Beverage Fermentation Class

Case Study Workshop

ESG Processes at Anheuser Busch, Inc.

Chemical & Biomolecular Engineering Department

Case Western Reserve University

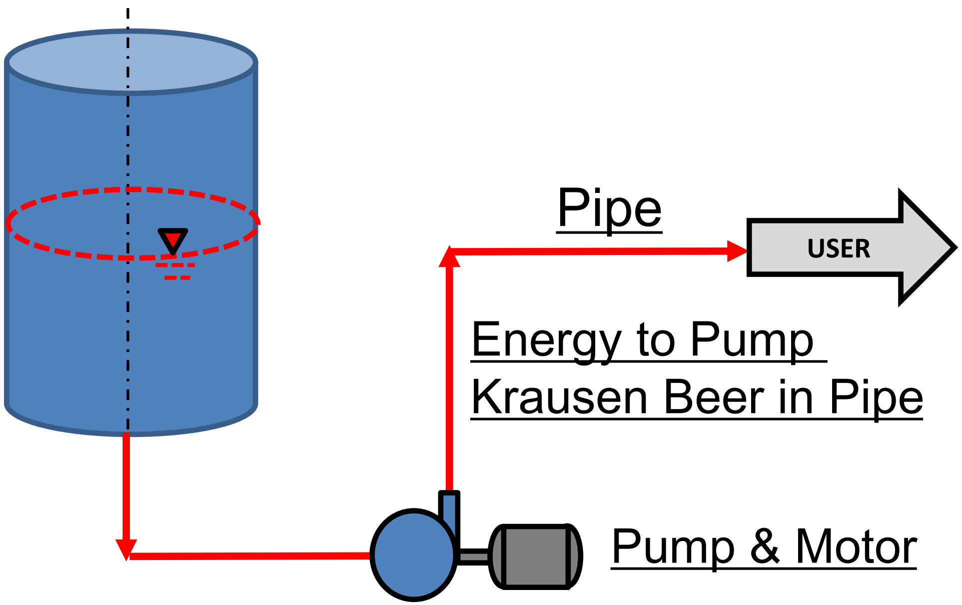
Joseph Yurko, PE, AIChE Fellow

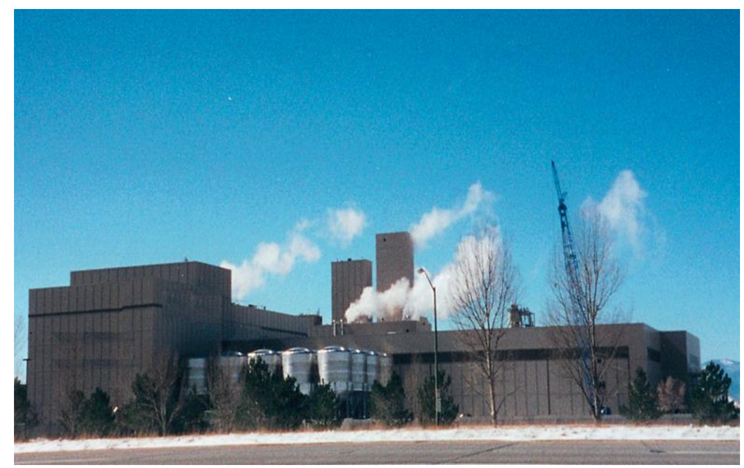
May 27, 2025

Beverage Fermentation Class Case Study Workshop
ESG Processes at Anheuser Busch, Inc.

Brewery Fermentation Transfer of Beer

Calculate the Energy to Pump a Fluid in a Pipe and the
Carbon Footprint of the Pumping Energy after Optimizing the Pipe Size





Carbon Footprint of Pumping Energy

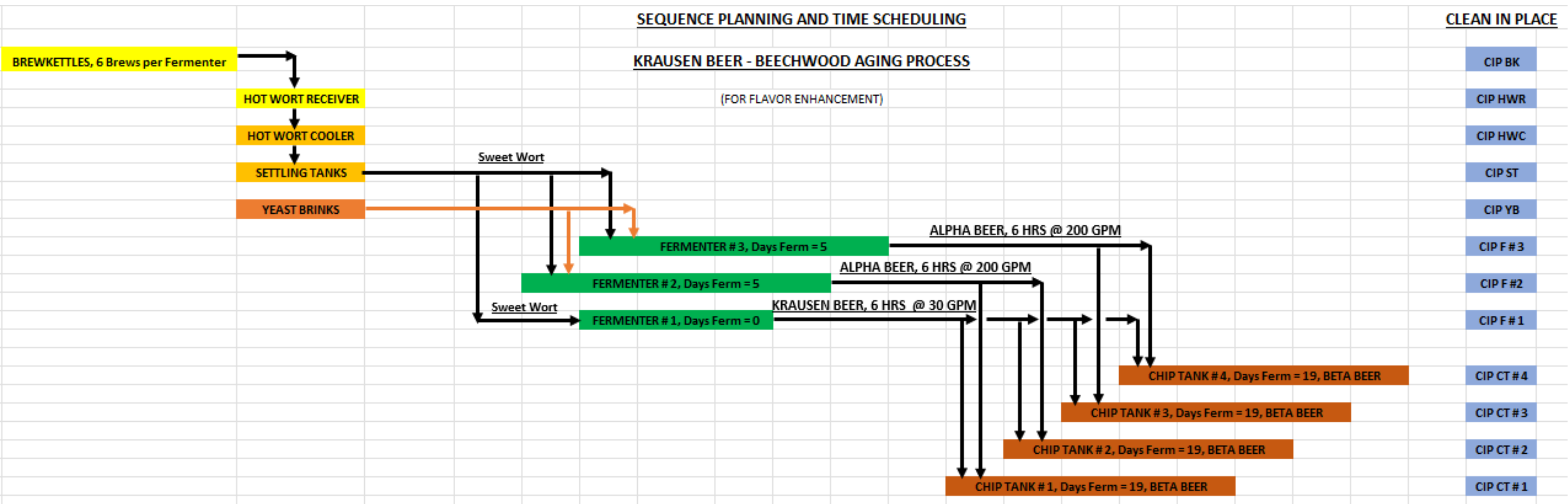
Beverage Fermentation Class Case Study Workshop
ESG Processes at Anheuser Busch, Inc.

Brewery Fermentation Transfer of Beer

Energy Calculations with Fluid Hydraulic Pump Head

Class needs to evaluate the optimum pipe size:

- **Exercise # 1 for Class**
- Beechwood Aging Process
- Krausening Transfer Line
- Motivation: Schedule Alpha Beer Transfer with Krausen Beer



Beverage Fermentation Class Case Study Workshop
ESG Processes at Anheuser Busch, Inc.

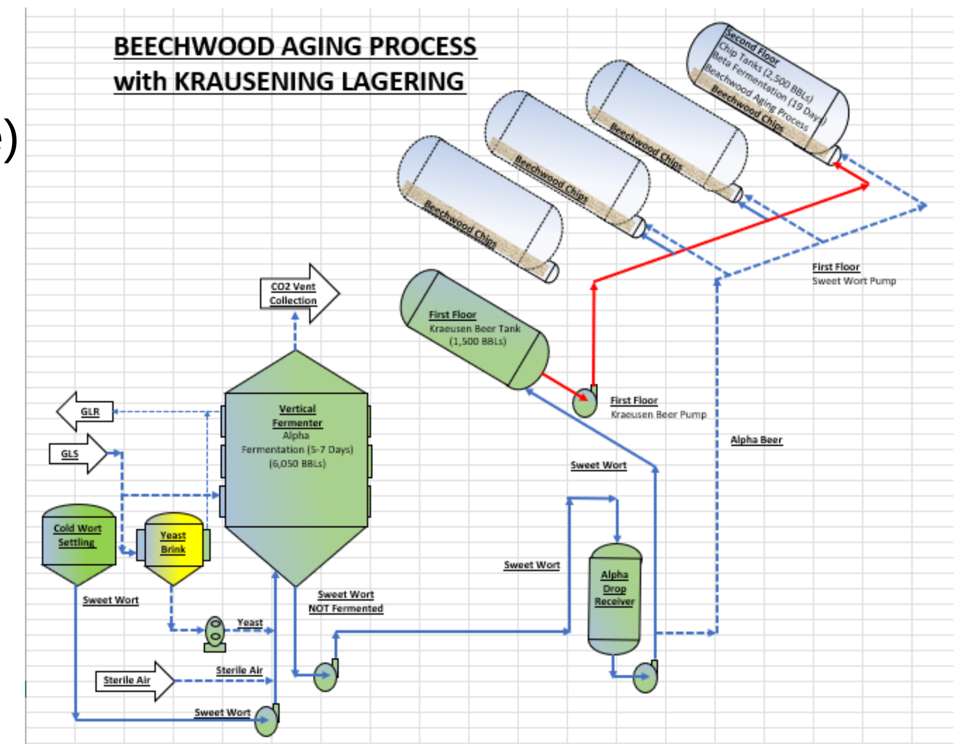
Brewery Fermentation Transfer of Beer

Energy Calculations with Fluid Hydraulic Pump Head

Class needs to evaluate the optimum pipe size:

- **Exercise # 1 for Class**

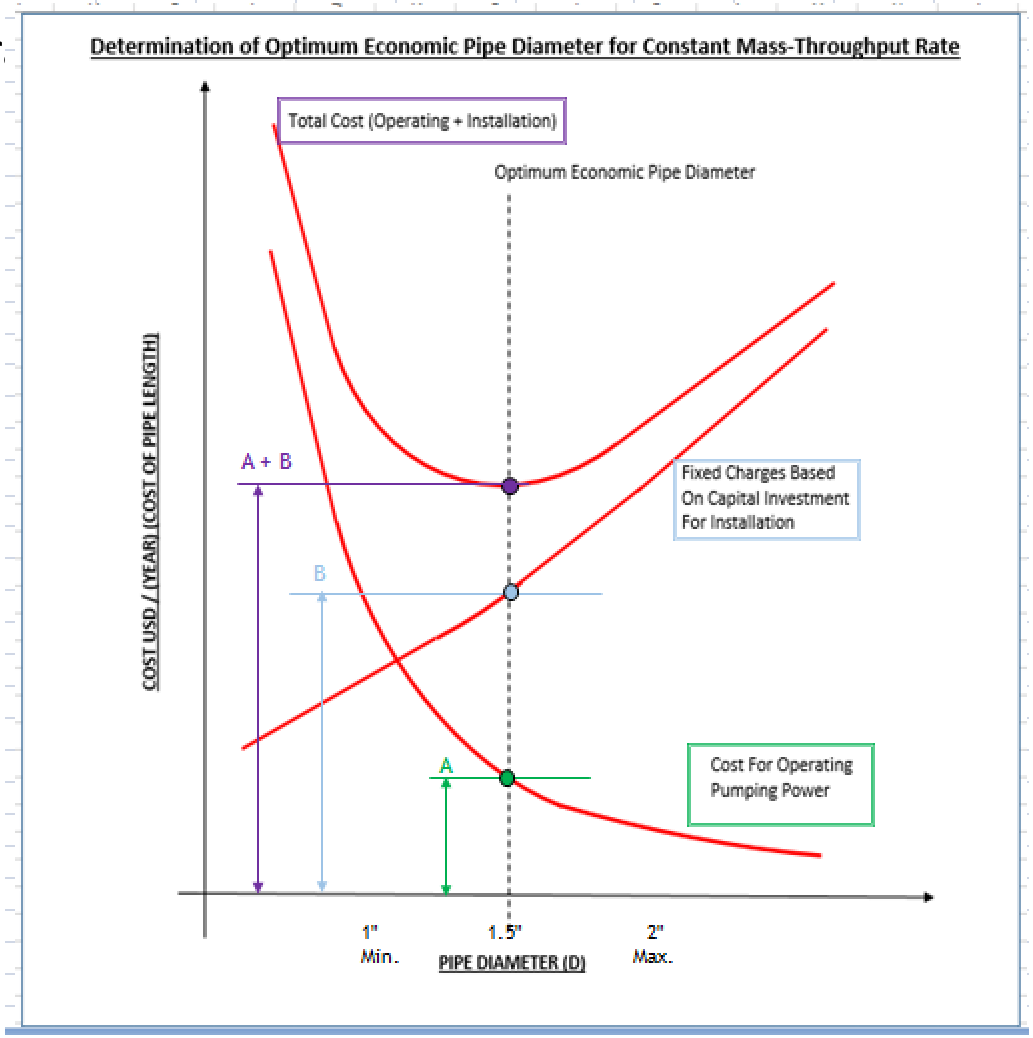
- Beechwood Aging Process
- Krausen Beer Transfer Line (Red Line)
- Criteria
  - Chip Beer from Alpha Fermenter
    - 2500 BBL, 200 GPM, 6 Hrs.
  - Krausen Beer from Settling Tank
    - 375 BBL, 30 GPM, 6 Hrs.
  - Yeast Injection to Krausen Wort
    - 11 BBL, 1 GPM, 6 Hrs.



Beverage Fermentation Class Case Study Workshop
ESG Processes at Anheuser Busch, Inc.

Brewery Fermentation Transfer of Beer

Energy Calculations with Fluid Hydr



How to calculate the Optimum Pipe Size (Min. – Max.):

- Trial & Error Technique
- Bisection Method
- Based on Flow Rate (gpm)
- First Try Minimum Dia. (1”)
- Secondly Try Maximum Dia. (2”)
- Select Value in between (1.5”)

Beverage Fermentation Class Case Study Workshop
ESG Processes at Anheuser Busch, Inc.

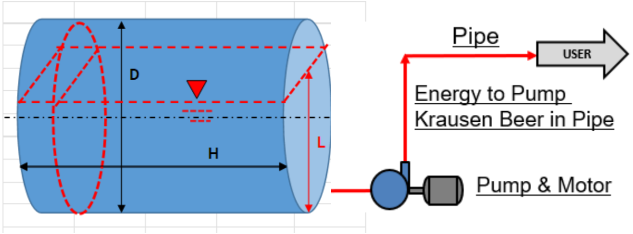
Brewery Fermentation Transfer of Beer

Calculate the Energy to Pump a Fluid in a Pipe and the
Carbon Footprint of the Pumping Energy after Optimizing the Pipe Size

Energy Calculations with Fluid Hydraulic Pump Head

Needed to calculate the optimum pump motor size:

- Pipe inside diameter (d)
- Pipe Equivalent Length (L)
- Installed Linear Length of pipe cost per foot ($/ft)
- Fluid (BKR) flow rate (gpm)
- Fluid (BKR) density (ro) and viscosity (cP)
- Pump efficiency (ep), estimated
- Pump motor cost ($) and motor efficiency (em)
- Pump operating electrical power conversion to a Carbon Footprint (not the pump Life Cycle Analysis, LCA is beyond the scope of this workshop)



Beverage Fermentation Class Case Study Workshop
ESG Processes at Anheuser Busch, Inc.

Brewery Fermentation Transfer of Beer

Class needs to evaluate the Optimum Pipe & Pump size:

- **Exercise # 1 for Class to generate the Optimum Pipe size**
- Using Fluid Flow Equations to the right, Calculate
    1. Three Velocities for Line sizes
    2. Three Reynolds Numbers for Lines
    3. Three Friction Factors for Lines
    4. Three Head Losses for Lines

					BISECTION METHOD SOLUTION			
					SMALL	LARGE	MIDPOINT	
				Nominal Size	1"	2"	1.5"	Inch
Pipe Fluid Flow Velocity		**Run # 1**	**Run # 2**	**Run # 3**	**Run # 1**	**Run # 2**	**Run # 3**	**Units**
Constant Flow Rate (Q) =	**(GIVEN)**			**Q**	30	30	30	**GPM**
Schedule 5 S Inside					Actual Inside Dimension			
Pipe Diameter (d) =	**(GIVEN)**			**d**	1.1850	2.2450	1.7700	**Inch**
Pipe Installed Cost/Foot =	**(GIVEN)**				$10.00	$20.00	$12.50	**$ / Ft**
Pipe Equivalent Length =	**(GIVEN)**				1,000	1,000	1,000	**Ft**
Pipe Installed Cost (est.) =	**(GIVEN)**	(Material Cost)			$10,000	$20,000	$12,500	**$**
Fluid Velocity (v) =		$\frac{0.408 * Q}{d^2}$ = **v**		**(FIND) V**				**Ft / Sec**
Fluid Density (ro) =	**(GIVEN)**		**(Krausen Beer)**	**ro**	62.6	62.6	62.6	**Lbs / Cu Ft**
Fluid Viscosity (cP) =	**(GIVEN)**		**(Krausen Beer)**	**cP**	1.1	1.1	1.1	**cP**
Reynolds Number (Nre) =		$\frac{123.9 * ro * v * d}{cP}$ = **Nre**		**(FIND) Nre**				N/A
Fluid Specific Gravity (SG) =	**(GIVEN)**		**(Krausen Beer)**		1.10	1.10	1.10	N/A
Friction Factor (f) =	1.8 LOG	$\frac{Nre}{7}$	^(-2) = **f**	**(FIND) f**				N/A
Head Loss (Ft/1,000')=	0.0311 * f * 1,000 * Q^2 / d^5			**(FIND) hL**				**Ft / 1,000'**

Beverage Fermentation Class Case Study Workshop
ESG Processes at Anheuser Busch, Inc.

Brewery Fermentation Transfer of Beer

Class needs to evaluate the Optimum Pipe & Pump size:

- **Exercise # 2 for Class to generate the Pump Horsepower**
- Using Fluid Flow Equations below, Calculate
    1. Three Pump Break Horsepower values for the Lines
    2. Three Pump Motor Horsepower values for Lines
    3. Three Pump Horsepower values for Lines
    4. Three Pump Motor Energies for the Lines

Pump Efficiency (ep)=	**(GIVEN)**	**ep**	0.70	0.70	0.70	N/A
Pump Brake Hp (BHp) =	Q * Ft * SG / 3,960 / ep =	**(FIND)**				**BHp**
Motor Efficiency (em) =	**(GIVEN)**	**em**	0.65	0.65	0.65	N/A
Pump Motor Horsepower (MHp) =	BHp / em =	**(FIND)**				**MHp**
Pump Horsepower (Hp) =	**(PUMP MOTOR HP TABLE)**	**(FIND)**				**Hp**
Pump Motor Energy (W) =	MHp * 745.7 Watts/Hp =	**(FIND)**				**Watts**

Beverage Fermentation Class Case Study Workshop
ESG Processes at Anheuser Busch, Inc.

Brewery Fermentation Transfer of Beer

Class needs to evaluate the Optimum Pipe & Pump Size:

- **Exercise # 3 for Class to generate the Pump Motor Operating Carbon Footprint**
- Using Fluid Flow Equations below, Select & Calculate:
    1. Select Three Pump Motor Costs from Table below
    2. Calculate Three Pump Motor Operating Costs
    3. Calculate the System Installation Costs for Three Pumps
    4. Calculate the Three Pump Motor Operating Carbon Footprint Values
    5. Select the BEST Pipe & Pumping Size

	Pump Motor Installed Cost =	**(PUMP MOTOR HP TABLI**	**(FIND)**				$
	Pump Motor Operating Cost =	Watts * $0.07 / W =	**(FIND)**				$
				1" Dia.Min.	2" Dia.Max.	1.5" Dia.	
	System Instal & Oper. Cost =	Pipe Cost + Motor Cost + Op Cost =	**(SOLUTION)**				$
*	Operating Carbon Footprint (CFP) =	Lbs CO2 / 1,000 Hr =	**(SOLUTION)**				**CFP**
	(Not a Pump CFP Life Cycle Analysis)						
	Most Sustainable (OPTIMUM) =		**(SOLUTION)**				

STANDARD PUMP MOTOR HORSEPOWER & COST (estimated) TABLE

0.25	Hp	$100	**3**	Hp	$1,200	**25**	Hp	$10,000	**100**	Hp	$40,000
0.5	Hp	$200	**5**	Hp	$2,000	**30**	Hp	$12,000	**125**	Hp	$50,000
0.75	Hp	$300	**7.5**	Hp	$3,000	**40**	Hp	$16,000	**150**	Hp	$60,000
1	Hp	$400	**10**	Hp	$4,000	**50**	Hp	$20,000	**200**	Hp	$80,000
1.5	Hp	$600	**15**	Hp	$6,000	**60**	Hp	$24,000	**250**	Hp	$100,000
2	Hp	$800	**20**	Hp	$8,000	**75**	Hp	$30,000	**300**	Hp	$120,000

Sustainable Engineering, Principles and Practices, Dr. Bakshi, Cambridge University Press, 2019
Chapter 9, Inventory Analysis
Table 9.2, Typical Life Cycle Inventory Data from Input-Output Models

Reference: 221100; Y. Yang, W.W. Ingwersen, T.R. Hawkins, M. Srocka, and D.E. Meyer; USEEIO: A New and Transparent United States Environmentally Extended Input-Output model, *Journal of Cleaner Production*, 158: 308-318, 2017

	Flow	**Units**	**Reference**	**Electricity**
*	CO2	kg / $	221100	6.27E+00

HIGH	LOW	MIDPOINT	
Run # 1	**Run # 2**	**Run # 3**	
INPUT	INPUT	INPUT	
OUTPUT	OUTPUT	OUTPUT	
18,248	863	2,682	Watts
1	1	1	Hours
18,248	863	2,682	Wh
18.2	0.9	2.7	kWh

The Bedford Industrial Cost of Electricity is : $0.07 kWh

Determine the Life Cycle of CO2 emissions for this system based on an Input-Output model

IO Model Life Cycle CO2 Emissions =

*	Run # 1 =	6.27E+00	kg / $	$0.07 / kWh	18.2	kWh =	8.0	kg CO2 =	**17.6**	**Lbs CO2**
*	Run # 2 =	6.27E+00	kg / $	$0.07 / kWh	0.9	kWh =	0.4	kg CO2 =	**0.8**	**Lbs CO2**
*	Run # 3 =	6.27E+00	kg / $	$0.07 / kWh	2.7	kWh =	1.2	kg CO2 =	**2.6**	**Lbs CO2**

Beverage Fermentation Class Case Study Workshop
ESG Processes at Anheuser Busch, Inc.

Brewery Fermentation Transfer of Beer

References: