Sustainable Processes at Anheuser-Busch, Inc.

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American Institute of Chemical Engineers

AIChE Cleveland Section

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Sustainable Processes at Anheuser-Busch, Inc.

Presentation Summary

- 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. CO_2 collection from Alpha Fermentation for re-carbonization of O'Doul's non-alcoholic beer
8. Spent Beachwood Chips (Beta Fermentation Process) shredded for use as landscape mulch
9. Recommendations

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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
  - 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 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 US $52 billion

Website: www.anheuser-busch.com

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 c**onvert 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 Kraeusened 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**

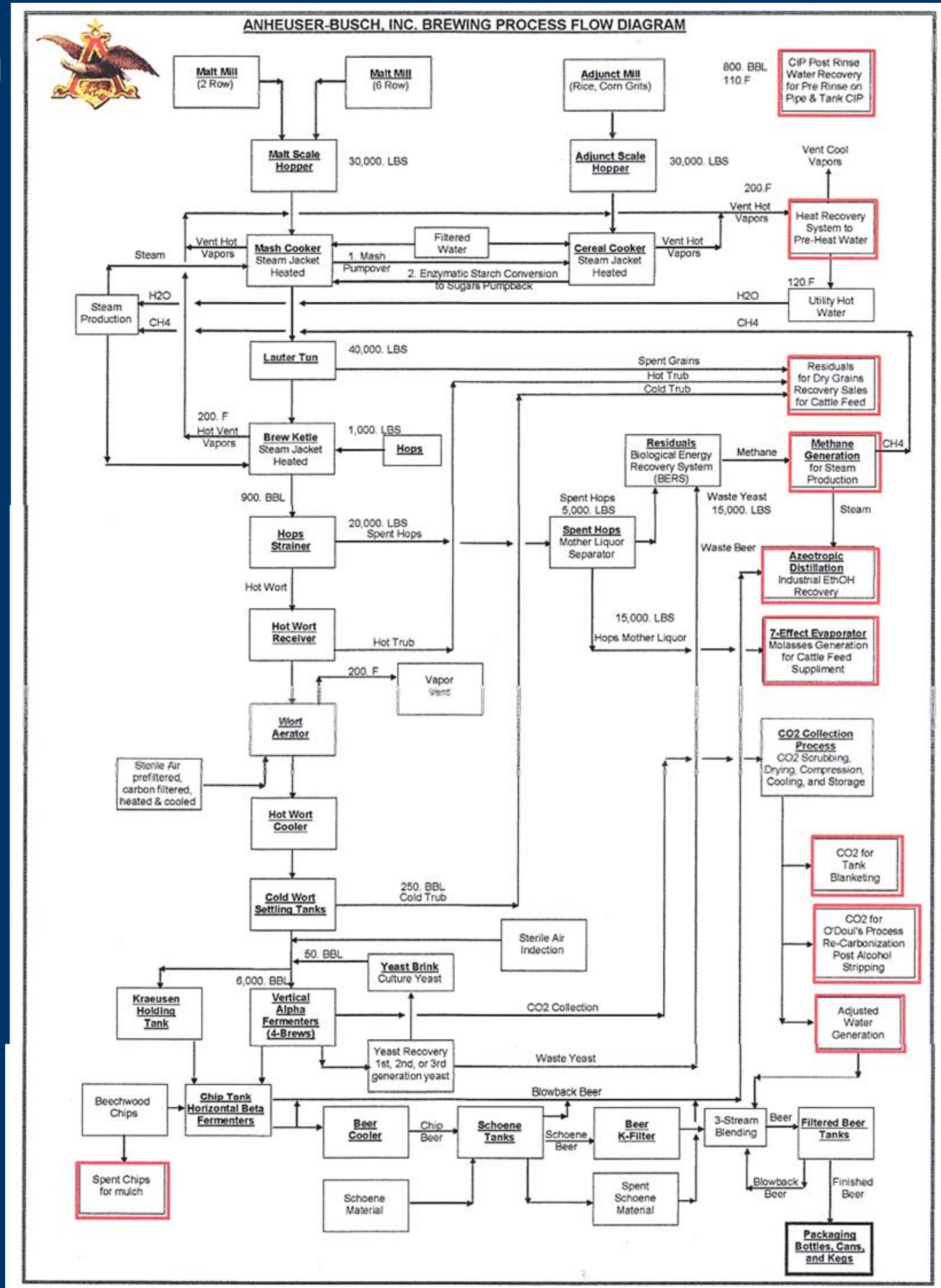
• **PACKAGING** Beer is placed into bottles, cans, or kegs; labeling cartons and pallets for shipment
•Filling: Bottles, Cans & Kegs
•Pasteurization: Bottles & Cans
•Labels & Cartons: Bottles & Cans

Brewery Process Operation Block Flow Diagram

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 Mother Liquor 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 Beachwood Chips shredded for sales as landscape mulch



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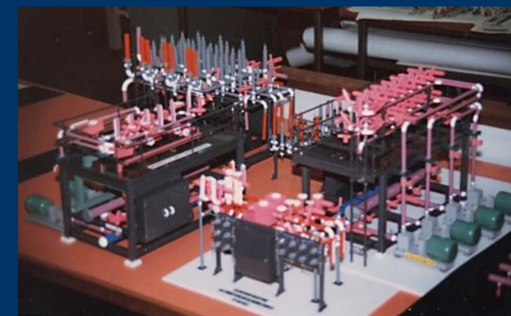
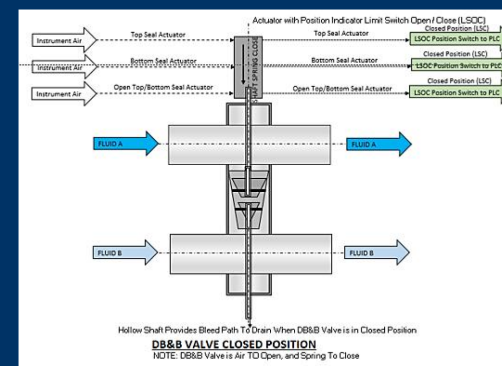
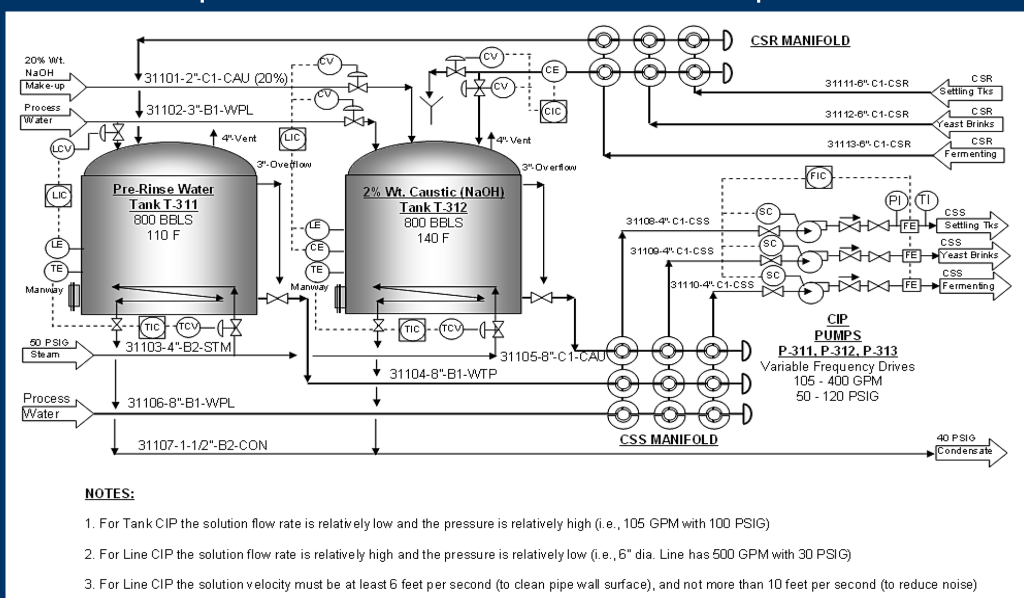
<u>Clean-in-Place (CIP) Operations</u> (Typical all Breweries)
(Reference # 2, Cleaning Technology, pages 1-16)



- Piping Lines: low pressure (50 psig) & turbulent flow (6 fps min)
- Vessels: high pressure (105 psig) at 100 gpm (GamaJet)
- <u>First Rinse</u> with hot water (110.F)
- <u>Second Rinse</u> with 2% hot caustic (140.F)
- <u>Final Rinse</u> 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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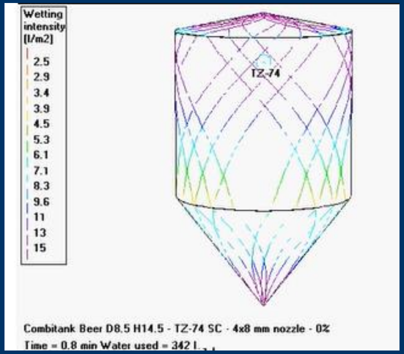
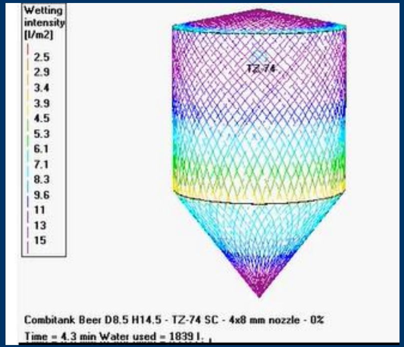
Clean-in-Place (CIP) Operations (Typical all Breweries)

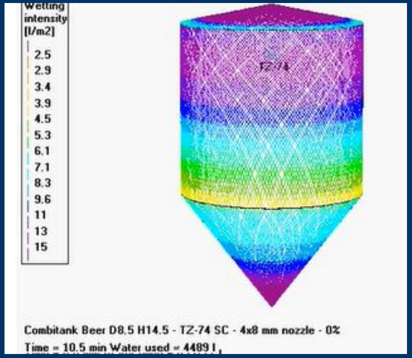
(Reference # 3, page 527)

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

- GamaJet (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
    - GamaJet 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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Columbus Brewhouse Operation Processes:

- 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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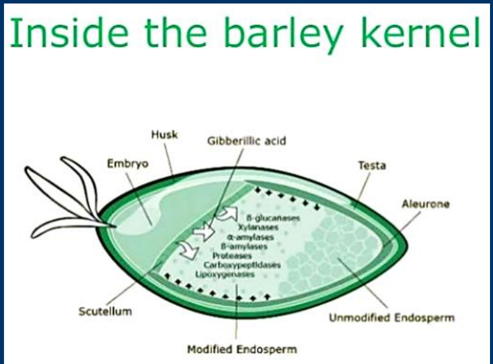
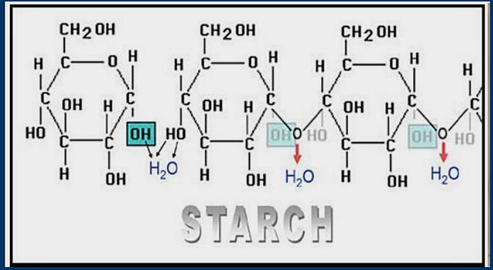
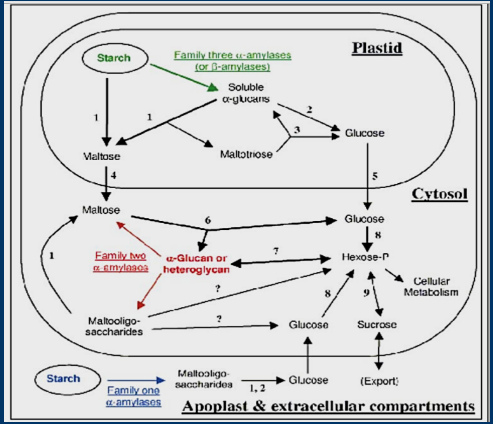
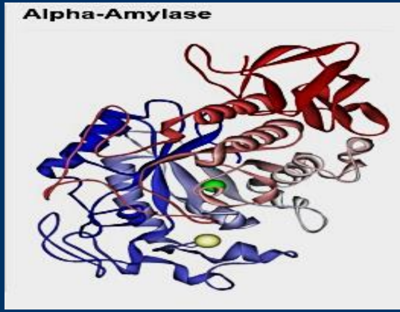
Columbus Brewhouse Operation Processes:

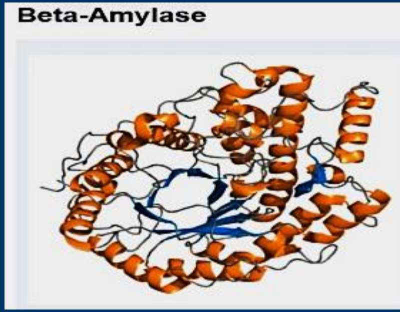
- Mill Tower: Grind grains for cookers
    - Mill barley kernels into components (like powder)
    - Recipe has **10k Lbs** barley & **15k Lbs** rice or corn grits
    - Makes a **900 BBL** brew, about $100k value at this point
- Mash & Cereal Cooker: Two Cooker Brewing
    - Activate enzymes to convert 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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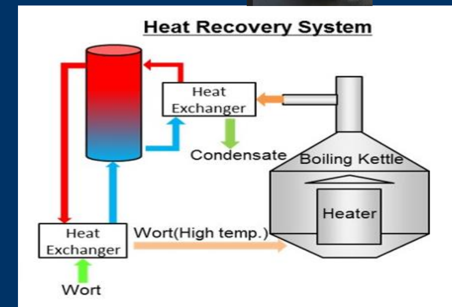
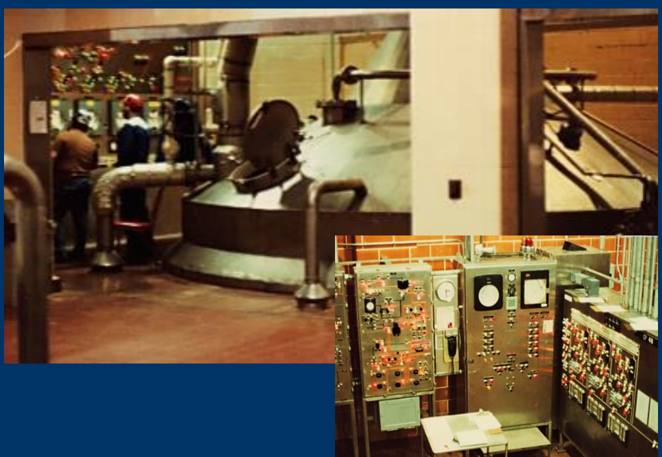
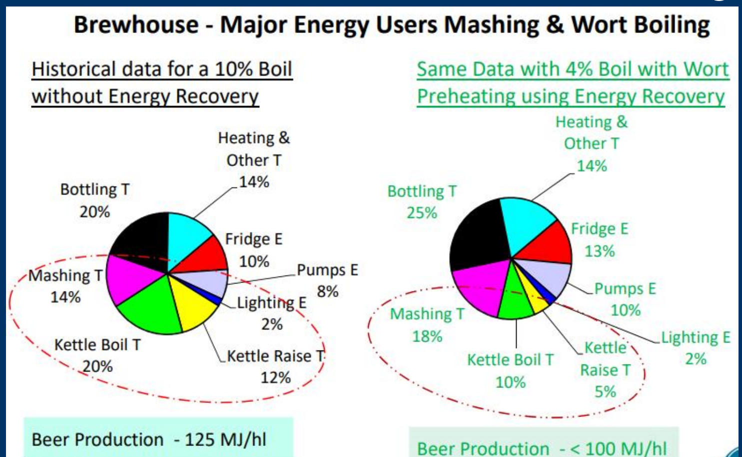


<u>Heat Recovery from Hot Vapor Vents</u>

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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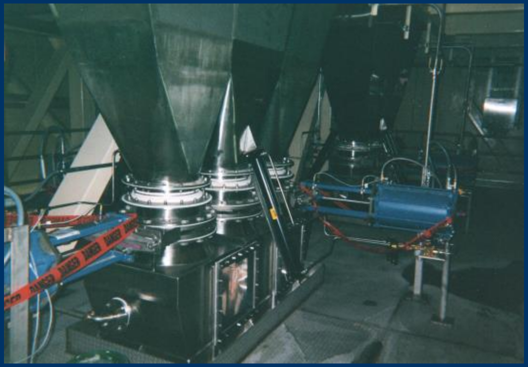
<u>Columbus Spent Grains Dried for Animal Feed</u>

Brewhouse (6 cookers, 2 Lauter Tuns & 4 Brew Kettles)

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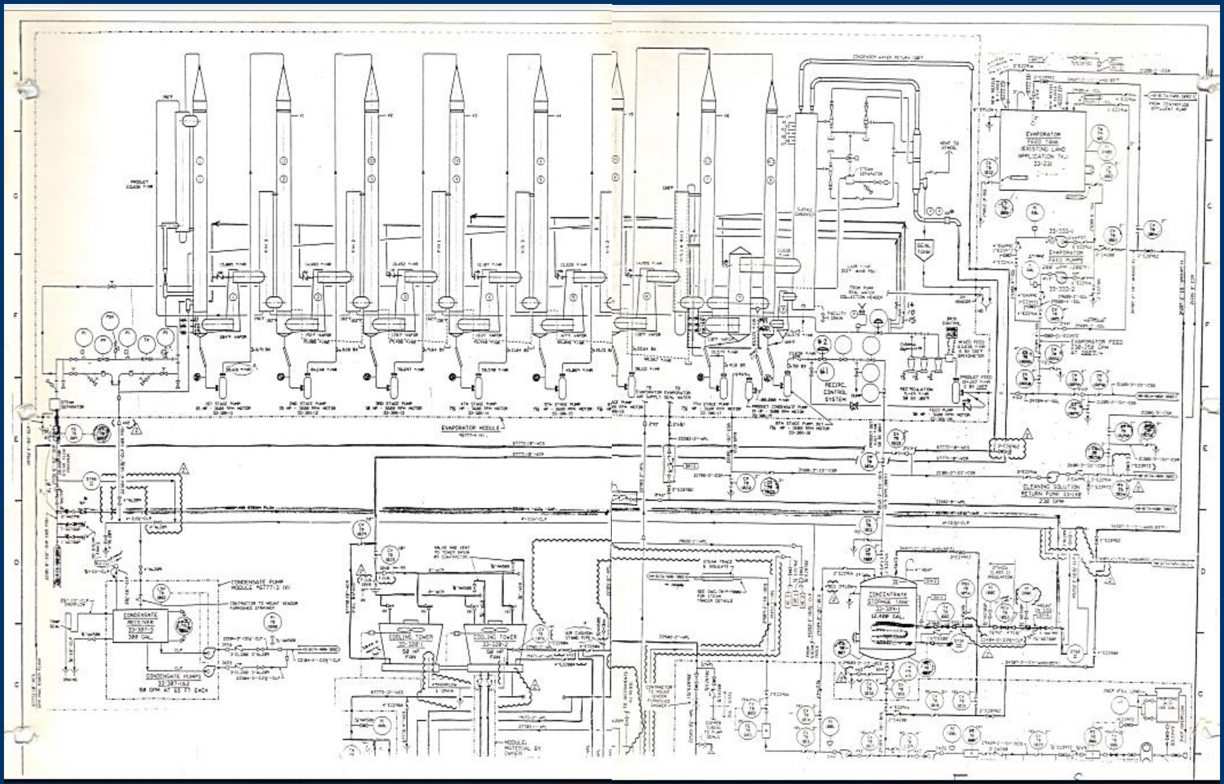
Houston 7-Effect Evaporator (JBT, T.A.S.T.E. Evaporator)

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



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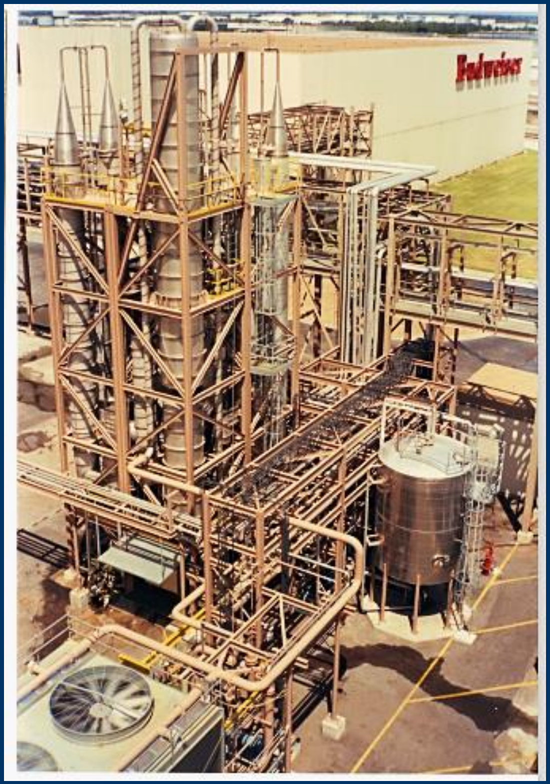
<u>Houston 7-Effect Evaporator</u> (JBT, T.A.S.T.E. Evaporator)

- BCS sent to TASTE evaporator to reduce the BCS daily fine 50%
- 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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Columbus & Cartersville Breweries

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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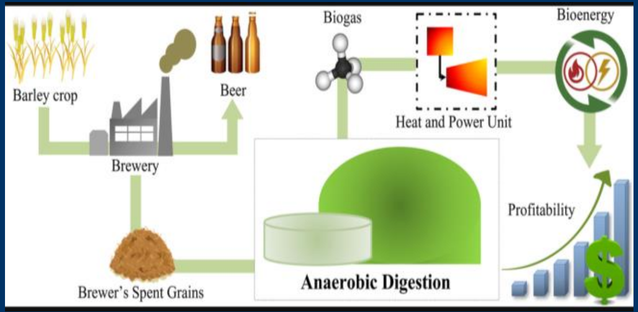
BERS Process Flow Diagram



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 BOD treatment
    - **Social**:
        - People safe automated operation remotely
    - **Governance**:
        - Automation saves time, utilities, and labor

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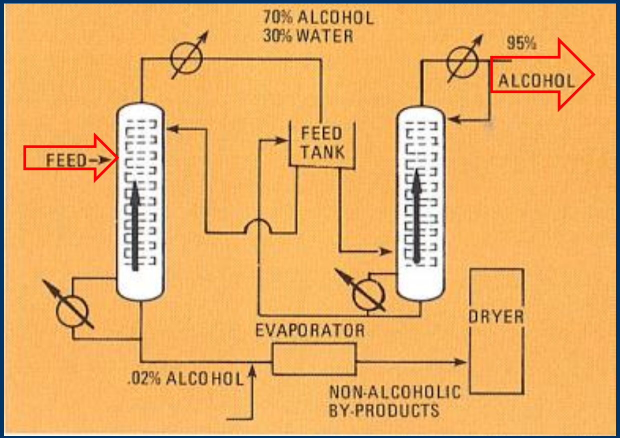
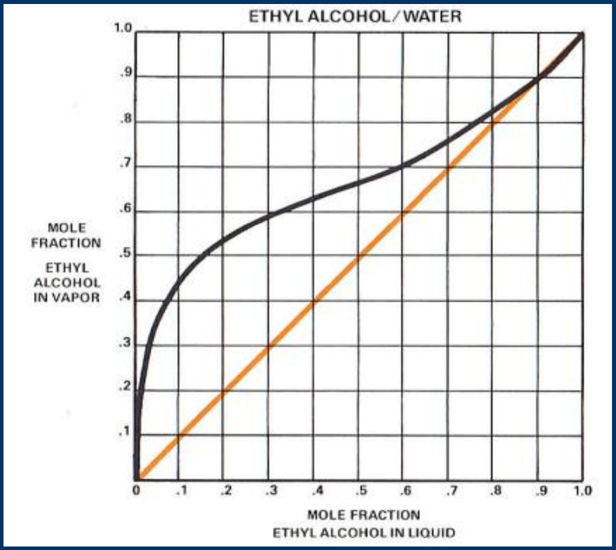
<u>Distillation of Waste Beer</u> (APV 2-Column Unit)
(Reference # 6, pages 32 – 37)

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 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





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<u>Columbus (L) & Houston (R) Distillation of Waste Beer</u>

(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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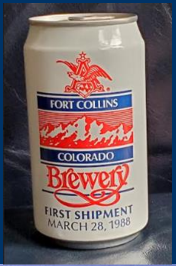

<u>Construction Site:</u>
<u>Fort Collins, Colorado</u>
<u>Subassembly Mobilization</u>

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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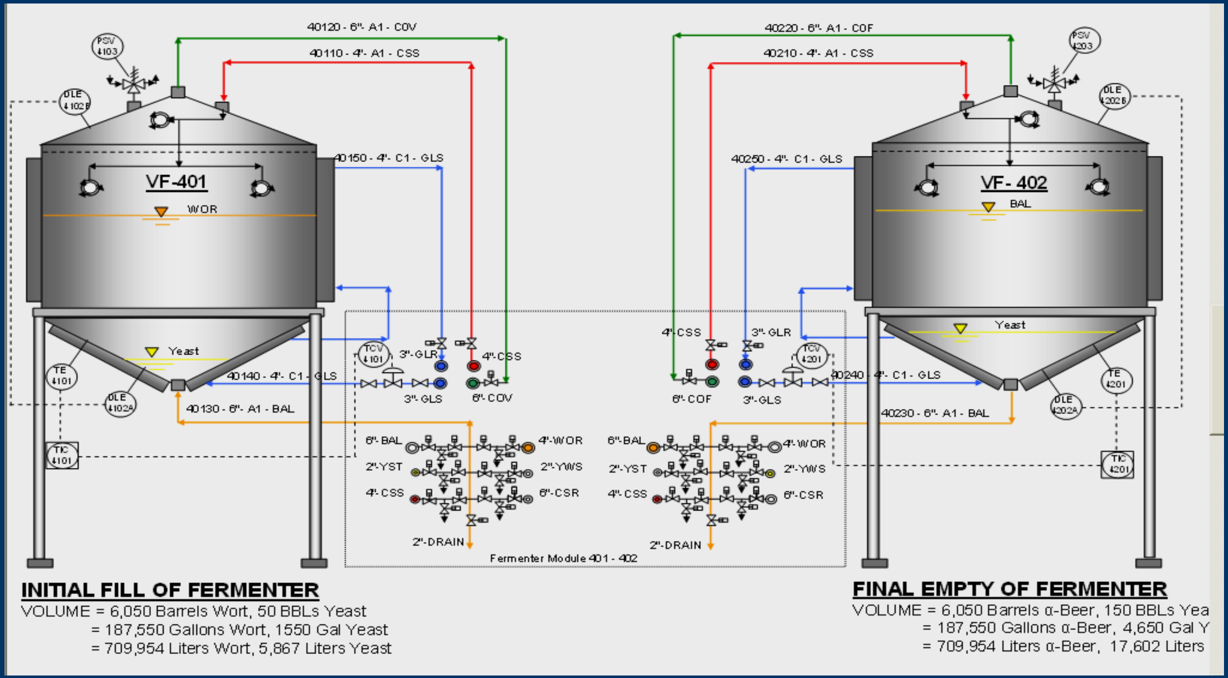
Alpha Fermentation Process

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



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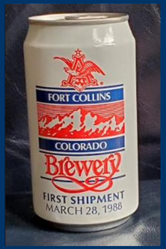
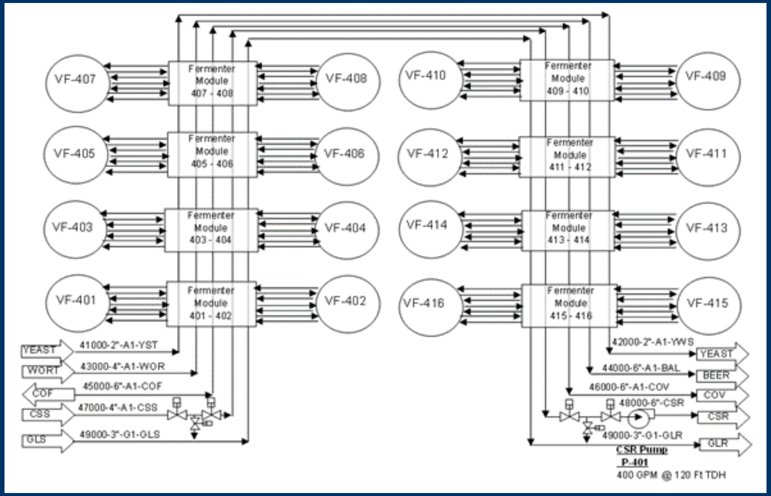


Alpha Fermentation Process

- 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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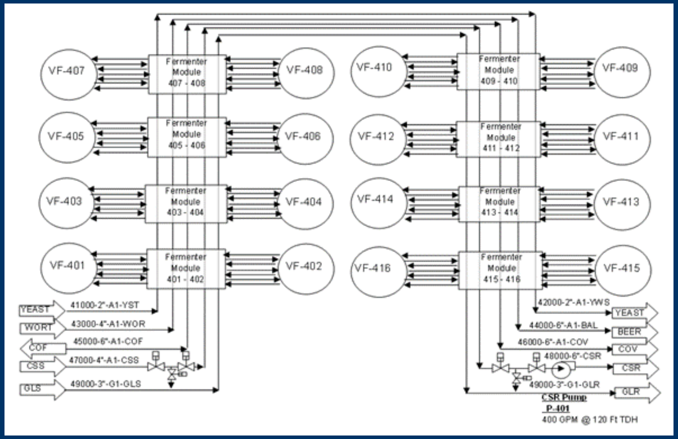
Primary Fermentation Process

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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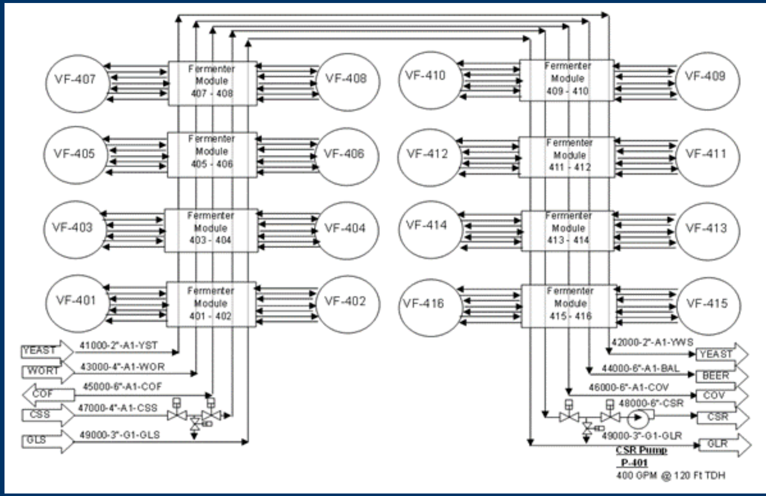
Alpha Fermentation

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

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



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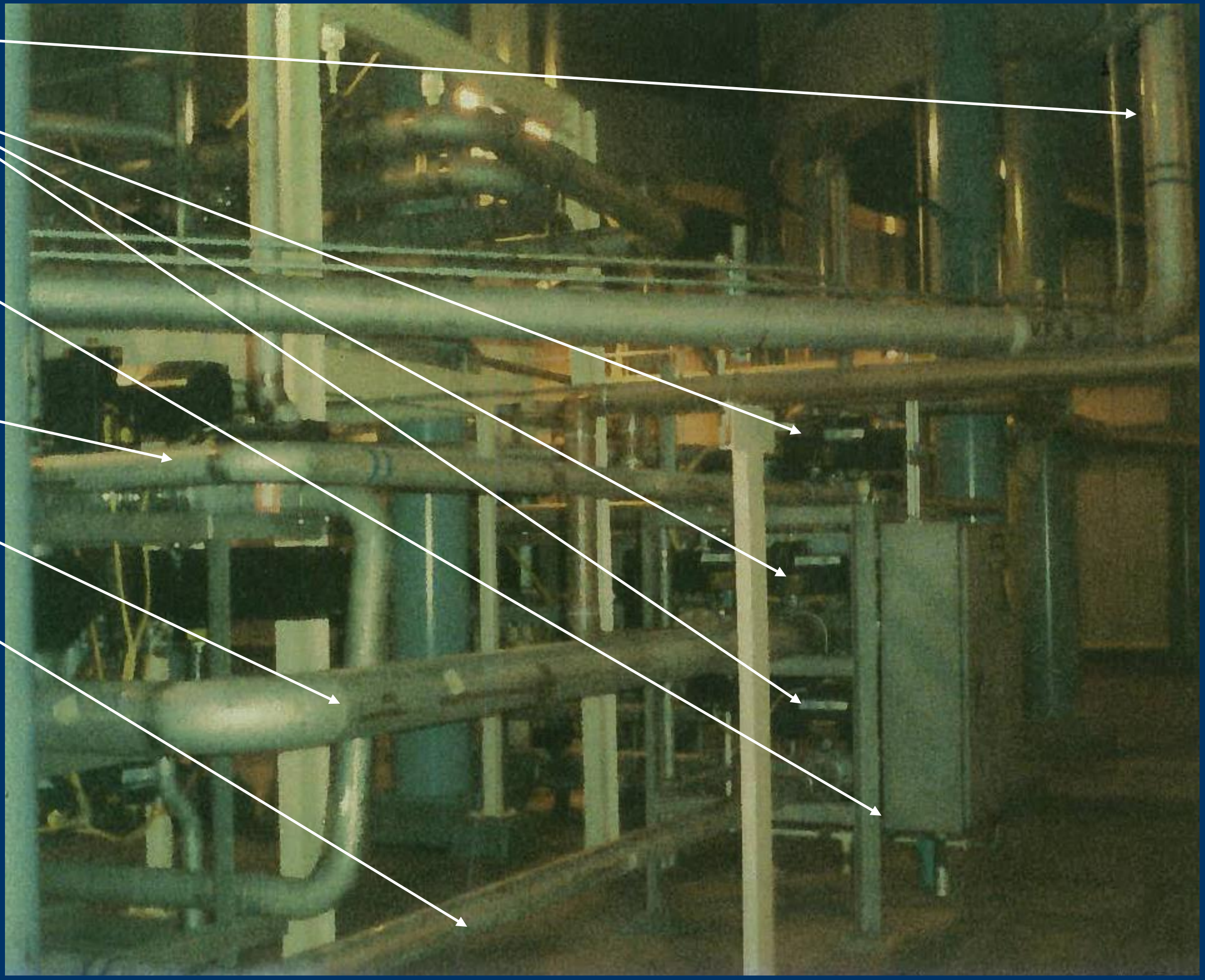
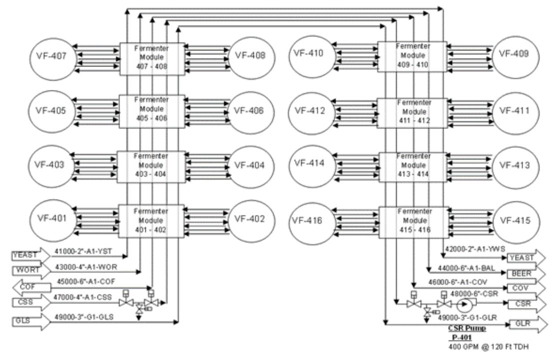
Alpha Fermentation

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





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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 1990-2000s

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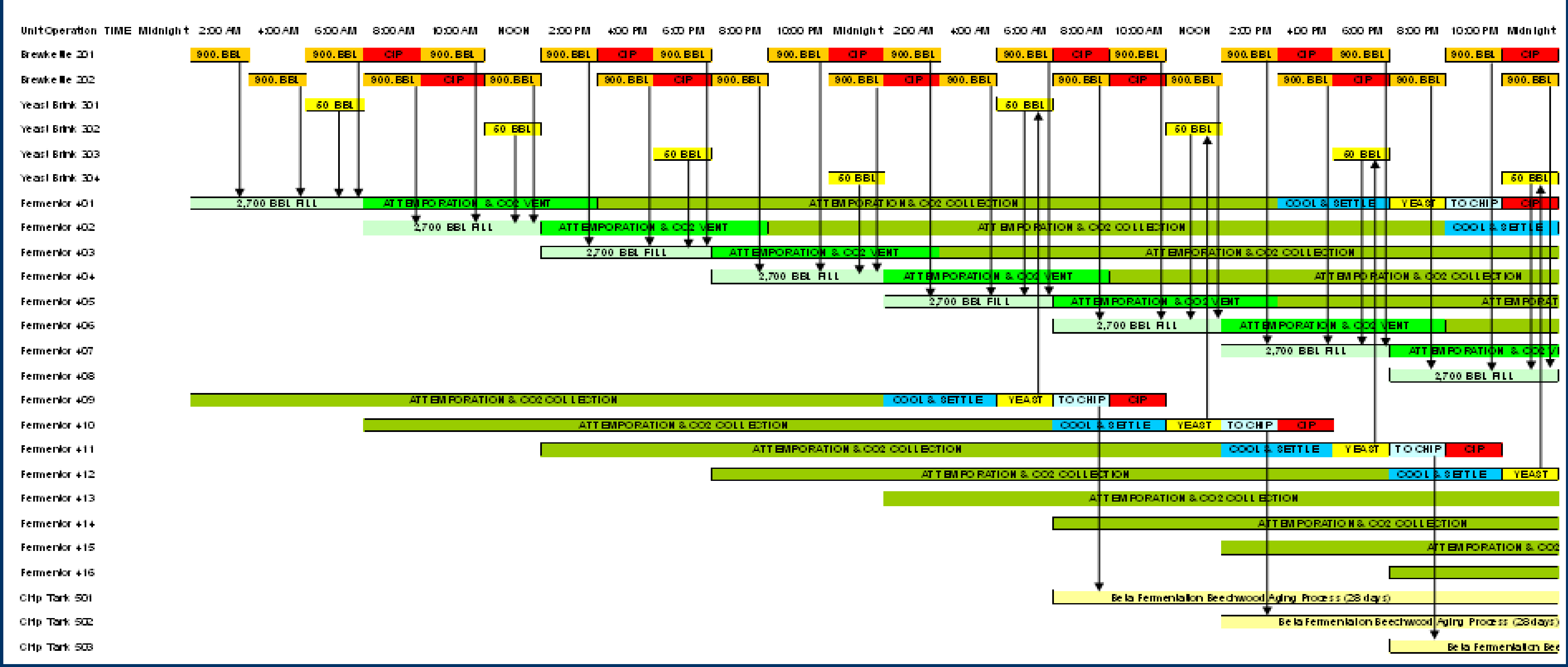
Brewing Operations Schedule With CIP:

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

- Alpha Fermentation Operations 7 days, 16 Fermenters
- Beta Fermentation Operations 21 days, 120 Fermenters



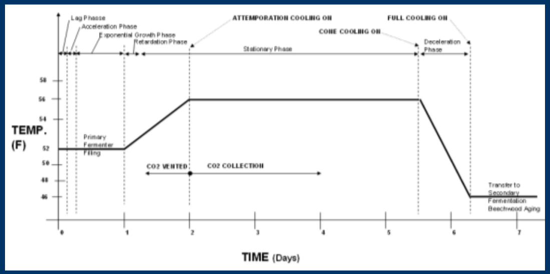
Sustainable Processes at Anheuser-Busch, Inc.

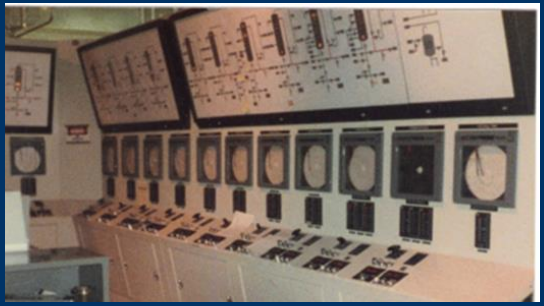
AB

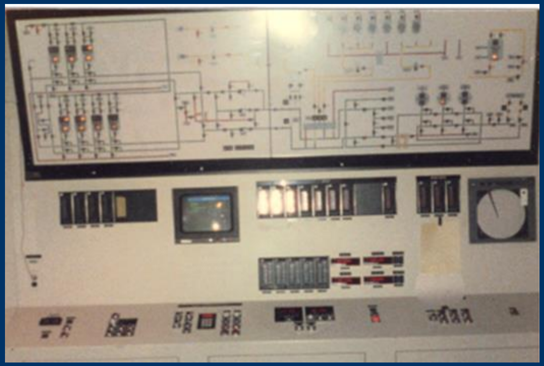
Alpha Fermentation Process

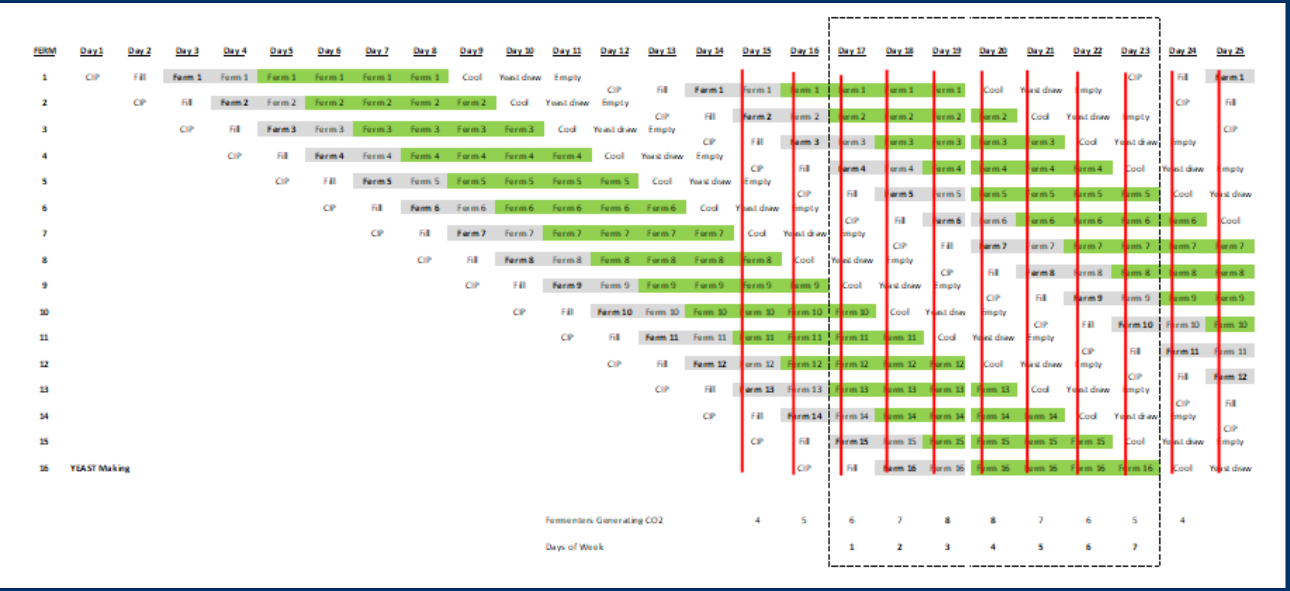
Columbus Brewery 16 Fermenter Schedule

- 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









Sustainable Processes at Anheuser-Busch, Inc.

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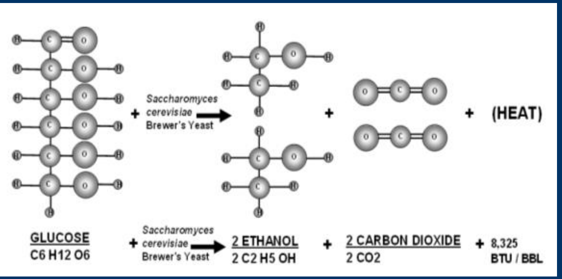
Alpha Fermentation Processes

Columbus Reaction Kinetics & Material Balance

(Reference # 3, Pages 480-481)



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

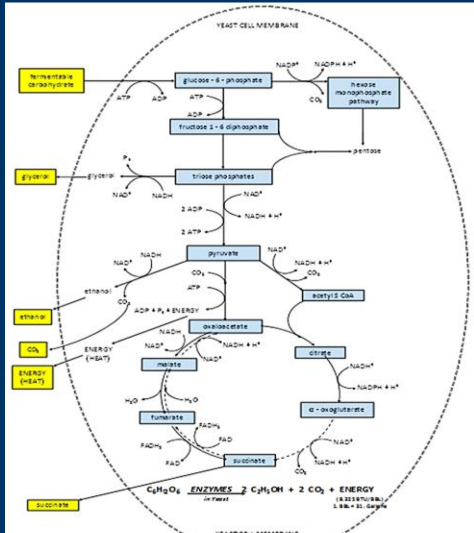
Start CO_2 Collection at Extract Balling = 13.4 ºB = 36.53 Lb Extract / BBL
End CO_2 Collection at Extract Balling = 4.4 ºB = 11.58 Lb Extract / BBL
Extract Fermented: (36.53 – 11.58) = **24.95** Lbs / BBL Total

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>

Sustainable Processes at Anheuser-Busch, Inc.

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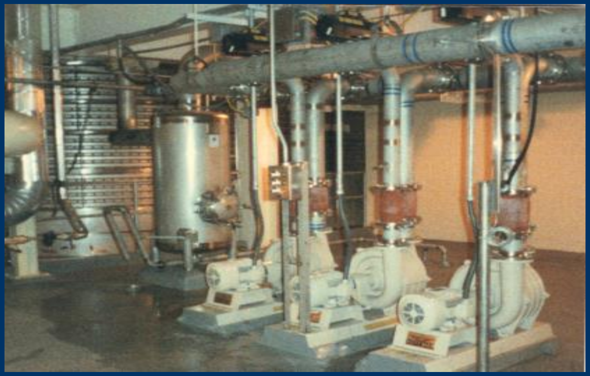


Columbus CO2 Collection: Alpha Fermentation PFD

(Carbon Collection and Storage, CCS)

(Reference # 3, pages 482 – 485)

1. CO_2 Foam Trap: 12,000 Lb/Hr CO_2 at 0.5 PSIG
2. CO_2 Blowers: 12,000 Lb/Hr CO_2
3. CO_2 Booster Compressor: P = 3.5 – 5 PSIG
4. CO_2 Scrubber Packed Columns: Removes keytones & amines
5. CO_2 Carbon Filter Purifiers: Removes organic compounds
6. CO_2 Compressor and Intercooler: P =250 PSIG, T =275-325 F
7. CO_2 Gas Aftercooler: Removes most H_2O, T = 40-45 F
8. CO_2 Dryers: Removes balance of residual H_2O
9. NH_3 Compressor and Cooler: P = 250 PSIG
10. CO_2 Gas Liquifier: Ammonia chilled, T = -8 to -10 F
11. CO_2 Liquid Storage Vessel: 700,000 Lbs (81k Gal) CO_2, 3-day storage
12. CO_2 Liquid Evaporator: Steam heated CO_2 evaporation

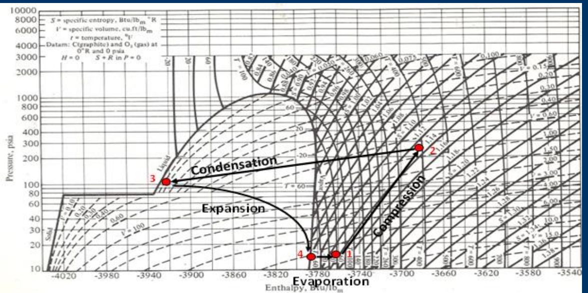
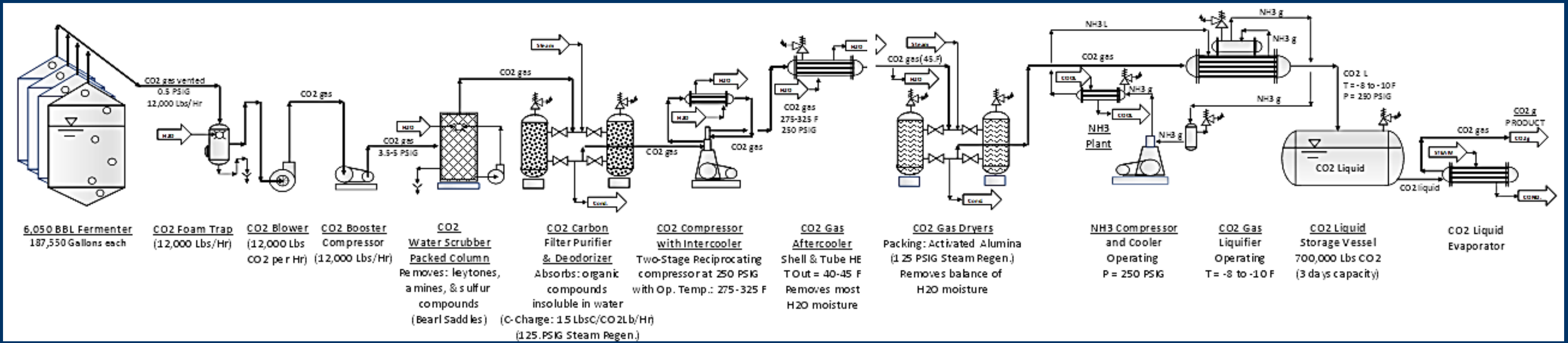


FIG. A-8. Carbon dioxide pressure-enthalpy diagram. (Reproduced by permission from L. N. Canjar and F. S. Manning, *Thermodynamic Properties and Reduced Correlations for Gases*, copyright Gulf Publishing Co., Houston, 1967.)



Sustainable Processes at Anheuser-Busch, Inc.

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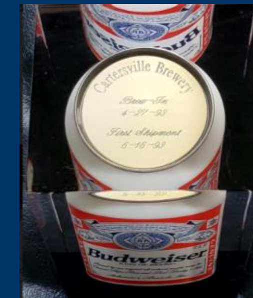
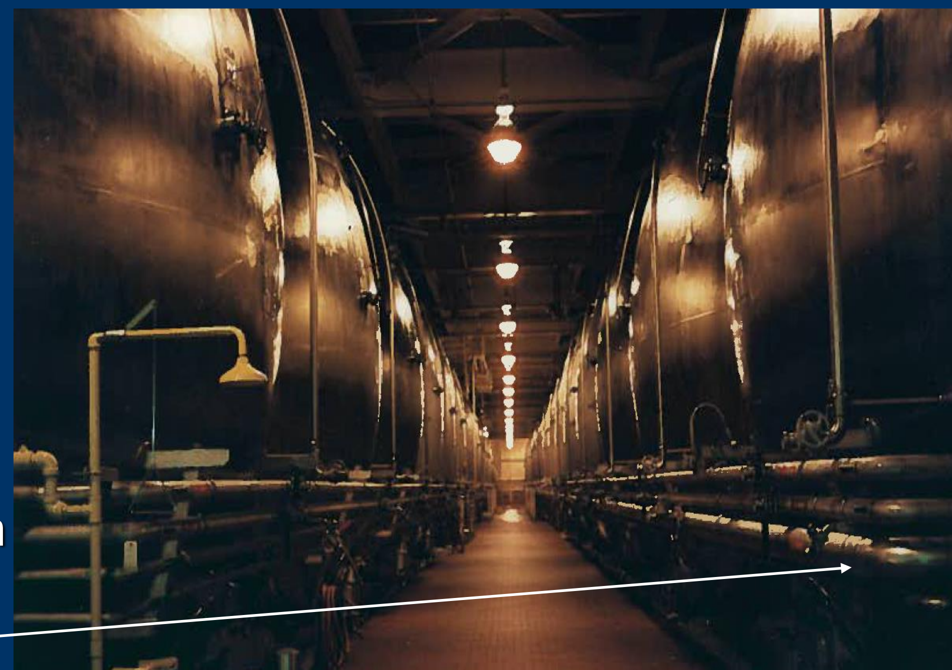
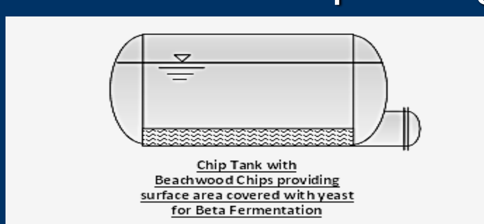


Beta Fermentation Process

Cartersville Brewery Beta Fermentation Cellar, Beachwood 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
- 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
- Manway at vessel bottom tangent for inlet-outlet & chip raking



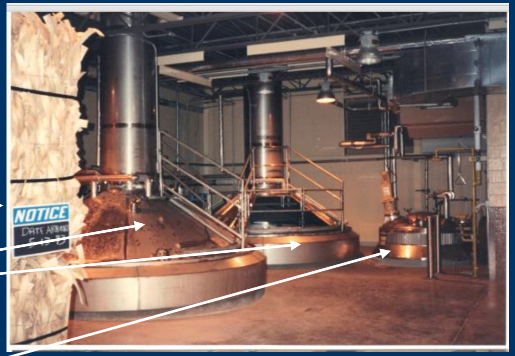


Sustainable Processes at Anheuser-Busch, Inc.

AB

Beta Fermentation Process

- Cartersville Brewery Beachwood Chip Preparation for Beachwood Aging Process in Beta Fermentation
- Chips provide surface area for yeast in Chip Tanks
- Beachwood Chip Bails (New)
- 2 Chip Cookers (one in use & and other in CIP)
    - Initial sterilization of new chips
    - 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



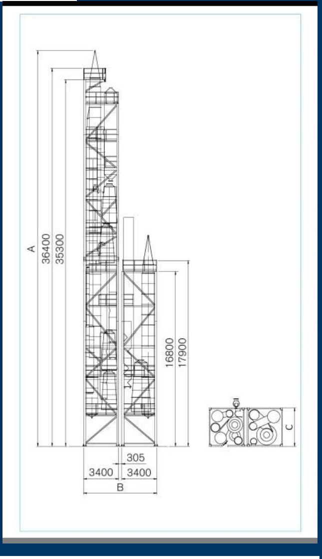
Sustainable Processes at Anheuser-Busch, Inc.

AB

Tampa O'Doul's Production Process:

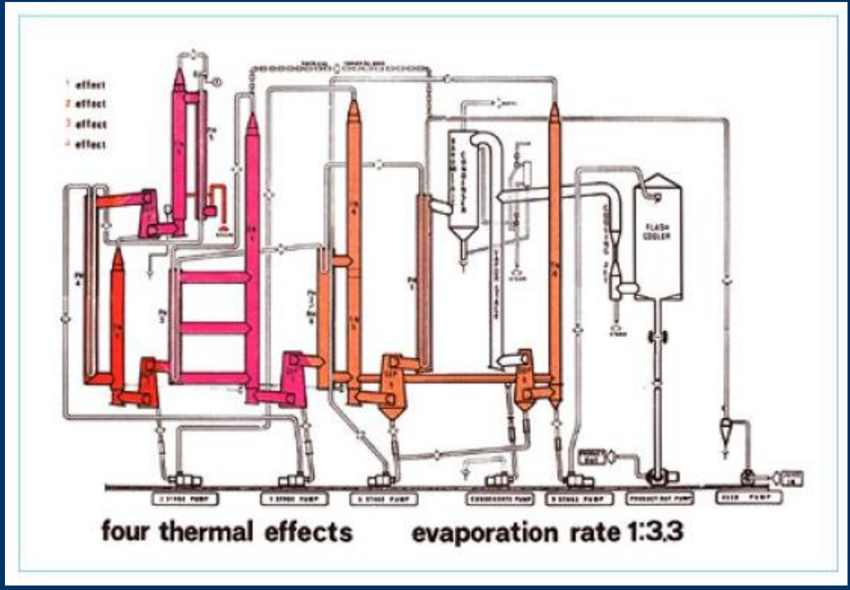
(Reference # 5, Pages 38 – 39)

- Re-carbonate O'Doul's non-alcoholic beer
- Capture CO2 & Ethanol from process for use later
- PFD of Tampa Brewery O'Doul's Evaporation Process (OLD DESIGN) to remove alcohol & CO2
    - 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 CO2 from beer
- CO2 is added after O'Doul's is chilled to 39.F



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)



Sustainable Processes at Anheuser-Busch, Inc.

AB

<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

Sustainable Processes at Anheuser-Busch, Inc.

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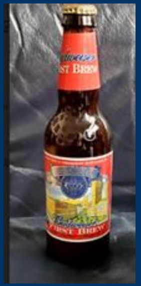
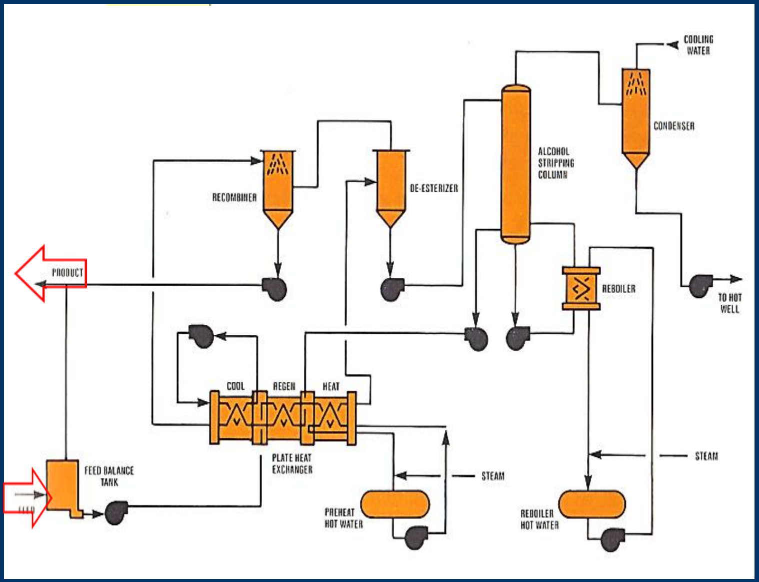


Columbus CO2 from Alpha Fermentation:

(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



Sustainable Processes at Anheuser-Busch, Inc.

AB

Columbus CO2 from Alpha Fermentation:

- 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 15GPM feed & 8,000 Hrs per year operation
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Sustainable Processes at Anheuser-Busch, Inc.

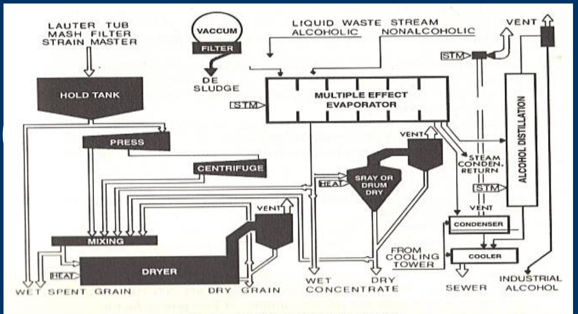

Figure 14. By-product recovery.

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 Mother Liquor into molasses for sale as a 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 Beachwood 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
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**
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 to replace their industrial CO2 purchases
8. Spent Beachwood Chips continue to be shredded for landscape mulch sales and **a new by-product stream** for BBQ wood chips

Sustainable Processes at Anheuser-Busch, Inc.

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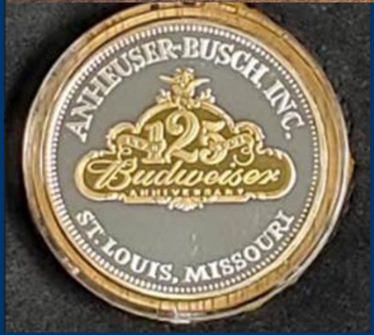

Problems! & Solutions?
Questions? & Answers!

Sustainable Processes at Anheuser-Busch, Inc.

References:

1. Anheuser-Busch, Inc., Introduction to Brewing, Brewing College Training Class
2. Anheuser-Busch, Inc., Basic Brewing, Brewing College, Training Class
3. The Practical Brewer, Master Brewing Association of Americas
4. APV, Dryer Handbook
5. APV, Evaporation Handbook
6. APV, Distillation Handbook