Solid/Liquid Separation in the Brewhouse

John Hancock & Paul Banham – Briggs of Burton

IBD Midlands / BFBi – Derby - February 2019

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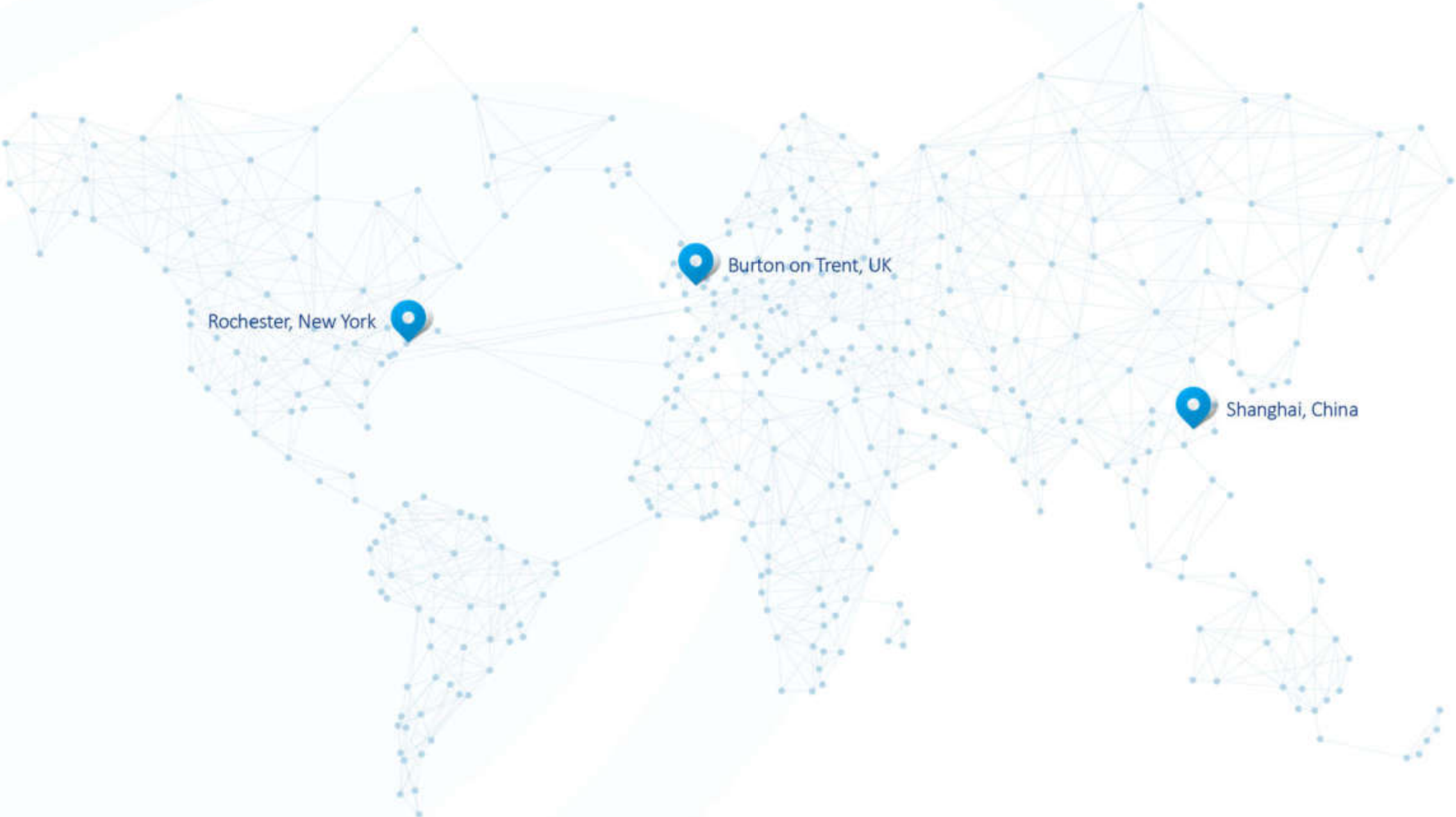
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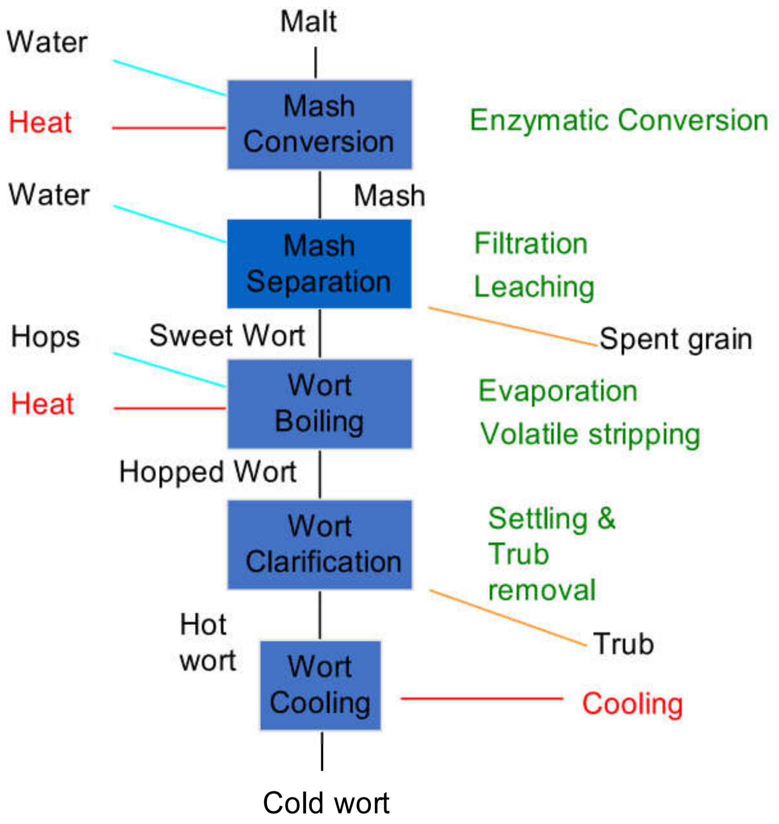
Solid/Liquid Separation in the Brewhouse

- Solid/Liquid Separation
- Mash/Wort Separation
  - Process
    - Filtration and
    - Leaching (Sparging)
  - Technology
- Wort/Trub Separation
  - Process
    - Sedimentation (Settling) or
    - Filtration
  - Technology

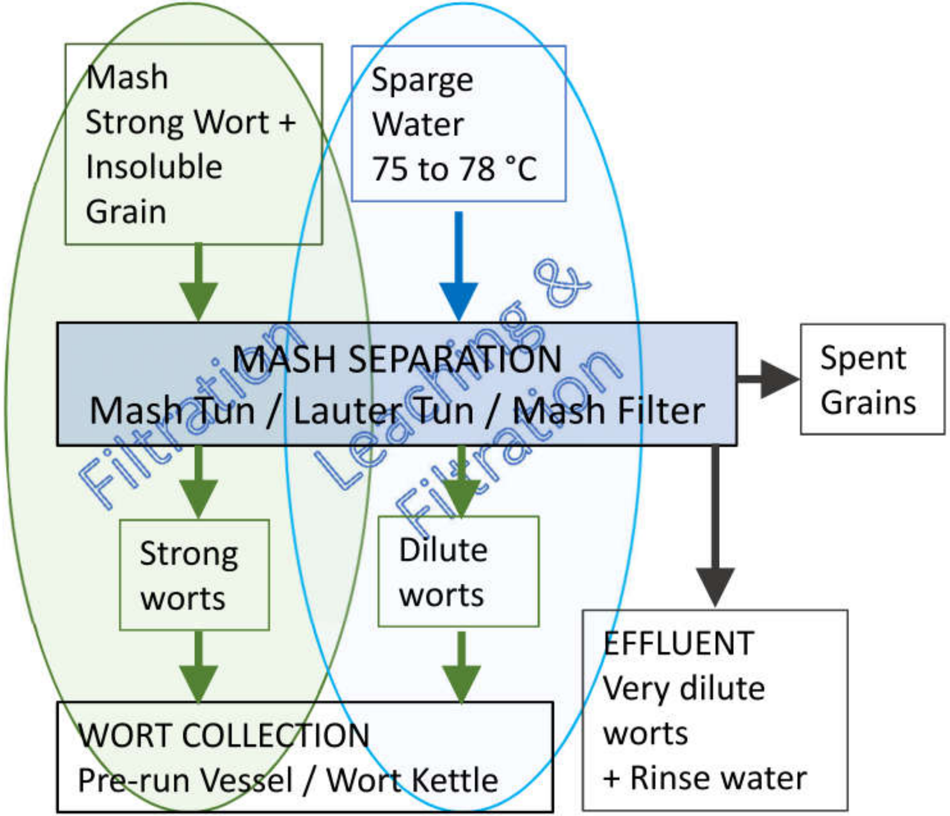
Separation in the Brewhouse Process

- Mash/Wort Separation
  - Process
    - Filtration AND
    - Leaching
  - Technology
    - Lauter Tun
    - Mash Filter
    - Infusion Mash Tun
    - Nessie
- Wort/Trub Separation (Clarification)
  - Process
    - Sedimentation (settling) OR
    - Filtration
  - Technology
    - Whirlpool
    - Hopback
    - Hot Wort Centrifuge



Mash Separation - Objectives

- Mash Filtration
  - Separation of Clear Wort from grain bed
  - Malt husks form a filter aid
- Sparging
  - Leaching of remaining extract from grain bed using hot Sparge water
  - Mass transfer from mash solids to clear wort
  - Filtration continues
- Spent Grains Disposal - by-product



Mash Filtration – Process Theory

- Filtration (Run-off) Flow ‘Q’ is increased by :
  - Increasing Porosity ‘K’ (Coarser grind, Lautering)
  - Increasing Pressure Difference ‘P’ (Sparge flood, Top Pressure)
  - Increasing Filter Area ‘A’ (Larger Tun diameter)
  - Reducing Filter Bed depth ‘L’ (Larger Tun diameter)
- Sparged Worts will also have to be Filtered
  - Coarser Grind will reduce extract recovery – see Sparging

$$Q = \frac{K \times \Delta P \times A}{\mu \times L}$$

Mash Filtration - First Worts Flow - Theory

$$\underset{\text{Wort Flow}}{Q} = \frac{\underset{\text{Grain Bed Porosity}}{K} \times \underset{\text{Pressure Drop across Grain Bed}}{P} \times \underset{\text{Filter Surface Area}}{A}}{\underset{\text{Wort Viscosity}}{\mu} \times \underset{\text{Grain bed Depth}}{L}}$$

(D'Arcy Equation)

Example based on 10 Te grist

				Mash Tun	Lauter Tun	Mash Filter
Ø	**Tun dia**	*m*		5.5	8.0	20.6
K	**Porosity**	*Coarse fraction - plansifter*		45	25	5
P	**Pressure - bar**	*Typical*		0.02	0.02	0.5
A	**Filter surface Area - m^2**			24	50	333
µ	**Viscosity**	*Inverse of mash L/kg ratio*		0.4	0.3	0.4
L	**Bed depth -m**	*Grain bed*		0.78	0.36	0.04
Q	**Flow**	*Relative*		69	231	53031
Q	**Theoretical Flow Ratio**		*MT = 100%*	100%	335%	76,850%
	Relative Flux Rate - Flow/m^2			2.9	4.6	159
	Theoretical Flux Rate Ratio		*MT = 100%*	100%	160%	5,500%

Note – This is an illustration only, using grist sieve analysis and mash ratio as indication of porosity and viscosity

Mash Filtration - First Worts Flow – Practice

		MASH TUN	LAUTER TUN	MASH FILTER
Tun Diameter	m	5.5	8.0	20.6
Wort Collection Volume	hl	155	200	200
Wort Collection Time	min	75	50	25
Wort Collection Flow	hl/hr	124	240	480
Actual Wort Flow Ratio	%	100%	195%	390%
Actual Filtration Flux	$hl/hr/m^2$	6.2	4.8	1.4
Actual Filtration Flux Ratio	%	100%	77%	23%
Theoretical Filtration Flux Ratio	%	100%	160%	5,500%

Mash Leaching (Sparging) - Theory

- Mass Transfer Rate 'W' is increased by :
  - Increasing 'K'
    (e.g. by higher temperature)
  - Increasing Interfacial Area 'A' (Finer grind)
  - Increasing Concentration Difference 'C' (More / better distributed sparge)
  - Reducing Diffusion Distance 'b' (Finer Grind)
- Sparged Worts also have to be Filtered
  - Finer Grind reduces Filtration rate

$$W = \frac{K \times A \times \Delta C}{b}$$

Mash Leaching (Sparging) - Practice

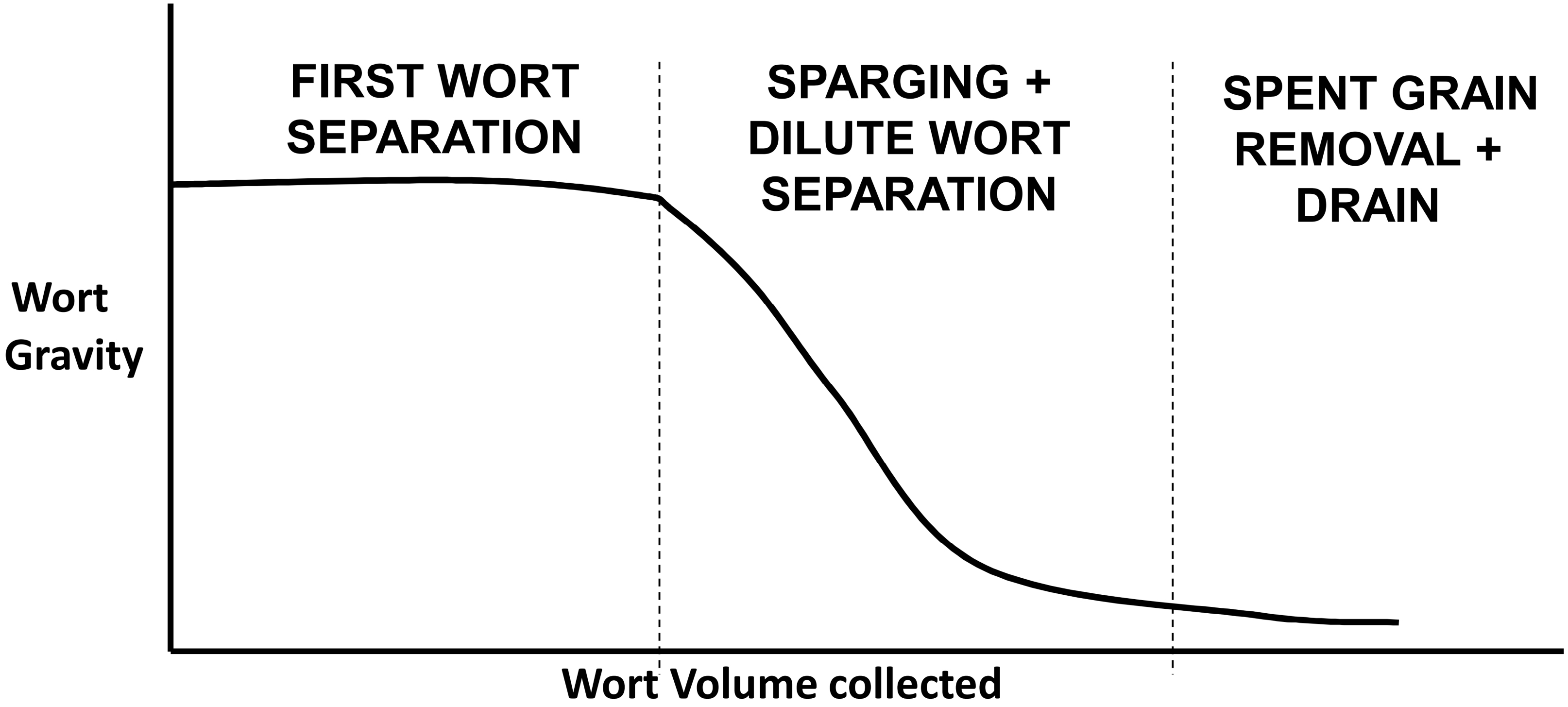
Example

10 Te grist

			Mash Tun	Lauter Tun	Mash Filter
	Tun Diameter (*or equivalent*)		**5.5 m**	**8.0 m**	**20.6 m**
A	Filter Area	m^2	24	50	333
	Dilute Wort Collection Volume	hl	520	440	280
	Dilute Wort Collection Time	min	150	55	60
	Average Wort Concentration	kg/hl	6.74	7.51	9.43
W	Average Mass Transfer Rate	kg/hl.h	2.7	8.2	9.4
	Mass Transfer Ratio		*100%*	*300%*	*350%*
	Relative Mass Transfer / unit Area	$kg/hl.h.m^2$	0.11	0.16	0.03
	Mass Transfer / unit Area Ratio		*100%*	*146%*	*25%*

Note – This is an illustration only.

Wort Collection – Gravity Profile



Mash Separation – Practical Objectives

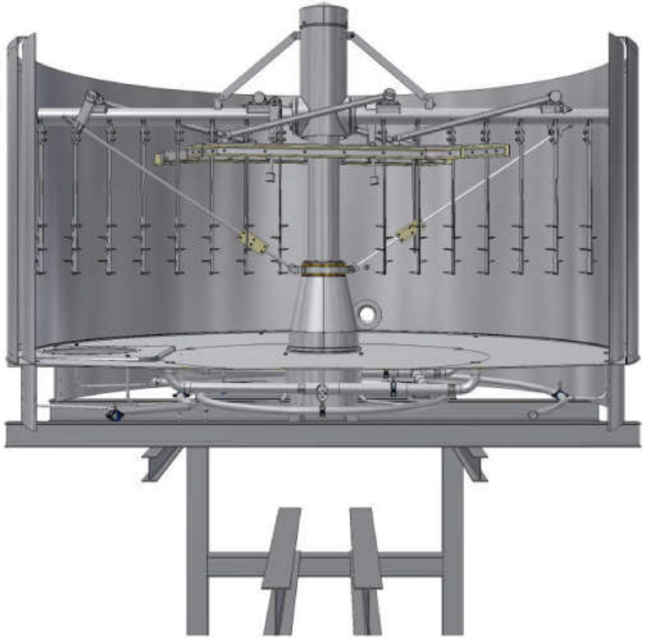
1. Turn Around Time
   - Consistent within design constraints
     - Bed loading, grist particle size, mash handling, malt quality
2. Extract Recovery
   - 100% recovery of soluble extract created at mashing using minimum sparge water (process intensification)
3. Wort Quality
   - Low settleable solids
   - Low colloidal fine particles
   - Low oxygen pick up
4. Spent Grains
   - Minimum Moisture
5. Minimum Operating Costs
   - Effluent
   - Consumables
   - CIP

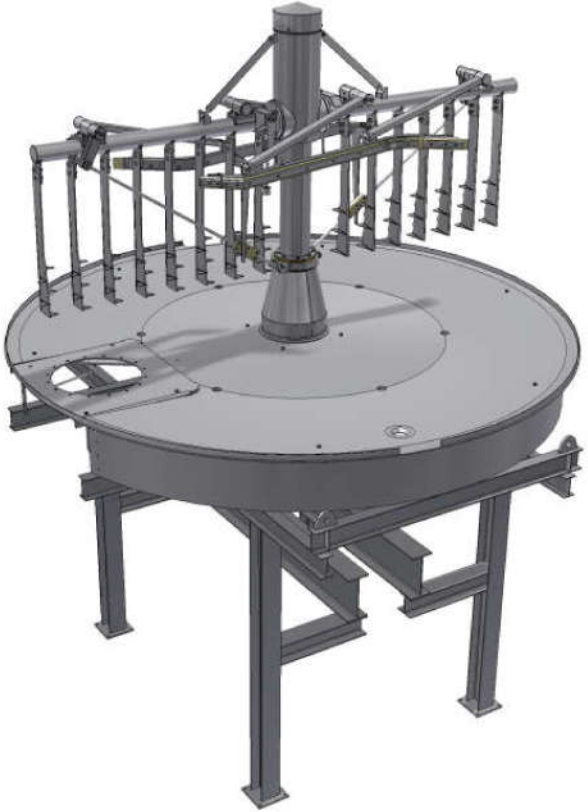
Lauter Tun - Design

- Lauter tun Size
- Mash Distribution
- Wort Collection
- Sparge Distribution
- Lautering
- Grains Discharge
- Underplate Flush
- Loading & Cycle time
- Low shear & Min O2 pickup
- Even run-off
- Sparge Nozzles
- Knife design & speed
- Plough & Grain Valves
- Jetting Nozzles

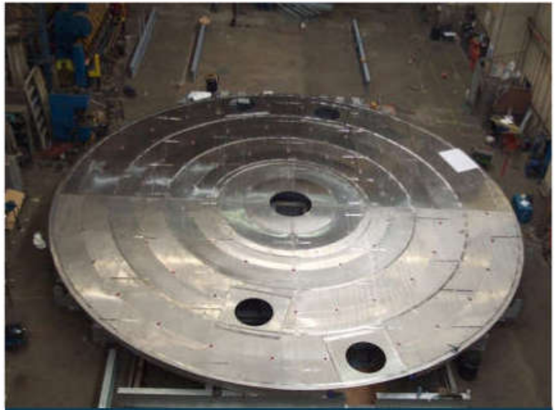
Lauter Tun - Features

- Large diameter
- Slotted False Bottom
- Mash Distribution
- Sparge Distribution
- Lauter knives
- Grains Discharge
    - Plough Bar
- Grains Valves
- Lauter Drive



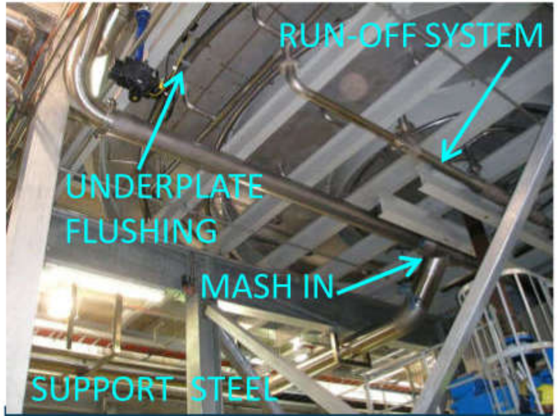


Lauter Tun - Features



Valley Bottom

Showing Grains ports



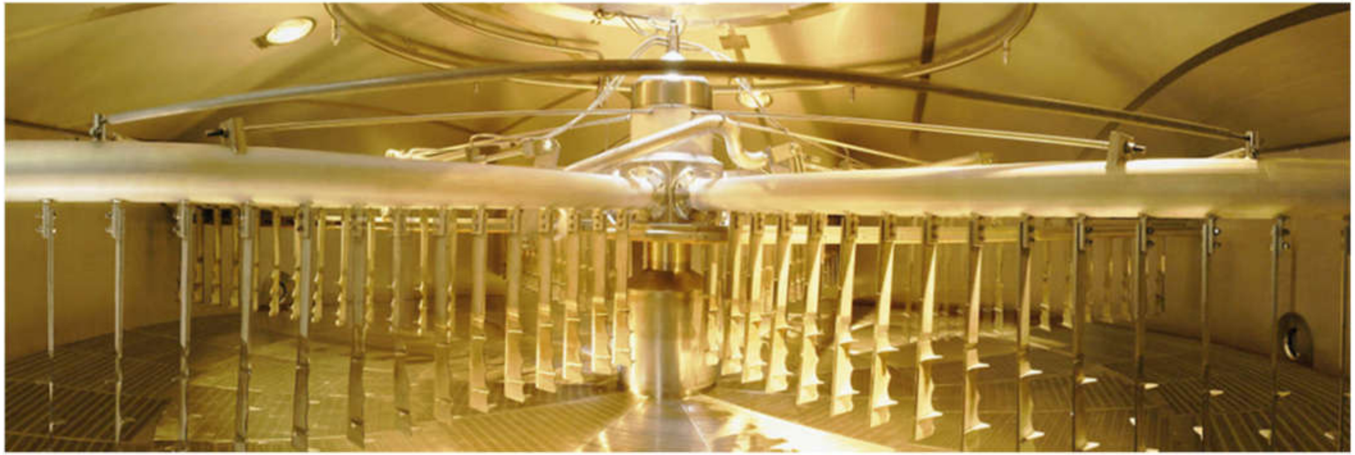
Below Tun

Mash, Wort & Flushing pipework

Grains Valve

800 mm dia with Machined False bottom

Lauter Machine



- 6 arms
- St St knives
- Plough Bar
- Height & Rotation
  - Auto control vs ΔP
  - VSD controlled

Brewery Lauter - Operation

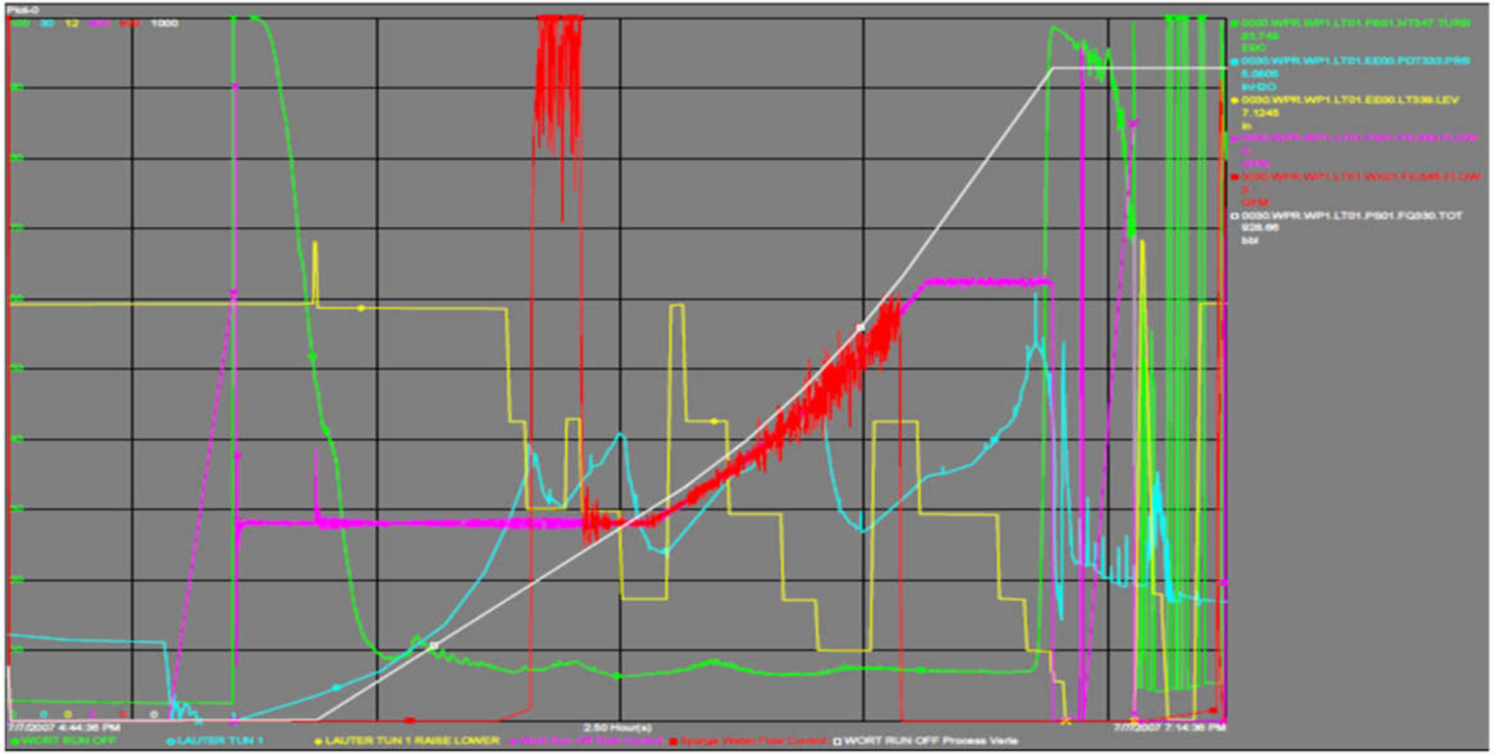
- Plate Flood
- Mash-in
- Recirc (Vorlauf)
- Wort Collection (Run-off)
- Drain
- Discharge Grain
- Underplate Flush

} *Overlap*

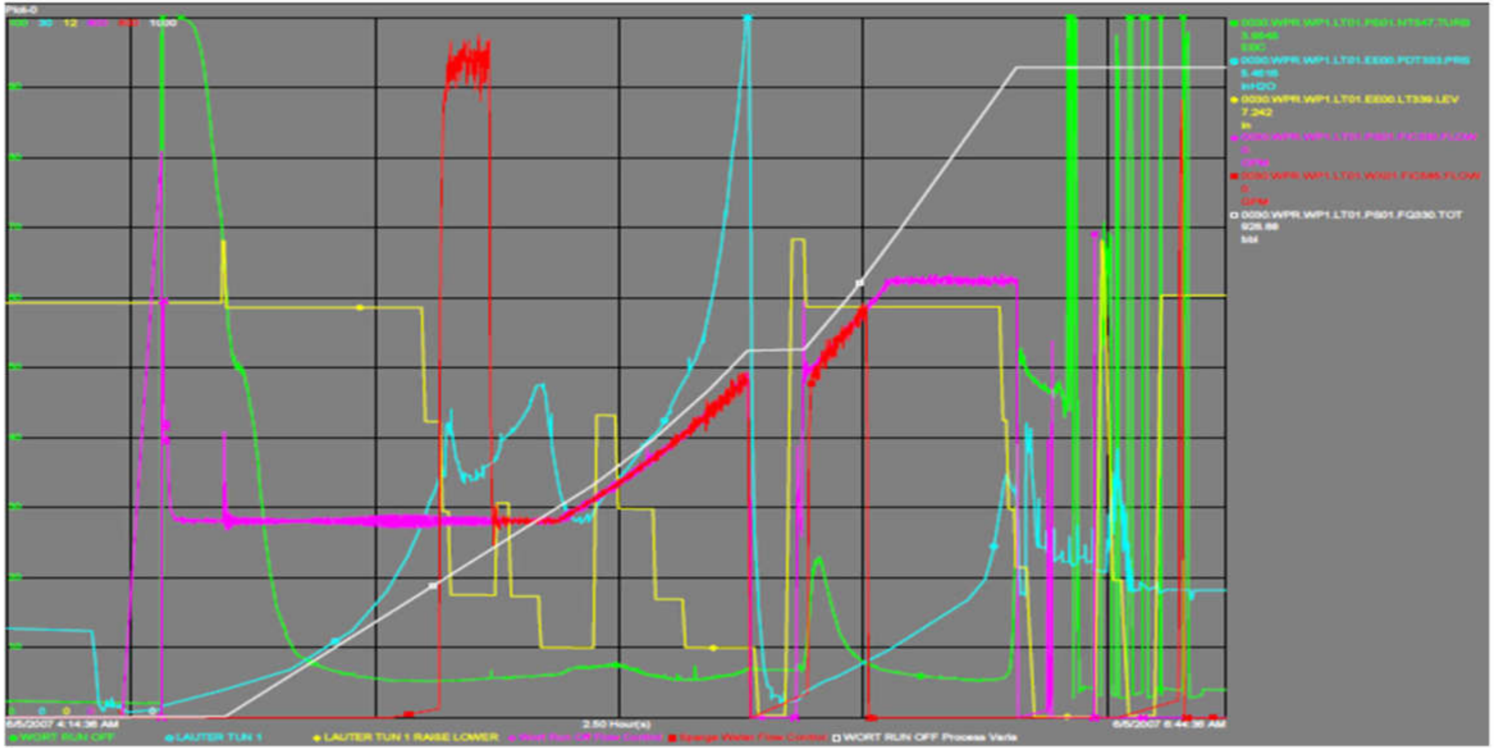
- First Worts
- Sparge
- Last Worts

} *Overlap*

Brewery Lauter Tun Operation - 12 Brews/Day at 160kg/m²



Brewery Lauter Tun Operation - 12 Brews/Day at 160kg/m² - with DBR

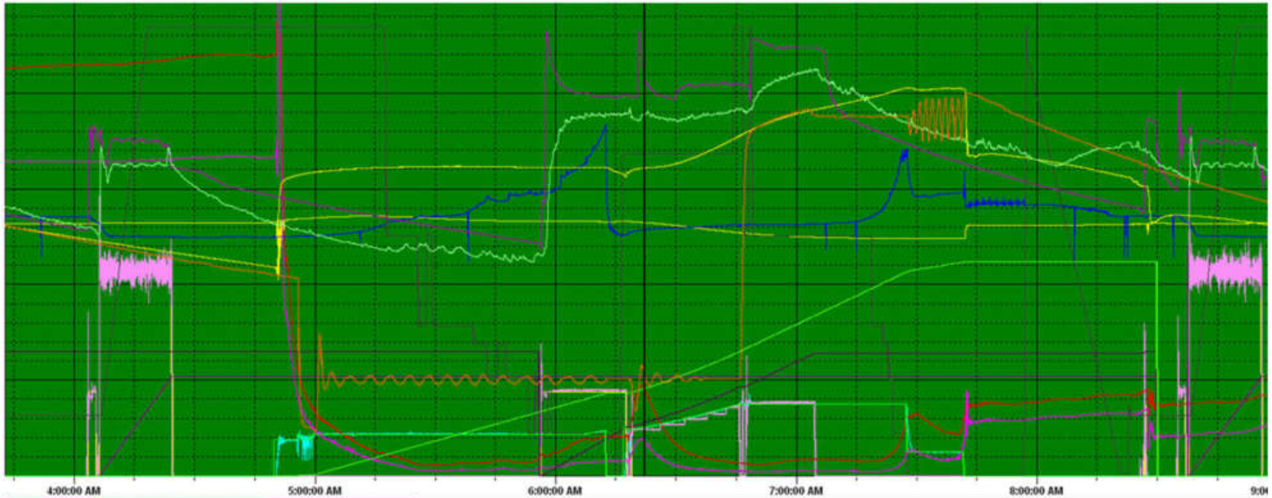


Malt Distillery Lauter Tun - with Steeles Masher

Steeles Masher

- Positive flow path
- Gentle mechanical mixing
- VSD Controlled
- Effective with –
  - fine grist
  - low (thicker) mash ratio
- Essential with Distillery Lauter Tun or Infusion Mash Tun
- Improved extract recovery with fine grist (MF)

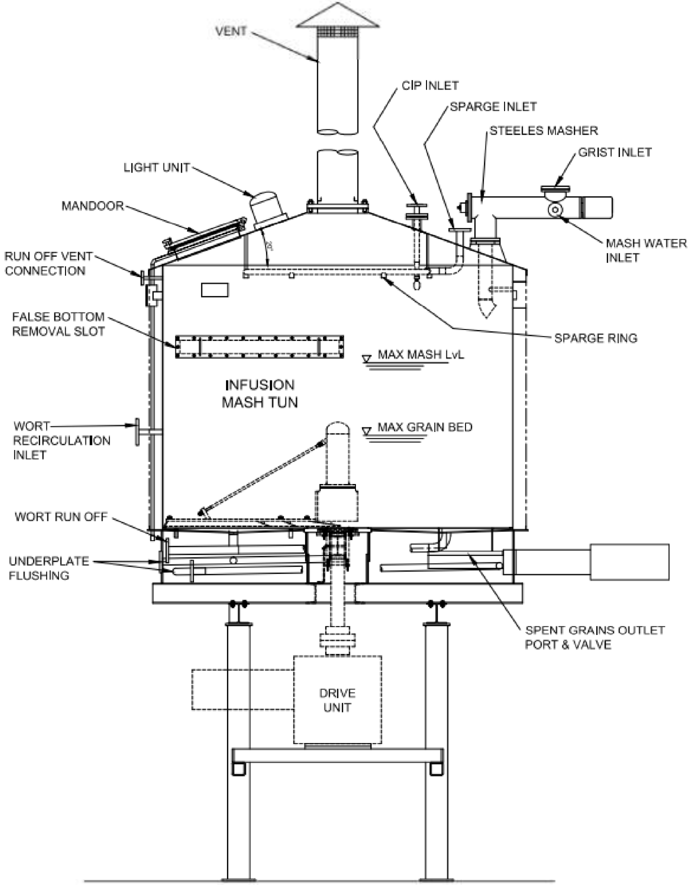
Malt Distillery Lauter Tun Operation



- Thin Mash – 4 L/kg
- Conversion in Tun (stand)
- Large Weak Wort Volume = Mash Water
- High final sparge temperature

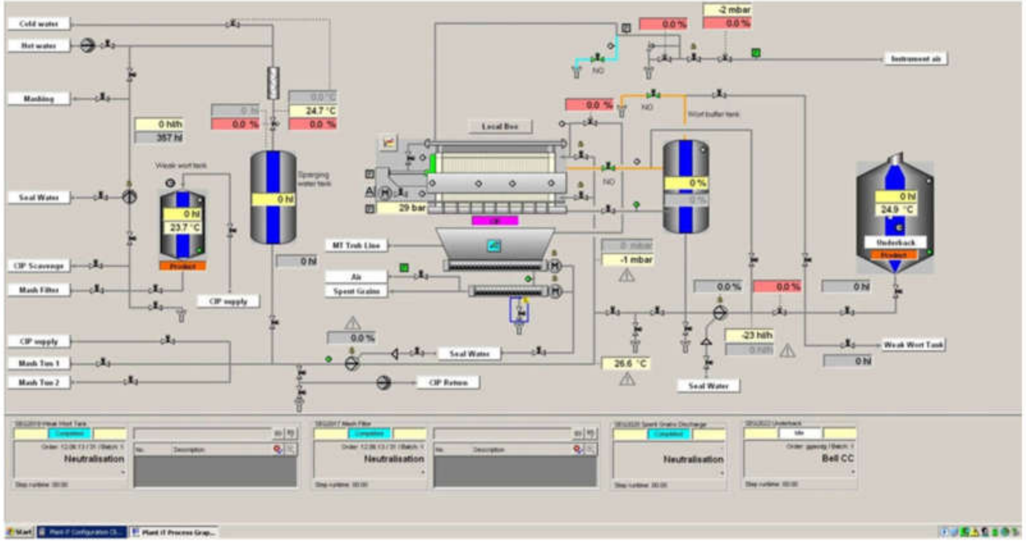
Infusion Mash Tun

- Traditional Ale Brewing
- Combines Mash Conversion & Separation in one Unit
- Similar to Distillery Mash / Lauter Tun
- Normally used with Steeles Masher
- Well Modified Malt
- Low Extract Recovery
- Simple & Effective
- Fixed Height Grain Discharge arms
- No Lautering capability



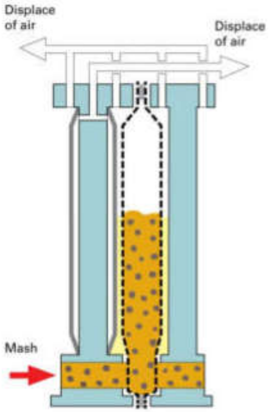
Mash Filter

- Installation in Uganda –
  - Meura 2001 Hybrid
  - 102 hybrid chambers
  - 7 to 10.2 Te grist
  - 320 to 400 hl cold wort
  - 10 BPD initially
  - 12 BPD future

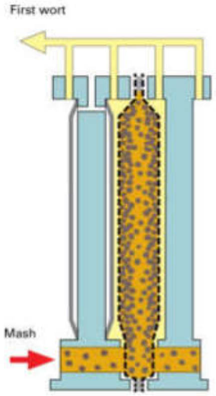


- Mash Filter Capability –
  - Up to 14 BPD
  - High extract yield (100% +)
  - Up to 100% adjunct
  - Minimal effluent
  - Drier spent grains
  - Limited flexibility

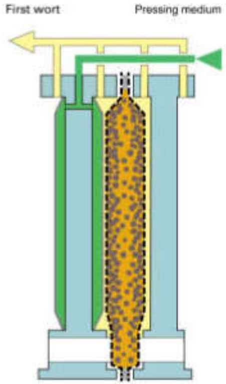
Mash Filter Operation - 1



1 FILLING



2 FIRST WORT RUNNING



3 PREPRESSING

Filling

From Mash Tun

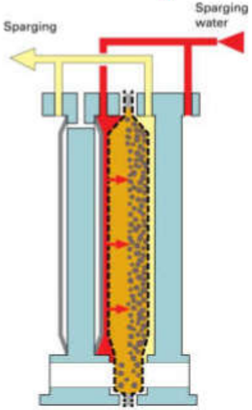
Filtration

Transfer from Mash Tun continues

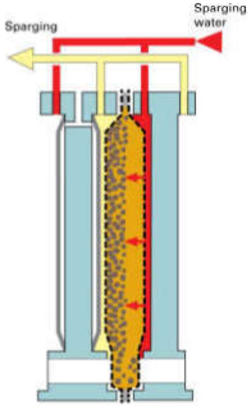
First Compression

Strong Wort pressed out

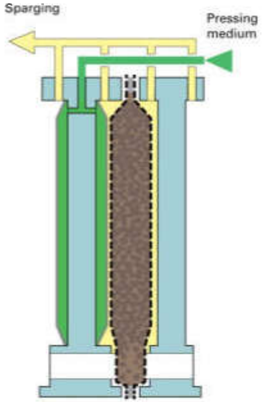
Mash Filter Operation - 2



4 SPARGING



5 SPARGING



6 FINAL PRESSING

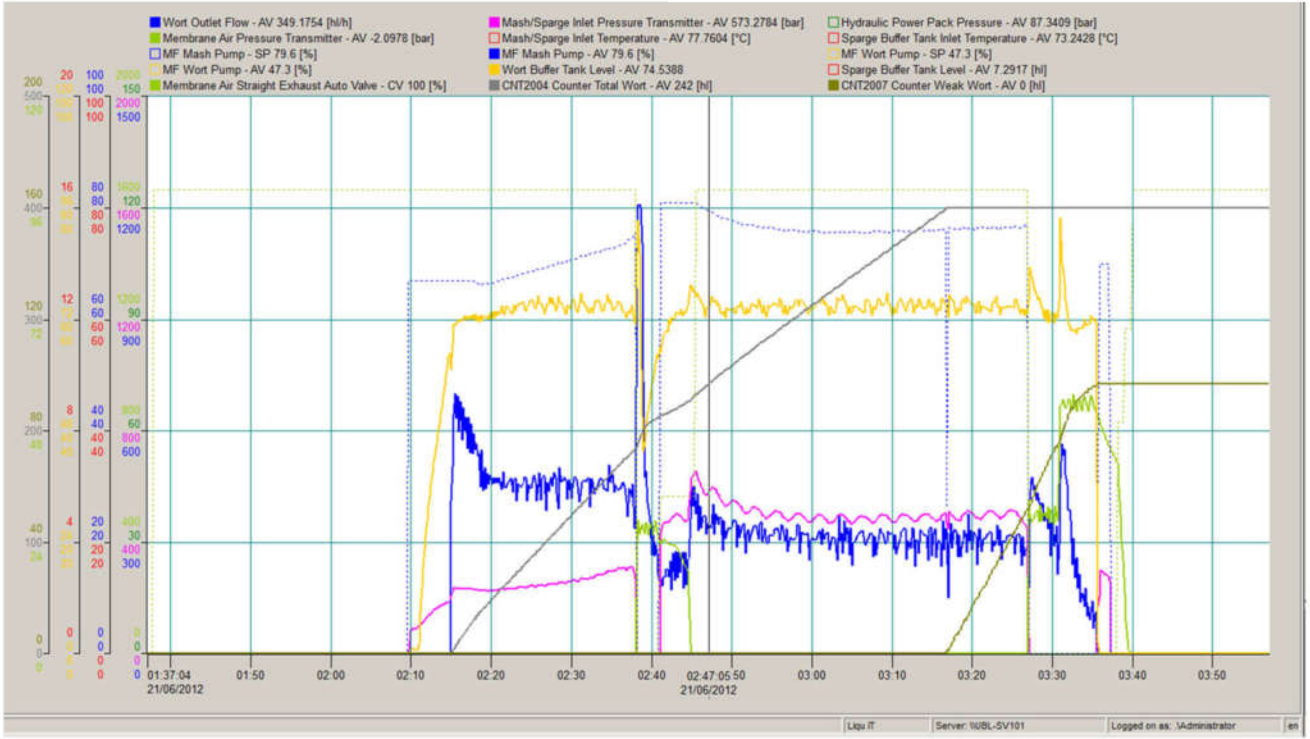
Sparging

Sparging

Final Compression

Weak worts pressed out

Mash Filter Operation



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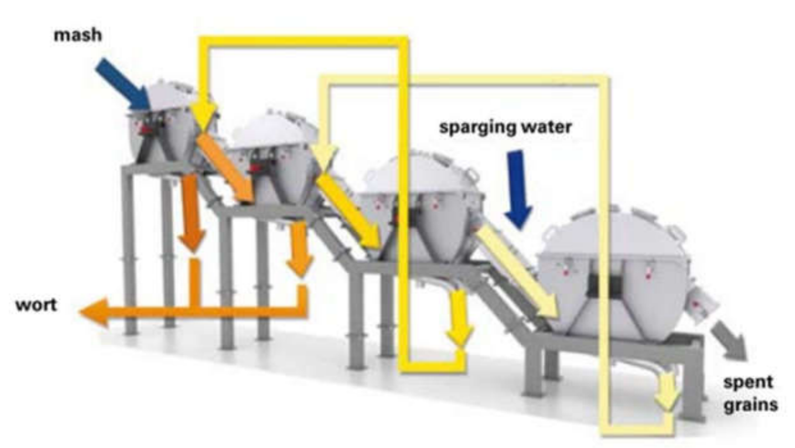
New Technology - Nessie

- Continuous Filtration and Sparging process
- Four rotary disk filters, connected in series
  - Can handle malt and adjuncts
  - Low space usage
- Batch Brewhouse
  - Effectively inline filtration & sparging during transfer from Mash Vessel to Kettle
  - Part of Ziemann Holvrieka Omnium Brewhouse
- Continuous Brewhouse



Mash Separation - Summary

	Infusion Mash Tun	Distillery Full Lauter Tun	Brewery Lauter Tun	Mash Filter
Throughput BPD	≤ 4 b.p.d.	4 to 7 BPD	8 to 12 BPD	12 to 14 BPD
Extract Efficiency	95 to 97%	99 to 101%	98 to 99%	>100 %
Flexibility - Capacity	30 to 100%	40 to 100%	40 to 100%	80 to 110%
Flexibility - Material	Malt only	Malt only	Malt & up to 50% Adjuncts	Up to 100% Adjuncts
CIP	Simple & effective	Simple & effective	Simple & effective	Inefficient 4 to 8 hrs
Complexity	Simple	Complex	Complex	Complex
Cost	Low	Moderate	Moderate	High

BRIGGS BREWING

Wort/Trub Separation - Objectives

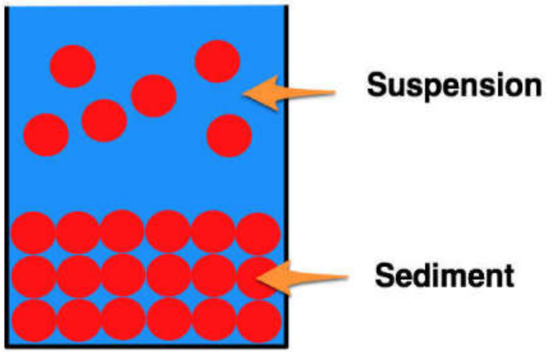
- Wort Separation
  - Separation of Clear Wort from Trub & Spent Hops
  - Settling / Clarification
    or
  - Filtration
    - Whole hops may be used to form a filter aid
- Sparging – For Hopback only
  - Leaching of remaining extract from spent hops using hot Sparge water
  - Mass transfer from mash solids to clear wort
  - Filtration continues
- Trub / Spent Hops disposal - by-product

Wort / Trub Separation - Process

- Settling / Clarification
  - Whirlpool
    - Enhanced Settling
    - Cannot handle whole hops
  - Combined Kettle-Whirlpool
    - Combines Wort Boiling & Wort Clarification in one unit
  - Hot Wort Centrifuge
    - Covered by separate presentation
    - Rarely used in practice
- Filtration
  - Hopback
    - Filtration only
    - Whole hops essential
    - Traditional UK Ale Breweries
  - Hop Strainer
    - Partial separation
    - Used to separate spent whole hops for clarification by Whirlpool

Sedimentation (Settling)

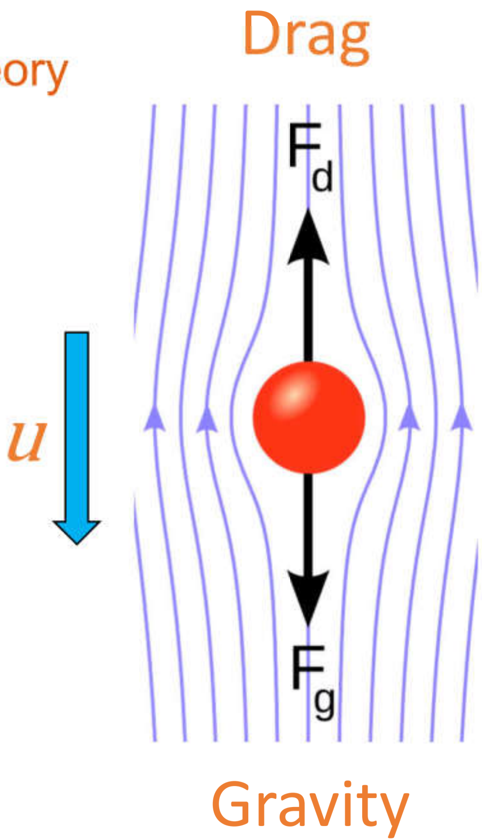
- Sedimentation occurs when suspended particles settle out of the fluid in which they are entrained and rest against a barrier.
- Settling forces can be generated from gravity, electromagnetism or centrifugal acceleration.



- Brewery Applications
  - Wort/Trub Clarification
  - Yeast and Protein Removal from Beer
- Theoretical knowledge helps explain observed facts
  - Theory difficult to apply
    - Variable particle size
    - Variable composition
    - Biological factors

Stokes Law – Settling Theory

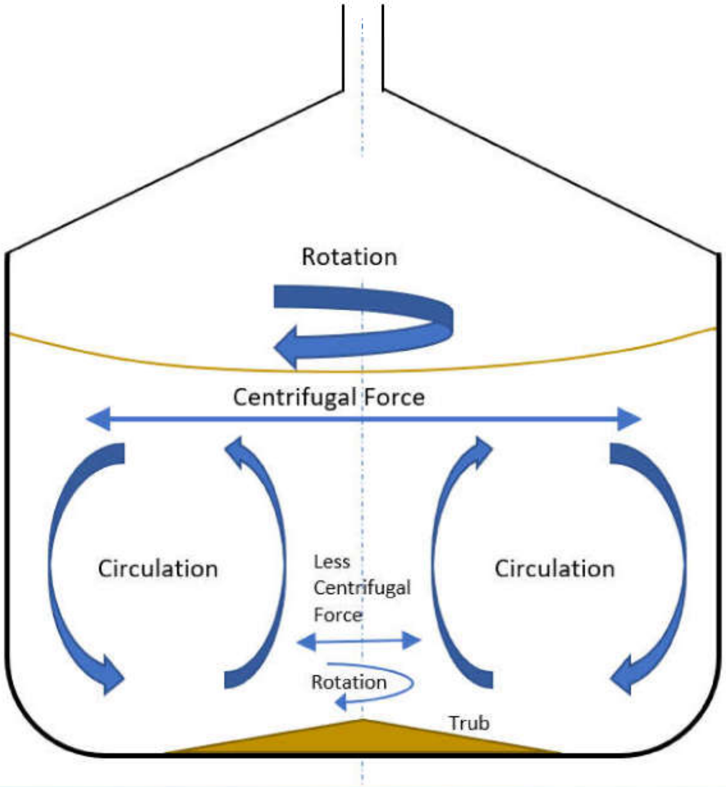
- Drag Force
  - $F_d = 3\pi.\mu.d.u$
- Gravitational Force
  - $F_g = \frac{\pi}{6}.d^3.(\rho_s - \rho).g$
- Terminal (settling) Velocity
  - $u = \frac{d^2 g}{18\mu}.(\rho_s - \rho)$



- Applying Stokes law, Settling Velocity is proportional to
  - Diameter (d) squared
  - Inverse of Viscosity (μ)
  - The Density Difference (ρs – ρ)
- Settling / Clarification is faster with
  - Larger trub particles
    - Wort boiling & gentle transfer
  - Lower gravity wort
    - Lower μ and ρ

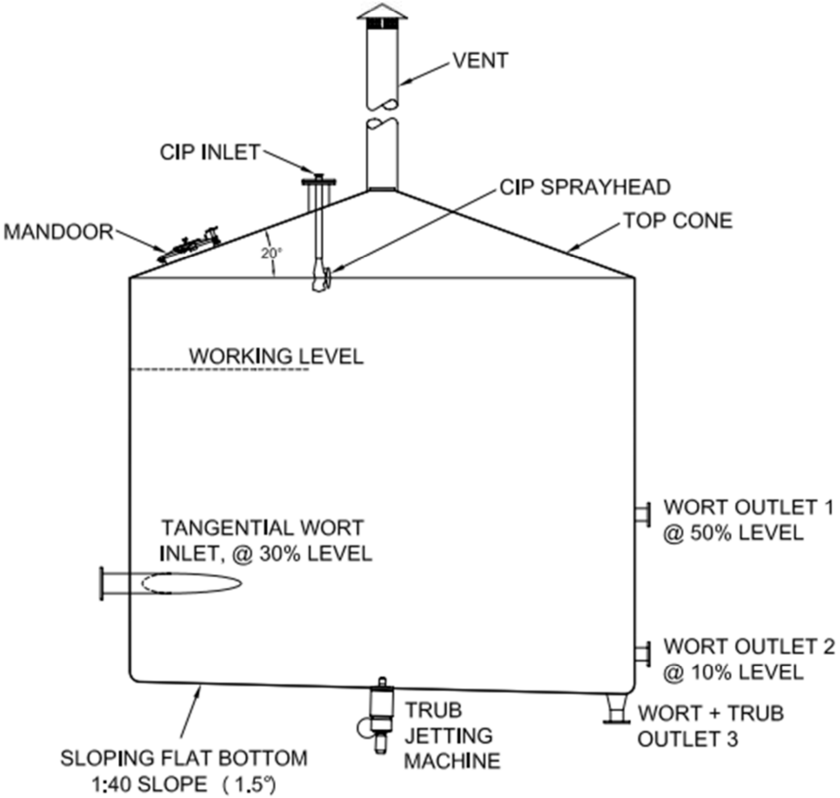
Whirlpool Process

- The Whirlpool is a settling vessel, with clarification faster than gravity settling
- The Whirlpool Clarification process can be explained as -
    - The rotating mass of liquid is braked unevenly by friction on the tank walls and bottom
        - Upper layers rotate faster than lower
    - Centrifugal force is higher at the top than the bottom
    - This induces secondary rotation
        - up the centre of the vessel
        - down the outside of the vessel
    - Secondary rotation sweeps the heavier particles inwards into a central cone
    - Collisions between suspended particles cause agglomeration into larger particles
        - Further enhancing settling



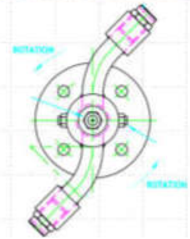
Whirlpool Process Design

- The Whirlpool Process can be considered in 3 stages
  - Supply of boiled wort from Kettle with trub flocs intact
  - Separation of trub and wort to form a trub cone in the vessel bottom, surrounded by clear wort
  - Transfer of clear wort from the vessel without trub cone collapse or leaving excessive wort (extract) in the Whirlpool
- Key Whirlpool design & performance factors
  - Aspect ratio (H/D)
  - Bottom shape
  - Wort Mass flow in
  - Wort treatment prior to Whirlpool
  - Wort removal – Multiple outlets
  - Trub removal – Water jetting



Whirlpool Design Features

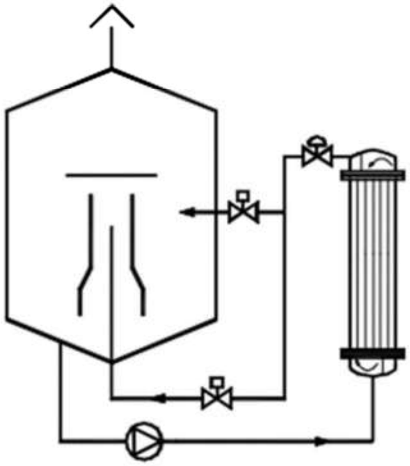
- Shape
  - H/D ratio and base area
  - Bottom shape
    - Flat / shallow slope - Dry trub
    - Cone – Wet trub
- Wort feed
  - Wort Boiling Process
  - Wort transfer from Kettle
  - Tangential Inlet



- Time
  - Stand time – Settling
  - Hot wort residence time
- Wort transfer to Cooler
  - Multiple Wort Outlets
  - Controlled wort flow out - ramped
- Trub Discharge
  - Trub jetting
  - Trub pump

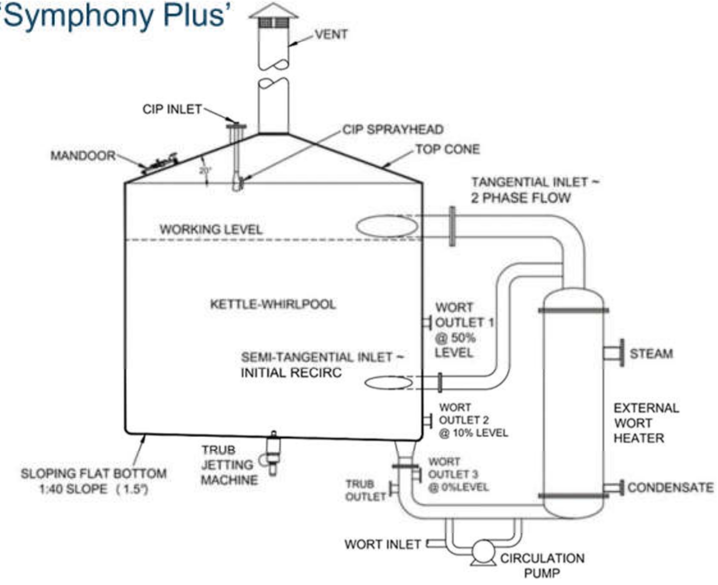
Kettle-Whirlpool – Alternative concepts

- Forced Circulation
  - High Shear



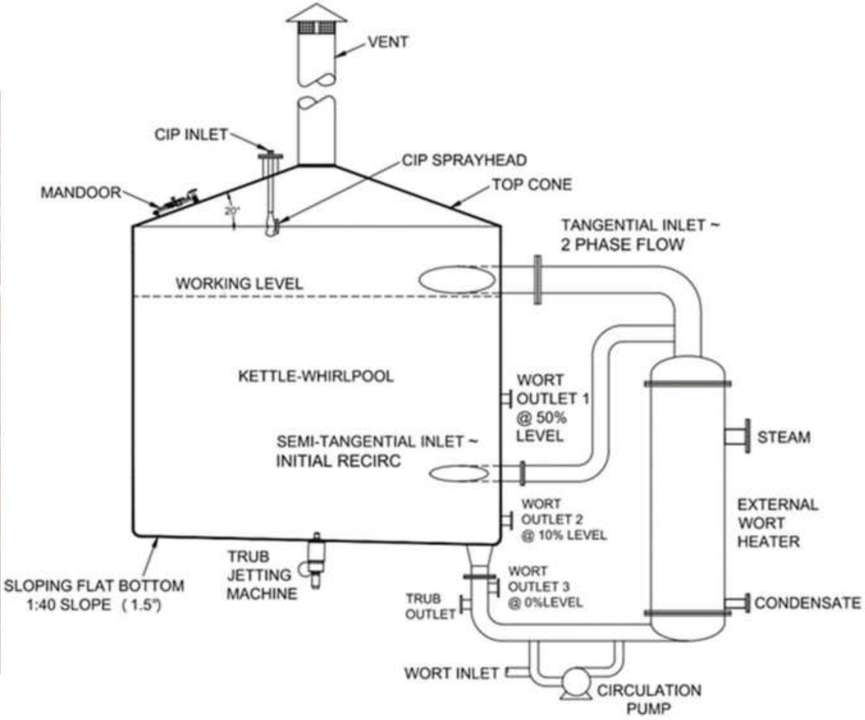
Forced Circulation
Seperate Boil &
Whirlpool Circulation

- Thermosyphon
  - 'Symphony Plus'



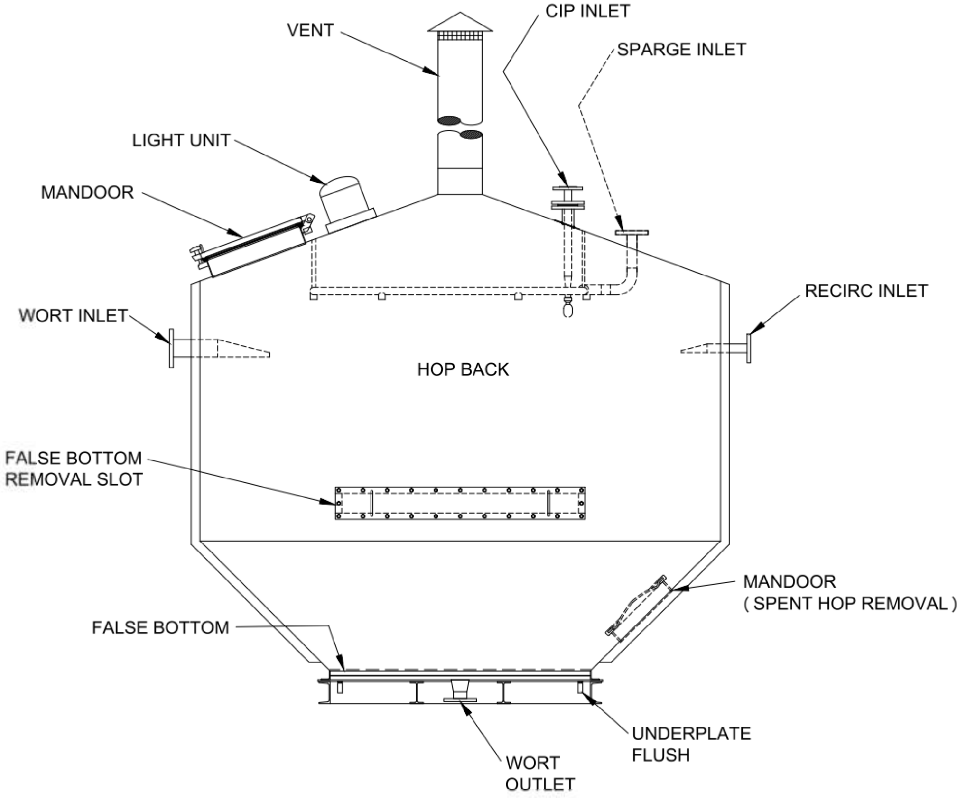
Kettle-Whirlpool – Symphony Plus

- Combined Kettle & Whirlpool
- Thermosyphon Circulation
- Eliminates Transfer to Whirlpool
- Reduced shear
- Improved Trub Separation



Hopback

- The Hopback uses a similar process to the Infusion Mash Tun
  - Filtration
  - Sparging
- Filtration
  - uses the whole hops as a filter aid, retained by the slotted false bottom
  - Sufficient depth of hop bed to filter effectively
- Sparging
  - Small volume of hot water
    - rotating sparge arm or
    - Sparge nozzles
- Spent Hop Disposal
  - Usually manual



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Solid/Liquid Separation in the Brewhouse - Summary

- Mash/Wort Separation
  - Process
    - Filtration AND
    - Leaching
  - Technology
    - Lauter Tun
    - Mash Filter
    - Infusion Mash Tun
    - Nessie
- Wort/Trub Separation (Clarification)
  - Process
    - Sedimentation (settling) OR
    - Filtration
  - Technology
    - Whirlpool
    - Hopback
    - Hot Wort Centrifuge

Thank you

Any questions?