BREWERIES

INTRODUCTION

Breweries make beer and ale from barley malt, unmalted grains, hops, water and yeast. The brewing process first converts grain starches to sugars, then ferments the sugars into alcohol and carbon dioxide.

Brewing takes many steps, including malting (germinating) the barley, mashing (cooking) the grain, lautering (removing spent grain from the wort), brewing (boiling the wort with hops), fermenting, chillproofing, filtering and pasteurizing. See Figure 1.

Barley is usually malted at facilities separate from the breweries. Large brewing companies may have their own malting plants. Smaller breweries buy malted barley from independent malters. The remaining steps described in this PRC Guideline are done at the brewery.

Preparing grains for brewing generates dust, which can explode. Boilers heat water for malting, mashing, brewing and pasteurizing. Boiler tubes can rupture, and accumulations of unburned fuel in boiler fireboxes can explode.

Wort cooling, fermenting, chillproofing and filtering require refrigeration. Most brewery refrigeration systems use ammonia, which can contaminate food products if it escapes. Ammonia can also explode. Loss of refrigeration or electrical power can spoil all the beer and ale in process at a brewery.

Breweries use cartons and cases to package bottles and cans of beer. Packaging materials include cardboard and plastic, and they present fire hazards both where they are stored and where they contain the finished product.

PROCESSES AND HAZARDS

Grain Storage And Handling

Breweries must store and handle large quantities of cereal grains. Grains are stored in large grain silos and are moved with conveyors and elevators.

Storing, transporting and the milling of grains presents a serious dust explosion hazard. Deep-seated fires are also possible. Common ignition sources include improper or poorly maintained electrical equipment and malfunction of grain-moving machinery.

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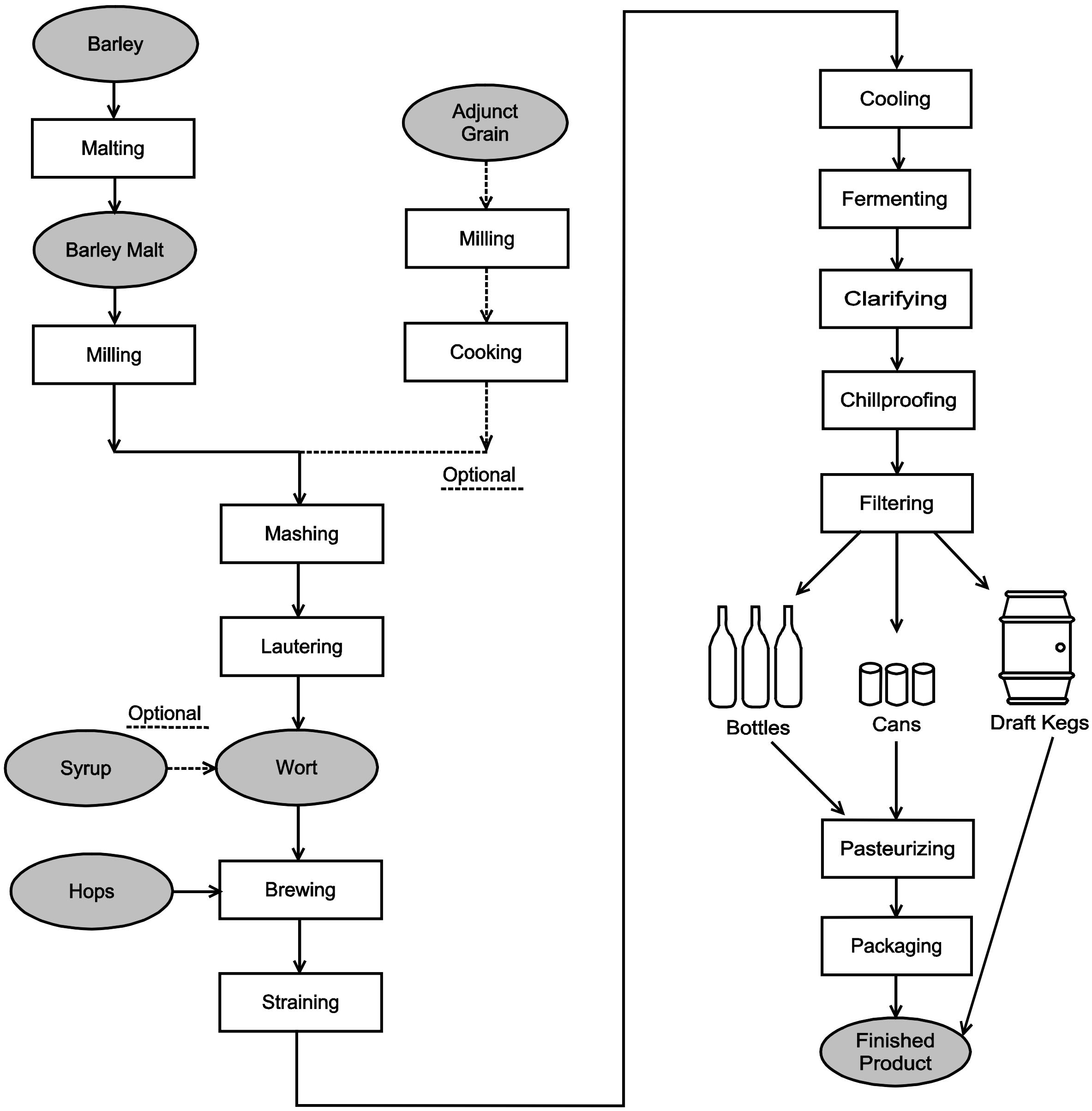

Figure 1. Brewery Flow Chart.

Malting

Malting converts the starch reserves in the barley to sugar. First, the barley is germinated without soil, which develops the grain's digestive system. Next, the germinated grain is dried to stop the new plants from using up any more starch. The sugar made by the digestive system then becomes food for the yeast that ferments the brew.

The main steps in the malting process are cleaning, sizing, steeping, germinating, kilning, separating, stabilizing and milling. The barley is cleaned by passing it over vibrating or gyrating screens. This removes broken kernels and foreign material. Positive air aspiration removes any dust generated by the movement.

Stationery gravity screens are used to sort the kernels into groups of roughly equal sizes. The grain in such groups germinates uniformly, which is important for achieving consistency in the final brew. Very small kernels not suitable for making beer are used by distillers to malt whiskey.

After sizing, barley is steeped by repeatedly submerging it in water held at a controlled temperature. This gives the barley the high moisture level necessary to begin germination. It also washes out impurities and lightweight kernels. Steeping takes approximately two days.

Steeped barley is germinated on a porous floor through which moist, cool air is continuously circulated. Roots begin to appear almost immediately, and the young barley plant inside the kernel starts pushing toward the top. The new plant's digestive system is now slowly converting the kernel's stored starches and proteins into sugars. The digestive system takes four to five days to develop.

As the young plant is beginning to emerge from the kernel, it is moved to the kiln where it is slowly heated to 220°F (100°C) and dried to stop further growth. A specified series of temperatures is used not only to dry the malt, but also to achieve the desired flavor, aroma and color of the final brew.

Roots or exposed sprouts still attached to the malt must be cleaned from the kernels. After cleaning, the malt is stabilized by storing it for several weeks prior to brewing. This also helps achieve consistency in the final brew.

The barley is dry during the cleaning and sizing steps. The dust generated in these steps can explode. Kilns are either gas or oil fired or they are heated with steam supplied by a boiler. The fuel fired equipment used in either case is subject to fuel fires, combustion explosions in the firebox and tube rupture from overpressurization.

After stabilizing, the dried, malted barley is milled. Milling is one of the most hazardous operations in a brewery. The mill crushes the grain through steel rollers. Friction in the mill can ignite grain dust and cause explosions and fires.

Refrigeration equipment needed for temperature control often uses ammonia, which can explode. Loss of electric power, heating or refrigeration equipment, or temperature control systems usually results in downtime and loss of product.

Preparing Adjunct Grain

Barley malt is the only grain necessary for brewing; however, unmalted grain or grain-derived syrup is sometimes added to many beers. These supplemental materials are called adjuncts. Adjuncts give beer a paler color and make it less filling than 100% malt-derived beer. They also increase the stability of the beer after packaging.

The most common adjuncts are rice, corn and grain-derived syrup. Rice and corn must be milled before they can be added to the brew. Milling removes the grain's skin and germ, which contain too much oil for adding to beer. Rice has the highest starch content of all cereal grains, but this starch is difficult to convert to sugars. Adding rice produces a pale beer with clean, crisp taste and enhanced hop character. Corn gives beer a mellower and grainier flavor than rice.

Brewing with syrup has become common. Most syrups used are corn syrups, which are sugars made from corn starch. Using syrup bypasses the need for converting adjunct grain starches to sugar in the mash kettle. Syrup produces a sweeter, blander beer than adjunct grains.

Cooking

Since the adjunct grains contain raw starch, they must be cooked to break down, or gelatinize, the starch. This is done in the mash cooker, which is a stirred vessel heated by steam.

In the double mash system, a portion of the barley malt is combined with the adjuncts. Malt and adjuncts are added slowly with water at a temperature of about 100°F (38°C). The temperature is then gradually brought to the boiling point and held there.

Mashing

Mashing the main malt promotes formation of lactic acid, degrades proteins and gums into products with lower molecular weight, and converts starches to sugars. This gives the liquid portion of the mash, or wort, the proper composition and acidity for brewing.

Different enzymes perform each of the above functions, and each enzyme reaches optimum activity within a narrow temperature and pH range. For this reason, the mashing process includes “rests” at four temperature ranges. Control of time and temperature is critical.

The main portion of the malt is combined with water in the mash tank at a temperature of about 95°F (35°C). This temperature is maintained for about 30 min to promote the formation of lactic acid. This step is called the acid rest.

The temperature is then increased to 113°F (45°C) for a 30 min – 60 min period. During this time, the enzyme proteinase attains its maximum activity and breaks down the larger proteins into lower molecular weight molecules. This step is called the protein rest. Some brewers start the mashing process at this temperature, eliminating the acid rest by adding acidifying agents.

The next step is the sugar rest. This step proceeds at 133°F – 144°F (56°C – 62°C) for 5 min – 20 min. During this time, the enzyme beta-amylase converts starch to maltose. The longer the sugar rest, the higher the alcohol content of the beer.

At 153°F – 160°F (67°C – 71°C), the enzyme alpha-amylase forms dextrin. This step takes 15 min – 45 min. Adjuncts from the mash cooker are added to the main mash during the last two steps. When the starch is completely converted to sugar, the enzymes are inactivated by raising the temperature to 167°F – 173°F (75°C – 78°C).

Mashing is a wet process using large horsepower motors for stirring and steam-jacketed vessels for heating. The primary loss potentials are electrical breakdown of motors and pressure vessel rupture. In addition, the boilers that produce the steam are subject to fuel fires, firebox explosions and pressure vessel rupture.

Lautering

Lautering separates the spent grain from the wort. This is done either in a combination mash-lauter vessel or a separate lauter tub. A lautering vessel has a perforated false bottom equipped with spargers and revolving rakes, and a real bottom with outlets leading to a tapping device called a pfaff.

The mash is allowed to settle on the false bottom for about 30 min. The spent grain settles out and form a bed about 18 in. (460 mm) deep. The faucets on the pfaff are then slowly opened, and the wort flows into an inspection receiver called a grant. The initial turbid (cloudy) flow is returned to the lauter vessel until the wort runs clear. When the wort surface reaches to top of the spent grain bed, the spargers spray hot water to extract the remaining wort. The wort is then piped to the wort kettle, or brew kettle.

Some breweries may transfer the spent grain to a drying operation (involving kilns or other gas-fired equipment) for potential use as a by-product such as feed.

Like mashing, the primary loss potentials with lautering are electrical breakdown of motors and pressure vessel rupture.

Brewing

The wort is boiled in the brew kettle to concentrate and sterilize it, to inactivate any remaining enzymes, and to precipitate proteins from the hops. Boiling time varies from 1½ to 2½ h, depending on wort composition, wort evaporation rate, hop characteristics, procedure for adding hops and the final flavor desired.

A total of 0.35 lb – 0.50 lb (0.16 kg – 0.23 kg) of hops per barrel of beer are added at various stages of the boiling process. A common procedure is to add ⅕ of the hops about one hour after boiling, ⅖ of the hops 30 min later, and the remainder (usually the best hops) just before boiling is complete. The first addition precipitates the maximum amount of protein, the second bitters of the wort, and the third imparts the hops aroma. At this point, the wort leaves the brew house and proceeds to fermenting and clarifying operations.

Like mashing and lautering, the primary loss potentials with brewing are electrical breakdown of motors and pressure vessel rupture. Additionally, the packaging for hops can also consist of significant quantities of combustible materials (boxes, plastic rap, etc) and can add fire loading to a normally noncombustible occupancy.

Straining

To prevent them from imparting undesirable flavors to the wort, the hops are removed right after brewing is complete. They are either continuously strained or are allowed to settle on a perforated false bottom. The spent hops are sometimes sparged with hot water.

Wort Cooling

After brewing, the hot wort must be aerated and cooled to the proper temperature for addition of yeast. This temperature is known as the pitching temperature.

The wort aerator, which is sometimes combined with the wort cooler, introduces sufficient air for the yeast to produce a normal fermentation. The air is filtered to remove microorganisms and heated to prevent vapors from condensing in the wort.

Tap water, chilled water, brine or ammonia can serve as the refrigerant for the wort cooler. The Baudelot cooler is an open type cooler through which wort flows by gravity over the outside of cooling tubes. Closed type coolers can be one of many types of counter-flow heat exchangers.

The loss potentials of cooling include product contamination from refrigerant leaks and product spoilage from inadequate refrigeration. Ammonia refrigerant presents additional concerns, because it is toxic and explosive.

Fermenting

To prevent infections, such as those from thermobacteria, yeast is added immediately after the wort has been cooled. The yeast can be put in the cooler pan, fed into the line coming from the wort cooler, placed in a starting tank, or added to the fermenters as they are being filled. The yeast must be well mixed with the aerated wort.

The wort pitching temperature is 45°F – 50°F (7°C – 10°C) for beer and 54°F – 59°F (12°C – 15°C) for ale. The pitching temperature affects the speed of fermentation and the character of the beer or ale.

Fermenting begins soon after the yeast is added. As the yeast is feeding on proteins, mineral salts (mainly phosphates) and sugar, it splits the fermentable sugars into alcohol and carbon dioxide. After the fermenting beer has become saturated, it gives off carbon dioxide.

While the beer or ale is fermenting, acidity increases and the temperature rises. Fermentation continues for seven to ten days. When fermentation is complete, the foam should have receded to a thin layer.

After fermentation, there may be a distillation process to modify the alcohol content of the beer. Some brewers may stop the brewing process early to create a non-alcoholic beer. However, other brewers may brew to completion, and then distill the finished product to remove the alcohol.

Like wort cooling, the primary loss potentials with fermenting are contamination from refrigerant leaks and ammonia explosions.

Clarifying

Beer is clarified by letting it settle in storage tanks, sometimes called lager tanks. A temperature of 35°F – 40°F (2°C – 4°C) is necessary to maintain the beer’s carbonation and stability and to prevent damage to the yeast. Storage time is from two to six weeks. This period can be shortened by filtering the beer through diatomaceous filters or by raising its temperature.

Some beers are further carbonated by introducing carbon dioxide at a higher pressure through orifices or porous stones, or by sparging the beer in an atmosphere of carbon dioxide.

“Fining agents” can also be added near the end of the brewing process. These are primarily added in order to remove (collect) impurities, improve clarity, or adjust flavor/aroma. Various substances can be used, including beechwood chips, egg whites, bentonite clay, or other solid materials.

Various flavorings (such as fruit flavorings, etc) can also be added to finished beer to make specialty products. Flavorings can consist of flammable liquids. These may be distributed via tanker truck or portable totes/drums. This is typically located at the stockhouses.

As in previous steps, the primary loss potentials with clarifying are contamination from refrigerant leaks and ammonia explosions. The storage of certain types of fining agents (such as beechwood chips, which can present a high-challenge fire commodity similar to wood pallet storage) can add fire loading to a normally noncombustible occupancy. Additionally, storage of flammable flavorings (or empty storage containers) requires adequate protection.

Chillproofing

The beer is pumped from storage and cooled to near freezing. At this temperature, additional protein becomes insoluble and makes the beer hazy. The haze is removed by adding chillproofing enzymes. This is because the filtering step cannot remove enough haze to result in the brilliancy (brightness and clarity) demanded of beers today.

As in previous steps, the primary loss potentials with chillproofing are contamination from refrigerant leaks and ammonia explosions.

Filtering

Pulp filters contain numerous filter cakes tightly held in plates or frames. The cakes are 2 in. – 2½ in. (50 mm – 65 mm) thick. The filter is first flushed with water to cool it and eliminate air. With water pressure maintained, beer is flowed through the filter. The initial mixture of water and beer is sent to tank for separate processing. When the beer is brilliant, it is sent to a pressure tank before being pumped to the bottling department.

This step has very little loss potential.

Filling

Beer is sold in bottles, cans or kegs. Bottle filling machines can fill 1000 – 1200 bottles per minute. Cans are filled at 1800 – 2000 cans per minute. Bottles and cans are then sent to pasteurizing. Draft beer is pumped directly into stainless steel half-barrels holding 15½ gal (59 L).

This step has very little loss potential. From a business interruption standpoint, there may be a single filling line travelling from the stockhouse to the beer filling area.

Pasteurizing

Pasteurizing is sterilizing at a high enough temperature to kill traces of live yeast and other organisms that could degrade the brew. It also preserves product uniformity under diverse retailer storage conditions and times. Almost all beer except for draft beer is pasteurized.

Filled bottles and cans are conveyed through a tunnel pasteurizer, which is sprayed with tempered water to maintain the desired temperature in each pasteurizer section. The temperature is held for a period of time, then decreased to cool the beer before it exits the tunnel.

Tunnel conveyors use rubber conveyor belts. These belts can be ignited by overheated bearings or motors, or by heat generated by friction on the belt. The tempered water for the pasteurizer is steam heated. Steam boilers are subject to fuel fires, firebox explosions and pressure vessel rupture.

Packaging And Finished Product Storage

Bottles and cans of beer are put in cardboard cartons or in high density polypropylene crates. Other combustible packaging materials may be present, including idle wood/plastic pallets, plastic shrinkwrap, plastic bulkheads (for trailer truck storage), slip sheets, plastic Hi-cone holders(for 6-packs). Filled cartons and crates are usually palletized. Sometimes packaging materials are stored in racks. Ignition of these materials can result in a serious fire.

The major loss exposure of finished product storage is from fire. Properly designed sprinkler systems can protect the storage building and keep a fire from spreading to other areas. Because beer is a food product, salvage of finished product in the warehouse would be minimal. Larger breweries may also have accumulators which hold the packaging containers in a 3-D array, and may required custom sprinkler protection due to shadowed areas.

LOSS PREVENTION AND CONTROL

Management Programs

Implement management programs in the areas discussed in *OVERVIEW*, AXA XL Risk Consulting's total management program for loss prevention and control. Tailor these programs to brewery processes, paying particular attention to the following areas:

Hazard Evaluation

Evaluate the potential for contamination of product in all parts of the facility. Design and protect the facility to minimize overall exposure to contamination.

Evaluate the importance of heating and refrigeration systems. Either install duplicate systems, design systems with extra capacity, or keep spare components of these systems so that loss of one system will not spoil a large amount of product. Also consider providing diesel-driven refrigeration compressors.

Evaluate the importance of electrical power. Provide emergency power supplies to minimize spoilage in the event of a power loss.

Maintenance

Implement preventive maintenance programs for the following equipment:

- Boilers, in accordance with NFPA 85 PRC.4.0.1, PRC.7.1.0.5 and PRC.7.1.0.6.
- Conveyors, in accordance with PRC.9.3.1.
- Motors and electrical equipment, in accordance with PRC.1.3.1.
- Emergency generators, in accordance with PRC.6.2.1.1.

In addition, conduct regular inspections and nondestructive testing of process pressure vessels, including the mash tank, the lauter tub, the brew kettle, the wort cooler, the fermenting tank and any piping connecting them that may be pressurized.

Housekeeping

Control accumulation of grain dust with well designed ventilation and dust collection systems. Keep combustible materials throughout the facility, including packaging materials, to a minimum.

Construction

Provide a 3-h rated fire walls between finished product warehouses and production areas, including packaging areas. Protect wall openings with 3-h rated, automatic closing fire doors. (Note that any exposure fire is likely to have more damage created due to *smoke contamination*, therefore smoke-operated fire doors may be advisable).

Provide 3-h rated fire barrier walls to isolate utilities buildings, grain handling areas, brewing operations and fermenting operations. Protect wall openings with single 3-h rated, automatic closing fire doors.

Interior Protection

Protect production areas other than grain handling areas with automatic sprinkler protection designed in accordance with the Ordinary Hazard, Group 1 requirements of NFPA 13 and with PRC.12.1.1.0.

Protect grain handling areas with automatic sprinkler protection designed in accordance with the Ordinary Hazard, Group 2 requirements of NFPA 13 and with PRC.12.1.1.0.

Protect storage areas in accordance with NFPA 13 and PRC.12.1.1.0. Finished beer (plastic, glass bottles, or cans) in cardboard cartons on wood or plastic pallets is considered a Class I commodity. Consider beer in polypropylene crates and empty polypropylene crates a Group A plastic. Consider carton flats a Class III commodity. Plastic shrink-wrap, bulkheads, and hi-cone storage are considered Group A plastics.

Install 1 in. (25 mm) hose connections with 1½ in. (40 mm) woven jacketed, lined hose and adjustable spray nozzles so that at least two hose streams can reach any point in the storage area.

Grain Storage And Handling

Design and protect grain handling equipment and buildings subject to accumulation of grain dust in accordance with NFPA 61. Design and install pneumatic grain conveying systems in accordance with NFPA 91.

Install deflagration venting for silos, elevators, bins, hoppers and mills in accordance with NFPA 68. As an alternate to venting, provide explosion suppression systems in accordance with NFPA 69.

Fuel Fired Equipment

Provide combustion safeguards for boilers in accordance with NFPA 85 and PRC.4.0.1.

Provide combustion safeguards for kiln dryers in accordance with NFPA 86 and PRC.4.0.1.

Cooling Towers

Use cooling towers of totally noncombustible construction. Protect cooling towers with combustible shell or fill in accordance with NFPA 214.

Refrigeration Systems

Arrange refrigeration systems in accordance with ANSI/ASHRAE 15. Design and install ammonia refrigeration systems in accordance with ANSI/IIAR 2. For more information, refer to the NFPA *Fire Protection Handbook*.

Locate ammonia refrigeration systems in separate areas cut off by 3-hr rated fire barrier walls. Install isolation valves on ammonia piping to limit the amount of leakage in the event of line ruptures. Provide sprinkler protection wherever combustible insulation is used.

Conveyors

Protect combustible belt conveyors in accordance with PRC.9.3.1.