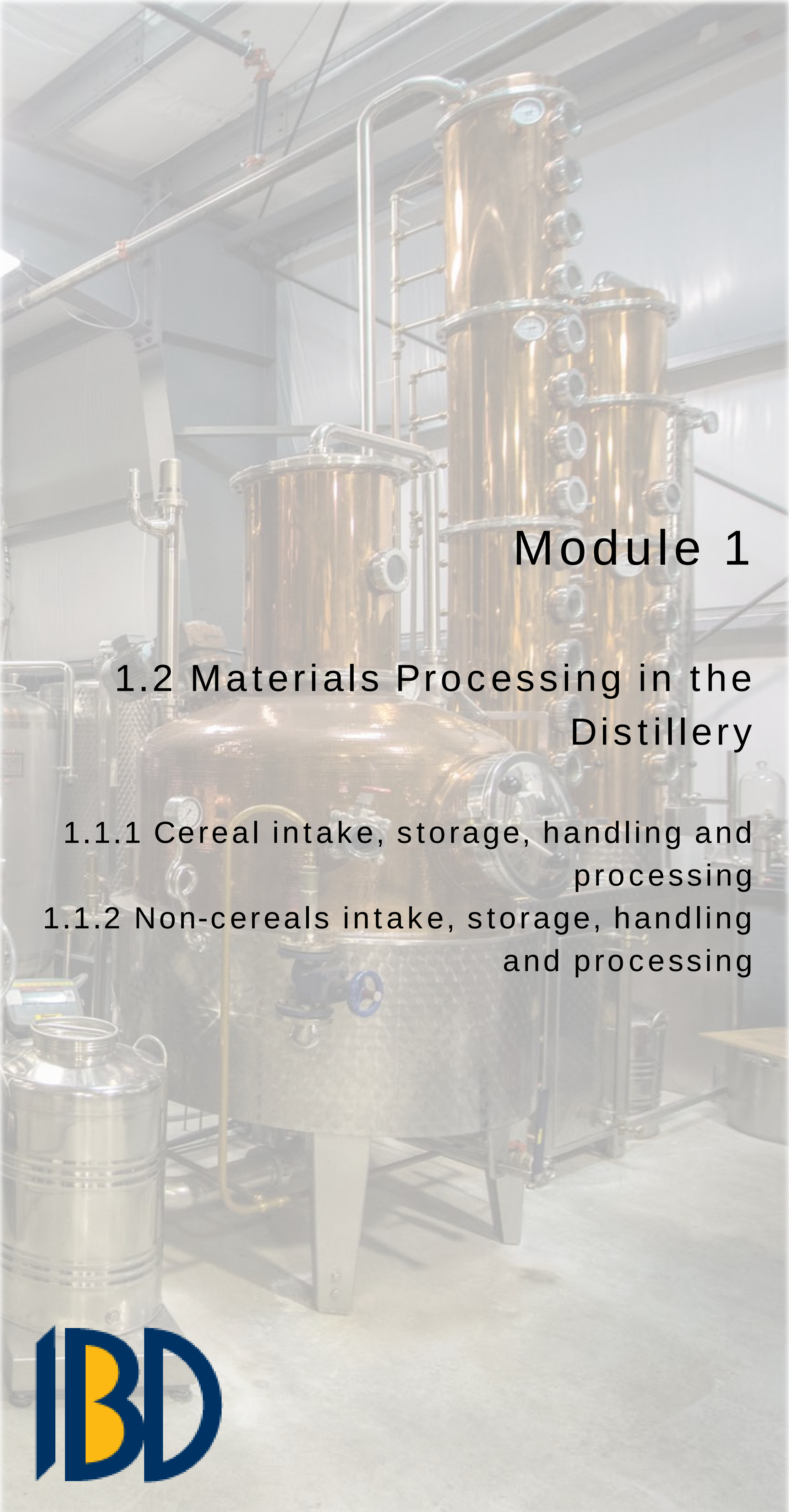


# Module 1

## 1.2 Materials Processing in the Distillery

1.1.1 Cereal intake, storage, handling and processing

1.1.2 Non-cereals intake, storage, handling and processing

DIPLOMA IN DISTILLING

# Contents

## ABSTRACT

In this Unit of the Diploma in Distilling, 1.2 Materials Processing in the Distillery, we will examine the distilling process from raw materials procurement and intake through to malt milling.

Firstly, in 1.2.1, we will look at a typical malt specification for both grain and malt whisky distillation processes. We will then examine malt intake, handling and finally milling.

In 1.2.2, we will look at specifications and materials processing in molasses-based distillation.


## LEARNING OUTCOMES

On completion of this section you should be able to:

1. *Provide an appropriate malt specification for a malt or grain whisky.*
2. *Describe the process of cereals intake into the distillery, including milling.*
3. *Explain the processing of molasses into wort.*

## PREREQUISITE UNDERSTANDING

Basic scientific knowledge and terminology.

## 1.2.1 Cereal intake, handling, storage and processing

### Requirements of good quality malt

#### Introduction

Two general types of distillers malts are produced commercially – malt for malt whisky and high diastatic malt for grain distillers (see Table 4.1). Malt whisky malts are made from plumper, heavier kernels with a friable starch mass. They are steeped and germinated at moisture contents ranging from 45 – 46%; the final temperature used in drying malts is in the range of 70 - 72°C. These malts are dried to 4.5 - 5% moisture. Unlike brewing malt there is no final high temperature cure so that all distilling malts should have negligible tint and produce almost colourless worts.

Grain distillers' (or high diastatic) malts are generally made from smaller barley kernels that are higher in protein and enzyme content. This barley is steeped and malted at a higher moisture content (48 – 50%) and dried at lower temperatures (50 – 60°C) to a higher final moisture content (ca 6%) than the malt whisky type of malt.

| Measurement | Barley | Malt: Malt Whisky | Malt: High DP |
|---|---|---|---|
| Kernel weight (mg) | 38 - 42 | 32 - 36 | 29 – 32 |
| Starch (%) | 63 – 65 | 58 - 60 | 50 – 55 |
| Sugars (%) | 0.5 – 1.0 | 8.0 – 10.0 | 8.0 – 10.0 |
| Total nitrogen (%) | 1.5 – 2.3 | 1.5 – 1.8 | 1.8 – 2.3 |
| Soluble nitrogen (% of total) | 10 – 12 | 35 – 45 | 40 – 50 |
| Diastatic Power | 50 – 60 | 70 - 80 | 180 – 200 |
| α-Amylase | Trace | 35 – 45 | 60 – 80 |
| Proteolytic activity (arbitrary units) | Trace | 15 – 20 | 20 - 25 |

*Figure 1 Comparative ranges in the composition of barley and malt.*

#### Malt Specifications

Barley and hence the malt are derived from living materials and so are subject to the variations that can occur as a result of genetic and environmental conditions. This means that no two batches of malt are alike. Malt analysis provides guidance on the effectiveness of the malting process and suitability of the malt for brewing.

Malt is tested in accordance with the Institute of Brewing (**IOB**), European Brewery Convention (**EBC**) and the American Society of Brewing Chemists (**ASBC**) methods of analyses. However, malt specifications are not always the most reliable indicator on how well the malt will perform in the brewery, and maltsters, brewers and distillers are continually looking for better predictions of brewing performance of malt.

#### Barley Variety

Each variety has its own characteristics; its genetic make-up determines whether it has qualities that are important to brewing. Some varieties produce better distilling malts than others.

The following characteristics will vary according to the barley variety:

- Percentage of nitrogen (protein) in the grain.
- Proportion of small to large starch granules.
- β-glucanase levels.
- Homogeneity of corn size.
- Ability to produce the necessary enzymes.

These factors are also influenced by environmental conditions, e.g. weather, soil type and fertilizer. The barley variety is also important not only because of its spirit yield but also its wort composition which may influence fermentation and spirit character.

## Key Malt Analytical Parameters

| Analytical Parameter | Abbreviation | Typical Distilling Malt | High DP | Range (Dist. Malt only) |
|---|---|---|---|---|
| Moisture (%) | | 5.0 | 6.0 | 4.5 – 5.0 |
| Hot Water Extract (%) | HWE | 76.5 | 71.7 | 76 - 78 |
| Fine Coarse Difference (%) | F/C Diff | 1.5 | 1.1 | 1.0 – 2.0 |
| Fermentability (%) | | 86.8 | 83.0 | 86.5 – 87.5 |
| Predicted Spirit Yield (litres of alcohol/ tonne) | PSY | 402 | 361 | 400 - 416 |
| Total Nitrogen (%) | TN | 1.65 | 1.95 | 1.5 – 1.7 |
| Soluble Nitrogen Ratio (%) | SNR | 38 .6 | 44.1 | 37 - 40 |
| Phenols (ppm) | | 4 | 0 | 0 - 80 |
| Colour (EBC units) | | 2.3 | 2.7 | 2 - 3 |
| NDMA (ppb) | | <1.0 | <1.0 | < 1.0 |
| α-Amylase | DU | 36 | 75 | 35 - 40 |
| Diastatic Power (°L) | DP | 88 | 180 | 80 - 90 |
| Friability (%) | | 96 | 95 | >95 |
| Homogeneity (%) | | 98 | 96 | >98 |

*Figure 2 Typical list of analytical parameters used in specifications for distilling malts.*

Key analytical parameters for malt distilling malt and examples of typical values are:

### Moisture < 5 %$H_2O$

In the last 20 years, the moisture content has been raised from 4 to 5 % for two main reasons. Firstly, gentler kilning helps preserve the activities of the more heat- sensitive enzymes, which can continue to work during the mashing and fermentation, releasing more fermentable carbohydrate. Second, there is a saving in energy. Malt is hygroscopic (attracts water) and there is normally a moisture pickup of around 0.5% between maltings and distillery. So, if the malt is required to be 5% moisture, the off-kiln moisture should be 4.5%.
Where there are adjacent maltings and distillery, it can be dried to 5%. Malt with moisture content of 6% or more is difficult to mill, and there is the possibility that 'green-malt' sensory notes may enter the spirit from lightly kilned malt.
However, grain distilling malt moisture content can be up to 6%, the lighter kilning preserving enzymes.

### Friability 96% of corns friable

### Homogeneity 98% of corns homogeneous

The Friabilimeter is a laboratory instrument in which a weighed amount of malt is subjected to pressure of a roller pressing it against a rotating perforated drum. The more friable the malt due to modification, the more passes through the drum.
This analysis is commonly used in malting as a check on the endosperm's modification of the malt, to determine the homogeneity of the modification and to measure the percentage of corns that have not grown. It is widely used in the plant as well as in the laboratory.
The information obtained from the Friabilimeter, while a useful early indicator of the quality of malting, must be taken as complementary to laboratory results. In recent years, there have been severe problems with calibrating these instruments, and results should be treated with caution, as they are also variety and operator dependent.

### Soluble Extract (SE)> 80%(dwb) of malt materials made soluble

The units used to describe SE are 'litre °/kilogram' or '% extract' (%). The two units are related by a factor. Both units are in use, depending on distiller's preference.
The SE2 figure is the maximum extract that is obtainable from the malt, as milling at this 0.2mm setting (fine grind) mechanically breaks up the cell wall material, releasing the starch granules. This figure varies little with the degree of modification of the malt. Milling at the 0.7mm setting (coarse grind) (SE7) releases only the starch granules that have been made available because of matrix breakdown during malting, so it is a measure of the degree of modification of the malt. The fine/coarse difference is normally about 1%.
Some distillers prefer to use a coarse SE figure obtained by milling the malt sample with a mill gap setting of 1.0mm, but the vast majority use 0.2 and 0.7mm SE's.
The SE7 figure was chosen when the Miag

laboratory mill became standard because its values were closest to the distillery's mash tun extract (mte), when the traditional mash tun was the norm. In the last about 30 years, there has been a gradual change in Scottish malt distilleries to lauter-type mash tuns, which have higher extraction efficiency. These tuns can achieve SE2 levels of extract, but the SE7 figure that is the most reliable figure for predicting spirit yield.

### Fermentability >88% (dwb) of the extract obtained is fermentable

This laboratory test is used to determine the percentage of the SE7 that is fermentable, and allows calculation of the Fermentable Extract (FE7).

The method of determining wort's Fermentability is by conducting a laboratory fermentation, and calculating it using the laboratory Original Gravity (OG) and Final Gravity (FG). Malt fermentabilities are normally up to in the range 86-90%. It should be noted that this laboratory test, based on IGB laboratory wort, is not suitable for malts that have high sulphur content or those that are highly modified to achieve high TSN values.

### Fermentable Extract>70%(dwb)

The % fermentability value multiplied by the SE7 value gives a figure for fermentable extract obtainable from the malt.
The fermentable extract value is used to calculate a predicted spirit yield from the malt.

### Predicted Spirit Yield (PSY)

It is possible to predict the distillery spirit yield from the laboratory data described above.

In a malt distillery, this can be done using the obtained values of the malt soluble extract (SE7), the % fermentability and a fixed factor: PSY (lpa/t, dwb) = fermentability (%) x SE7 (dwb) x 6.06 (where lpa/t = litres of pure alcohol per tonne, and dwb = dry weight basis).

In a grain distillery, the calculation is a little more complicated due to the use of both malt and wheat (or maize). The first step is to calculate separately the PSY of the malt and the PSY of the other cereal. Then it is an easy matter to calculate the PSY of the particular mash recipe in use at the time.

For instance, in a distillery using 10% malt with a PSY of 420 lpa/t and 90% wheat with a PSY of 370 lpa/t, the calculation and result is:
420 x (10/100) + 370 x (90/100) =375 lpa/t

### Total Soluble Nitrogen (TSN)

Free α-amino nitrogen in the wort is required for the yeast growth that occurs at the start of fermentation. If wort is deficient in this respect, the performance of the yeast fermentation will be affected. TSN measurement is used when there is any doubt about there being enough. It is unlikely that there will be a shortage in malt whisky production. Some distillers specify high TSN values, which tend to depress laboratory fermentability values. Grain distillery wort can be deficient particularly if the proportion of malt in the mash is lower than 9% (w/w).

### Malt enzyme levels

Sometimes it is necessary to measure the enzyme levels in malt. Two measures are used: the dextrinising units (DU) that gives an indication of the content of alpha- amylase in the malt and the diastatic power (DP) power that gives an indication of the content of beta-amylase in the malt.

## Malt Delivery and Handling

### Malt Delivery Procedures

The maltster has responsibility to deliver malt of the specified quality in each load. In the past malt samples would be taken at the distillery and re-analysed and compared with the maltster's data. This was expensive and time consuming. Now, with quality management systems in place and guaranteed quality assurance schemes, the maltster provides an analysis with PSY on each load for comparison with actual spirit yield in the distillery. However it may be necessary to check deliveries if there is non-compliance with the purchasespecification.

### Malt Intake

The responsibilities of the distiller start as soon as malt is delivered. It is important to routinely check for malt parameters that can be affected in transit such moisture uptake, broken corns, dust, and delivered weight.

### Sampling

When the consignment of malt arrives at the distillery, the delivery vehicle is weighed in and then again before it leaves; this is to check that the quantity delivered is correct. At this point the materials are randomly sampled and checked for the quality parameters mentioned above.

The sampling of malt can be carried out using spears. These are hollow spikes that are pushed into the load (see Figure 4.1), and when withdrawn retrieve a sample of the grain.

Many designs are available, but to avoid bias results samples must be taken from randomly defined points throughout the grain bed.

The main priority is to obtain a homogeneous batch of malt; this helps avoid production problems.

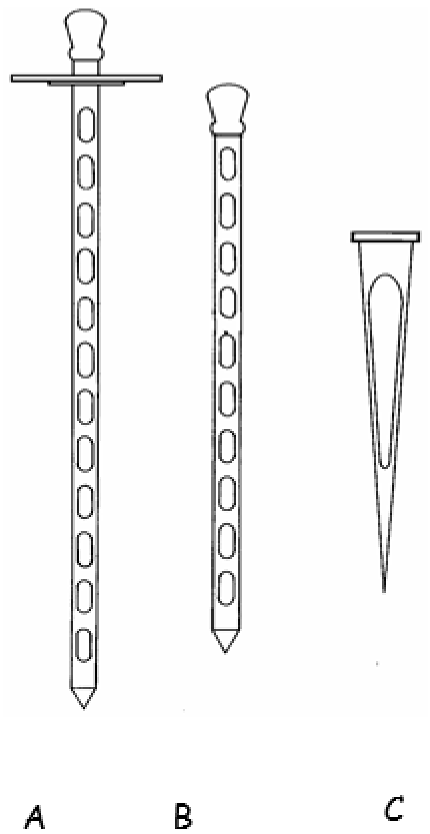



*Figure 3 Compartmented spear samplers. A) and B) are examples of whole bed samplers whilst C) is used for sampling bags of cereal.*

**KEYPOINT:** The most important issue for malt, whether during production in the maltings or during processing in the distillery is HOMOGENEITY. Non homogeneous malt can cause problems such as reduced extract recovery.

Sampling is therefore very important. In modern times a more refined method of sampling is by use of a trickle filter or diverter system. This equipment either continuously takes small samples of material as it is conveyed to the grain store or diverts the occasional sample into a collection chamber as the conveyor transports the cereal.
The majority of distilleries unload their malt into a delivery bay from where the malt will be transported to a storage silo, by pneumatic methods or conveyor belt.

### Storage

The storage of malt requires the same diligence as storage of barley. Most storage silos are constructed from stainless steel but they can be made from concrete. Silos have smooth walls with hopper bottoms to ensure easy grain withdrawal. The malt is stored at delivery moisture levels to:

- Discourage the growth of pests such as insects, moulds, fungi and bacteria.
- Prevent alteration to the biochemical structure of malt prior to use (i.e. turning slack).

Of course all storage silos should be cleaned at regular intervals to prevent the build up of soil and contaminants.

KEYPOINT: Hand evaluation of the malt's appearance and odour should never be overlooked; it is a quick and easy method of analysis.

Malt should be delivered and stored in sufficient quantities to defend against unforeseen shortages that could halt production. However, storage should not be excessive – providing for only a few days' requirements. Otherwise capital becomes unnecessarily tied up in expensive material and storage capacity.

### Screening/Grading and Dressing

Prior to despatch from the maltings the malt is screened and dressed. To ensure uniformity of milling, it is necessary to have a reasonable consistency in the size of corns. To obtain such consistency, bulks of malt are often graded. The malt is carried by pneumatic or mechanical means past magnetic separators to rotating, cylindrical, oscillating or flat-bed screens. Not only are corns of unwanted size rejected (these are sold for animal feed wherever possible) but residual malt culms, broken corns and dust are removed. In maltings where cleaning and grading is carried out on the barley prior to steeping there should be a negligible amount of small corn removal in the finished malt and only deculming and dust extraction are necessary. Nevertheless, some additional dressing is required at intake especially to remove accidental pick-up of metallic objects and to remove small stones and gravel which have the same size as malt grains.

### Magnets

It is essential that pieces of metal that may be in the malt should be removed before they reach the mill, because such metal can cause a spark and start a fire or explosion. Separation is effected by placing permanent magnets either in the malt chute to the dressing machine or across the feed to the mill.
Malt should flow over the magnet in a thin layer and at the same rate as it is being ground, thus allowing the magnet to extract any metal that may be in the malt.

### Dressing and destoning

The malt dresser was usually a cylindrical screen revolving inside a wooden casing that has detachable doors on either side for easy access. The last part of the screen consists of a mesh large enough to let malt pass through to a small hopper feeding the weigher or the mill. Any foreign matter such as pieces of wood, metal, or stone, which are too large to pass through this mesh, is carried forward to the end of the screen where it is rejected via a spout into a bag. When the culms were separated from the malt during screening at the maltings, circular brushes revolved against the exterior of the screens thereby ensuring that the apertures were kept clear.

In modern installations there is a separator/dresser to remove foreign material based on size, and in addition a de-stoner that separates material according to density. Usually these are inclined vibrating table separators on which higher density stones and gravel fall to one side and can be collected. Most stones and gravel of this type are the result of high speed combining, especially in wet harvest years when barley may have become lodged in the field and cutter bars have to be lowered. In this way small stones of the same size as the malt grains can be removed and it has been found that the amount of stones can vary considerably according to the source of the barley.

## Dust Removal

Dust is a dangerous substance because of the risk of explosion and also irritation to the lungs. It is now covered by COSHH (Control of Substances Hazardous to Health Act) regulations and it is extremely important that dust is not allowed to accumulate. If a film of dust appears, measures must be taken to eliminate the source of dust and vacuum any deposits – the presence of dust would indicate a failure in the dust extraction system or leak in the plant.

An electrically driven fan sucks the dust through metal ducts or pipes from various points such as the elevator, dresser and weighing machine. There are several ways of dealing with the dust collected; it may be blown into a cyclone from which it drops down into a bagging point. In some installations dust is blown into sleeves mounted inside a metal unit, on a frame that can be vibrated at the end of the grinding or malt intake operation to shake off the dust. The dust then falls into a container at the bottom. A regular system of emptying the dust sacks or containers is necessary to allow the plant to work at maximum efficiency, and a periodical examination must be made of the pipe ducts to and from the fan to avoid build up and blockage by dust.

Even if there is good housekeeping, it may not be possible to completely eliminate the risk of explosions in hoppers and conveying equipment. For this reason, explosion vents are provided to allow an explosion to pass harmlessly into the atmosphere without damage to equipment and people.

## Safety Concerns (Dust)

The operations encompassed within grain intake and milling are potential hazard areas within any brewery:

- Health hazards as a result of dust exposure. Dust has long-term effects upon the human mucous membranes causing diseases such as pulmonary alveolitis.
- Risk of dust explosions.

Why should the intake of malt and adjuncts cause such problems? Although the maltster scrupulously cleans barley on intake and malt prior to dispatch, it is essential that the distiller also carry out rigorous screening of the materials on intake at the brewery. Even after malting and cereal processing, it is quite normal to find grain- sized stones, grits, string, and straw and metal particles that have escaped the cleaning operation. If these objects are not removed they can pass through the mill into the mash. These objects can cause damage to mill rollers or even nudge their alignment; this can affect the milling operation and therefore extract recovery. The most important objective during the removal of debris is to minimise the risk of explosion.

Vast quantities of dust are produced when handling grain, especially during malting. For instance, values quoted for dust production are in the range of 0.4 to 1.4 kg of dust per 100 kg of malt – a considerable volume. This dust is extremely dangerous and easily combusts. One spark produced from a piece of stone or metal can be sufficient to cause an explosion. This explosion can cause significant damage to plant hardware, and is an obvious fire risk. It is for this reason that smoking is prohibited throughout the brewhouse (in addition to food safety issues) whilst all equipment should be electrically earthed to avoid the production of sparks.

Supplementary safety measures are also employed in connection with dust explosions:

- Metal explosion sheets are located below the mill rollers. These hold back the grist to prevent the formation of an explosive air-grist mixture below the mill.

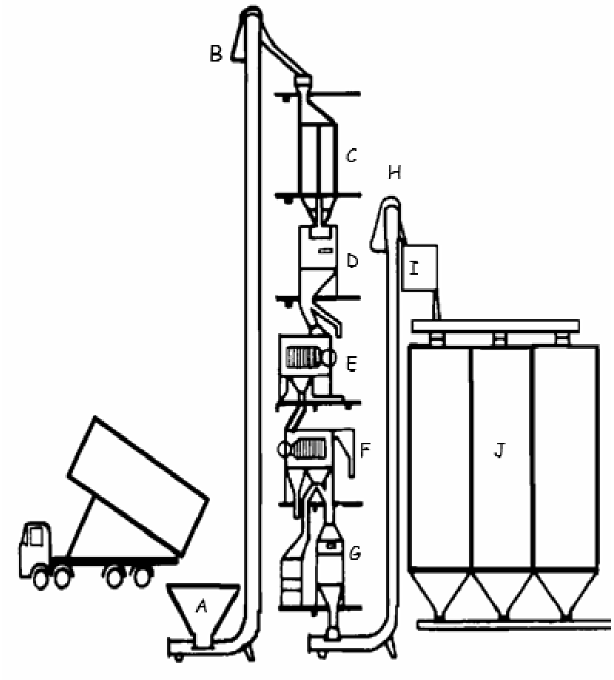
- Pressure release pipes (quench pipes) are installed that convert the kinetic energy of an explosion into thermal energy, which is released to the atmosphere. This prevents damage to the plant; however, they must be cleaned after each discharge.

- Explosion suppression; inert gas is injected into the chamber milliseconds after an explosion to prevent its spread.

Extraction systems are installed to remove all dust from the atmosphere in the mill room and ancillary plant. This minimises health concerns and the risk of dust explosions. This material can be recovered and mixed with the grist, a valuable method of extract recovery. Alternatively it can also be mixed with the spent grains produced during wort separation and sold as animal feed.

| Risk | Potential Effect | Prevention |
|---|---|---|
| Damage | • Poor mashing performance.<br>• Excessive dust generated. | • Gentle handling |
| Moisture pick-up | • Biochemical change.<br>• Infestation. | • Keep system dry.<br>• Intake under cover. |
| Consistent corn size | • Maximise milling and extract efficiency | • Screen to remove large and small corns. |
| Protect plant | • Damage to mills.<br>• Explosion risk. | • Magnetic extractor.<br>• Screens/ explosion vent/ dust extraction. |
| Hygiene | • Food safety.<br>• Infestation. | • Pest control.<br>• Cover intake hopper. |

*Figure 4 Malt Intake – The Key Risks.*



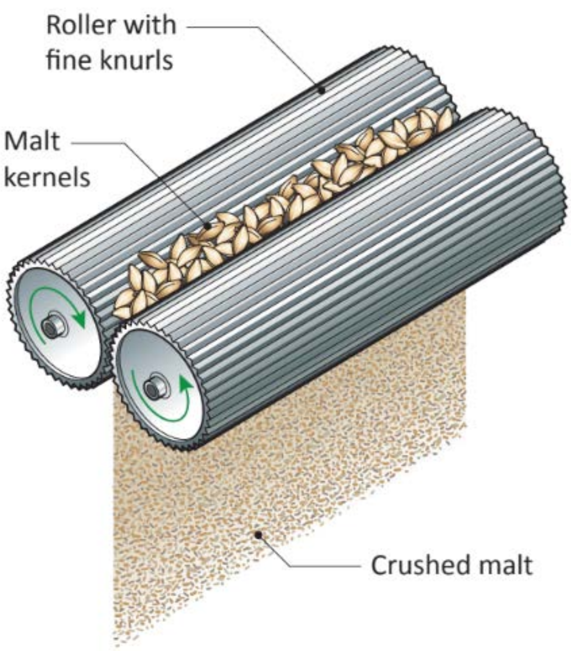

*Malt/ adjuncts are loaded into the intake hopper (A) and are transferred via the elevator (B) to the grain receiver (C). The grain may then be weighed before passing through the magnetic separator (E). The cereals then move through the cleaning screens (F) prior to a final weighing (G), along the elevator (H) and conveyor (I), for storage in the silos (J).*

## Milling

### Introduction

In a malt distillery, milling must crush the starchy endosperm into fine particles while preserving the husk. The fine particles are needed to expose the starch and enzymes to liquid so that they can disperse in the mash. The husk is needed as a filter bed for the extraction.

This process is illustrated below:




In practice there are usually four rolls in a mill in order to give the distiller good control of the particle size needed for the type of mashing vessel that the distillery possesses. The milled malt is called 'grist'. It consists of malt flour, malt grits and malt husks.

### The Purpose of Milling and Mill Types

The purpose of milling is to prepare the malt, wheat and maize for mashing and starch conversion by making the centre of the malt corn accessible.

Where a wort separation system like a mash tun or lauter tun is used, milling must crush the starch into fine particles while preserving the husk so that it can be utilised as an effective filter during separation.

Distillery mills are designed to meet the requirements of different types of malt and inert cereals and the different mashing and mash separation systems that are in use.

**Four roll mills** are often used for milling well-modified malts where the starch is readily accessible and a mash tun will be used for mash separation.

**Six roll mills** are sometimes used for milling less modified malts where the starch needs to be finely ground and the husk protected because of the aggressive treatment that the mash receives during cooking and transfer to lauter tun. They are not widely used in malt distilleries since the specification is for well modified malt.

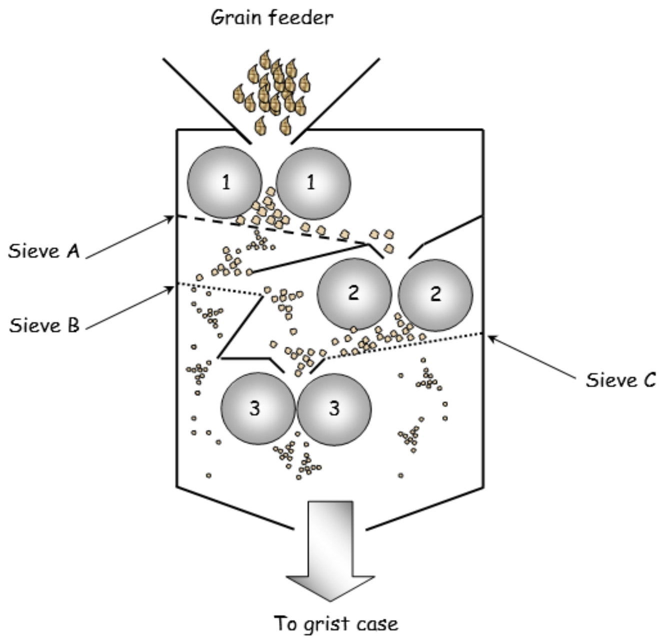



*Figure 5 A diagrammatic representation of a 6-roll mill (3 pairs of rollers).*

In grain distilleries, it is not usually necessary to preserve malt husks for filtration purposes. **Hammer mills** are used to achieve a fine malt grind, maximising the availability of the malt enzymes for the conversion of the maize or wheat starch to sugars. The preferred particle size specification, assisted by screening as in the malt distilleries, could be < 4mm, most particles being at 2mm.

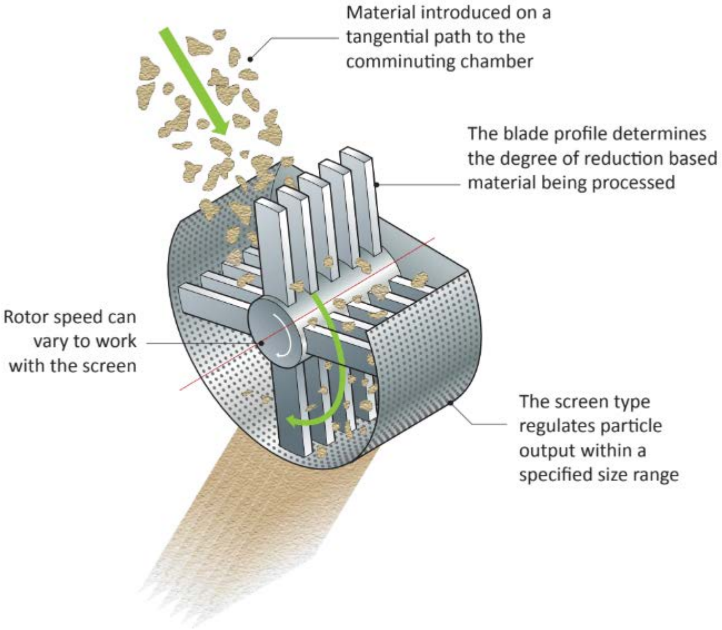



*Figure 6 A diagrammatic representation of a hammer mill*

Some distilleries use **green malt**, freshly produced malt that has not been stabilised by kilning. In this case, the milling is done in a wet hammer mill. Again, the objective of the milling is to expose the enzymes need to effect
conversion. Milled green malt has the consistency of a thin porridge, no particles being greater than a quarter of a corn in size. Obviously, all green malt has to be kept as cool as possible and used as quickly as possible, for it would deteriorate rapidly in storage.

KEYPOINT: In general 2- & 4-roll mills are suited to and used in combination with over/well-modified malts (e.g. malt distilling malts) infusion mashing systems obviating the need for more complex 5- and 6- row mills.

## Comminution

Malt contains all of the essential ingredients for spirit production, all the distiller must do is open up the malt and add water, yeast and energy.
The first step is to mill the malt and adjuncts to produce the **grist** (cereal flour). From the flour grist we **extract** the sugars, proteins and other nutrients essential for yeast fermentation.

There are two main objectives of milling malt and cereals for distilling:

1. Particle size reduction
2. Particle size control

During milling, the malt grain is crushed so that the highest possible yield of soluble nutrients can be extracted during mashing. This physical degradation of the malt into an array of small particles is called **comminution**.

The greater the degree of comminution (i.e. the finer the flour produced) the larger the surface area available for enzymatic attack – this means there will be a better extract efficiency. As a comparison it takes longer for a sugar lump to dissolve in your coffee than a spoonful of granulated sugar.

## Friability

The action of comminution is influenced by malt **friability**. What is friability? The friability (extent of modification) of malt is a measure of the amount of energy required to “crush” the grain.

During malting of barley the endosperm is modified to differing extents with particular areas prone to under-modification (high nitrogen, steely areas) and over-modification (the low nitrogen, mealy areas). The internal structure of well-modified malts fully degraded by diastatic malt enzymes are said to be friable – they are easily crushable and therefore require only a small input of mechanical energy (**milling**) to break them up.

In the case of poorly modified malt, the internal structure of the grain remains fairly intact (they are less friable) and requires a high input of energy via milling to comminute the grain.

Milling of well-modified malts yields grist with a large proportion of fine flours and small grits, whilst under-modified malts produce coarser grist. This is because the endosperm cell walls that survive in an under-modified grain bind the particles together giving coarse grits. Therefore, inhomogeneous batches of malt subject to the same milling operation (i.e. the same mill setting) will breakup into different sized particles – this is dependant upon the extent of modification.

If milling is excessive the grist produced will be too fine for Lautering (but may be suitable for **Mash Filters**). Extremely fine grist will theoretically yield maximal extract but hinder the separation of wort to the extent that wort filtration can be halted (a "set mash"). Wort filtration (**lautering**) is affected by particle size because very small particles reduce the porosity of the filter bed, which can become compressed. This causes process down time, and various quality issues associated with extended processing.

There is therefore a trade off between extract yield and process efficiency.

| |
|---|
| **Large grist particles**<br>Fast filtration = Reduced extract recovery |

| |
|---|
| **Small grist particles**<br>Slow filtration = Increased extract recovery |

## Compression and Shear

The milling operation crushes the malt to release the extract for mashing. The milling action is performed by pairs of rollers (set in sequence) or by steel beaters (hammer mills). When using roller mills the disruption of the grain structure is effected by:

- Direct compression on the grain.
- Shear forces.

The grain is compressed as it passes between the two rollers, which rotate towards each other (Figure 1). The rollers squeeze the grain disrupting its structure to produce particles of varying sizes. The shearing energy applies additional destructive force – this force is dependent upon the difference in the peripheral speeds of the rollers. High shear is produced when only one of the rollers is rotating. The second roller is turned by the action of the first, its rotational movement (and therefore destructive energy) transmitted through the grain as it passes between the two rollers.

Rollers arranged in parallel (essential for uniform milling) should have a minimum diameter of 250 mm, otherwise the **angle of nip** (the area which initially receives the grain to be crushed) is too small and performance is reduced (i.e. the crushing time is too short). The surfaces of the rolls are fluted like a cog but do not run in parallel to the roller axis; they are set with a slight lateral twist. This design intensifies the "cutting" action applied to the malt as it is drawn through the rollers.

The efficiency and capacity of the mill are therefore controlled by:

- Roller length.
- Roller diameter.
- Roller speed.
- The mill setting (the gap between the rollers).
- The friction between the malt and roller surface (increased by fluting).

## Mechanism of Grain Destruction

We have established that malt passing through the mill breaks up according to the friability of the kernel and the force placed upon the individual grain sections. In Figure 1 we can see how the grains are fed to the roller for crushing. In practice the grains are sorted and pass through the preliminary crushing rollers end-on; this means that crushing occurs over the whole length of the grain. Typically, transverse breakage of the grain occurs, whilst the husk is inclined to split longitudinally. This ensures that the endosperm fragments are released whilst the husk is separated but remains intact (remember the husk is important for Lauter filtration).

During milling for Lautering, it is important not to completely disintegrate the grain. The husk plays an important role, during lautering, as it forms part of the filter bed through which the wort is separated. This proportion of husk in the mash provides and helps maintain bed porosity. If the husk is completely shattered during milling, increased run-off times and inefficient wort clarification can detrimentally affect lautering. Furthermore, the husk is a potential source of polyphenols, which if extracted into the wort will affect beer flavour and shelf life. Polyphenols give beer an astringent flavour and contribute to haze formation. This is exacerbated if the husk is completely comminuted during milling.

If a mash filter is used to separate wort none of the problems with grist particle size are applicable as the filtration is performed through a polypropylene cloth. This cloth (an artificial filter bed) comprises a huge number of very fine pores. The wort is run-off through these pores, assisted by pneumatic compression of the mash within the filter chambers.

## Grist Evaluation

One of the most important tools the distiller has available is the plansifter. The plansifter consists of a series of sieves (stacked as a column) through which a 100 to 200 g sample of grist is shaken. Each sieve is sequentially set with a finer pore diameter. There are five sieves that separate the grist sample into a total of six fractions.

| Sieve Number | Fraction | Wire Thickness (mm) | Mesh Hole Size (mm) |
|---|---|---|---|
| 1 | Husk | 0.31 | 1.27 |
| 2 | Coarse grits | 0.26 | 1.01 |
| 3 | Fine grits I | 0.15 | 0.547 |
| 4 | Fine grits II | 0.07 | 0.253 |
| 5 | Flour | 0.04 | 0.152 |
| Sieve Bottom | Fine Flour | - | - |

*Figure 7 Plansifter sieve specifications.*

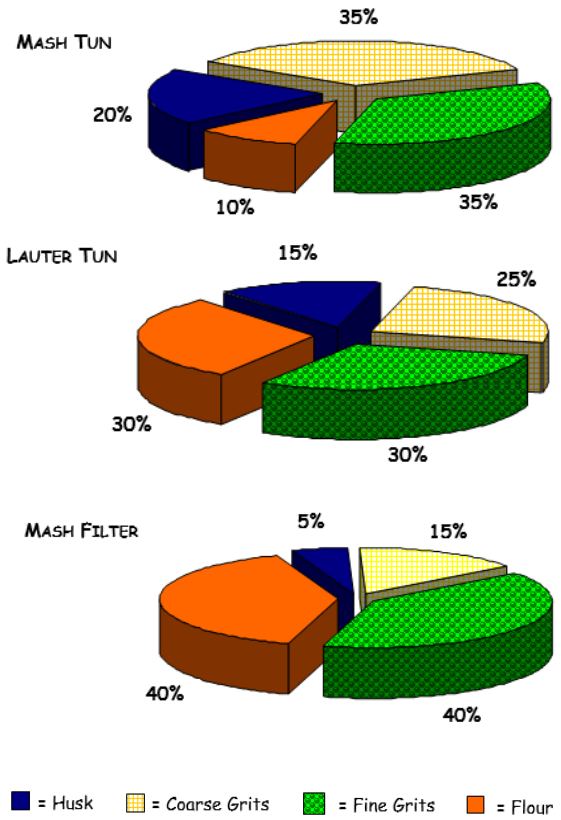
It is important to check that milling achieves the correct specification for the grist. By analysing the grist in this manner it is possible to diagnose and pre-empt mashing problems. Checking the grist allows us to check the integrity of the milling operation. If the mill operation has deteriorated (i.e. the rollers have become worn or the mill setting disrupted) the extract recovery value will suffer.

It is important though to set differing grist specifications depending on whether a lauter tun or mash filter is to be used to separate wort. Remember the mash filter can cope with much finer grist than the lauter tun.

## Grist Analyses

The quality of the grist or crushed malt that leaves the mill has a major effect on subsequent performance in the mashtun. If it is too coarse, the starch will remain protected and the enzymes will not be able to convert it into sugar.
If it is too fine, wort separation will be slow because the filter bed will become choked.
Grist quality can be judged by 'eye' or by sieve analysis.
To the eye, the grist should display large pieces of empty husk and small pieces of white grist and flour.
A traditional sieve box or more modern mechanical six sieve apparatus as described above is more objective and the ideal grist analysis for the malt and the mashhouse plant in use should be specified.

Examples of typical grist analyses for mash tun, lauter tuns and modern mash filters are illustrated in the charts below:




### Milling Safety.

Malt dust is hazardous, fine dust in the atmosphere is explosive and breathing in the dust can cause respiratory problems.

Malt mills are designed to prevent explosions. Magnets fitted to collect any steel or iron debris that could cause a spark. Stone separators are also installed to prevent sparks and to protect the rolls from damage/wear.

The modern mill and malt handling plant is fitted with explosion doors that would direct a blast safely outwards should an explosion occur.

People working on the malt plant need to wear dust masks to avoid breathing in any dust.

Safe systems of work (permits to enter confined spaces) are required for people entering malt silos.

## 1.2.2 Non-cereals intake, handling, storage and processing

### Molasses

The sugar in cane molasses is mainly sucrose with some glucose and fructose. Glucose and fructose are formed by the breakdown of sucrose during the sugar extraction process described above.
It is not possible to give a typical chemical analysis of cane molasses because of the variability referred to above. Composition of molasses varies/depends on:

- sugar cane variety
- maturity of the cane
- climate
- soil type and condition
- processing conditions in the sugar factory
- storage and handling conditions

An example of the chemical analysis by weight of one sample of blackstrap (cane molasses) is given below:
Typical analysis - % w/w unless stated: -

| | Range | Good |
|---|---|---|
| °Brix | 75 – 88 | 87 |
| Total sugars as invert (TSAI) | 50 – 58 | 58 |
| Sucrose | 31 – 37 | 37 |
| Reducing sugars | 13 – 20 | 20 |
| Ash (inorganic salts) | 7 – 14 | 7 |
| Other plant material | 20 | |
| Nitrogen | 0.4 – 1.2 | 1.2 |
| Gums | 2 – 4 | 2.0 |
| pH | 4.5 - 6.3 | 5.5 |
| Volatile acids ppm | 500 – 25000 | <5000 |
| F/N ratio | 0.9 – 1.6 | >1.0 |
| Sugar/Ash ratio | 4 – 8 | 8 |

Analyses such as these are important to a distiller because the content of fermentable sugars determines how much alcohol can be produced. The fermentable sugars are sucrose and its breakdown products, glucose and fructose (the latter two sugars are sometimes called the 'reducing sugars'). Most strains of yeast can quickly ferment all three of these sugars.

The importance of parameters on fermentation is as follows:-

- An F/N ratio – Fermentable to non-fermentable matter – of >1.2 is desirable, since it correlates with alcohol yield.
- The Ash content gives an indication of the sludge and calcium content. Inhibition of the yeast during fermentation and scaling deposition inside the stills are likely to be problems if the level is high. Levels up to 14% ash can are experienced.
- The pH is important and a pH of 4.5 is ideal for fermentation. However the natural cane juice pH will be typically 5 – 5.5, but after lime treatment (see later) the pH can be as high as 7 or even higher. Low pH can be indicative of heavy microbial infection.
- The level of volatile acids can inhibit the yeast and they can cause fermentations to stop early if the level is as high as 0.15% butyric acid.Yeast inhibition can also be caused by sulphurous acid. High levels of $SO_2$ can cause a lighter coloured molasses due to "bleaching" and give rise to $H_2S$ aromas on processing.
- °Brix or less for fermentation to proceed successfully.

The gravity of the molasses gives an indication of the total solid content. As can be seen from the example analysis above, most of the solids content is dissolved sugar. However, 30% of this molasses could be non-sugar material: so specific gravity measurements on molasses cannot be used to estimate the sugar content.

Main sugars present: -
–Fermentable – 40 – 50%
 •Sucrose, Fructose, Glucose
–Unfermentable – 4 – 5%
 •Galactose, Pentoses
Other non-sugars
–Protein
–Carbohydrate polymers – starch, gums
–Organic acids – acetic, propionic, valeric, butyric
–Waxes
–Vitamins,
–Salts – cations and anions

Despite this fact, it is a useful to measure specific gravity. This is because molasses must receive some treatment before it is used in the distillery. It is necessary to keep track of the specific gravity to show that pre-treatment is proceeding to plan.

The specific gravity can be obtained quickly by using a hydrometer. This is a glass instrument with a floatation bulb connected to a stem that has a scale of marks on it. The hydrometer is allowed to float in the molasses and a reading is taken on the scale at the level at which it settles in the molasses.

There are various types of hydrometer, one of which gives a reading of specific gravity directly. In the sugar industries another hydrometer is used, the 'Brix hydrometer'. In a pure sugar solution, the degrees Brix figure gives a direct reading of sugar concentration. For instance, a hydrometer reading of 49 degrees Brix (49ºBrix) in a pure sucrose solution indicates that there is 49% by weight of sugar in the solution. In molasses there is a lot of dissolved and suspended matter, other than sugar, so the Brix hydrometer can not be used to find the exact sugar concentration of molasses. Laboratory analysis for sugar content is also needed. There are other % w/w sugar scales:-

- ° Brix is used in the wine, sugar and fruit juice industries
- ° Plato is used in the brewing industry
- ° Balling is used in the South African wine industry

The differences between these scales are minor.

Specific gravity varies with temperature so the temperature of the molasses must be taken at the time of the hydrometer reading. A correction to the reading is added or subtracted as indicated by the Brix tables. The standard temperature for the Brix hydrometer readings is 20ºC.

The water content of the molasses received is of no direct importance to the distiller, apart from the fact that purchased molasses should not contain too much water and too little sugar.

The plant materials are a complex mix of compounds originating from the cane. Within this mix are:

- A small amount of nitrogen-containing compounds that can be used by the yeast to grow at the start of fermentation,
- The vitamins biotin and pantothenate for yeast growth and
- The vitamin thiamine for yeast fermentation.

The mineral salts are also important for yeast growth and fermentation.

## Molasses pre-treatment

Molasses must be prepared in suitable form just before fermentation. This process is sometimes called 'mashing', or it might be called 'molasses pre- treatment'. When the molasses has been prepared it is sometimes called 'the mash'. Alternative names are 'unfermented molasses' or 'molasses wort or wash'.

Pre-treatment includes some or all of the following:

- Dilution with water to say 55º Brix to reduce viscosity
- Removal of materials to avoid contamination of the distillation equipment with solids and scale
- Pasteurising, at say 75ºC, the molasses before fermentation or sterilising the molasses.
- Adjusting the acidity to neutralise the lime, to aid clarification and to set the pH level to the correct value for start of fermentation, say 4.5 – 5
- Clarification in centrifuges or clarifiers
- Diluting with water to the desired ºBrix, say 14ºBrix, for the start of fermentation
- Cooling to the fermentation temperature

- Addition of yeast, from propagator or "bubbing" tank
- Addition of yeast nutrients to ensure a satisfactory fermentation

Molasses clarification involves the removal of solids and scale-forming compounds. The types of compounds present and the processing for their removal are as follows:-

There are two groups of molasses constituents that could cause handling problems in a distillery:

- Various plant materials, about 20% by weight of the molasses and
- Dissolved salts (ash), about 10% (but up to 14%) by weight of the molasses.

The first group could settle out or be deposited in various parts of the plant, particularly in holding tanks, fermentation vessels and the still. Such deposits have to be removed and this leads to extra cleaning and increased plant downtime.

The second group, the mineral salts, can form a hard scale in the still. The compound responsible for most of the scale is calcium sulphate (gypsum). If this is deposited on the sieve plates of a column still, it reduces the size of the sieve plate holes. This alters the amount of contact between the vapour and the liquid on the plate, which is a critically important design factor. The result is reduced efficiency of distillation.

There are various methods for the reduction of the amount of these two types of material in the molasses.
In the first example below, temperature alone is used and the effect is to remove some of the plant material but not much of the calcium that leads to scaling:

- Molasses is diluted to below 50°Brix and held at about 75°C for some hours and then either centrifuged to remove the solids or the solids are allowed to settle out and the partially clarified molasses is decanted from the vessel.

In the second treatment, the chemical addition (sulphuric acid) causes the formation of insoluble calcium sulphate that is removed by centrifugation:

- Molasses at about 45 - 55°Brix is acidified using sulphuric acid, held at 90°C for one hour and then passed through a centrifuge or clarifier/s.

The second treatment also removes much of the plant material and both treatments simultaneously achieve pasteurisation on account of the elevated temperatures used. .

Dilution of molasses to the start gravity for fermentation has to be done since yeast cannot ferment concentrated sugar. The osmotic pressure is too high and there is too little water available to the yeast cells to support growth or fermentation.

For most yeast strains, the molasses must be diluted with water to below 25°Brix for fermentation to start. Fermentations work better at 22°Brix and better still at lower gravities such as 17°Brix, or even at 14°Brix for example, yielding 6 – 7% abv in the final wash. However this must be offset against the increased costs of distilling a lower alcoholic strength wash.

In order to increase the final wash alcoholic strength, but holding the initial starting gravity to say 14° Brix, incremental feeding can be used and this can lead on to either a semi-continuous or continuous operation.
For example:-

- Start the fermentation at say 14° Brix
- Feed with diluted molasses at 35 ° Brix, keeping the FV contents between 12 and 14 ° Brix until the vessel is full.
- Allowing overflow into one or more vessels, can create continuous or semi-continuous operation