Chapter 14

Production of American whiskies: bourbon, corn, rye and Tennessee

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Introduction: definitions of bourbon, corn, rye, wheat, and Tennessee whiskies

The US Bureau of Alcohol, Tobacco and Firearms (BATF) has set specific guidelines to define all types of alcoholic beverages produced in the United States. The general definition of whisky is 'a spirit aged in wood, obtained from the distillation of a fermented mash of grain.' This spirit can be produced from any grain or combination of grains; but corn, rye and malted barley are the principle grains used. Whisky is an alcohol distillate from a fermented mash produced at less than 190° proof in such a manner that the distillate possesses the taste, aroma and characteristics generally attributed to whisky; stored in an oak container, and bottled at not less than 80° proof. Also, whisky may contain mixtures of other distillates for which no specific standards of identity are noted.

Bourbon, rye, wheat whiskies are produced (distilled) at a proof no higher than 160° from a fermented mash of not less that 51% corn, rye or wheat and aged in new, charred oak barrels at a proof no greater than 125°. Also, these whiskies may include mixtures of whiskies of the same type. Corn whisky differs in that it may be aged in used or uncharred new oak barrels. Also, corn whisky may include a mixture of other whiskies. Tennessee whisky has the same definition of all four whisky types, but to be labeled 'Tennessee' it must be produced and aged in wood in the state of Tennessee.

All whiskies conforming to Section 5.22 of the BATF regulations must be aged a minimum of two years. To be designated a 'straight' whisky, it must conform to all regulations for its type and be aged not less than two years. 'Light' whisky is another type of whisky produced in the US. It is distilled at more than 160° but less than 190° proof and aged at least two years in used or uncharred new oak barrels.

In the US regulations, neutral spirits, vodka, Scotch whisky, Irish whiskey, and Canadian whisky are further defined. Neutral spirits are distilled spirits produced from any material distilled at or above 190° proof and bottled at not less than 80° proof. Vodka is a neutral spirit distilled and treated with charcoal or other materials to be without distinctive character, aroma, taste or color. Scotch, Irish and Canadian whiskies are defined as 'distinctive products of Scotland, Ireland, and Canada, respectively, and produced and distilled under the laws of those countries'.

History of North American whisky production

Whisky production began in the US in 1733 when the British government passed the Molasses Act. Until that time, the colonists produced distilled spirits from molasses. The Molasses Act imposed a duty on molasses of non-British origin. Since the American colonists imported most of their molasses from the French and Spanish islands, they were greatly concerned. Since non-British molasses was cheaper and more abundant, smuggling and ignoring the Molasses Act (and the later Sugar Act) was the basis for much of the 'Spirit of '76'.

Pre-revolution grain whisky production was small; although history notes that settlers in western Maryland and Pennsylvania produced rye whisky from their abundant rye grain crops and that rye whisky began to replace the popular molasses-based rums. After the Revolution, the Embargo Act cut off the supply of molasses; and with abolition of the slave trade by the new Congress, both molasses and slaves were smuggled into the US. These events increased the cost of molasses and accelerated the decline of rum.

The westward migration

Early settlers crossing the Allegheny Mountains included many Scots and Irish immigrants who were grain farmers and distillers with knowledge of pot still operation from their homelands. They produced the rye whisky that became the first 'American' whisky. When Alexander Hamilton needed money to pay the debts incurred during the American Revolution, he pushed an excise tax levied on distilled spirits through Congress. As news of the tax spread, the uproar and public outrage was so intense that President Washington sent 13,000 troops into western Pennsylvania to quell the 'Whisky Rebellion'. As the troops entered from the east, many farmer-distillers packed their stills and headed west to Kentucky to avoid both the tax and the army.

The farmers found Kentucky soils not as suitable for rye and wheat crops as soils in Pennsylvania and Maryland. They discovered that corn was much easier to cultivate. The first writing that expounded on corn growing in Kentucky comes from the Jesuit Hierosm Lalemont. He noted 'to mention the Indian Corn only, it puts forth a stalk of such extraordinary thickness and height that one could take it for a tree, while it bears ears two feet long with grains that resemble in size our large Muscatel grapes' (Carson, 1963).

Whisky production grew rapidly in the early frontier areas as the settlers found in whisky a means of moving grain to market. A pack horse could carry only four bushels of corn, rye or wheat; but that same horse could carry 24 bushels of grain that had been mashed and distilled into two kegs of whisky. Also, the price of whisky was more than double the price the farmer could get for grain.

Bourbon's 'accidental' history

As settlements moved westward, the demand for spirits increased. Riverboats had become a means for shipping barrelled whiskies to their destinations. A version of 'bourbon history' recounts how a Baptist minister, Elijah Craig, burned or 'charred' the inside of fish barrels to rid them of the fishy smell so he could fill the barrels with whisky to be shipped by raft down the Mississippi River to New Orleans. The whisky from the charred oak barrels 'aged' during shipping and storage. This aging improved the character of the whisky, gave it color and smoothed the taste (Carson, 1963).

Another version of this history tells of a careless cooper who accidentally let the staves catch fire (char) when heating them for pliability to make into barrels. Not wanting to lose money, he did not tell his distiller customer about the charred staves in the barrels. Months later, after the distiller filled the barrels and shipped the whisky downriver, the distiller heard pleasing compliments about his whisky. After discovering

the cooper's 'mistake', the distiller asked him to repeat the charring process for all of his barrels.

Contrary to popular belief, none of this 'history' occurred in Bourbon County, Kentucky, and no one really knows how bourbon whisky was first made. The only historical evidence indicating Bourbon County as the source of bourbon whisky comes from a 1787 indictment of James Garrad (later a Kentucky governor) and two others by a Bourbon County grand jury for retailing liquor without a license. The only certainty in any of the lore is that Kentucky has a county named Bourbon and produces a whisky by the same name (Connelley and Coulter, 1922).

Essential traditions

Despite uncertainty about origins of the bourbon name, a tradition of good whisky making was handed down from fathers to sons for generations. Formulas, mash bills, yeasting methods and skills for operating the stills were passed along, even though many farmer-distillers could not read or write. They did not know acrolein from fusel oil, but they did have the special knack for making the 'cuts'. They knew good, clean yellow corn and plump rye. They faithfully guarded their yeast and yeast methods though many could not have said whether yeast belonged to the animal or vegetable kingdoms. Two exceptional bourbon whiskies of the 19th century were Old Taylor and Old Crow. Old Overholt was reportedly the best of the rye whiskies.

During the 19th century, the pot still evolved into the continuous column 'beer still' with a doubler or thumper. The continuous still operations allowed distillers to move to larger fermenters, more and larger cookers and automated grain handling. As the distillery operations grew and became increasingly automated, some of the smaller distilleries fell by the wayside or promoted their brands as better as a result of their 'old time, small distillery tradition and quality'. They touted this tradition and sold it as part of the product. The well known Maker's Mark bourbon is a prime example of tradition and sound practice bottled and successfully marketed to modern consumers.

As grain whisky and bourbon production grew in the 19th century, the US government increased the excise tax and the number of regulations. Costs passed on to the consumers dampened their enthusiasm for drink; but government regulation incensed leaders of the Temperance Movement because the tax and regulations drew attention to the production and sales of liquor. Most whisky at that time was sold 'from the barrel', and quality standards were almost nonexistent. It was not until the end of the century that consumers could purchase whisky sold in a corked and sealed bottle. Old Forester was the first product with 'guaranteed quality' put on the label. Old Heritage was the first bourbon with a strip stamp over the cork, thereby becoming the first 'bottled-in-bond' bourbon.

The prohibition era

All of the improvements in the 'character' of whisky production and consumption were to no avail when at 12:01 a.m. on Saturday, January 17, 1920 all beverages containing more than 0.5% alcohol were outlawed in the US (Tennessee, the state with the first registered distillery in the country, Jack Daniel Distillery, became the third state to vote to go dry in 1910, ten long years before the passing of the Volstead (Alcohol Prohibition) Act.) The 18th amendment to the Constitution, which prohibited the production and sale of alcoholic beverages, sounded a death knell for many distilleries. A drive through the countryside revealed closed distilleries choked with weeds with facilities in ruins. Brown-Forman Distillery in Louisville, Kentucky, was one of the few that survived because it produced its Old Forester Bourbon 'for medicinal purposes only'. Other distilleries lay in wait for 'the experiment' of prohibition to end.

Passage of the 21st amendment ended Prohibition after 13 years. At midnight on April 7, 1933 wines and beer were again legally sold; and on December 5 of that year at 5:32 p.m. bour-bon was again on the market. The American distilled spirits industry surged into production, building larger, more modern distilleries. The resumed legal production and sales were reinforced by the federal government when it passed the Federal Alcohol Control Act, which eliminated the sale of bulk whiskies to the wholesale and retail trades. This Act also formed the Alcohol and Tobacco Tax Division of the Internal Revenue Service. Though creating bureaucracy and taxation, the new Act also set regulations and definitions for producing spirits in the United States.

Distillation's new era

The new regulations defined the production of bourbon, rye, corn and blended whiskies as well as gin, brandies, rums, cordials and vodka according to their spirit type. The Act also noted the use of geographical designations with an origin defined for Scotch, Canadian, and Irish whiskies. This evolution of the industry led to the organization of companies that had goals of producing top quality spirits within the new regulations. New companies such as National Distillers and Schenley joined the American distilleries that survived prohibition, Brown-Forman and Jim Beam, along with the Canadian distillers, Seagrams and Hiram Walker. These distillers based their production methods on precisely defined procedures from yeasting to maturation.

During World War II, North American distilleries ceased whisky production and began manufacturing industrial alcohol for the war effort. Distillers gained the resources for further technical improvements; and at the War's end, the industry in the United States was technically ready to produce better bourbons, ryes, and Tennessee whiskies than ever before.

While the basis for modern American whisky production was developed during World War II, today's modern American distillery operates with recent innovations in controls (including computerization) and heat reclamation as the most significant advances. Even with all of the modern technology, the US distiller still carefully controls his yeasts, mash bills, distillation methods and maturation criteria, essential factors for good quality products initiated by the early pioneer distillers.

Production and maturation operations

In the production of American whiskies, six factors determine the character and flavor for each type of whisky:

1) Grain proportions in the mash bill
2) Mashing technique
3) Strain of yeast
4) Fermentation environment
5) Type and operation parameters of distillation equipment
6) Type of barrel used and the maturation process

These factors were recognized and carefully controlled in the distilling operations of the early settlers (Lyons, 1981). Families and companies that ensured consistency and control over these factors remain in business today. Those who failed to strictly adhere to a regimen controlling each factor have fallen by the wayside.

A matter of distinction

Popular bourbon producers use specific process differences to make their products distinct. The Jack Daniel Distillery continues to produce its whisky with the same processes used more than 100 years ago. Their strict adherence to tradition along with a down-home, folksy image have proven successful marketing tools for the whisky.

At Maker's Mark, grain selection and proportions are used to produce a superior whisky. They use wheat instead of rye in the mash bill. The wheat and good, consistent control of all factors, especially the barrels, make Maker's Mark the smoothest of the bourbons. Their claim of 'handmade' is justified because of their intense attention to production parameters.

All American whiskies maintain standards for the six production factors; and the variations among distilleries in adherence to standards for these factors determine flavor and cost differences. All American distillers start with a careful grain purchasing program. Though price is a criterion, they all use #1 or #2 yellow corn, #1 plump northern rye, and choice northern malted barley. Any off odors or below-grade grain are rejected at the distillery. Very stringent grain standards are a common feature of all American distilleries (Table 1).

Mash bill

The mash bill may vary, with a typical bourbon having a mash bill of 70% corn, 15% rye and 15% malt. A typical Tennessee whisky may have 80% corn, 10% rye and 10% malt while a typical rye whisky will have a mash bill of 51% rye, 39% corn and 10% malt. All grains are ground, with the hammer mill being the most common type of processing; however some roller and attrition mills are still in use. The milling (Figure 1) is checked for grind by a sieve analysis. A typical

Table 1. Specifications and analyses of corn, rye, wheat and malt.

	Specification		*Typical analysis*
Corn (#2 recleaned)			
Grain odor	No musty, sour or off odor		'Meets spec'
Moisture, %	14.0	(maximum)	12-14
Cracked grains and foreign material, %	2.0	(maximum)	1-2
Damaged kernels, %	3.0	(maximum)	0-1.5
Heat-damaged kernels, %	0.2	(maximum)	0-0.1
Bushel weight, lbs	55.0	(minimum)	55-60
Rye (#1 plump)			
Odor	None	'Meets spec'	
Moisture, %	14.0	(maximum)	10-14
Thins, %	2.0	(maximum)	1-2
Dockage, %	2.0	(maximum)	1-2
Bushel weight, %	56.0	(minimum)	56-60
Malt			
Bushel weight, lbs	35.0	(minimum)	35-38
Moisture, %	6.0	(maximum)	4-6
α-amylase	60.0	(minimum)	60-64
Diastatic power	22.0	(minimum)	22-26
Bacteria count, CFU/g	1,000,000.0	(maximum)	400-500,000
Wheat			
Odor	None	'Meets spec'	
Moisture, %	14.0	(maximum)	10-14
Thins, %	2.0	(maximum)	1-2
Dockage, %	2.0	(maximum)	1-2
Bushel weight, lbs	56.0	(minimum)	56-60

sieve analysis for grains in a bourbon mash bill is shown in Table 2.

Mashing

Mashing techniques vary considerably, but the major difference is whether pressure or atmospheric batch cooking is used. Bourbon, rye, wheat, Tennessee and corn whisky are mashed using batch cookers. Only the 'blend' or 'light' whisky producers use continuous cookers. Pressure cooking is usually done at 124°C while atmospheric cooks are done at 100°C. Cooking time varies from 15 minutes to 1 hr. Conversion time and temperature are very consistent among distilleries. Malt is never subjected to temperatures greater that 64°C; and conversion time is usually less that 25 minutes to minimize contamination. All distillers use backset (centrifuged or screened stillage from the base of the still), but the quantity of backset will vary based upon the beer gallonage (gallons of water per 56 lb distillers bushel of grain) to be used. American whiskies have beer gallonages in the 30-40 gallon range. High energy costs for by-product recovery have encouraged some distillers to use lower beer gallonage ratios for spirits. However, bourbon and Tennessee whisky producers continue to use 30-40 gallon beers. The cooling of cooked mash to fermentation temperature is achieved using vacuum (barometric condensers) or cooling coils.

Yeasting

All whisky producers use *Saccharomyces cerevisiae*, however the yeasting techniques vary tremendously between the 'modern' and 'traditional' distillers. The modern distillers have elaborate yeast laboratories and will propagate a new yeast from an agar slant every week. They are very aseptic and accurate, assuring continuity of the same flavor. The 'traditional' distillers use yeast stored in jugs; and though they backstock weekly, the potential for gradual yeast culture changes and contamination can lead to flavor variances. These distillers take extra effort and care to ensure that their yeasting does not cause ester, aldehyde or fusel oil variances in the distillate.

The most common grains used for yeasting are small grains, rye and malted barley. These grains are cooked in a separate cooker to about 63°C, and the pH is adjusted to 3.8 with lactic acid bacteria grown in the yeast mash. Lactic acid production is then stopped by increasing the temperature to 100°C for 30 minutes to kill the bacteria. This aseptic, sterile mash is then ready for the yeast from the dona tub grown in the laboratory (Figure 2). The yeast fermentation temperature is controlled at 27-30°C; and the yeast propagates until the Balling drops to half the original 22° Balling reading. This yeast mash will have a yeast concentration of 400 million cells/ml. Both modern and traditional distillers regularly have clean, sterile yeasts free of bacterial contamination that may cause side fermentations and unusual congeners in the

Table 2. Typical sieve analysis for grains in a bourbon mash bill.

US Sieve #	*Corn*	*Rye*	*Malt*	*Wheat*
16	15	22	2	20
20	21	25	8	26
30	17	13	14	12
40	13	9	16	8
50	10	7	13	6
60	3	2	8	2
Through 60	21	22	34	22

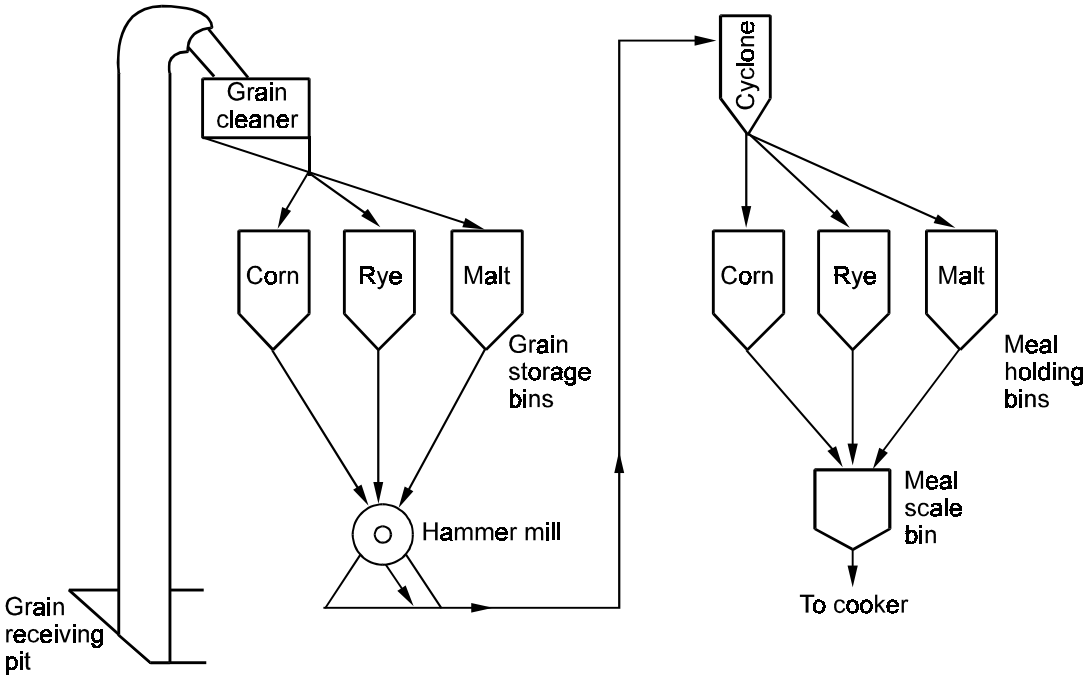

Figure 1. Typical grain-handling and milling facility.

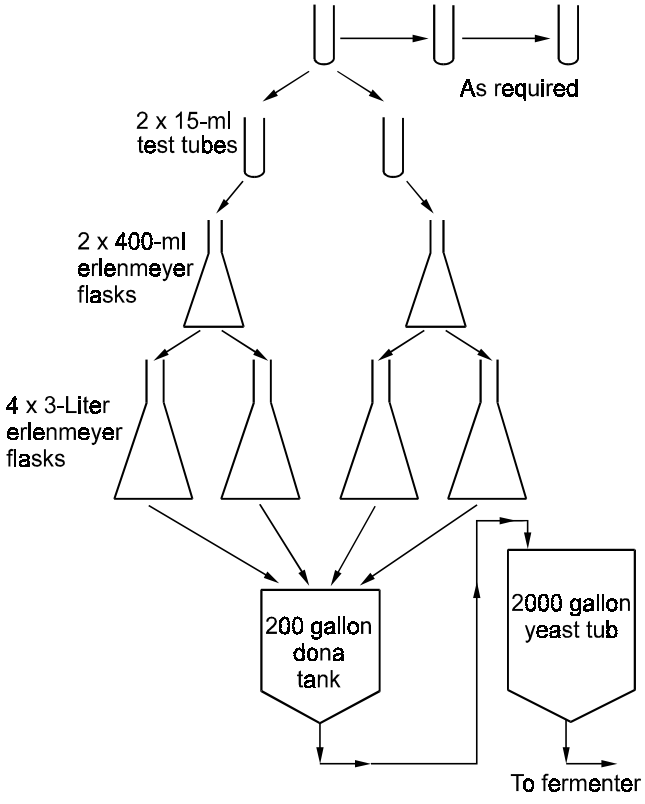

Figure 2. Stages in yeast propagation.

distillate. The 'lactic souring' and the alcohol content of the finished yeast mash (8%), along with sterile dona and yeast tank methods contribute to the excellent reputation American whiskies have for fermentation congener consistency. The advantage of using small grains are: preservation of enzymes for secondary conversion, low steam requirements and shorter processing time. Also, because of its nutrient value, barley malt is the most important constituent of yeast mashes. Corn is not used in a yeast mash because it does not contain the growth factors required for yeast and lactic bacteria growth.

Fermentation

Fermentation is the simplest part of the production process, but requires more control with efficient equipment in order to have stable, consistent results. After the two or three cooks required are completed, cooled, and transferred to the fermenter, the fermenter is 'set'. Setting the fermenter means filling the fermenter with cooked mash, inoculated yeast and backset. The yeast mash is pumped in as soon as the first cook is added to the fermenter. The addition of backset and/or water is done at the end of filling to bring the fermenter to the desired final beer gallonage. Most distillers use a 30-36 gallon mash, and the water:backset ratio determines the set pH. Set pH values of 4.8-5.2 are considered to be the best starting point. The modern distillers have closed-top fermenters with cooling coils or external heat exchangers to control fermentation temperature. They usually set fermenters at 27-29°C and control at 30-31°C. Traditional distillers will have metal or wood open-top fermenters without any device to control fermentation temperature. They usually set their fermenters as cool as they can (18-21°C) and let the fermenters work up to 31-32°C. All of this is controlled by mash cooker cooling, addition of cold water and weather factors. Contamination is controlled by cleaning fermenters, ensuring no mash pockets in pipes and regular steaming of fermenters.

Both traditional and modern distillers ferment their beers for at least 72 hrs, and some for as long as 96-120 hrs. Three and five day fermentations are the norm. During these periods the Balling will drop to 0.0 and the pH from 5.0 to 3.8 while the alcohol concentration rises to 8-10%. All the changes that happen during fermentation are checked daily by performing 'beer chemistry'. Balling, pH, acids, and fermenter temperature are monitored and recorded daily. The pH is the main indicator of contamination and potential fermentation problems and is regularly measured by traditional and modern distillers (Table 3).

Distillation

Upon completion of the fermentation process, the beer with 8.0-10.0% alcohol is transferred from the fermenter to the beer well. The beer well is a holding tank for the fermented beer, such that a continuous feed to the beer still can be maintained. Beer wells are usually 1-1.5 times the size of a fermenter. They also have continuous agitation to prevent solid grain particles from settling to the bottom of the vessel. All American whisky producers use a continuous still (Figure 3), though some have a second distillation 'doubler' or 'thumper' (Figure 4). The basic difference between a doubler and a thumper is whether the unit is operated with a liquid level (doubler) or essentially dry (thumper). Both the doubler and the thumper provide a second distillation.

The beer is pumped into the upper section of the first continuous column, the beer still, six to ten plates from the top. Live steam is introduced at the bottom. Beer stripping plates 1-18 have perforations, a downcomer from above and a dish on the plate below to hold the beer liquid at a set level so the plates are never dry, as the beer moves back and forth across each plate. The steam passing up and through the perforations, controlled by pressure or flow rate, strips the lighter, more volatile alcohol from the water/grain mixture on the plates. When

Table 3. Typical analysis of beers from bourbon, rye and corn whisky production.

	Bourbon	*Rye*	*Corn*
Set sample			
Balling	13.4	13.4	12.3
Titratable acidity	4.5	3.6	2.8
pH	4.5	5.0	5.2
Temperature, °C	27.0	24.0	27.0
24 hr sample			
Balling	2.6	4.0	3.6
Titratable acidity	5.1	4.6	4.2
pH	4.2	4.4	4.3
Temperature, °C	30.0	31.0	29.0
48 hr sample			
Balling	2.4	3.6	1.0
Titratable acidity	7.8	7.5	6.1
pH	3.8	3.9	3.8
Temperature, (°C)	30.0	30.0	30.0
Drop sample			
Balling	0.4	1.5	-0.4
Titratable acidity	8.2	7.9	7.1
pH	3.8	3.9	3.8
Temperature, °C	30.0	30.0	30.0
Alcohol, % by volume	6.73	5.8	6.8
Residual carbohydrates, %	8.0	8.4	4.2
Residual carbohydrates, % maltose	0.73	0.6	0.46

this alcohol gets to the top 4-8 bubble cap plates it is concentrated to about 100° proof (50° GL). As the vapors continue up into the beer preheater (a heat exchanger to heat beer going into the column), some alcohol is condensed and refluxed to the top of the beer column. The rest flows to the doubler or thumper as vapor. From either of these pot still-type chambers, the vapor goes to the condenser where the product is drawn off at 130-140° proof (65-70° GL). Bourbon cannot be distilled above 160° proof (80° GL). If it comes off at more than 160° proof, it must be called 'light' whisky. The stillage from the base of the beerstill is pumped to the dryer house to be processed. The 'high wine' from the stills is pumped to the cistern room where it is held, tested and reduced to barrelling proof (Table 4).

By-product recovery

The by-product recovery does not usually receive the same care that the other processes demand. The only essential for this process is ensuring that the backset stays hot, around 99°C, so that it is absolutely sterile when used in the mash tubs, yeast tubs and fermenters. (Most distillers use 20-30% backset in their total process.) Furthermore, the hotter the backset remains, the greater the savings in energy costs during the cooking process. The stillage from the base of the beer still has about 7-10% total solids. When used for backset it is screened or centrifuged to prevent solids accumulation in the cooker and fermenters. Nearly all distillers have a dryer house, though a couple of traditional distillers continue to sell their 'slop' to nearby farmers.

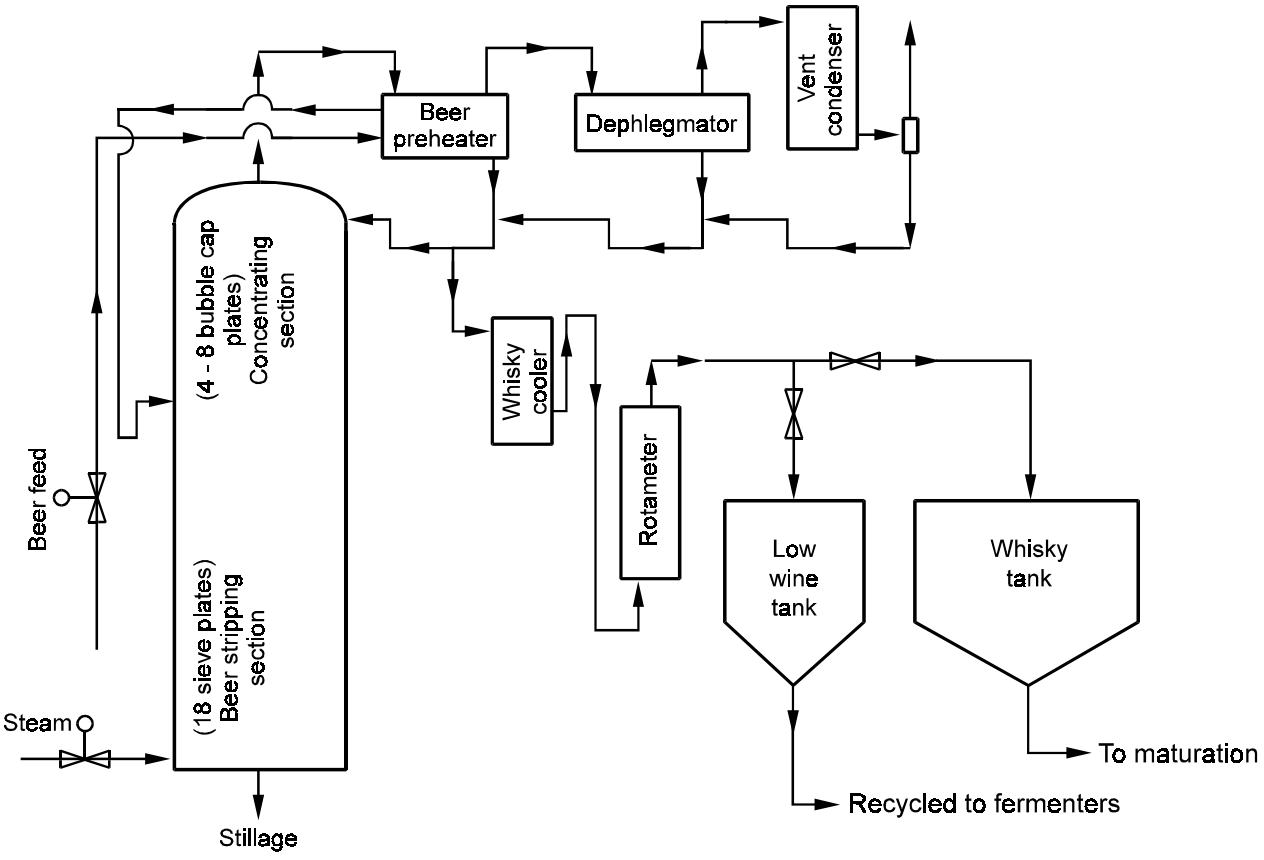

Figure 3. Bourbon whisky still.

Table 4. Typical operating data for whisky distillations.

	Bourbon	*Rye*
Product proof	130°	130°
Still pressure (inches of water)	48	42
Steam rate, lb/hr	12,000	12,000
Beer feed rate, gallons/minute	120	117
Reflux rate from beer preheater, gallons/hr	350	300
Reflux rate from dephlegmator, gallons/hr	700	750
Reflux rate from vent condenser, gallons/hr	30	65
Draw-off of product, gallons/minute	12.5	10.0
Still losses, %	0.0004	0.00025
Water temperature to vent condenser, ^{0}C	21	21
Water temperature from dephlegmator, ^{0}C	79	79
Beer solids, %	0.06	0.06

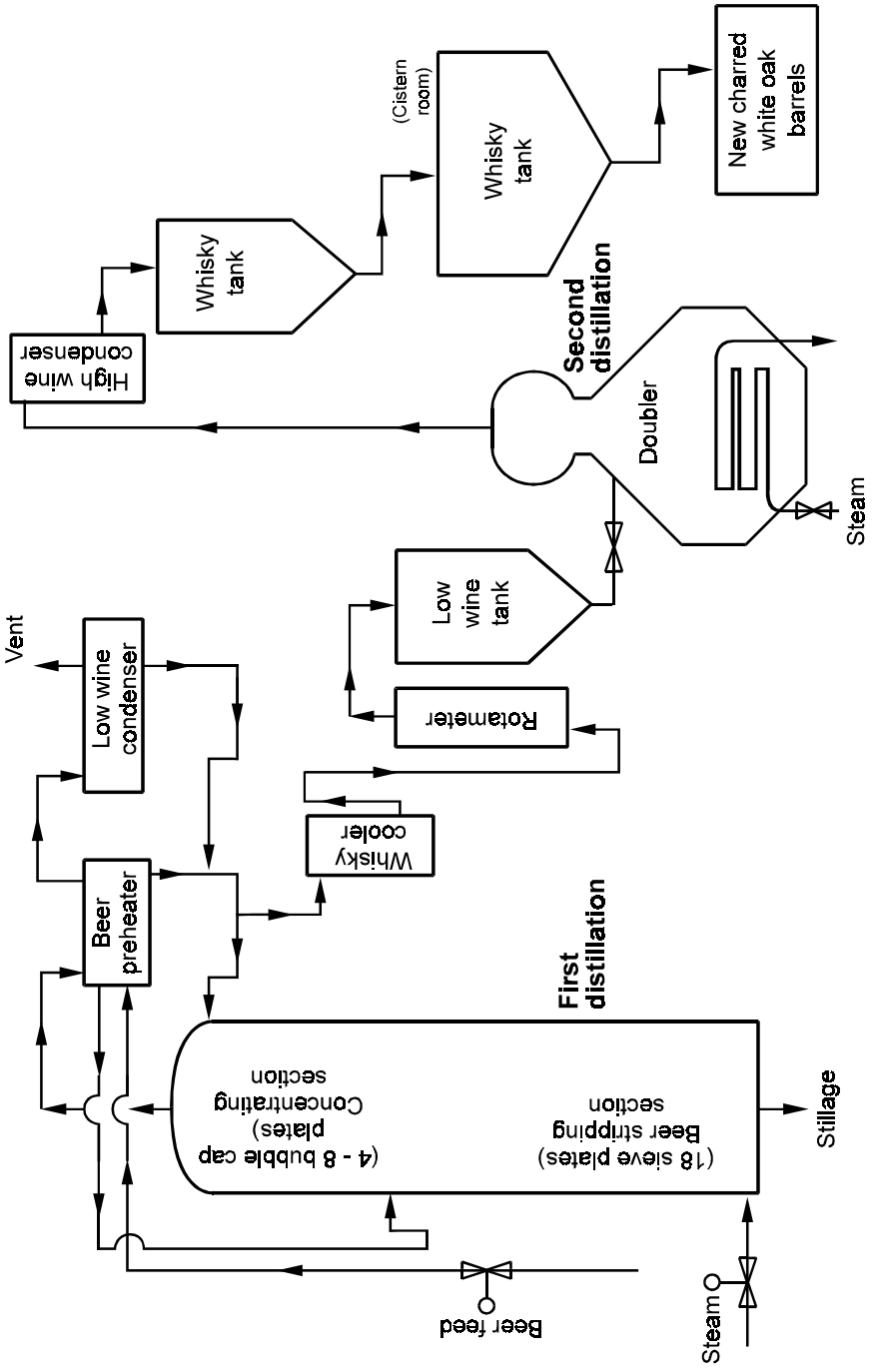

Figure 4. Bourbon whisky distillation system, including doubler.

For a while some, like the Jack Daniel Distillery, fed the stillage to cattle in wet-feeding operations; but environmental restrictions have generally eliminated such practices. Also, modern dryer house operations have become very profitable and the profit helps lower the cost of making whisky.

A modern dryer house will have a whole stillage tank, a centrifuge, press or screen device, thin stillage tank(s), fiber dryer, evaporator and dried grains storage bins. The centrifuge, press or screening device separates the heavy, fibrous grains, which are fed to a dryer. The thin stillage is fed into an evaporator and concentrated to a syrup with 40% solids. This syrup is mixed with dried fibrous material in a mixer and fed to the dryer(s), where it is dried to 8-10% moisture (Table 5).

Distillers dried grain is high in protein (24-30%), and is sold primarily in the cattle feed market. One distiller dries the fiber and solubles portions separately, selling the fiber portion based on its fiber content and the solubles as distillers solubles in the high protein (40%) markets. The distillers dried grains with 24-30% protein will sell for $180/ton, making it a very profitable by-product. Distillers solubles will bring a greater return owing to its higher protein content. In the modern distillery, the value of the by-product recovered will be credited against grain costs and is a major factor in maintaining low proof gallon production costs.

Cooperage and maturation

Cooperage and maturation are the processing factors that distinguish bourbon and American whisky from the other whiskies of the world. Only bourbon whisky regulations require that it be matured in a new charred, white oak barrel. Other whiskies of the world may require the use of small wooden barrels, but no other whisky but bourbon goes through the care and expense of requiring small white oak barrels to be freshly charred.

The making of the bourbon whisky barrel is a very traditional, but exact science and craft. Staves and heading are quarter-sawed from mature, white oak timber. Actually, some physical variance exists within a single tree, but no more than between trees. After being quarter-sawed with the medullary rays not less than 45 degrees to the stave surface, the staves and heading are air-dried in a stave yard. The more traditional distilleries require wood to be air-dried at least one year. The modern distillery usually has no air-drying specifications and allows its barrels to be produced from wood that has been air-dried for six months or less. All of the wood is kiln-dried at the cooperage, with staves and heading dried to 12 and 10% moisture, respectively. The kiln-drying is essential to prepare the wood for the planing, milling, edging and joining operations that cannot be done on wet wood. More important, however, is that proper drying (air-drying a year followed by kiln-drying),

Table 5. Specifications and analyses for wheat, rye and corn distillers dried grains (DDG).

	Wheat and rye DDG		*Bourbon and corn DDG*	
	Guaranteed analysis	*Typical analysis*	*Guaranteed analysis*	*Typical analysis*
Moisture, %	-	5.0	-	7.0
Protein, minimum %	20.0	22.0	25.0	27.7
Crude fat, minimum %	5.0	5.5	5.0	6.6
Crude fiber, maximum %	17.0	14.8	16.0	13.7
Ash, %	-	2.2	-	1.7

makes the wood chemistry satisfactory for flavoring the whisky during maturation.

As the whisky goes through maturation (3-4 years for the modern distillers and 4-8 years for the traditional distillers), two distinct types of reactions occur: reactions between the distillate components (regardless of the barrel); and reactions that occur when the distillate extracts chemical compounds from the wood. A major factor differing among the distillers is the warehouse environment. Most modern distillers heat their warehouses in winter. One particular distiller even controls the heat cycles to ensure constant aging. The traditional distillery seldom has heated warehouses and depends strictly on Mother Nature to determine the number and range of its heating and cooling cycles.

Whether the heat cycle is natural or forced, the greatest rate of change or formation of congeners occurs in the first 12-16 months. Only ester formation occurs at a fairly constant rate. Proof increases at a fairly constant rate of 4-5% each year of aging. Other specific changes occuring when the distillate reacts with the charred wood are: a) aldehyde formation, specifically acetaldehyde, which comes from the alcohol via oxidation, b) acetic acid formation with greatest activity in the first year of maturation, and c) ester formation (ethyl acetate) from the alcohol via oxidation. The components coming from the wood are tannins, sugars, glycerol and fructose. The hemicellulose in the wood appears to be the source of the sugars found in aged American whiskies.

The depth of charring and 'toast level' in the barrel determines the color of the whisky. Color formation is almost instantaneous when the distillate is put into the charred barrel, with 25-30% of the color formed in the first six months. Some color development occurs each year of maturation until the whisky is dumped from the barrel. The final product is then filtered, its proof reduced with demineralized water and bottled. Compared to the sweet rums, 'breathless vodka', fruity gins, light Canadians and Scotches, the American whiskies have flavor and bravado with a balance that is pleasant to the taste. American whisky produced and matured as described has a big, pungent aroma that leaves no doubt that it is bourbon or Tennessee whisky.

Though the modern and traditional distillers have different levels of technology, they both use the same basic processes for making bourbon or other American whiskies. Individual plant nuances produce different flavors, but they all have an American whisky bouquet and taste.

References

Carson, G. 1963. The social history of bourbon. Dodd, Mead & Company, New York.

Connelly, W.E., and E.M. Coulter. 1922. History of Kentucky, Vol. II. The American History Society, Chicago and New York.

Lyons, T.P. 1981. Gasohol, A Step to Energy Independence. Alltech Technical Publications, Nicholasville, Kentucky.