Mash separation systems

Once mash conversion is completed, when all the starch has been broken down to sugar, it is necessary to separate the sugar solution from the malt solids to produce clear sweet wort.

Technical Summary 12

By Tim O'Rourke

Continuing this series of technical summaries for the Institute & Guild's AME candidates.

The basic principals of mash separation are the similar. The wort is strained through a filter bed made up of the husk and solid material remaining from the malt which is held on a course septum such as a screen or filter sheet.

The principles of filtration are defined in terms of Darcy's equation:

$$\text{Flow rate } u = \frac{\text{filter surface area (A) x pressure differential across filter (P)}}{\text{Beer viscosity x resistance to the flow of beer (L)}}$$

Therefore the highest flow rate is achieved with:
- Large filter surface area (A)
- Increased differential pressure across the filter bed (P)
- The lower the wort viscosity
- The shallower the filter bed (L)

Darcy's equation describes the conditions for optimum flow not optimum wort quality. It is also necessary to obtain the maximum recovery of extract (sugar) and to produce bright wort free from suspended solids.

There have been a number of different designs of wort separating equipment, but currently three basic types are commonly used.

Isothermal Mash Tun

This is a combined conversion and wort separation vessel. Since it has no form of agitation or heating it operates at a single temperature in the range of 65°C.

Mash tuns have the smallest filter surface area with the deepest bed depth (up to 1 meter deep) which applying Darcy's equation will explain why it has the slowest filtration and poorest extract recovery. The poorer run performance is partially compensated by using a coarse grist but this could lead to poorer extract recovery. It does produce the brightest worts.

Extract performance is a result of the combined effects of the malt grist and the bed depth. The poorer potential performance of the mash tun is partially offset by using a low volume of water in mashing (water: grist ratio of 2:1) this allows a higher volume of sparge water to optimise the leaching effects.

The flow rate of wort from a mash tun is usually controlled manually. The run-off taps are set and adjusted to prevent pulling the bed down on to the plates. Unlike the other wort separation systems the mash in a mash tun floats on the wort, at least during the strong wort recovery.

During the initial run-off, the flow rate is low to allow for the high viscosity of the wort and to prevent the floating bed of mash being drawn down on to the false bottom of the vessel. The flow rate can be increased during sparging as the wort viscosity falls.

Typical mash tun cycle

Mashing in	20 minutes
Mash conversion stand	75 minutes
Run off	185 – 330 minutes
Drain down & Spent grains removal	20 minutes
Total turn around time	300 -–440 minutes

Excluding the time taken for the mash conversion, the mash tun is the slowest wort separating system. Mash tuns are well suited to their traditional use in producing wort from well modified malt. They are the cheapest system in terms of capital outlay and are the simplest to operate with little or no automation.

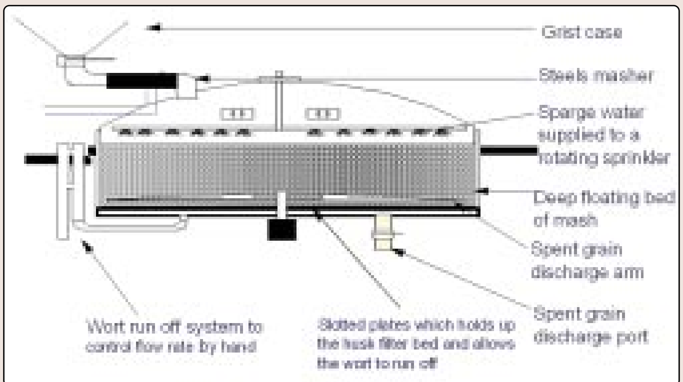
Mash tuns can only use a single temperature for mash conversion and as a result poor quality malts or malts requiring a protein or glucanase stand cannot be handled. Mash tuns are also less well suited to modern large batch production where high brewhouse utilisation and extract efficiency are expected.

When using a Lauter Tun or Mash filter the mash is converted in a separate mash conversion vessel often using a range of temperature stands. The function of the Lauter tun and Mash filter is purely to separate the solids.

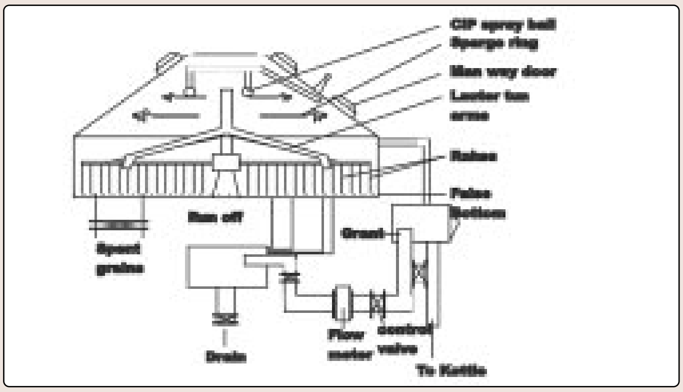
Lauter Tun

Before transferring mash from the mash conversion vessel a layer of brewing water or "underlet" is added to cover the plates in the lauter tun. The transferred mash is allowed to settle on the lauter plates. The bed in the lauter tun is shallower (around 0.5 m) and the vessel has a larger diameter (greater surface area) than the mash tun. This gives it a better filter performance and allows the use of finer grist, which helps extract performance.

The initial wort collected from the lauter tun is re-circulated to ensure that only bright wort (haze less than 5 EBC) runs to the kettle. The medium fine grist used in the lauter tun causes an increase in the resistance of wort run off, which has to be compensated by the use of rakes to open the bed and allow faster filtration. The rakes must operate in such a way to avoid the sparge being channeled through the bed and to avoid the filter bed being totally disrupted. Slight increases in wort viscosity can have a dramatic effect on run off performance.



Isothermal Mash Tun.



Lauter Tun.

There are a number of different ways of running a lauter tun which vary according to beer type, installation and tun design. Raking can be continuous in a "wave", or using a number of discrete steps The sparge can be added continuously or as a batch addition when it is often accompanied by a total break up and re-mash of the bed.

Most lauter tuns are fully automated and as well as controlling the wort run-off rate, they also measure and control the differential pressure above and below the lauter plates. When this pressure falls below a set pressure it has reached a "set bed" condition. The run-off is stopped and the rakes are lowered to the bottom of the bed and used to beak up the bed for 5 to 10 minutes before normal filtration is resumed.

To control a lauter tun run-off, the following properties can be measured:

- Wort flow rate (which can be accumulated to give total volume of wort collected)
- Flow rate and volume of underlet and sparge
- Differential pressure which is the difference in pressure above and below the later tun false bottom. This directly measures resistance to flow through the filter bed.
- Wort clarity – wort should have a haze less than 5 EBC with less than 1 mg per litre of suspended solids.
- Wort density – as the density decreases, the wort viscosity also falls allowing the lauter tun to run off more quickly.
- Temperature of sparge
- Dissolved oxygen is reduced by gentle filling usually from the bottom of the vessel and through gentle operation.

These measurements can be used to control the lauter through:

- Controlling flow rate – rate of run off
- Sparge rate, that is the rate of re-hydrating the bed and the amount of water on top of the bed.
- Sparge temperature (higher temperature reduces wort viscosity, but also increases extract of unwanted husk compounds).
- Raking and set bed routines (these are primarily to relieve the build up of differential pressure across the lauter bed).
- Re-circulation – at the start of run off and often after a set bed the worts are re-circulated on top of the lauter tun until they are bright before running to the kettle.

A typical lauter tun cycle

Stage	Time in mins	Volume Hl
Underletting	3	23
Filling	11	
Re-circulation	4	20
First worts	41	205
Second worts	74	475
Last worts	10	141
Weak worts	16	179
Drain down	8	93
Grain removal	25	
Total	**192**	**1000**

Modern Mash Filter

The modern generation of mash filter is typified by the Meura 2001. This filter has a large surface area because of the number of filter plates. It uses a very thin filter bed a few millimeters thick, and operates at up to 1.5 bar pressure, which provides a significant driving pressure to aid filtration.

Through its design, the mash filter is able to optimise the filtration conditions defined in the Darcy equation and is therefore able to handle very fine grist. Mash filter grist is produced using a hammer mill; the very fine grist ensures an excellent extract recovery.

The mash filter is charged with converted mash from the mash mixer. The mash filter is fitted with fine pore polypropylene filter sheets suitable for fine grist, without particles bleeding through the sheets. The fine filter sheets and grind result in a tight filter bed which means that no re-circulation is required before first worts are drawn off which can run straight to the kettle.

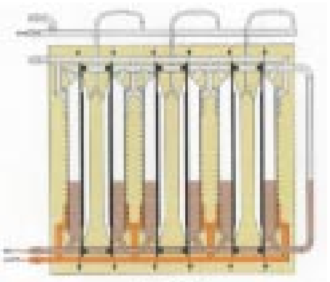
The large number of plates and shallow bed depth gives a high filter flow rate and the fine grind coupled with a thin filter bed results in high extract efficiency without the reduction in wort quality.

The sequence below shows the series of events during a mash filter run.

Filling

Mash is pumped at low pressure from the mash conversion vessel

Duration	5 mins
Pressure	0.7 bar
Volume of run off	nil

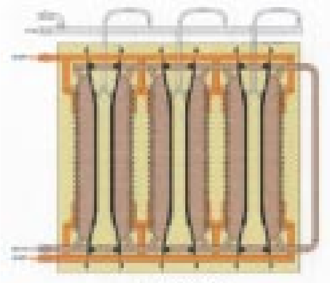


Filling

Filtration

The solids in the mash form a cake on the surface of the filter cloth. Clear wort is run off to the kettle.

Duration	30 mins
Pressure	0.7 bar
Volume of run off	175 hl

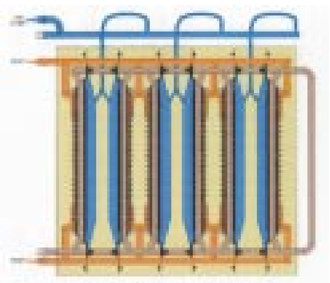


Filtration

Pre-compression

After all the mash has been transferred from the mash mixing vessel, gentle air compression is applied to the membrane which forces the strong wort through the bed.

Duration	5 mins
Pressure	0.9 bar
Volume of run off	10 hl

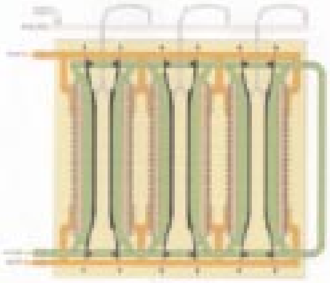


Pre-compression

Sparging

When most of the strong worts has been squeezed from the grain, the membrane pressure is slowly released and sparge water is pumped through the mash inlet;

Duration	35 mins
Pressure	0.7 bar
Volume of run off	175 hl

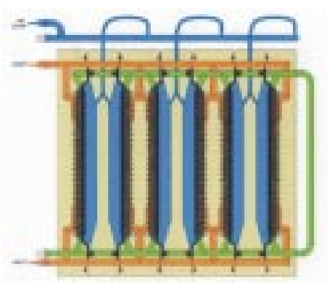


Sparging

Final Compression

When all the sparge has been supplied the membrane is compressed at high pressure and the grain bed squeezed dry.

Duration	10 mins
Pressure	1 to 1.5 bar
Volume of run off	20 hl



Final Compression

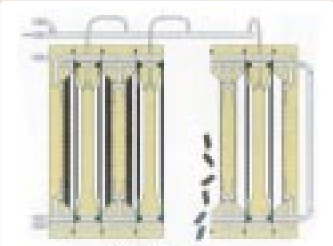
Cake discharge

Once all the extract has been squeezed from the grain, the pressure is released and the filter is opened up. The gains fall into a grain hopper for removal.

Duration	10 mins
Pressure	none
Volume of run off	nil

The new mash filter is able to use a very fine grist which allows a high extract recovery usually in excess of

Illustrations of the mash filter by kind permission of Meura


Discharging

100% laboratory extract. In addition because it requires a lower sparge volume than the other systems it can readily produce high gravity worts from an all malt brew.

Summary of the advantages of a mash filter over a lauter tun.

Property	**Mash Filter**	**Lauter Tun**
Extract efficiency	Circa 102 %	Circa 97.5 %
Sparge volume	Less sparge – Higher gravity worts	Higher sparge lower gravity wort
Turn around	Circa 2 hours 12 brews/day	Circa 3- 4 hours 8 - 10 brews/day
Flexibilty	Full charge + 5 % -10%	Full charge ± 35 %
Operation	No underlet Easier run off	More problematical run off
Footprint (10 tonnes)	Small 3 x12m	8m dia.
Maintenance	Low – few moving parts	Higher – more moving parts
Quality (under) correct operation	Good – improved foam stability	Good
Spent grains	Dry – moisture < 65 %	Wet – moisture > 78 %
Capital Cost	Can be cheaper depending on civil costs	

One of the principal differences between the three separation systems is in composition of the grist required, which is shown below:

Summary of the principal differences in grist composition based on the standard EBC Pfungstat Plansifter sieving of grist.

Mesh size (mm)	Fraction	Mash Tun	Lauter Tun	Mash Filter
>1.27	Husk	20%	15%	<5%
1.01 to 0.547	Coarse Grits	35%	5 %	5%
0.253	Fine Grits	35%	30%	35%
0.152	Flour	10%	30%	>45%

Spent Grains

After wort separation is complete the waste material left behind called spent grains and is drained down and sold for cattle feed.

The removal of the grains depends on the mash separation system:

- Mash Tun – thrown out by hand, or removed by a mechanical arm which rotates over the false bottom of the tun and pushes the grains towards outlet ports.
- Lauter Tun – usually combined with the lauter rake equipment, where either the rake arms turn to present a flat surface pushing the grains towards outlet ports, or a bar attached to the rake arms descends to achieve the same purpose.
- Mash Filter – the filter is opened up and the grains fall out, occasionally with sticky grains the cloths may require scraping.

After grain discharge the plates or cloths are usually hosed off, in preparation for the next brew, and the vessels will receive a full hot CIP at least once per week. The discharged grains are usually conveyed either by a screw conveyor or using compressed air to a storage silo, where they can be loaded into local transport for removal.

The % solids of the grains is between 19 and 36% depending on wort extraction system and drainage, where there is no concern over effluent and when the brewery is adjacent to suitable agricultural sites, the grains are discharged wet and removed for storage and ensiling on the farm.

If the grains cannot be taken away wet then it is necessary to dry the grains. In which case after draining down, the grains may be passed through a decanter centrifuge to remove excess moisture before being dried in a drum oven. ■

References and further reading

O'Rourke T — *IoB Blue Book* – Brewhouse and Brewing Materials – (in print)
Meura – technical literature
Briggs – technical literature
Malting and Brewing Science - Hough, Briggs and Stephens
O'Rourke T – Back to Basics – *Brewers Guardian* July 1999.