BICEP #9

This session covers Boiling, Racking, Fining, Conditioning, Packaging and Aging, Haze and Categories 18 & 19 - Belgian Strong Ales & Strong Ales

Key to Abbreviations and Text

Bolded Text (except for headers) is important information which you should know for the exam.

Italic Text is "just for fun" and won't be covered on any of the exams.

***** This material might appear on the Online Qualifier Exam.

† This material might appear on the Tasting Exam.

‡ This material will be (or might be) tested on the Written Proficiency Exam.

Part 1: Boiling, Racking, Fining and Conditioning *‡

A. Wort Boiling

While the BJCP Written Proficiency Exam doesn't ask you specifically about wort boil, you might get a question related to it on the online qualifier exam, and some off-flavors you might encounter on the tasting exam can develop in the boil.

Why Boil Your Wort?: While it is possible to make beer without boiling your mash run-off, there are many good reasons to do so. In rough order of importance, the reasons to boil your wort are:

1. Isomerization and Extraction of Alpha Acids: Alpha acids don't dissolve in ordinary tap water, but the acidity of the wort and the heat of the boil isomerizes them (i.e., changes their chemical shape) so that they are soluble in wort. Length and vigor of wort boil is directly related to increases in hop utilization - the degree to which alpha acids are extracted from the hops. Maximum utilization is achieved after about 2 hours.

2. Sterilization: A boil of at least 20 minutes at temperatures of 200 °F is necessary to kill any bacteria, fungi or wild yeast which might have fallen into the mash, or which were present on the grains in the mash.

3. Good Hot Break: A rolling boil of at least 60 minutes is necessary to precipitates and coagulate undesirable proteins which are carried into the wort from the mash. See Hot and Cold Break, below.

4. Stops Enzymatic Activity: Boiling the wort kills any enzymes which might have survived doughing out, preventing them from continuing to act on your fresh wort. Technically, boiling isn't necessary to kill enzymes, however. Any temperature above about 168 °F, for 15-20 minutes is sufficient to kill the enzymes, but wort boil just speeds up the process.

5. Lowers pH: Boiling the wort slightly lowers its pH by about 0.2-0.3 pH. Proper post-boil wort pH is 5.2-5.5, which allows proper cold break to form and puts the wort in an optimum pH range for yeast activity. If wort pH is already at 5.2 or below before boiling begins, protein precipitation will be retarded, so a bit of carbonate salt (e.g., calcium carbonate - chalk) should be added to slightly increase alkalinity. If the wort is above the optimal wort pH range, it will increase hop utilization but will also extract tannins and make it harder for the hot break to form.

6. Drives Off Undesirable Aroma and Flavor Compounds: Boiling drives off harsh hop oils, ketones and esters, as well as sulfur compounds formed in the malt (e.g., DMS). A full, rolling boil of at least 60 minutes, with some method of keeping the condensate from dripping back into the kettle (e.g., an open boil or a fan to pull off steam) is necessary to reduce DMS in worts made from malts which are high in SMM (S-methyl methionine) - notably German Pils malts, but also potentially Munich and Vienna malts. Worts made using high sulfate water might also benefit from a long wort boil, since this drives off sulfur compounds.

7. Melanoidin Formation: Wort boil encourages Maillard Reactions, which promotes the formation of melanoidins. This is highly desirable in some beer styles, especially amber or dark malt-focused beers, but undesirable in extremely light-colored beers.

In extreme cases, particularly in the case of very concentrated wort boils, melanoidin formation can result in licorice-like or inky notes, which can be described as "extract twang"

8. Caramelization: Wort boil, especially in a directly-heated boil kettle (typical for most homebrew systems) exposes sugars in the wort to high temperatures, cooking them into denser compounds with additional flavor components. This is also highly desirable in some styles (e.g., Scottish ales), but undesirable in others (e.g., Vienna lagers, Oktoberfests). Excess heat on the bottle of the boil kettle can scorch the wort, resulting in unwanted dark roast, bitter burnt or smoky flavors and aromas.

9. Decreases Wort Volume: Boiling reduces wort volume by approximately 5-10% per hour (less on closed systems), which boosts specific gravity of the wort and IBU from early hop additions by a similar amount, as well as concentrates any brewing salts in the wort. If you wish to make a specific volume of finished beer, or a beer of a particular ABV or IBU level, you must take decrease in wort volume into account. In some cases, decrease in wort volume is desirable, because it allows you to bring slightly weak wort up to the desired specific gravity for a particular recipe. In other cases, it is undesirable, due to loss of wort volume and concentration of flavors.

Losses of wort volume due to boiling can be made up by adding a bit of deionized or distilled water to the boil at least 20 minutes before the boil ends.

To estimate wort volume losses due to the boil, you should measure specific gravity of the wort before and after the boil.

10. Mixing and Extraction of Adjuncts: Boiling the wort allows soluble additives added to the wort to dissolve and mix evenly throughout the wort. This is particularly important if adding syrups, since if not properly mixed they can sink to the bottom of the kettle and form a "density gradient" which can result in scorching of the syrup, excessive caramelization and false readings of specific gravity.

Other adjuncts, such as Irish moss or similar kettle finings, must be rehydrated before they can work properly, and exposure to hot liquid speeds the rehydration process.

Finally, in some beers herbs or spices might be added to the wort kettle, either during the boil or by steeping them in the hot wort after the end of the boil but before the wort is chilled.

Chemistry and Physics of Wort Boiling: During wort boil, many chemical and physical reactions are going on besides just boiling water.

Caramelization: Caramelization only occurs at very high temperatures (230 °F for fructose, 320 °F for glucose and sucrose, 356 °F for maltose). For this reason, it doesn't occur in indirectly-heated (i.e., steam or water jacketed) boil kettles.

It can easily occur in direct-fired homebrew equipment, however, particularly if a thin-bottomed (i.e., cheap) or poorly conductive (i.e., stainless steel) pot is placed directly over a very powerful propane burner. Thin-bottomed pots placed directly on electric heating elements can also get hot enough on the bottom to caramelize, or even scorch, the wort. Caramelization or scorching can also occur around or on electrical heating elements placed in the wort.

Coagulation of Proteins: Coagulation of proteins mostly occurs in the first 20 minutes or so of the boil and results in the "hot break" which forms on top of the boil kettle. This material should be skimmed off to help remove harsh tannins and other polyphenols from grain husks and hop material. Continued boil helps to further coagulate and flocculate the hot break.

Rapid temperature rise to boiling and a subsequent rolling boil helps to form and further coagulate and precipitate the hot break.

Isomerization of Alpha Acids: Isomerization starts at about 175 °F, but between temperatures of 194-212 °F, isomeration rates are halved. (By contrast, maximum hop isomerization actually occurs most rapidly at temperatures of up to 220 °F, although the alpha acids are rapidly broken down above that point.) For this reason, rapid rise to a full, rolling boil is essential. A weak boil, with a slow temperature rise, like that obtained using a typical electric stove burner and a 5 gallon stock pot, results in reduced alpha acid extraction.

Maillard Reactions: Maillard reactions increase as the wort gets closes to boil temperatures and then continue at a somewhat steady rate from there. They consist of reactions of amino acids (liberated during mashing and wort boil) interacting with reducing sugars to give nutty, toffee, biscuity, cracker-like or bread crust notes. Maillard reactions are increased in high-gravity worts, or "partial boil" batches of beer made using extracts, where the brewer only boils part of his extract and then adds it to water to dilute it to pitching strength.

Thermodynamics of the Wort Boil: *Since wort is mostly (e.g., 90-95%) water, it can be treated as water when figuring how much energy is needed to heat and cool it.*

The main problem with heating and cooling water is that water is dense for its molecular size and has a high specific heat. Practically, that means that it absorbs and releases heat slowly. This means that water is a great insulator and temperature buffer, but it also means that it takes a lot more energy to heat it to a boil, and it cools down much more slowly than we'd like when it's time to chill the wort.

The thermodynamics of boiling a pot of water are actually rather complex once you take into account things like vapor pressure of the surrounding air, heat transfer efficiency rates, cooling due to the surrounding air, and so forth. Since this class is on brewing, not physics, we'll skip all that.

But, while it's annoying if you're trying to do physics, the British Thermal Unit is great if you're trying to boil water and you're used to English measurements, since it's a measure of the energy needed to raise the temperature of one pound of water (about 0.12 of a gallon) by 1 °F.

Even better, in the United States, the term BTU is used to describe the heat value (energy content) of fuels, and also to describe the power of heating and cooling systems. When used as a unit of power (i.e., amount of work done by a unit of energy), BTU per hour (BTU/h) is actually the correct unit, although this is often abbreviated to just BTU.

To figure out how many BTU are needed to raise or lower the temperature of a volume of water in an hour, use the following formula:

(T1-T2) x M = BTU

Where T1 is your initial temperature, T2 is your desired temperature and M is the weight of water in pounds. For convenience, we can assume that the mass of a gallon of water is 8.3 pounds (it actually varies a bit based on temperature).

If you must want to know how much energy it takes to alter the temperature of 5 gallons of water just use a conversion factor of (8.3 x 5 =) 41.5, or a conversion factor of 83 for 10 gallons.

For example, to raise the temperature of 5 gallons of water from 170 °F to 212 °F (i.e., from mash-out to boil temperature) over the course of an hour, you'll need to raise the temperature by 42 °F, so you'll need 42 x 41.5 = 1,743 BTU.

But, brewers generally want faster increases or decreases in temperature, which means that even more BTU are needed. In those cases, divide the desired temperature change in BTU by the desired fraction of an hour. For example, to bring that pot of water to a boil in just 30 minutes you'd need twice as much energy (divide by 0.5), and to bring it to a boil in just 15 minutes you'd need four times as much energy (divide by 0.25).

To determine how fast a particular energy source will actually alter the temperature divide the required BTU by the BTU/hour rating of the energy source. For example, to heat the water in the example above to a boil using a 7,000 BTU gas stove burner would theoretically just take 1743 BTU/7000 BTU/h = 0.249 hours, or about 15 minutes.

Of course, these calculations assume 100% efficiency, which isn't realistic. These energy calculations also assume perfect energy transfer. Heat loss is based on a whole host of factors, making for very complex calculations. A simple rule of thumb is about 50% efficiency, meaning that it's more realistic to assume that a typical gas stove burner will heat a 5 gallon pot of water in about 30 minutes.

Things get more complex once water reaches a boil, since extra energy is needed to turn liquid water into steam (chemists and physicists call this heat of vaporization). To maintain a rolling boil which evaporates 1 pound of water in an hour requires 970 BTU. For example, for a 5 gallon batch where you want approximately 10% volume reduction, this means that you want to boil off half a gallon of water, you will need to vaporize about 4.1 pounds of water, which would require just 485 BTU. As a rule of thumb, any heat source capable of raising the temperature of water to a boil can easily keep it at a boil.

So, a 54,000 BTU burner should easily boil a 62 quart pot in about 41 minutes (assuming the 50% efficiency) and hold that pot at a rolling boil. However, if you move to a 104 quart pot (26 gallons), the heating time almost doubles and now you are sitting around an hour or more waiting for the pot to boil. When boiling these large volumes of water, you may want to consider moving up to a higher BTU propane burner. A 110,000 BTU *burner would approximately cut these boil times in half. Cast iron propane burners are best suited for pots that are below around 40 quarts and jet burners are best suited for pots above 40 quarts if you are concerned about boil times.*

For the most part, you can ignore thermodynamics of boiling, except that having a very powerful heat source is handy if you want to boil a lot of water (or wort) quickly. Scaling up from 5 gallon batches to 10 gallon batches at least doubles the amount of time required to heat or cool your wort, and in some cases slow heating or cooling can lead to problems, such as longer brew days, poor hot break formation and increased risk of infection (from slow cooling of wort).

Of course, bigger heat sources aren't always better. Unless the extra heat is well distributed across the bottom of your boil kettle, you might caramelize or even scorch your wort. In extreme cases, you might even damage your pot or other brewing equipment! Big propane burners will also use lot of fuel, create a lot of waste heat and produce lots of waste gas - including potentially deadly levels of carbon monoxide.

Big propane burners will also go through fuel fast, so you will need to figure out how much energy your propane tank has (a pound of propane has 21,591 BTU/hour fuel value) against how many BTU your burner uses per hour to figure how long your tank of propane will last. You don't want to run out of fuel just when you need it most!

Finally, how much heat propane burners actually deliver depends on things like gas regulators and availability of oxygen for the flames.

Typical BTU/hr Ratings of Common Heat Sources

Source	***BTU/hour***
Electric Stove Burner	*4,000-7,500*
Gas Stove Burner	*3,000-7,000*
Hurricane/Banjo Burner	*60,000-210,000*
Jet Burner	*Up to 880,000*
Typical Propane Burner	*54,000*

B. Hot and Cold Break‡

While both hot break is properly part of the boil, and cold break is properly part of wort chilling, they both have important effects on the quality of the finished beer. More to the point, a potential question on the BJCP Written Proficiency Exam requires you to understand the hot and cold breaks in detail.

1) Hot Break (AKA Kettle Break): Hot break is an albuminous precipitate formed primarily during the first 5-20 minutes of the wort boil, consisting of denatured high molecular-weight proteins which have polymerized with carbohydrates and polyphenols (especially tannins, but also anthocyanogens and Flavanols) but also containing contains lipids and other compounds. The exact composition is about 50-60% protein, 20-30% polyphenols, 15-20% hop resins, and 2-3% "ash" (i.e., other materials, such as insoluble salts).

Hot break forms at a rate of about 20-40 ppm. When it first forms it appears as a brownish or greenish scum on the top of the boil kettle and is a major factor in boil-overs. In suspension, the trub particles initially have the appearance of small whitish flakes which grow larger as flocculation continues. By the end of the boil, the break can have the appearance of egg whites in egg-drop soup. When precipitated, it mixes with hop debris and has a greenish-brown slimy appearance.

What's Happening: Hot break begins forming at the start of the wort boil (at 212 °F). 60% of the hot break is formed within the first 5% minutes of boiling, but longer boils times will increase this figure, up to 95% protein removal after a 2 hour boil. The proteins coagulate, clump together and sink to the bottom of the brew kettle. They can then be separated from the rest of the wort when it is transferred to the fermentor.

The chemical process which causes the hot break is electrostatic attraction - the same principle which allows various types of finings to work. At wort boiling temperatures, normally soluble proteins are denatured by the heat, increasing their positive charges, making them more electrostatically attractive. They then interact with negatively charged polyphenols (mostly tannins), carbohydrates, lipids and other materials to form larger molecules which precipitate more quickly and which can be more easily filtered.

Hot break should be removed from the wort before it is chilled. Methods of removing the hot break include settling, filtration, hopbacks and whirlpooling. It can also be skimmed off the top when it foams up as the kettle comes to a boil.

Factors Affecting Hot Break Formation: There are many factors which affect how much hot break is formed.

1) Type and amount of malt and adjuncts. Grains higher in proteins and beta-glucans produce more hot break. This includes malts made from poor-quality (i.e. high nitrogen) or poorly modified malt (e.g., traditional American 6-row, although modern malts are all relatively low in nitrogen). This also includes other types of grains or malts with high proteins or beta-glucan levels, such as wheat, rye and oats.

2) Mashing schedule: An excessively short or long protein and/or beta-glucan rest will reduce hot break formation. An insufficiently long rest leaves most of the proteins and beta-glucans in the grain, while an excessively long rest will break down long-chain proteins into polypeptides and peptides, which are more soluble in wort.

3) Boil Time: A full, rolling boil of 60+ minutes is necessary for sufficient **proteins to precipitate**, but hot break is **maximized by a 2 hour, extremely agitated boil**. With well-modified modern malts, however, there is less need for long or aggressive boils (as little as a 2% volume reduction using modern malts). At wort boiling temperatures, normally soluble proteins are denatured by the heat, increasing their positive charges, making them more electrostatically attractive.

4) Boil Vigor: Rolling boils are necessary to agitate the wort, so that the molecules which form the hot break can better interact. **Hot break is improved by a quick rise to boiling temperature.**

5) Wort pH: Low pH worts (below 5.3 at room temperature) render proteins more soluble, making them harder to precipitate. Worts below pH .50 make hot break impossible.

6) Presence of polyphenols: The presence of tannins, and to a lesser extent, anthocyanogens and Flavanols, increases hot break formation. In properly produced wort, most of these products will come from boiling hop additions, but in wort where particles of grain husks have been carried into the wort, or where tannins have been extracted from grain husks by improper mashing techniques, there may be significant levels of malt-derived tannins as well. If not precipitated, these will be a major contributor to chill haze.

7) Kettle finings: Kettle finings, such as Irish Moss or WhirlflocTM™, aid in the precipitation of the hot break. Bentonite added to the boil achieves the same effect. The positively charged fining particles attract negatively-charged tannins and carbohydrates helping them to flocculate and increasing the rate at which they precipitate. They are typically added 15-20 minutes before knock-out so they have time to work.

Why is it Important?: A good hot break is necessary for storage stability and to reduce haze formation. If not precipitated, tannins and proteins can complex at cool temperatures to form an unsightly haze, while suspended medium- to long-chain polypeptide and starch molecules can form hazes at any temperature. Just as important, if not precipitated and removed from the wort before it is pitched, fatty acids (lipids) present in the beer can oxidize during conditioning or storage to produce a variety of unpleasant oxidized notes, primarily papery, cardboard-like aromas and flavors (trans-2-nonenol), but also goaty, sweaty or rancid notes (caproic, caprylic and capric acids). Polyphenols carried into the wort can oxidize to produce harsh, astringent "solventy stale" (furfural ethyl ether) notes and haze. Oxidation of proteins can result in permanent haze. **If hot break isn't removed from the wort before it goes into the fermenter, it will be carried over into the finished beer, where proteins in the hot break can cause off-flavors, chill/protein haze and flavor instability. High levels of hot break products in the fermenter can also cause the yeasts to produce excessive levels of fusel alcohols & sulfur compounds.**

2) Cold Break: Cold break is the coagulation and precipitation of proteins, carbohydrates and other materials during wort cooling. It consists of short- and medium-chain proteins polymerized with carbohydrates and polyphenols not precipitated during the hot break, as well as up to 50% fatty acids (mostly oleic and linoleic acids). It has the appearance of egg whites in egg-drop soup.

What's Happening: Cold break **begins at about 140 °F** and is **maximized if the wort is rapidly cooled to a temperature of less than 70 °F.**

Short- and medium-chain protein and carbohydrate molecules, which were previously soluble in the wort at boiling temperatures, become insoluble as the wort cools and its saturation point decreases. As the molecules fall out of solution, they are electrostatically attracted to each other, flocculate and precipitate just like the hot break.

Material congealed by the rapidly cooling temperatures sinks to the bottom of the kettle, so that it remains behind when the wort is transferred to the fermentor. Commercial breweries sometimes **increase removal of cold break by whirlpooling** the cooled wort or by running it through a **hopback or filter**. **Some cold break should remain** in the wort to provide yeast nutrition, however.

Factors Affecting Cold Break Formation: Several Factors influence Cold Break Formation:

1) Type and amount of wort and adjuncts: As for Hot Break.

2) Wort pH: As for Hot Break.

3) Presence of polyphenols: As for Hot Break.

4) Use of Finings: As for Hot Break.

5) Rapid Cooling: Quick cooling results in better cold-break formation. Ideally, the wort will be chilled to as low a temperature as possible (down to 32 °F)

Why is it Important?: **If cold break isn't removed from the wort before it goes into the fermenter, it will be carried over into the finished beer, where proteins and polyphenols (tannins) in the cold break can cause off-flavors, chill/protein haze and flavor instability.** High levels of cold break products in the fermenter can also cause the yeasts to produce **excessive levels of fusel alcohols & sulfur compounds (DMS).** Reduced cold break also increases the clarity of the finished beer.

A good cold break is necessary to remove lipids from wort, as well as additional proteins, tannins and carbohydrates not precipitated by the hot break. Removal of lipids results in better head formation and stability, and prevents staling. Some of the fatty acids present in cold break are necessary for yeast development and health (they are used for form yeast cell walls), so some cold break should be carried into the fermenter. Trub particles can also act as nucleation sites for CO2 bubbles to form, helping to remove CO2 from the fermenting wort, further aiding yeast metabolism. Some commercial breweries pitch their yeast into partially clarified wort, let the yeast work for 12-24 hours and then transfer the fermenting wort into the main fermentation tank, leaving most of the break behind.

The Cold Break also helps to precipitate complexed proteins and polyphenols responsible for chill haze, as described for hot break.

If hot and/or cold break are carried into the fermenter, the higher levels of amino acids and fatty acids will result in the yeast producing higher levels of higher alcohols (and lower levels of esters.

C) Chilling the Wort

Rapid Wort Chilling is necessary for proper cold break, to limit DMS formation, and to minimize the time that the boiled wort spends in the "danger zone" between the temperature at which it can be infected by spoilage organism and the temperature at which the yeast is pitched.

Homebrewers typically chill their wort using water baths or water-cooled wort chillers. Commercial brewers use refrigerated heat exchangers.

Many homebrewers don't cool their wort sufficiently, either due to desire to finish the wort chilling process sooner, or due to equipment limitations. While yeast can survive in wort chilled to 5-10 °F above optimum fermentation temperature, doing so promotes formation of off-flavors and can also shock the yeast if the fermenting wort is cooled to proper fermentation temperatures too quickly.

The two critical temperatures when wort chilling are 140 °F - the temperature at which DMS no longer forms and where bacteria can survive, and yeast pitching temperatures (50-65 °F).

Methods of Wort Chilling: *There are three basic methods of chilling the wort:*

1) Adding Cold Water: *Extract and partial grain brewers sometimes do a "partial boil" where only part of the total water needed for the full batch of beer is used to rehydrate the extract and boiled. After the boil ends, the rest of the water is added to make up the required wort volume and to cool the hot wort.*

This can work well, as long as the brewer is willing to accept the limitations of a highly concentrated boil (e.g., reduced hop utilization rates, increased color and melanoidin development) and he uses very cold water. Attempting to cool boiling wort using ground temperature (55-65 °F) water just cools the wort to about 100-120 °F.

A typical strategy is to boil the extract in just two gallons of water and cool using three gallons. To get maximum cooling, the water must be refrigerated to near freezing temperatures. To limit the risk of contamination (since most refrigerators are *swarming with bacteria), the brewer must used boiled (or otherwise sterile) water stored in sealed, sanitized storage containers. The necks and lids of the containers should be dipped in or sprayed with a good contact sanitizer (e.g., isopropyl alcohol or a sufficiently dilute bleach solution) and the sanitizer left to work for a sufficiently long time just before they are opened.*

If using a glass fermentation vessel, the cold water should be added to the fermenter first, and then the hot wort added slowly while mixing thoroughly.

A variation of this method is to use sterile ice which is added to a plastic fermentation bucket. The boiling wort is then poured over the ice. This can work well, but it is difficult to get sterile ice in a form which can be easily transferred to the bucket!

Obviously, this method isn't appropriate for all grain brewers or extract brewers who do don't use partial boils.

***2) Cooling Baths:** The wort kettle is left to stand in cool water or ice. If cold running water is used, or if the brewer has sufficient amount of ice, this method can work well for small batches of beer, although it takes time since the transfer efficiency of heat through the walls of the boil kettle is poor, and the contact surface between the pot and the water is relatively small. To speed things along a bit, the brewer can stir the water bath, the wort or both. Even so, it takes several hours to cool a five gallon pot of hot wort to room temperature using a flowing water bath of cellar temperature water, which is unacceptably slow. Ice baths work better, but they require a lot of ice to work properly.*

Keep in mind that most kitchen sinks are also bacterial havens, so they must be thoroughly sanitized before being used as water baths.

This method is also potentially dangerous unless the brewer is strong enough to easily lift and carry a stock pot filled with five or more gallons of boiling liquid!

A poor cousin to this method of wort chilling is to just cover the boil kettle and let it cool overnight. This minimizes cold break formation and invites bacterial contamination by wort spoiling organisms. If you chill your wort in this fashion, you're asking for trouble.

***3) Heat Exchangers:** Some form of heat exchanger is the best method of wort chilling. Commercial brewers use elaborate heat exchangers which are cooled using some form of refrigerant. Homebrewers use plate chillers, wort chillers or counterflow wort chillers.*

All homebrew heat exchangers are dependent on the ambient temperature of the groundwater used to cool them. This makes it hard to cool wort to lager pitching temperatures in warm weather, or in areas of the world where the water never gets that cold. They also require large amounts of water. Although waste water can be used for other things (especially the extremely hot water which comes out of the exchanger when it first starts the heat exchange process) they are still potentially wasteful, particularly in regions where water is scarce.

Efficiency of heat exchanger designs is improved by greater contact area between heat exchange surfaces and liquid, turbulence within the chiller (more is better), material used to make the heat exchange surface and slower flow rates. Practically, this means that coiled or bent small diameter copper pipe makes an excellent heat exchanger.

***A) Immersion Wort Chillers:** A simple immersion wort chiller consists of a coil of copper refrigerator tubing with a hose on each end. The hose on one end has fittings which allow it to be attached to a faucet, while the other end is the outflow pipe. The chiller is filled with deionized water and put into the boiling wort for 10-20 minutes at the end of the boil in order to sanitize it. At knockout, the brewer attaches the hose to the water source and turns on the faucet. Water moving through the copper coil picks up heat from the hot wort, quickly chilling it.*

In a 5 gallon pot, cellar temperature water running through an immersion chiller can cool the wort to ale pitching temperatures (65 °F) in about 30 minutes, which is an acceptable rate. Larger batches take much longer to cool.

To speed the process, the brewer can stir the wort. This also creates a minor "whirlpool" effect which concentrates the break and hop trub in the center of the pot, making it easier to rack just the wort into the fermenter.

Immersion wort chillers have the advantage that they leave all the break and hop trub behind in the brew kettle. They are also simple to make and easily to clean.

They also cool the entire batch of wort at a uniform temperature, rather than rapidly cooling just a bit of the wort at a time. This makes them better for limiting DMS formation.

***2) Counterflow Wort Chillers:** Counterflow wort chillers consist of copper coil wrapped inside either a larger copper coil or rubber garden hose. A fitting on each end makes the gaps between the inner and outer coil watertight. Valves allow water to be pumped through the outer coil. This design is more efficient that an immersion chiller because wort is pumped in one direction through the inner coil, while water is pumped in the other direction through the outer coil.*

These designs can cool a 5 gallon batch of wort to ale pitching temperatures in about 15 minutes using cellar temperature water, or cool a 10 gallon batch in 20-30 minutes.

They are much harder to clean, however, since the brewer must remove all the wort (and beer stone) from the inner coil. They also require the brewer to pump the wort through the coil, which almost demands some sort of pump.

Counterflow chillers can be kept clean by running hot water and sanitizer through them immediately after use. All metal chillers can be boiled in order to sanitize or sterilize them.

***3) Plate Chillers:** These are basically improved versions of a counterflow wort chiller. They are commercial designs which consist of a number of metal plates, sometimes pierced with holes, sometimes cut in a "baffle" pattern which are riveted or welded together, and which are fitted with hose attachment points for wort and water. Since they use more efficient materials and designs, they cool wort faster and use less water. They can chill a 5 gallon batch of wort to ale yeast pitching temperatures in 5-10 minutes.*

They have all the same advantages and drawbacks as a counterflow wort chiller.

Commercial brewers use variants of plate chillers, but often substitute refrigerant for tap water. They also have larger pumps to get faster flow rates, allowing them to rapidly chill hundreds or thousands of gallons of wort in just a few minutes.

A few homebrewers have built refrigerant-cooled plate chillers using window air conditioners.

D) Racking

Racking is the process of transferring wort or beer from one vessel to another. It is a relatively straightforward procedure, but there are a few problems which can arise.

The major problem is risk of contamination. This is a serious risk for homebrewers who just use siphon using a length of hose which they start by sucking on one end. The human mouth is filled with bacteria and it is impossible to adequately sanitize your mouth. (Minimum contact time for sanitizers such as ethanol is at least two minutes. Try gargling with vodka for two minutes . . .)

An easy way to start a siphon is with an auto-siphon or siphon pump. These gadgets are cheap, easy to clean and use, and quickly pay you back in time and trouble saved. Wealthier, more technically-oriented homebrewers substitute pumps for siphons.

A lesser risk is trub pickup, which can lead to off flavors in your beer. This is easily avoided by using a rigid racking cane at the end of your hose (or pump), since it allows you to control exactly where you rack from within the liquid. Most racking canes have small plastic caps which can be fitted on the end to limit trub pickup. A more effective, but clumsier, design is to attack a stainless steel scouring pad to the end of your racking cane, which serves as a filter.

When racking, attempt to keep the wort of beer from splashing as much as possible. No bubbles should be visible within your hose or siphon tube or cane.

If using a pump, make sure that there is no air within the pump housing, and that the pump is running slow enough that it doesn't cause cavitation (i.e., form air bubbles).

E) Finings‡*

While knowledge of finings isn't necessary for the BJCP Online Qualifier exam, some faults you might encounter on the BJCP Beer Tasting Exam require you to understand the basics of how finings work. The BJCP Written Proficiency Exam might have a question which requires you to describe how finings work in more detail.

During conditioning, brewers sometimes add finings to "brighten" or clarify the beer. Fining helps precipitate haze-forming starch and protein compounds, as well as precipitating tannins, phenols and suspended yeast.

Finings are a solution of fine particles which are added to wort or green beer in order to increase the rate at which suspended material flocculates and falls out of solution. Fining particles are positively or negatively electrostatically charged, so that they attract other particles to them. The larger clumps of material precipitate faster. <u>At least 50 mg/l calcium</u> is necessary in the wort or beer in order for most finings to work. All types of finings clarify beer and aid flavor stability.

Effects on Beer: There are two classes of finings, which can be added at different stages of the brewing process:

1) Kettle/Copper Finings: Help coagulate hot break, - proteins responsible for protein/chill haze and flavor instability. Typical kettle finings are **Irish moss** (dried seaweed - Chondrus Crispus - at 50-150 mg/l), Protofloc™ (30 mg/l), carrageen (a gum used in food production - derived from seaweed), and **Whirlfloc™** (20-60 mg/l). **All are added at the rate of approximately 1 tsp/5 gallons in the last 15 minutes of the wort boil.**

2) Fermenter/Cold Side Finings: Either added to conditioning tank near the end of conditioning period or added to the cask (for cask-conditioned ales). Used to remove yeast, protein or starch hazes. These fining are often packaged as powders and must be rehydrated using sterilized hot water. Common types are **isinglass** (dried collagen obtained from the dried swim bladders of fish, historically sturgeon or cod, now various fish species from the South China Sea. Added at 1-3.5 mg/l at 42-55 ºF), **brewers' gelatin, Polyclar™** (tiny beads of PVP - polyvinyl pyrrolidone - plastic) **or silica gel** usually added at 1 - 3.5 mg/l.

Isinglass is collagen derived from the dried swim bladders of fish, and is traditionally used to treat English cask-conditioned ales. It is excellent at making suspended yeast and lipids drop out of solution, but not so effective at settling proteins and not effective at all in removing the polypeptides responsible for chill haze. Isinglass works quickly and should be added 2-3 days before the beer is racked to secondary. It should be added cold to your raw beer since heat denatures it. It works at temperatures of up to 60 °F, but it performs better in colder beer. Two ounces of liquid will treat 5 gallons.

Gelatin is also used as yeast flocculent. It works on the same principle as isinglass, but is only a half to a third as effective. The beer must be colder than 50 °F, and like isinglass, gelatin works better on colder beer.

PVPP is a plastic called polyvinylpolypyrrolidone or povidone, sold under the trade name of Polyclar™ which takes the form of white, microscopic beads. It readily absorbs phenols, which smoothes beer flavor and helps prevent protein haze. It is commonly used by commercial brewers as a clarifying and stabilizing agent. It should be mixed with cooled boiled water to form a slurry and then and gently mixed into the finished beer. It mostly settles out after a day, but since Polyclar is not approved for human consumption, the beer should be racked off the sediment before it is packaged. Commercial breweries remove it by filtration. 6-10 grams will treat 5 gallons.

Polyamides, such as nylon, work identically to PVPP.

Silica gels, such as silica hydrogels and xerogels, are protein binding compounds, used by commercial brewers to remove polypeptides and proteins which contribute to haze and beer staling. They are particularly effective at removing protein haze-forming compounds since they bind to the same sites as polyphenols (tannins) do. It is typically added at the same time, in the same amounts, and in the same way as PVPP, since the two compounds have synergistic effects. As with povidone, it should not be ingested, so beer treated with silica gel must be racked off the sediment or filtered.

3) Other Fining Materials: In addition to the typical hot- or cold-side finings, some additional materials have traditionally been used to fine beer.

Beech or hazelnut chips or strips are traditionally used in German brewing to precipitate yeast. They are boiled for 12-24 hours in a sodium bicarbonate solution and then rinsed. The process is then repeated, sometimes using bisulfate of lime. Finally, the shavings are rinsed in a cold-hot-cold water cycle. The pH of the water from the last rinse should be neutral, indicating that all the bicarbonate has been washed out. Once prepared, the chips are laid on the bottom of the lagering vessel to form a loose lattice. There they bond yeast cells to them, thus clearing the beer.

F) Conditioning and Lagering

While beer can be consumed directly from the primary fermenter, most brewers don't package it in this form, instead preferring to let it condition for a period of time. Extended conditioning at cold temperatures is referred to a lagering, and is essential for the production of high quality lager beers. Extended conditioning, either in a conditioning vessel such as a barrel, or after packaging is called aging. Conditioning, lagering and aging are all appropriate for certain types of beers and certain processes happen during each phase.

Commercial brewers refer to the vessel used to store beer after it has finished primary fermentation as the Conditioning or Brightening Tank. Homebrewers generally refer to the vessel used for this purpose as the secondary fermenter. These terms will be used interchangeably in this discussion.

2) Conditioning: Conditioning is the simplest and shortest form of "secondary fermentation." During this time, after the yeast has converted most fermentable sugars into alcohol, it begins to reprocess compounds it produced during primary fermentation, notably diacetyl and acetylaldehyde. The yeast also converts some fusel alcohols into esters, especially if conditioned at higher temperatures. As these processes wind down, the yeast flocculates, dropping out of suspension, along with high gravity proteins. As these proteins settle, they carry tannins and phenols along with them, smoothing the flavor of the beer. Lagering helps protein precipitation, as does adding finings.

When to Condition: Beer should be transferred to a secondary fermenter when yeast action has slowed dramatically. This is usually 2-6 days after fermentation begins for ales or 4-10 days for lagers, when the kräusen begins to settle and the surface begins to clear. A rule of thumb is that you should transfer when the airlock only produces 5 bubbles or less per minute, when a hydrometer reading stays relatively constant for two or three days and when you have reached three quarters of your intended final gravity. While bubbling will increase after transfer, this is due to suspended carbon dioxide coming out of solution rather than an increase in yeast activity; fermentation continues at its previous rate.

Your secondary fermenter should be airtight and designed to minimize headspace, to prevent oxidation of the raw beer. For homebrewing this means a glass carboy rather than a plastic bucket.

Time required to condition a beer depends on the beer style. Small beers conditioned at ale temperatures condition sooner than stronger beers conditioned at lager temperatures. Small beers reach peak flavor within two weeks, while stronger, more complex beers require up to a month. Very strong beers, particularly strong lagers can require six months or more to reach their peak.

If you bottle condition your beer after prolonged conditioning, you might need to add fresh yeast at bottling, since the original yeast is probably insufficient for the job.

Lagering: Lagering is a technique of fermenting beer at lower temperatures to produce a smoother flavor. For beers which don't require lagering, a similar process is called cold conditioning. Lagering also refers to the extended conditioning times used to bring lager beers to peak flavor.

Lager Beers: Lager beer is fermented using strains of yeast (originally called Saccharomyces Uvarum or Saccharomyces Carlsbergensis) adapted to life at temperatures between 45 and 60 °F. Because of the cooler fermentation temperatures, however, lager beer requires a larger yeast starter and longer primary fermentation time – one to three weeks for a lager as opposed to 2 to 6 days for ale. Lager yeasts also produce large amounts of sulfur compounds, which must be dissipated by conditioning.

Starters for lager beers should be fermented at a temperature no more than 5 °F higher than the primary fermentation temperature and starter volume should be 50% or more larger than a starter for ale of equivalent strength. Lager starters should also be chilled in the refrigerator overnight to settle all the yeast. On brewing day, pour off most of the starter beer, swirl the remaining beer and yeast, and pitch this into the chilled wort while the yeast is still cold. Pitching the chilled starter into the relatively warmer wort shortens the acclimatization time, while throwing away most of the starter beer avoids off flavors from the starter culture.

Primary Fermentation for Lagers: Lager beers must be fermented at lower temperatures to prevent the production of undesirable esters and fusel alcohols which interfere with the "clean" flavor expected of a lager. Since these products can also be produced as a result of inadequate yeast activity, it is critical that the wort has proper yeast nutrient levels, is thoroughly aerated, that the fermentation temperature isn't too warm or too cold, and that the yeast culture is sufficiently large.

Diacetyl is a byproduct of yeast fermentation, encouraged by warm fermentation temperatures and the presence of oxygen after fermentation has started. Diacetyl is mostly reduced as the beer conditions, but any notes of vanilla, honey or butterscotch from remaining diacetyl are considered a fault in a lager. Typically, 6-14 days after the wort is pitched, the foam head on the fermenting beer begins to drop. This is the point at which you should employ a diacetyl rest, by raising the temperature of the beer to 55-60 °F for 2 days. After that, lower the temperature again, bringing the beer down to 38-40 °F at a rate of 3-5 °F per day.

Acetylaldehyde is produced early in the fermentation cycle and is scavenged by the yeast at the end of fermentation. Like diacetyl, it is encouraged by high fermentation temperatures. It can be removed by encouraging the yeast to work longer and more effectively, by keeping the beer on the yeast longer and by keeping the yeast in suspension, as well as by fermenting at higher temperatures. It can also be removed during lagering by keeping the temperature at 40-45 °F, to favor yeast action.

Even if the yeast is working properly, because lager beers ferment more slowly, they can pick up off flavors if they stand on sediment of autolyzed (dead) yeast cells for more than a few weeks. Mildly autolyzed beer will have yeasty, brothy aromas and flavors. Moderately autolyzed beer will have meaty or "vitamin B" aromas and flavors. Severely autolyzed beers will have rubbery aromas and flavors and will be virtually undrinkable. For this reason, lager beers must be racked off of the yeast into a secondary conditioning tank.

Secondary Fermentation for Lagers: A lager beer should be transferred to a secondary vessel as soon as fermentation has mostly stopped. As a rule of thumb, the beer is ready to transfer when the kräusen begins to fall, when the airlock bubbles at a rate of 4 bubbles per minute or less, and when a hydrometer reading is three quarters of the way to anticipated Final Gravity. As for normal conditioning, the secondary fermentation vessel should be airtight and should minimize headspace. If necessary, add raw wort or distilled water to bring up the beer volume within the secondary fermenter. It is critical that the beer is not oxygenated during transfer, since oxygen can produce irreversible formation of diacetyl and the oxidation of fusel alcohols and lipids, leading to staling.

If the hydrometer reading at racking is one-third the density of the O.G. or greater, ferment it for 7-21 days, reducing the temperature from 38-40 °F down to 33-37 °F when carbon dioxide production falls off. If the reading is less than one-third the O.G. reading, the beer should ferment for 7-10 days.

Beer that will not be cold conditioned is usually conditioned for 1-2 weeks.

Cold Conditioning: Once the beer has gone through secondary fermentation, it can be slowly cooled (at a rate of 1-2 °F per day) to a temperature 10-15 °F below the primary fermentation temperature. The exception is that if you are attempting to reduce acetylaldehyde or diacetyl, it should be lagered at 40-45 °F. Cooler temperatures aid in precipitating yeast, tannins and proteins which produce chill haze, producing a smoother-flavored, clearer beer.

Suggested conditioning times are 3-4 weeks at 45 °F, 5-6 weeks at 40 °F or 7-8 weeks at 35° F. Higher alcohol beers and beers with more complex flavors will need longer conditioning times than weaker, simpler beers. Light lagers with higher malt concentrations, such as Munich Helles or Czech Pilsner require a minimum of 4 weeks, preferably 7-8 weeks. Darker lagers, such as Oktoberfest and bock, benefit from even greater lagering periods, ranging from 8 weeks to a year. Traditionally, it takes 7-12 days per 2 ° Plato (1.008 S.G.) of the original gravity reading. But, if the hydrometer reading at racking was less than one-third the value of the Original Gravity of the wort, the beer should only be lagered for 4-5 days per °Plato, and not more than 1 week per 2 °Plato. Lowering the temperature to 30-33 °F immediately after secondary fermentation reduces lagering times.

If the beer freezes during lagering, you will need to pitch new yeast, since freezing kills 80% or more of the yeast cells. Likewise, if you intend to bottle condition a beer after cold conditioning it for a long period of time, you will need to add new yeast at bottling.

Part 2: Off-Flavors

Cloudiness

Detected in: Appearance.

Described As: Cloudy, foggy, hazy, opaque, turbid, yeasty.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: Haze is cause by tiny particles suspended in beer. There are five types of haze:

1) Biological Haze (AKA Bacterial or Yeast Haze): Caused by suspended microorganisms.

2) Oxidation Haze: Haze formed when protein compounds in beer become oxidized. With sufficient aging, oxidation haze will eventually form in all beer.

3) Pectin Haze: Haze cause by suspended pectin (polysaccharide) from fruit. Only found in fruit beers.

4) Protein Haze (AKA Chill or Tannin Haze): Caused when high molecular-weight proteins (from malt) & polyphenols (from husks & hops) complex and begin to precipitate. It is especially noticeable when beer is chilled to 55 ° F or lower, since cooling accelerates the rate at which the particles bind together.

5) Starch Haze (AKA Permanent Haze): Caused by large molecular weight carbohydrates, including beta-glucans, suspended in beer.

To Avoid or Control Cloudiness

1) Filtration: 10-20 micron "trap filtration" removes most sediment & ice crystals. 3-5 micron filter removes dead yeast and most starch and hop particles, giving brilliant clarity. 1 micron filter removes yeast and chill haze particles. 0.65 - 0.5 micron filter removes most bacteria. 0.2 micron filter removes all bacteria.

2) Cold Conditioning: Extended cold-conditioning/lagering time can help yeast flocculate and allows protein or starch particles which come out of solution at lower temperatures to precipitate. Lagering is cold conditioning at ~32 °F for 2 or more weeks.

3) Finings: All finings require at least 50 mg/l calcium in water to work. Most work by electrostatically attracting suspended particles to the particles of fining material, forming larger particles which precipitate more quickly.

A) Kettle/Copper Finings: Help coagulate hot break, preventing haze forming material from getting into beer. Irish moss (dried seaweed - Chondrus *Crispus* - at 50 - 150 mg/l), Protofloc™ (30 mg/l) carrageen (a gum used in food production - derived from seaweed), or Whirlfloc™ (20-60 mg/l) in last 15 minutes of boil to aid in precipitating proteins.

B) Fermenter/Cold Side Finings - Added to fermenter near the end of conditioning period. Used to remove yeast, protein or starch hazes. Common types are isinglass (dried collagen obtained from the dried swim bladders of fish, historically sturgeon or cod, now various fish species from the South China Sea. Added at 1-3.5 mg/l and 42-55 °F), brewers' gelatin, Polyclar™ (tiny beads of PVP - polyvinyl pyrrolidone - plastic) or silica gel (usually added at 1 - 3.5 mg/l).

4) Other Methods: Depending on the type of haze and beer style, other methods might work:

A) *Biological Haze:* Yeast strain (some yeasts don't flocculate well). Increase conditioning time. Use proper sanitation to avoid bacterial or wild yeast infection. Fine using cold side finings (see above). Use protease enzymes such as papain.

B) *Oxidation Haze:* Avoid aeration of wort & beer, except after pitching yeast. Store beer at cool temp. (32 -55 °F).

C) *Pectin Haze:* Don't expose fruit or fresh fruit juice to temperatures above 170 °F. Add papain or pectinase enzyme as necessary.

D) *Protein Haze:*

- *Alter Grain Bill:* Use malt with lower protein content. Limit the use of protein-rich grains (e.g., wheat, rye, oats). Use adjunct grains to reduce overall protein content of grist.

- *Use a protein rest (113-131°F).*

- *Avoid Polyphenol/Tannin Extraction.* Don't over-crush grain to avoid getting polyphenol/tannin rich husk particles into wort. Don't over-sparge mash (i.e., pH above 5.8, S.G. below 1.008). Don't heat mash above 168 °F. Don't heat grains or tannin-rich fruits, herbs, spices or vegetables above 168 °F. Recirculate or vorlauf mash runoff until it runs clear to avoid carrying husk particles into copper.

- *Get a good hot break.* Boil wort for at least 1 hour at a rolling boil. Use hot-side finings (see above)

- *Get good separation of hot break from wort so trub isn't carried into the fermenter.* Commercial breweries sometimes use filtration or a hopback to achieve this.

- *Quickly cool wort to precipitate cold break.* Ideally, temperature should drop from boiling to below 100 °F within 30 minutes.

- *Get good separation of cold break* so trub isn't carried into fermenter. But, some cold break in the fermenter is necessary for yeast health.

- *Use cold side finings in the conditioning tank*, as described for Biological haze. Papain can break down proteins, but its action is indiscriminate and can affect body and head formation.

- *Increase cold conditioning time.*

- *Serve beer at temperatures above 55 ° F.*

E) *Starch Haze:*

- *Use high-quality malt* (lower beta-glucans).

- *Don't over-crush grains* to avoid getting starch particles into beer.

- *Use a beta-glucan rest during mashing* (110 °F for 15 min.).

- *Improve mashing technique.* Increase mashing time to insure complete starch conversion. Make sure that mash temperature is in the correct range for optimal starch conversion (~143-158 °F). Test for complete starch conversion before mashing out. Recirculate or vorlauf mash runoff until it runs clear (to avoid carrying starch particles into copper).

- *Some brewers use amylase enzyme* in the fermentation or conditioning tank, but this is problematic since amylase will eventually destroy all starches in your beer, not just beta-glucans.

When is Brilliant Clarity Expected?: Brilliant clarity is expected in: Light lagers, German pilsner, Bohemian pilsner, amber lagers, cream ale, blonde ale, Kölsch, northern German altbier, Düsseldorf altbier, Scottish ales.

When is Cloudiness Appropriate?: Whether haze is appropriate depends on the type of haze and the beer style:

* **Biological Haze:** Usually a fault, except in German wheat or rye beers served *mit hefe* (with the yeast roused). Slight biological haze is acceptable in straight (unblended) lambic).

* **Chill Haze:** Chill haze is acceptable in barleywines.

* **Oxidation Haze:** Never appropriate.

* **Pectin Haze:** Never appropriate.

* **Starch Haze:** Slight to extreme cloudiness due to suspended particles of wheat or rye are appropriate in American wheat or rye beers, German wheat and rye beers and Belgian witbier. Slight starch haze is acceptable in saison, bière de garde, straight (unblended) lambic and Belgian strong dark ale.

Part 3: The Care and Feeding of Big Beer

The major problems a brewer faces when attempting to produce a beer with an ABV of 10% or more are producing sufficiently concentrated wort, getting enough and getting the yeast to perform properly under hostile conditions.

Mashing: *Homebrewers who insist on brewing all-grain strong ale face a long, possibly frustrating brew day. Big beers require a huge grain bill, often larger than a 5 or 10 gallon mash tun can comfortably hold. To maximize wort gravity, big beers also require a stiff mash and a limited amount of sparge water, making for liquor runoff, limited wort production and increased risk of problems during mashing and sparging. Rather than pushing the limits of your mashing system, it is better to either brew smaller batches of high gravity beer or collect sufficient wort for a standard-sized batch from two or more separate mashes.*

A traditional method of obtaining a strong wort is the "parti-gyle" mash, where first runnings from the mash tun are collected and set aside without sparging (or with limited sparging), yielding a small amount of highly concentrated liquor. The grains are then mashed again with more water, and the runnings from that mash are collected separately from the runnings from the first mash, producing a second wort of middling gravity. Historically, the grains were mashed a third time to get the weak last runnings, producing a very weak wort which was made into small beer. As a rule of thumb, each mashing extracts about 80% of the available sugars from the mash.

A second historical method of obtaining a strong wort is the "doble-doble" technique, where the runnings from a first mash are used as the hot liquor or sparge water for a second mash, allowing the liquor to pick up more sugars the second time around. There are limits to the effectiveness of this technique, since the higher the concentration of sugars within the liquor, the less sugar it will pick up as it passes through the mash.

Wort Boiling: *The second simplest way of producing high-gravity wort is to remove some of the water from the liquor – usually by boiling. Boiling high-gravity wort is somewhat tricky, however, since the higher concentration of sugars and starches makes it more prone to boil-over and scorching. Prolonged boiling also affects caramelizes sugars, breaks down proteins and darkening the color of the wort, affecting the appearance, aroma and flavor of the finished beer.*

The higher concentration of sugars also makes it harder for the wort to absorb oils and resins from the hops, which means you must use more hops than you would for a lower-gravity beer. More hops, however, means that more wort remains in the hops when you transfer your wort to the primary fermenter, further reducing wort volume, requiring an even bigger mash. One way of rescuing some of the wort trapped in the hops is to carefully squeeze the chilled hops using sanitized utensils. (Some homebrewers use a sanitized salad spinner!)

Concentrated Wort the Quick and Dirty Way: *The easiest way to get high-gravity wort is to use malt extract or other concentrated sugars, such as maple syrup, molasses or honey. Even all-grain brewers resort to such tricks when brewing extremely strong beers. For example, Sam Adams uses maple syrup to increase the strength of their 25%+ ABV Utopia.*

Fermenting: *Highly concentrated raw wort is a hostile environment for yeast. Not only does do high concentrations of sugar reduce the amount of oxygen which can dissolve in the wort, but the high osmotic gradient between the sugar solution on the outside of the yeast cells and the lower concentration on the cell interiors interferes with yeast metabolism and reproduction. Not only does this result in slower fermentation, it also increases levels of fermentation byproducts, such as esters, phenols and higher alcohols. Fortunately, the metabolic pathways which produce these unwanted chemicals are also inhibited by the high sugar concentration, making it possible to slightly speed fermentation by keeping the fermenting wort at a slightly higher temperature than normal.*

High ethanol concentrations also inhibit, and ultimately kill, yeasts. Typically, even the best yeast dies or goes dormant when alcohol concentrations rise much above 10% and many strains of beer yeast perform poorly above 5-6% ABV. High-alcohol concentrations also affect the flavor and aroma chemicals the yeast produces. The higher the gravity the more *wine-like the finished beer will be. Above 10%, many types of yeast produce more phenols, while beers over 16% ABV begin to taste less like beer, and more like fortified wines such as sherry.*

For these reasons, you must choose a strain of yeast which will survive in a high-sugar and then high-alcohol environment. Unfortunately, the yeasts which work well under such conditions are mostly wine yeasts, which produce very bad-tasting beer. A compromise is to use two or more yeast strains; initially pitching a strain which works well at lower alcohol concentrations and which produces desirable flavors and aromas, then introducing a strain, such as champagne yeast, which ferments well in the presence of high concentrations of alcohol once the initial yeast strain has stopped working. Even so, the best beer and wine yeasts stop working when alcohol concentrations reach 12-16%, requiring "distillers" or "turbo" yeast, such as Wyeast "Pac Man", White Labs WLP099 "Super High Gravity Yeast" and/or "Liquor Quik" to achieve higher levels of alcohol.

Even then, to achieve alcohol concentrations above 16% ABV you must baby your yeast:

- *Heavily aerate your wort, introducing four times as much air as you would for a normal gravity beer.*
- *Pitch a huge yeast starter – 3-4 times as much yeast as normal.*
- *Aerate the wort intermittently during the first 5 days of fermentation. Aerate with oxygen for 30 seconds or air for 5-10 minutes each day.*
- *Double the amount of yeast nutrient you use, especially when fermenting beverages with high levels of adjunct sugars, which naturally have few yeast nutrients.*
- *Add yeast energizer.*
- *"Feed" the fermentation, rather than fermenting all your wort at once. Begin fermentation with a wort which will produce a moderately strong (6-8% ABV) beer, and add wort (which can be concentrated) each day for the first 5 days until the desired level of wort gravity is achieved.*
- *Once fermentation slows, rouse the yeast back into suspension by gently agitating the fermentation vessel without aerating the raw beer. Historically, casks of barleywine were periodically rolled around the brewery yard to rouse the yeast.*
- *Even using these tricks, expect a low, slow fermentation where the beer spends at least a month in the primary fermenter.*

Part 4: BJCP Category 18 - Belgian Strong Ales

As with other Belgian beers, each brand of Belgian Strong Ale attempts to be unique from its competitors, so "style" guidelines for more style suggestions.

History: *While Belgian Strong Ales were inspired by traditional Belgian brewing traditions they date to the first half of the 20th century, when legendary brewing scientist Jan De Clerck isolated the strains of yeast which give Belgian Strong Ales their unique character. Working in conjunction with the monastic breweries at Westmalle and Notre-Dame de Rochefort (Chimay), he developed the precursors of today's Belgian Dubbel and Tripel styles.*

Note that Belgian Strong Ales only represent the strongest versions of Belgian Abbey Style ales. Weaker beers brewed using the same ingredients, and with similar flavor profiles are also produced, but usually aren't exported. Belgian Strong Ales are as strong as they are because Belgian law prohibited bars from selling distilled spirits, so local brewers made strong, highly alcoholic beers designed to appeal to hard liquor drinkers. Like Barleywines, Belgian Strong Ales are designed to be consumed in small quantities on special occasions or as a *disgestif* after a meal.

Trappist Ales: *Trappist Ales were the original Abbey Ales, but now represent a minority of "Abbey" and "Abbey Style" ales. The Dubbel and Tripel styles were first developed at the Abdij der Trappisten van Westmalle, in order to provide income for the abbey.*

Trappist monks are Cistercian monks of strict observance, whose religious vows include silence (although they can speak when necessary) and supporting their monastic community by physical labor. Since the Trappists consider their labor to be a form of religious observance, rather than just a way to make money, the goods they produce are of the highest quality. Trappist abbeys frequently produce prepared gourmet foodstuffs as a way of fulfilling their vows; Trappist houses in the U.S. produce jam and cheese, for example. Only the six Belgian Trappist monasteries brew beer, however, and not all beer they brew fits into the category of Strong Belgian Ale.

To be considered an "Authentic Trappist" product, an item must be produced by, or under the direct supervision of, Trappist monks. Goods which meet this standard are labeled with a special hexagonal trademark. This means that only beers which are "Authentic Trappist" products can be called Trappist Ales.

The Trappist commitment to quality and lack of interest in sheer profit motive has profound effects. First, and most importantly, Trappist breweries will collaborate with each other. Several Trappist abbeys get their yeast from Westmalle, and if one Trappist brewery encounters a technical problem, they can call upon technical expertise from the others. Trappist ales are also made from the finest ingredients, with attention to quality first and profit margin and market share second.

While some of the Trappist breweries (in particular Chimay) have expanded production to meet demand, some Trappist breweries, notably Westvleteren, brew only enough beer to support their abbey, ignoring commercial pressures to expand their business. The monks of Westvleteren sell unlabeled bottles of beer only in the abbey café and to a few select local restaurateurs. To prevent their beer from being resold, they place limits on the number of bottles customers can buy each day.

The Trappist Breweries and Their Products[1]

Brand Name	Brewery
Achel	St. Benedictus Abjij de Acheles Kluis
Chimay	Abbaye Notre-Dame de Scourmont
Rochefort	Abbaye Notre-Dame de Saint Remy
Orval	Abbaye Notre-Dame d'Orval
Westmalle	Abdij der Trappisten van Westmalle

[1] There was a seventh Trappist monastery, Schaapskooi, in the Netherlands, which briefly brewed beer under the "Authentic Trappist" label, but they lost the right to label their products as such after they sold brewing rights to Bavaria Brewing rather than producing the beer themselves. It is now sold under the La Trappe/Konigshoeven label.

Westvleteren	De Sint-Sixtus Abdij van Westvleteren

Abbey Ales: *Because of the success of ales brewed by Trappist abbeys, other brewers began brewing similar beers, calling them "Trappist style" ales. In some cases, the only monastic link was the fact that a secular brewery operated on the site of a destroyed monastery, or that it had once contract brewed beer for monks. The Trappists reacted by trademarking their name, so other brewers were forced to refer to their products as "Abbey" beers. The standards for what constitutes an Abbey beer are much looser than those for Authentic Trappist beers. Even if an existing monastic house is involved, the monks usually license the rights to brew beer in their name to a local brewery.*

In Belgium, the standards are a bit stricter. To be considered an Certified Belgian Abbey Beer, the brewer must have a link to an existing or former monastery, they must pay royalties to cultural organizations which preserve monastic sites or to charitable institutions which represent the monastery and the abbey or institution to which the brewer pays royalties must have control over advertising materials.

Beers inspired by Trappist or Abbey beers, but brewed by secular brewers with no monastic links, are sometimes referred to as "Abbey Style" beers.

Abbey Beers and their Brewers

Brand Name	Abbey	Brewer
Affligem*	Affligem	Affligem (Heineken)
Bonne Esperance*		Lefebvre
Bornem*		Van Steenberge
Cambron*		Silly
Corsendonk, Agnus	Corsendonk (extinct)	Corsendonk
Cuvee' de L'Ermitage	St. Idesbald Abjij	St. Idesbald Abjij
Dendemonde*		Block
Ename*		Roman
Floreffe*		Lefebvre
Grimbergen, Ciney*	Grimbergen, Ciney (both extinct)	Union (S&N Alen-Maes)
La Trappe/Konigshoeven	Schaapskooi	Bavaria
Leffe*	Leffe	Hoegaarden/Artois (InBev)
Maredsous*	Maredsous	Moortgat
Postel*		Affligem (Heineken)
St. Feuillen*	St. Feuillen (extinct)	St. Feuillen
Steenbrugge*		Palm
Tongerlo*	Tongerlo	Haacht
Val Dieu*	Val Dieu (extinct)	Val Dieu
Witkap, Witkap Pater	None	Slaghmuylder

* Certified Belgian Abbey beers.

Brewing Belgian Strong Ales: Strong Belgian Ales are brewed using Belgian malts (mostly from Dingemans and De Cosyns). Hop character is minimal in most cases and hops are used only for bittering. Many Belgian Strong Ales have low levels of spicing, but spiciness should never be so obvious that the drinker can identify the spice.

Water: Water profiles for various Belgian brewers vary widely, as listed on the table below. In some cases, brewers will treat their water to make it harder or softer.

Water Profiles for Trappist Ales[2]

Brand	Ca+	HCO3-	Mg+	Na+	SO4-	Cl-
Westmalle	41	91	8	16	62	26
Orval	96	287	4	5	25	13
Rochefort	82	240	10	6	32	17
Chimay	70	216	7	7	21	21
Achel	64	157	7	12	28	24
Westvleteren	114	370	10	125	145	139

Malt and Adjuncts: Belgian Strong Ales are brewed using continental pilsner malt as a base, with crystal malts to add body and flavor notes. Very few, if any, Belgian brewers use rock candy. Instead, they use caramel syrup or ordinary sucrose or dextrose (corn or cane sugar.

Mashing is usually a step infusion mash, designed to produce highly fermentable wort.

Yeast: Belgian Strong Ales depend on unique strains of yeast. In some cases, the same strain of yeast is fermented at different temperature to produce different flavor profiles. In all cases, however, the goal is to produce estery and phenolic spicy notes without producing higher alcohols or excessive levels of phenols. This requires the brewer to pitch lots of healthy yeast (one brewer describes pitching rates as "too high to count."). Often yeast from a batch of ordinary gravity beer is pitched into a batch of strong ale.

Usually the yeast used to ferment the beer is filtered out and fresh yeast cropped from another batch of fermenting beer is added at bottling. This means that the yeast can work to carbonate the beer without lag time and without producing off flavors, as the exhausted fermentation yeast might if it was forced for work further.

If there is any real secret to brewing Belgian Strong Ales, it lies in getting the right strain of yeast and treating it well.

Part 5: BJCP Category 19 - Strong Ales

History: *As long as people have been producing fermented beverages there has always been the desire to produce a drink with a bigger kick, which perhaps explains why wine has usually been the drink of choice among the upper classes. It is, however, possible to brew beers which rival or exceed the potency of wine and approach the alcohol content of some distilled beverages.*

Traditionally, strong ales were brewed on, or in anticipation of, special occasions, such as a wedding, an anniversary, a birthday, the coronation of a king or the birth of a royal heir. Since they represented the very best beer a brewery could make, strong ales were made from the finest ingredients available and were brewed with the utmost care. The resulting beer was strong enough that it could be cellared for years, developing complexity of flavor as it aged. If carefully protected, strong ales can mature for decades. Beers aged before they were consumed were described as "Old" or "Stale" Ales. As with most other aged beers, strong ales had distinct flavors

[2] Copied from p. 158 of **Brew Like a Monk**.

associated with spontaneously fermented, wood-aged beers – making them much more "lambic-like" than modern Strong Ales.

The first modern barleywine was Bass #1, and other English brewers often called their strongest beer "#1" in imitation of Bass. In 1903, Bass also invented the term "Barley Wine" to describe their #1 Ale. Again, other breweries followed Bass's lead. Sadly, from the late 19th century on, due to changes in consumer preferences, temperance movements, war rationing and laws which discouraged the production of high-alcohol beers, the major British brewers first made their strong ales progressively weaker and then eliminated them altogether. In the 1970s and 80s, Bass and Courage, two breweries once famous for their strong ales, first destroyed the reputation of their brands by using higher levels of adjuncts while reducing alcoholic strength and then discontinued production in the face of limited market share and declining sales. By the late 1990s, both breweries had stopped production of strong ales, leaving just Samuel Smith's and the Eldridge Pope Thomas Hardy brewery to continue the tradition of brewing English Barleywines.

Fortunately, just as the major English breweries were ending barleywine production, West Coast American craft brewers and homebrewers were rediscovering the style and making it their own. Anchor Brewing released Old Foghorn, the first American-style barleywine, in 1975, and Sierra Nevada's Bigfoot appeared just a few years later.

Brewing Strong Ales: Strong ales are were originally an English style, so traditional English barleywines and old ales are brewed using ingredients similar to those used to produce an English Pale Ale, albeit in much greater amounts. The grain bill is predominantly English pale malt, with a bit of amber, crystal or dextrin malt. Typical adjuncts include a bit of wheat malt or sugar.

Old Ales differ from barleywines in that they are brewed using a greater proportion of adjunct sugars and darker specialty malts to produce a darker, more attenuated brew. Both English Old Ales and Barleywines use traditional English hop varieties, but English barleywine is noted for its use of East Kent Goldings hops, both in the kettle and for dry-hopping. Both styles of beer are fermented using strains of English Ale yeast which will stand up to the higher wort gravities and alcohol concentrations. Even so, many English beers which claim to be barleywines" or old ales are actually no stronger than 7-8% ABV. Water profile is that of Burton or London.

American strong ales are similar to their English cousins, except that American malts and American yeast strains which produce more neutral flavors can be substituted for English types. The distinguishing feature of American Barleywines, however, is the heroic level of hop bitterness; usually featuring the American "C" hops – Chinook, Columbus, Cascade or Centennial – although in the past few years a number of Barleywines have been produced using high-alpha acid, dual-use hops such as Simcoe or Warrior.

As with Imperial IPA, U.S. craft brewers often hop their barleywines beyond the upper threshold of bitterness perception (100 IBU), although this arguably helps preserve the hop flavor of the beer as it ages. Water profile can vary more than for English-style barleywines, but moderately hard, relatively low sulfate water is typical.

The best strong ales are robust and complex. When formulating recipes, design the beer's "profile" around a "backbone" of pale malt, with numerous small additions of specialty grains to add flavor and body. Likewise, use multiple, complementary varieties of hops, both in the kettle, and, if appropriate, for flavor, aroma and dry-hopping.