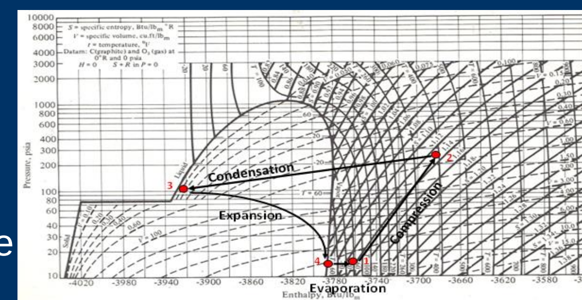
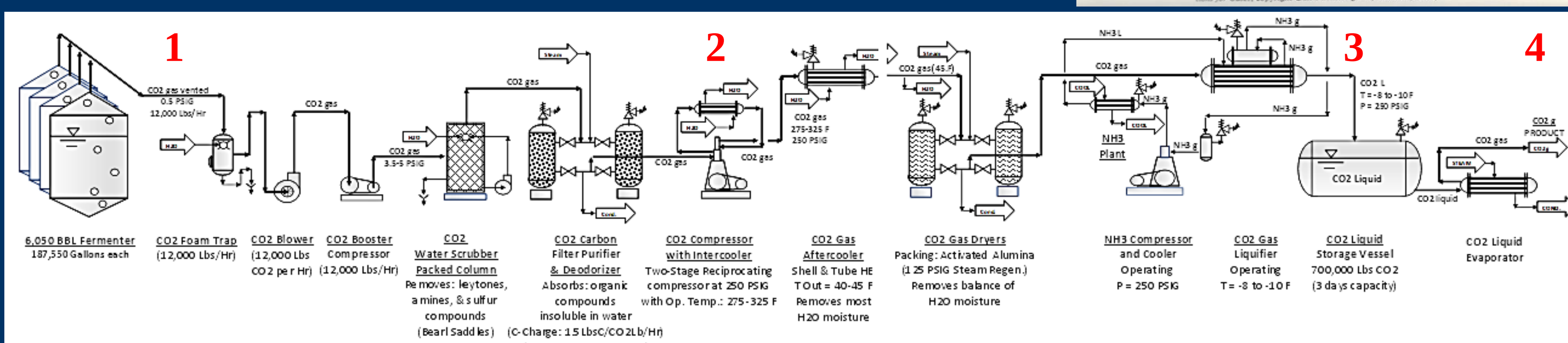


FIG. A-8. Carbon dioxide pressure-enthalpy diagram. (Reproduced by permission from L. N. Canjar and F. S. Manning, *Thermodynamic Properties and Reduced Correlations for Gases*, copyright Gulf Publishing Co., Houston, 1967.)



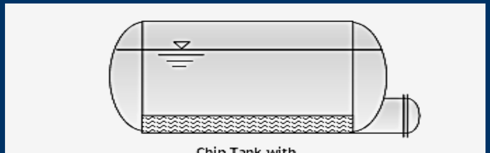
ESG Processes at Anheuser-Busch, Inc.

AB

<u>Beta Fermentation Process</u>

Cartersville Brewery Beta Fermentation Cellar, Beechwood Aging Process (120 fermenters, 40 / floor with 3 floors @ 2,500 BBLs or 77,500 Gal. each)

- Each tank has 15-17 PSIG CO_2
- Major uses of collected CO_2 is tank counterpressure, CO_2 H_2O & O'Doul's
- As tank empties, CO_2 fills to keep 15-17 PSIG of CO_2
- Manway at vessel bottom tangent for inlet-outlet chip raking
- As tank fills, CO_2 is exhausted out of the brewery
    - **Environmental**: Carbon Capture CO_2 for reuse in brewery & resale
    - **Social**: Contain CO_2, asphyxiation
    - **Governance:** Automated system



Chip Tank with Beachwood Chips providing surface area covered with yeast for Beta Fermentation

ESG Processes at Anheuser-Busch, Inc.

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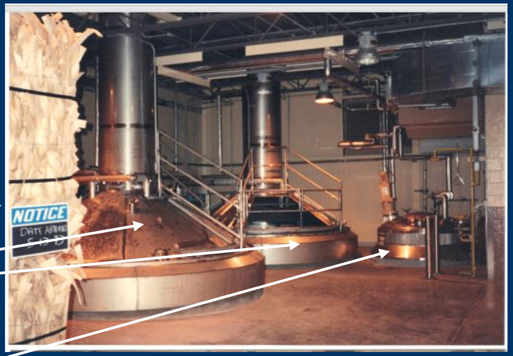
Beta Fermentation Process



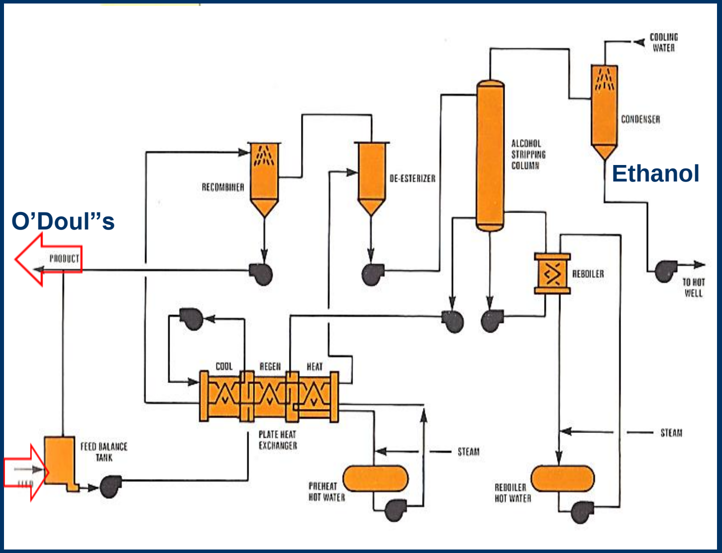
- Cartersville Brewery Beechwood Chip Preparation for Beechwood Aging Process in Beta Fermentation
- Chips provide surface area for yeast in Chip Tanks
- Beechwood Chip Bails (New)
- 2 Chip Cookers (one in use & and other in CIP)
  - Initial sterilization of new chips with steam
  - Sterilization of used and recycled chips
- Bicarbonate of Soda treatment tank (flavor removal)
- Used and recycled chips are moved inside “torpedo” carts
  - Torpedos are small horizontal cylinder carts
- Chip Strainers collects broken fragmented chips
  - Spent broken and fragmented chip collection
  - Spent chips are air dried for recycle
  - Spent chips are sold to landscaping as mulch
- ESG Impact
  - **Environmental**: Waste stream spent chips removed
  - **Social**: People replacing waste stream with revenue
  - **Governance**: Revenue source of new by-product

ESG Processes at Anheuser-Busch, Inc.

Columbus CO2 from Alpha Fermentation:

(Reference # 5, pages 38 – 39)

- Re-carbonate O'Doul's non-alcoholic beer
- Capture CO2 & Ethanol from process for use later
- PFD from Columbus Brewery O'Doul's Evaporation Process (NEW DESIGN), APV 304SS construction
    - Beer flows into preheating Plate Exchanger
    - Flow goes into a high vacuum De-Esterizer vessel where components flash to a vapor
    - Then flows into a Recombiner Vessel where the amount of esters and flavors is controlled
    - Vacuum operation enables low temperature product flavor protection
    - Flow to the top of a Stripping Column removes the alcohol for collection
    - O'Doul's exits at Column bottoms
    - O'Doul's is cooled and sprayed in the Recombining Vessel with condensed vapors
    - CO2 is added after O'Doul's is chilled to 39F
    - System also has automated CIP operation



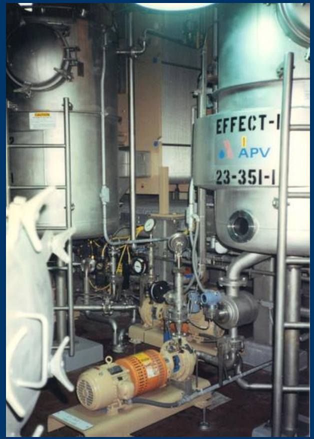
ESG Processes
at Anheuser-Busch, Inc.

<u>Columbus CO2 from Alpha Fermentation:</u>

- Re-carbonate O'Doul's non-alcoholic beer
- Photos from Columbus Brewery O'Doul's Evaporation Process (new design, APV)
    - Vacuum stripping of alcohol from beer
    - Also removes all CO2 from beer
- ESG Impact:
    - **Environmental**
        - Capture Ethanol & CO2 streams for use
        - Reuse Alpha Fermented CO2 stream
    - **Social**
        - Non-alcoholic beer yields safer driving
        - Automated process safer for operators
    - **Governance**
        - Captured CO2 stream to CO2 Collection
        - 95% Ethanol stream is 280,000 Gal at $1.5/Gal based on 15 GPM feed & 8,000 Hrs per year operation
        - Automated system saves labor & utilities





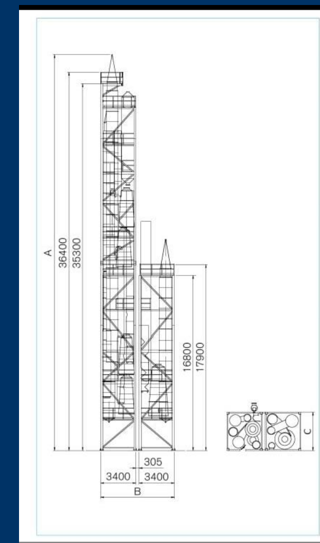



ESG Processes
at Anheuser-Busch, Inc.

<u>Tampa O'Doul's Production Process</u>:

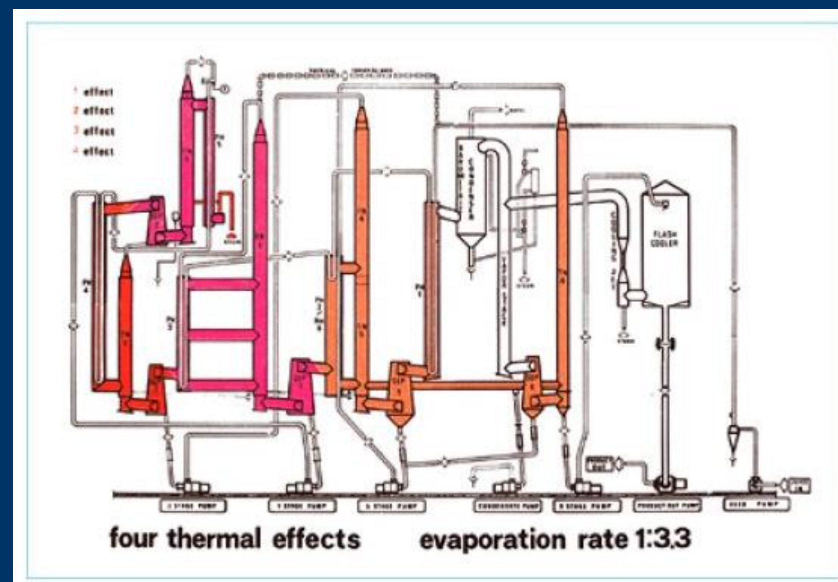
(Reference # 5, Pages 38 – 39)

- Re-carbonate O'Doul's non-alcoholic beer
- Capture CO_2 & Ethanol from process for use later
- PFD of Tampa Brewery O'Doul's Evaporation Process (OLD DESIGN) to remove alcohol & CO_2
  - Vacuum stripping of alcohol from beer
  - JBT T.A.S.T.E. 4-Effect Evaporator, 304SS
  - Up to 3.3 kg/Hr of water removed per kg/Hr of steam used
  - Minimal product degradation with short evaporator residence time of 2.5 minutes
  - Low operating costs & low capital investment
  - Automated operation & control with CIP
  - Also removes all CO_2 from beer
- CO_2 is added after O'Doul's is chilled to 39.F
- Evaporator is 304SS equipment with 5S piping
- Evaporator receives CIP after each product run



Specification approximate

A*=	Overall height	39100 mm (128.3 ft)
B*=	Overall width	7105 mm (23.3 ft)
C*=	Overall length	3700 mm (12.1 ft)



ESG Processes at Anheuser-Busch, Inc.

<u>Tampa CO2 from Alpha Fermentation</u>:

- Re-carbonate O'Doul's non-alcoholic beer
- Photos from Tampa Brewery O'Doul's Evaporation Process (OLD DESIGN)
    - JBT, T.A.S.T.E. Evaporator
    - Vacuum stripping of alcohol from beer
    - Also removes all CO2 from beer
      Initial design was to remove alcohol

•ESG Impact

- **Environmental**
    - Capture Ethanol & CO2 streams for use
    - Reuse Alpha Fermented CO2 stream
- **Social**
    - Non-alcoholic beer yields safer driving
    - Automated process safer for operators
- **Governance**
    - Captured CO2 stream to CO2 Collection
    - 95% Ethanol stream is 280,000 Gal at $1.5/Gal based on 15GPM feed & 8,000 Hrs per year operation
    - Automated system saves labor & utilities

ESG Processes at Anheuser-Busch, Inc.

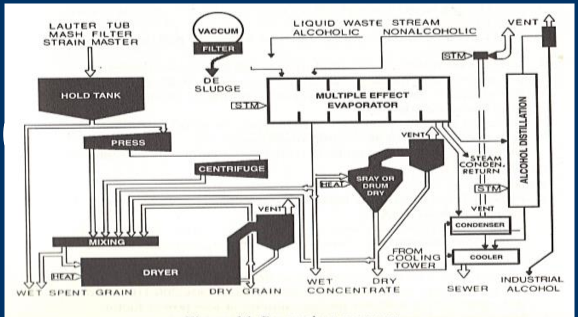


Figure 14. By-product recovery.

ESG Sustainable Processes:

(Reference # 3, pages 491-492)

1. Clean-in-Place (CIP) Post-Rinse recovered as Pre-Rinse for Vessel and Line CIP
2. Heat Recovery from Hot Vent Vapors to Pre-Heat utility water for process uses
3. Spent Grains dried for sales as animal feed
4. Biological Energy Recovery System (BERS) converts spent hops and waste yeast into methane for steam boiler combustion
5. Distillation of Waste Beer to generate ethanol for industrial use sales
6. 7-Effect evaporator conversion of Hops BCS, Brewer Condensed solubles, into molasses for sale as an animal feed nutrient supplement
7. CO2 collection from Alpha Fermentation for re-carbonization of O'Doul's non-alcoholic beer, tank blanketing, and generating Adjusted Water for 3-stream blending of Finished Beer.
8. Spent Beechwood Chips shredded for sales as landscape mulch

Recommendations:

1. CIP continues recovery of Post-Rinse for use as Pre-Rinse to conserve water, chemicals and energy
2. Vent Heat Recovery continuation with brewkettles and cookers to pre-heat CIP Post-Rinse Water and pre-heat Wort feed into Brewkettle
3. Spent Grains dried for animal feed continues as is
4. BERS methane generation process continues with **added methane** to feed distillation reboiler and evaporator vacuum steam ejectors
5. Distillation of Waste Beer process continues with **added O'Doul's ethanol by-product stream or PI ultrasonic separation in bioethanol refining**
6. Evaporation process continues with molasses generation for animal feed nutrient supplement
7. CO2 collection for O'Doul's carbonization, tank blanketing, Adjusted Water generation, and as **a new by-product stream** for sales to soft drink mfg. beverages & supercritical CO2 extraction processes
8. Spent Beechwood Chips continue to be shredded for landscape mulch sales and **a new by-product stream** for BBQ wood chips

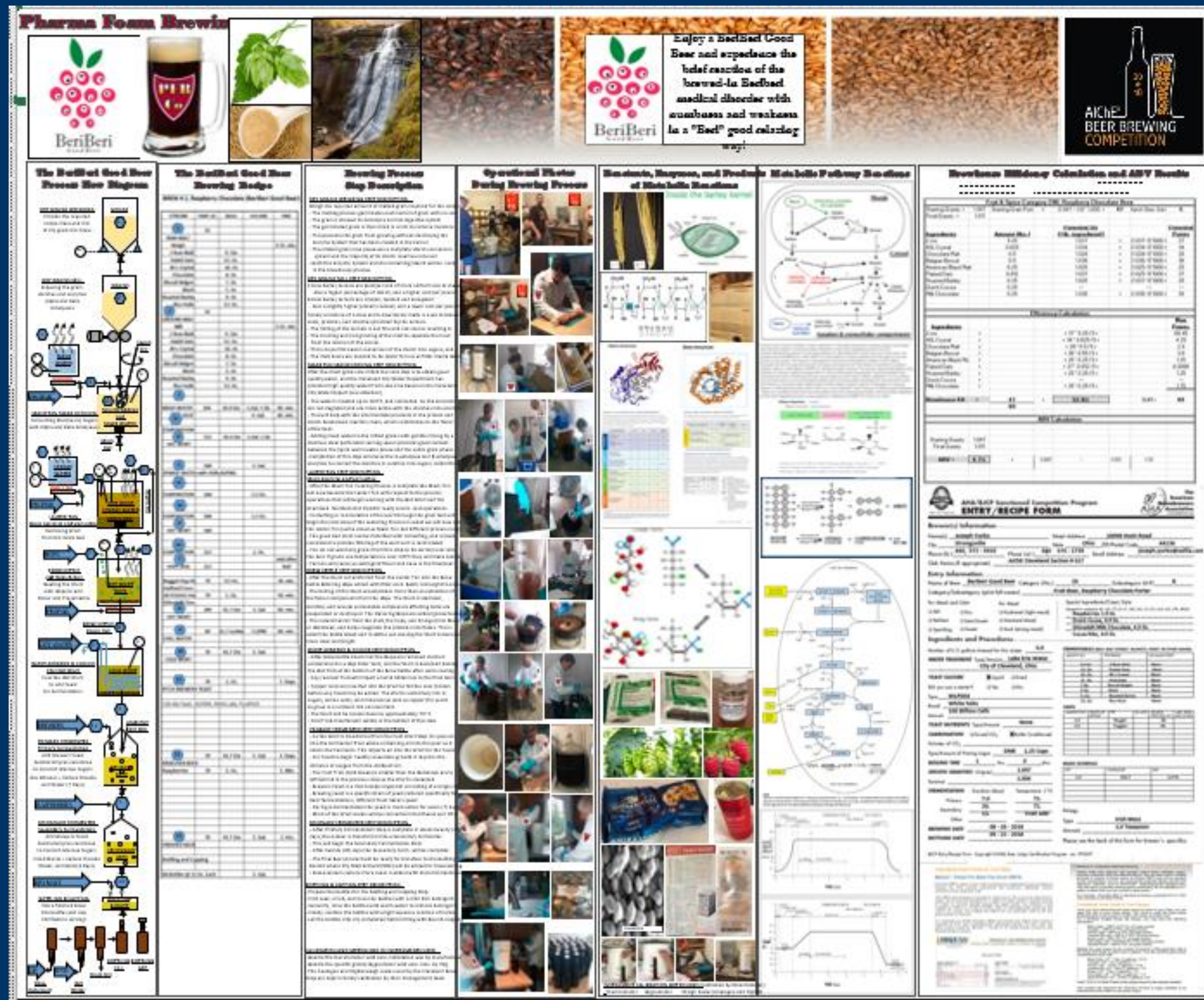
ESG Processes at Anheuser-Busch, Inc.

2018 ABBC AIChE Beer Brewing Competition:

Xellia Pharmaceuticals
5 Person Team
3 Young Professionals
2 Professionals

Home Brewing Apparatus

National Team Finals
Pittsburgh, PA
AIChE National Meeting



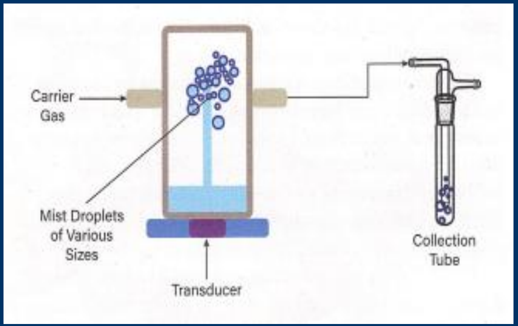
ESG Processes
at Anheuser-Busch, Inc.

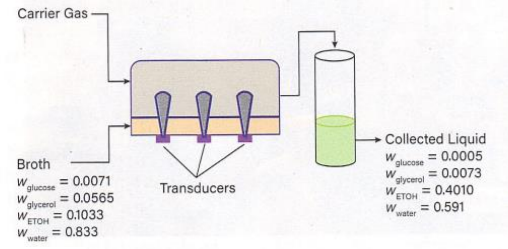
AIChE The Global Home of Chemical Engineers

ESG Sustainable Processes:

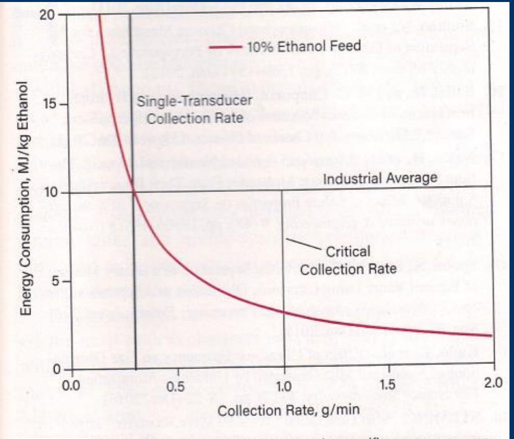
(Reference: CEP March 2023, Pages 24-30
Univ. of Illinois at Urbana-Champaign, Purdue Univ. and
North Carolina Agriculture and Technical State Univ.
Funding by US DOE Grant DE-EE0007888 and NSF Grant NSF IIP 16-24812 I/UCRC 1A)

1. **Process Intensification with Ultrasonic Separation in Bioethanol Refining**
2. Compared to distillation Ultrasonic Separation has a high energy efficiency and lack of phase change equilibrium constraints
3. A piezoelectric transducer creates high-frequency vibrations causing cavitation in the bulk solution
4. Bubbles of ethanol form and rise from the bulk solution
5. A vertical fountain jet of ethanol bubbles is created
6. The collapse of these bubbles at the top of the fountain jet ejects mist droplets of ethanol
7. A carrier gas moves ethanol mist droplets from the fountain jet in the batch to a collection tube
8. Ethanol liquid is ejected from the fountain jet and is not vaporized
9. Very little energy goes into phase change in this process
10. Ultrasonic separation of ethanol from aqueous solution is achieved by surface enrichment from excess mass fraction of ethanol on the liquid side adjacent to the gas-liquid interface
11. Fuel grade ethanol is produced with this process powered by 24 VDC and at 0.55 A yielding about 1.0 grams/min for a single transducer.
12. Process improvements needed to be more competitive:
    1. Improve the electrical efficiency of the process for better yield
    2. Determine the optimal carrier gas flow rate for better yield





A single-stage ultrasonic system consisting of three transducers produced excellent enrichment of ethanol from a real fermentation broth containing both glucose and glycerol among other solutes. In addition, the system reduced the mole fractions of glucose and glycerol fourteen-fold and eight-fold, respectively.



For an ultrasonic separation process, the specific energy consumption decreases as the collection rate increases. In this example, the ethanol mass fraction of the feed was 0.10.

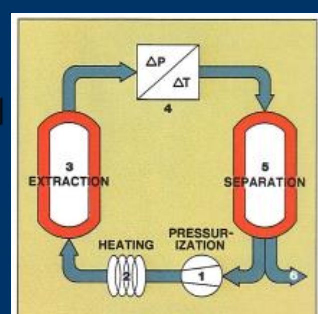
ESG Processes
at Anheuser-Busch, Inc.

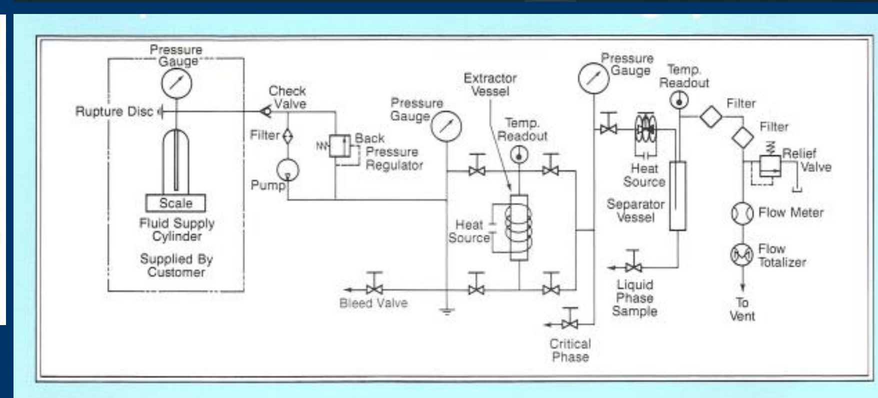
Figure 6.2 Temperature-entropy diagram for pure carbon dioxide.

Sustainable Processes:

(Reference # 8, Autoclave Engineers, SCE System)

1. **Supercritical Fluid Extraction with CO2**
2. Operating temperatures of 212 F and pressures of 1,500 psi with CO2 flowrate range from 46-460 mL/hr
3. CO2 is linear and non-polar molecule
4. Supercritical CO2 has density of a liquid and the diffusivity of a gas
5. Preferred sample characteristics to work with:
    1. Heat-sensitive compounds with low vapor pressure and will see no thermal degradation
    2. Remove specific compounds in multi-component mixtures (flavors & fragrances)
    3. Supercritical Fluids are more environmentally acceptable than solvents (coffee decaffeination)
    4. Supercritical Fluids do not leave a solvent residue
6. Basic Process Flow, CO2 recycled
    1. Solvent fluid is pressurized
    2. Fluid is then heated to its Supercritical State
    3. SCF enters extractor vessel
    4. SCF exits extractor vessel with extracted component
    5. SCF has dP & dT to release extracted product





ESG Processes at Anheuser-Busch, Inc.

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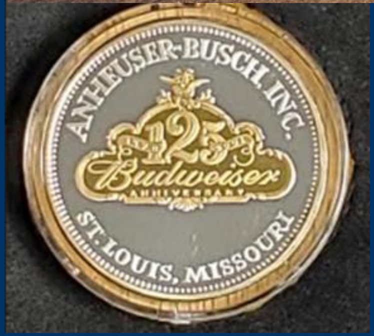

Problems? & Solutions!
Questions? & Answers!

ESG Processes at Anheuser-Busch, Inc.

References:

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3. The Practical Brewer, Master Brewing Association of Americas, 1999
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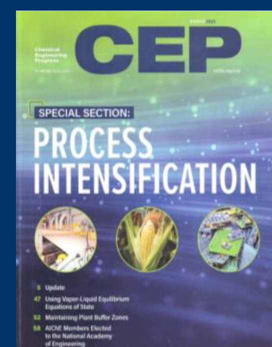

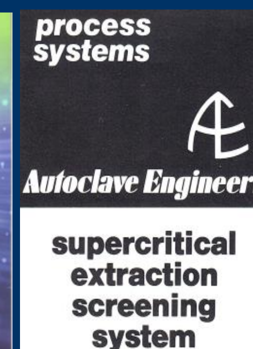

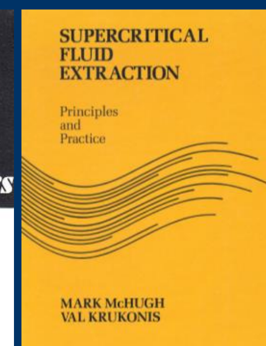

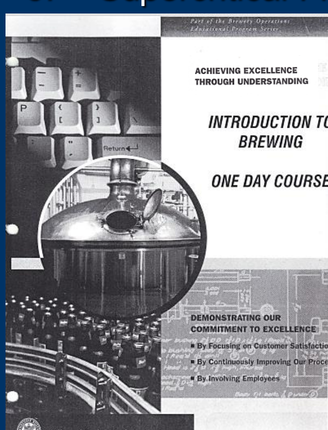

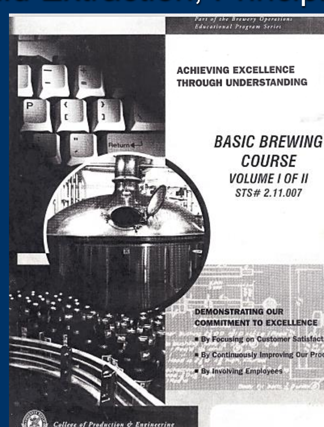

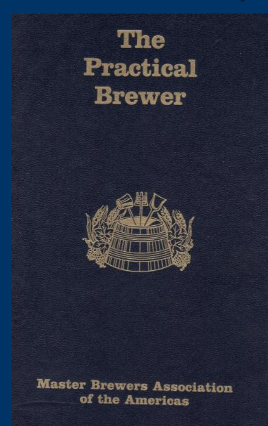

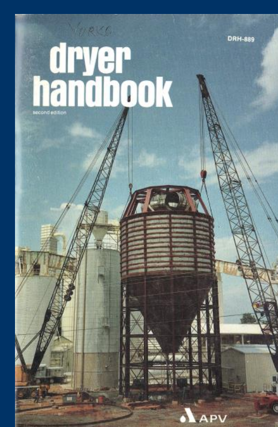

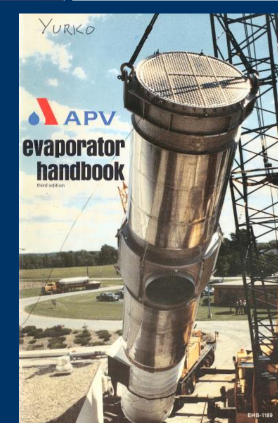

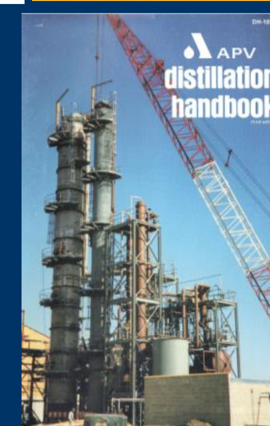

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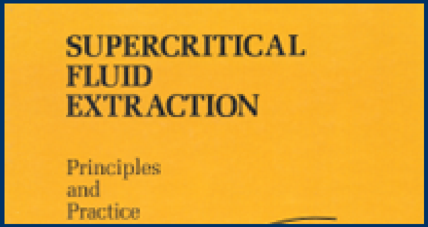
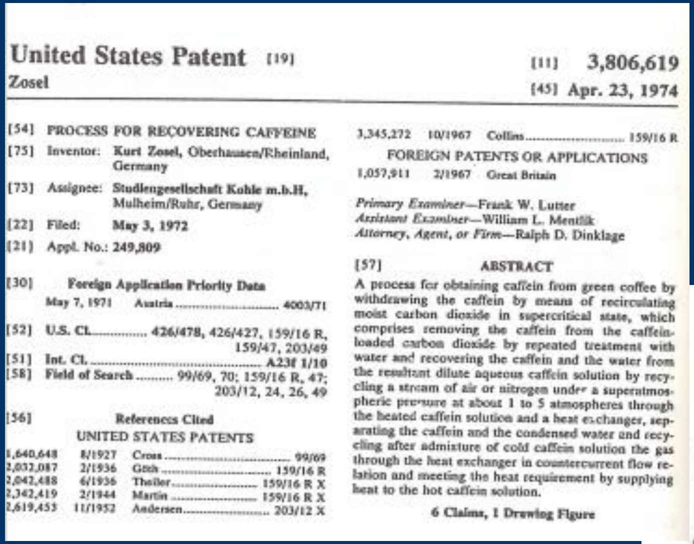
at Anheuser-Busch, Inc.



Appendix 1: CO2 SCFE of Caffeine, First U.S. Patent (May 3 1972):

(Reference # 8, SCFE Principles & Practices, page 333)



United States Patent [19]
Zosel

[11] **3,806,619**
[45] **Apr. 23, 1974**

[54] PROCESS FOR RECOVERING CAFFEINE

[75] Inventor: Kurt Zosel, Oberhausen/Rheinland, Germany

[73] Assignee: Studiengesellschaft Kohle m.b.H., Mulheim/Ruhr, Germany

[22] Filed: May 3, 1972

[21] Appl. No.: 249,809

[30] Foreign Application Priority Data
May 7, 1971 Austria 4003/71

[52] U.S. Cl. .... 426/478, 426/427, 159/16 R, 159/47, 203/49

[51] Int. Cl. A23f 1/10

[58] Field of Search .... 99/69, 70; 159/16 R, 47; 203/12, 24, 26, 49

[56] References Cited
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2,032,087	2/1936	Géth	159/16 R
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FOREIGN PATENTS OR APPLICATIONS

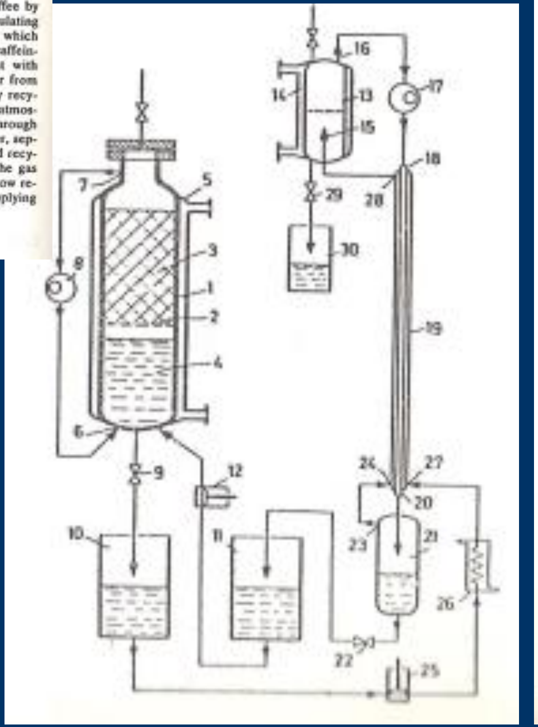
1,057,911	2/1967	Great Britain

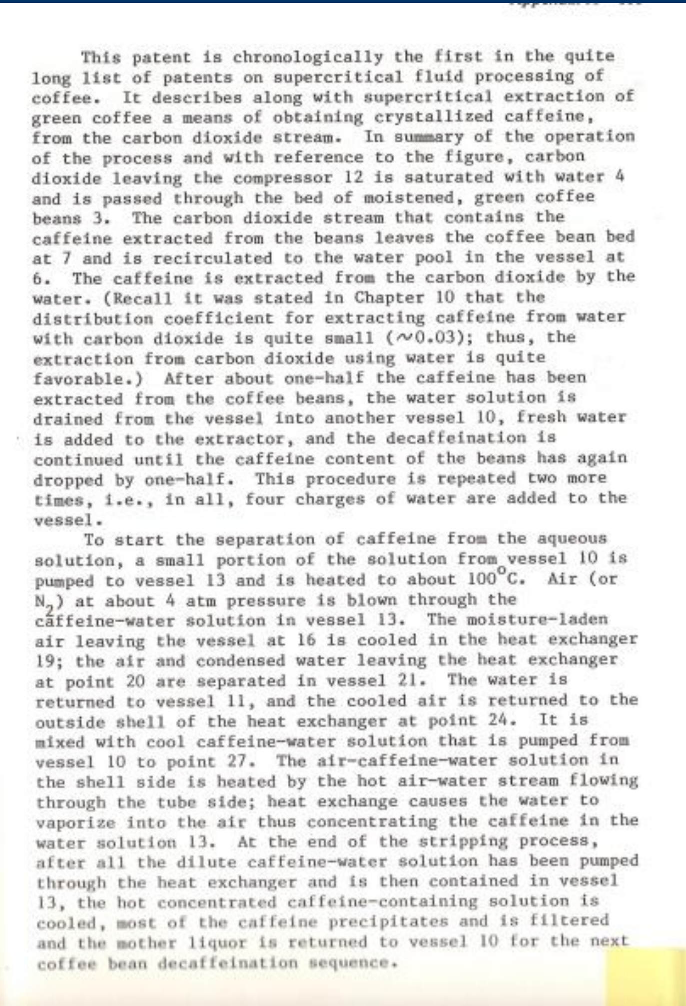
Primary Examiner—Frank W. Lutter
Assistant Examiner—William L. Mentlik
Attorney, Agent, or Firm—Ralph D. Dinklage

[57] ABSTRACT

A process for obtaining caffein from green coffee by withdrawing the caffein by means of recirculating moist carbon dioxide in supercritical state, which comprises removing the caffein from the caffein-loaded carbon dioxide by repeated treatment with water and recovering the caffein and the water from the resultant dilute aqueous caffein solution by recycling a stream of air or nitrogen under a superatmospheric pressure at about 1 to 5 atmospheres through the heated caffein solution and a heat exchanger, separating the caffein and the condensed water and recycling after admixture of cold caffein solution the gas through the heat exchanger in countercurrent flow relation and meeting the heat requirement by supplying heat to the hot caffein solution.

6 Claims, 1 Drawing Figure





This patent is chronologically the first in the quite long list of patents on supercritical fluid processing of coffee. It describes along with supercritical extraction of green coffee a means of obtaining crystallized caffeine, from the carbon dioxide stream. In summary of the operation of the process and with reference to the figure, carbon dioxide leaving the compressor 12 is saturated with water 4 and is passed through the bed of moistened, green coffee beans 3. The carbon dioxide stream that contains the caffeine extracted from the beans leaves the coffee bean bed at 7 and is recirculated to the water pool in the vessel at 6. The caffeine is extracted from the carbon dioxide by the water. (Recall it was stated in Chapter 10 that the distribution coefficient for extracting caffeine from water with carbon dioxide is quite small (~0.03); thus, the extraction from carbon dioxide using water is quite favorable.) After about one-half the caffeine has been extracted from the coffee beans, the water solution is drained from the vessel into another vessel 10, fresh water is added to the extractor, and the decaffeination is continued until the caffeine content of the beans has again dropped by one-half. This procedure is repeated two more times, i.e., in all, four charges of water are added to the vessel.

To start the separation of caffeine from the aqueous solution, a small portion of the solution from vessel 10 is pumped to vessel 13 and is heated to about 100°C. Air (or N_2) at about 4 atm pressure is blown through the caffeine-water solution in vessel 13. The moisture-laden air leaving the vessel at 16 is cooled in the heat exchanger 19; the air and condensed water leaving the heat exchanger at point 20 are separated in vessel 21. The water is returned to vessel 11, and the cooled air is returned to the outside shell of the heat exchanger at point 24. It is mixed with cool caffeine-water solution that is pumped from vessel 10 to point 27. The air-caffeine-water solution in the shell side is heated by the hot air-water stream flowing through the tube side; heat exchange causes the water to vaporize into the air thus concentrating the caffeine in the water solution 13. At the end of the stripping process, after all the dilute caffeine-water solution has been pumped through the heat exchanger and is then contained in vessel 13, the hot concentrated caffeine-containing solution is cooled, most of the caffeine precipitates and is filtered and the mother liquor is returned to vessel 10 for the next coffee bean decaffeination sequence.

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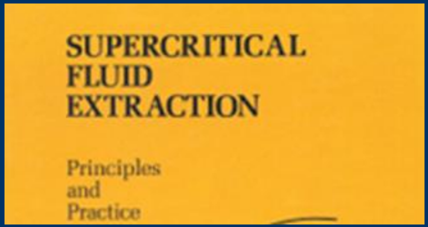

Appendix 2: CO2 SCFE of COCOA Butter, U.S. Patent (May 23 1973):
(Reference # 8, SCFE Principles & Practices, page 365)

United States Patent [19] — [11] **3,923,847**
Roselius et al. — [45] **Dec. 2, 1975**

[54] METHODS OF PRODUCING COCOA BUTTER

[75] Inventors: Wilhelm Roselius, Bremen-St. Magnus; Otto Vitzthum, Bremen; Peter Hubert, Bremen-Lesum, all of Germany

[73] Assignee: Studiengesellschaft Kohle m.b.H., Mulheim (Ruhr), Germany

[22] Filed: May 23, 1973

[21] Appl. No.: 363,098

[52] U.S. Cl. 260/412.8; 260/412.8
[51] Int. Cl.² C11B 1/10
[58] Field of Search 260/412.8

[56] References Cited

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3,093,480	6/1963	Arnold	260/412.8

FOREIGN PATENTS OR APPLICATIONS

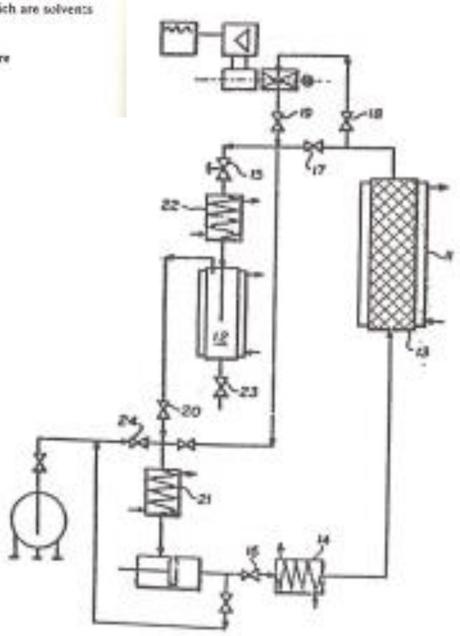
1,057,911	2/1967	United Kingdom	260/412.8

Primary Examiner—Elbert L. Roberts
Attorney, Agent, or Firm—Burgess, Dinklage & Sprung

[57] ABSTRACT

Process of extracting cocoa butter from sources thereof by use of supercritical gases which are solvents therefor, especially carbon dioxide.

9 Claims, 1 Drawing Figure



Cocoa butter is the triglyceride which derives from cocoa beans; it is composed of a large amount of palmitic acid on the glyceral backbone. Because of the high saturation, cocoa butter is a solid and exhibits a rather sharp melting point at about body temperature which incidentially, is partially responsible for the pleasant mouth feel of high quality chocolates.

The invention concerns the use of supercritical solvents to extract the cocoa butter from cocoa nibs (comminuted cocoa beans) and cocoa mass (finely crushed beans). The description of other processes in the prior art section of the patent points out that organic solvent extraction results in the presence of residual solvents; additionally, some of the newer pressing methods, via expellors, for example, introduce waste bean contaminants into the butter which must be removed with economic and taste penalties.

Examples of the application of supercritical carbon dioxide at typically, 200–400 atm, 40–60°C to extract both finely crushed cocoa mass and cocoa nibs are presented. It is related that cocoa mass can be extracted of 99% of its cocoa butter and that cocoa nibs, whether roasted or not or whether treated with caustic or not, can be extracted of 74% of their cocoa butter. One of the authors (VJK) has verified the results with cocoa mass, but finds that less than 5% of the cocoa butter can be extracted from raw, untreated cocoa nibs, even if the extraction is carried out at 7000 psi, 40–60°C for a period of 8 hours! On the other hand theobromine and caffeine can be extracted from the nibs almost quantitatively at much less severe conditions resulting in a cocoa product containing almost all its original cocoa butter and flavor but no adverse stimulants (Krukonis unpublished data, 1982).

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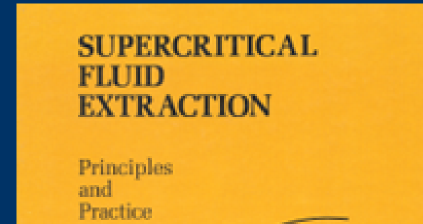

Appendix 3: CO_2 SCFE of Nicotine from Tobacco, U.S. Patent (Aug. 23 1973):

(Reference # 8, SCFE Principles & Practices, page 377)

United States Patent [19]

Roselius et al.

[11] **4,153,063**

[45] **May 8, 1979**

[54] PROCESS FOR THE EXTRACTION OF NICOTINE FROM TOBACCO

[75] Inventors: Wilhelm Roselius, Magnus; Otto Vitzthum, Bremen; Peter Hubert, Bremen-Lesum, all of Fed. Rep. of Germany

[73] Assignee: Studiengesellschaft Kohle mbH, Mülheim, Ruhr, Fed. Rep. of Germany

[21] Appl. No.: 390,967

[22] Filed: Aug. 23, 1973

Related U.S. Application Data

[63] Continuation of Ser. No. 177,220, Sep. 2, 1971, abandoned.

[30] Foreign Application Priority Data

Sep. 2, 1970 [DE] Fed. Rep. of Germany 2043537
Aug. 23, 1971 [DE] Fed. Rep. of Germany 2142205

[51] Int. Cl.[2] A24B 3/14
[52] U.S. Cl. ...... 131/143; 131/17 R; 131/144
[58] Field of Search ...... 131/17, 143, 144, 135, 131/140 C; 260/291

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1057911 2/1967 United Kingdom 131/135

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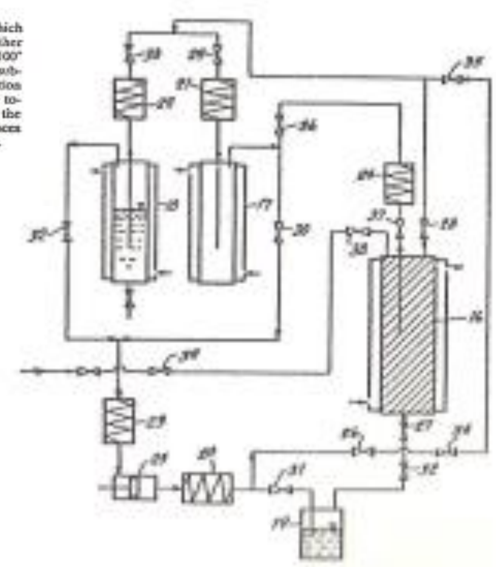
Luganskaja, L. N. et al., "On the Aromatization of Tobacco" and "Use of Tobacco Dust Extract for Aromatizing Purposes", pub.—from "Tobacco Abstracts", vol. 12, #6, Jun. 1968, pp. 394 and 395, abstracts 1258 and 1259.

Primary Examiner—Robert W. Michell
Assistant Examiner—V. Millin
Attorney, Agent, or Firm—Sprung, Felfe, Horn, Lynch & Kramer

[57] ABSTRACT

Process for extracting nicotine is disclosed in which tobacco is exposed to an extracting solvent in either liquid or gaseous state at temperatures below about 100° C. and at high pressures. The aroma generating substances can be removed by conducting the extraction with the tobacco in dry condition. Thereafter the tobacco can be moistened, and on further contacting the nicotine is removed. The aroma generating substances can then be recombined with nicotine free tobacco.

32 Claims, 6 Drawing Figures



Extraction of nicotine from tobacco using supercritical fluid is carried out in a manner quite similar to the decaffeination of roasted coffee described in U.S. 3,843,824. With reference to the figure, tobacco in vessel 16 is first contacted with dry supercritical carbon dioxide entering at point 27. Aroma constituents are dissolved by the dry carbon dioxide; the stream leaving the extraction vessel is expanded to subcritical via valve 29 and is passed into separator vessel 17, where carbon dioxide is vaporized, resulting in the precipitation of aromas. The vapor is recompressed, is adjusted in temperature to supercritical conditions via heat exchangers 23 and 20, and is recycled to the extractor via the compressor 25; the aromas extraction step continues until the aroma constituents are removed from the tobacco.

In the second step of the process, the supercritical carbon dioxide is humidified (in vessel 19) before being passed through the tobacco; nicotine is extracted by the wet carbon dioxide. Nicotine is removed from the carbon dioxide by passing the stream through vessel 18 containing a sulfuric acid solution that reacts with the nicotine to form a salt insoluble in carbon dioxide. The nicotine-free carbon dioxide leaving the vessel is adjusted in temperature and moisture and is recycled until a satisfactory level of nicotine removal has been achieved. At the end of the nicotine extraction cycle, the tobacco in vessel 16 is dried. The aroma constituents contained in vessel 17 are dissolved in a liquid solvent and the solution introduced into the extractor containing the tobacco. The solvent is vaporized resulting in the precipitation of aromas in the tobacco.

As a variation of the three step procedure described above, the patent also relates that if tobacco is first moistened, solely nicotine can be extracted with supercritical carbon dioxide. For example, carbon dioxide at 70°C, 300 atm passed through moistened tobacco reduced the nicotine content from 1.36 to 0.08% (dry basis) while leaving the aromas untouched. One of the authors (VJK) has not been able to reproduce this finding in tests with moistened tobacco from commercial cigarettes; aromas were found to be extracted along with the nicotine. Another example in the patent contains some other curious information, viz., it is related that 5 wt-% ammonia is added to supercritical carbon dioxide at 70°C, 250 atm and the mixture used to extract nicotine. One of the authors (VJK) has tested this mixture and finds that carbon dioxide and ammonia react to form a compound, probably ammonium carbamate, which is insoluble in supercritical carbon