Solid/Liquid Separation in the Brewhouse

John Hancock & Paul Banham – Briggs of Burton IBD Midlands / BFBi – Derby - February 2019







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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

 $K \times \Delta P \times A$ $\mu \times L$

Mash Filtration - First Worts Flow - Theory



Mash Filtration - First Worts Flow – Practice

		MASH	LAUTER	MASH
		TUN	TUN	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/m²	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

 $K \times A \times \Delta C$

Mash Leaching (Sparging) - Practice

	<u>Example</u> 10 Te grist		Mash	Lauter	Mash
			Tun	Tun	Filter
	Tun Diameter (<i>or equivalent</i>)		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
- 2. Extract Recovery
- 3. Wort Quality
- 4. Spent Grains
- 5. Minimum Operating Costs

- Consistent within design constraints
 - Bed loading, grist particle size, mash handling, malt quality
- 100% recovery of soluble extract created at mashing using minimum sparge water (process intensification)
 - Low settleable solids
 - Low colloidal fine particles
 - Low oxygen pick up
 - Minimum Moisture
 - Effluent
 - Consumables
 - CIP

Lauter Tun - Design

• Lauter tun Size

• Loading & Cycle time

- Mash Distribution
- Wort CollectionSparge Distribution
- Lautering
- Grains Discharge
- Underplate Flush

- Low shear & Min O2 pickup
- Even run-off

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- 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



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





Mash Filter Operation



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	Distillery	Brewery	Mash Filter
	<u>Mash Tun</u>	Full Lauter	<u>Lauter Tun</u>	
		<u>Tun</u>		
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

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.



Suspension

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**



- 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

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Forced Circulation Seperate Boil & Whirlpool Circulation Thermosyphon

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PUMP

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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Thank you

Any questions?