REPEAL *means* **REVIVAL** *of another Process Industry*

DISTILLING BEVERAGES FROM GRAIN

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WITH REPEAL of the Eighteenth Amendment a *fait accompli,* many people will consider it a propitious time to enter or re-enter the manufacture of alcohol in the form of whiskey, gin or spirits. Considerable strides have been made along technical lines since 1918 and under the present business conditions only the manufacturer who is able to erect a well designed plant, applying on a large production scale continuous beer and rectifying stills and other efficient chemical engineering equipment and having fermentation and other process steps under strict chemical control can hope to survive the keen competition ahead.

Chiefly grain will be used for the manufacture of beverage alcohol, but there are, of course, several other processes by which alcohol can be produced economically. These belong to two groups, one is by fermentation and the other is by synthesis. In the first group, the raw materials are grain, fruit, molasses and cellulosic materials, while the second group embraces ethylene, natural or coke-oven gas, calcium carbide and carbon monoxide. The present article will deal mainly with the manufacture of alcohol from grain but Fig. 2, shows the general process steps with various raw materials. A second article discussing alcohol from molasses will appear in a later issue.

Before Prohibition ethyl alcohol produced from agricultural products was made chiefly from malt, wheat, rye, barley, corn, and oats. (See Tables I, II, and III.) The theoretical and practical yields of alcohol from these raw materials are as follows:

	Lb. per bu.	Fermentable sugar and starch (Per Cent)	Fermentable sugar & starch per lb. per bu.	Absolute alc. theoretically lb. per bu.	Alcohol practically proof gals. per bu.
Barley	48	65.5	31.4	17.75	4.50
Malt	34	60.6	20.6	11.57	3.00
Wheat	60	64.8	38.9	22.02	5.90
Maize (Indian corn)	56	66.0	36.9	20.94	5.00
Rye	56	59.3	33.2	18.75	4.75

The first process step in the manufacture of alcohol from grain is the milling, which consists of conveying, cleaning and grinding. The distiller has considerable flexibility in choosing the right equipment depending on the capital and floor space available and quality of product desired.

The grain is received, usually by rail, in cars containing approximately 600 bu. It is conveyed to a hopper scale and from there it passes first through a separator before it is stored in iron, wood, or reinforced concrete silos. In this separator most of the dirt and dust is carried away into a dust collector. The partially cleaned grain is stored in silos and from there is conveyed to the milling department. All the grain entering the mill is weighed and records are kept according to Government regulations. The grain is cleaned a second time and before being ground to the desired fineness, it passes over a magnetic separator for the removal of metallic substances which might injure the mills.

When constructing a distillery, careful study should be made of the grinding equipment as we have three types of mills from which to choose, viz., the extensively used roller mill, the attrition mill and the hammer mill. Each one has its defects as well as its good points. When it comes to the power requirement, the roller mill is by far the most efficient. But in addition to power requirement consideration should be given to the amount of fine material present in the ground material as well as floor space available.

The old type of distillery with its large and wasteful layout and floor space, contrasts with the compactness noted in distilleries under construction at present. In some instances today the milling equipment is being erected in the same building with the mashing and fermenting tubs. Because of smaller investment it sometimes pays to be quite liberal with mechanical conveyors rather than to build a high gravity-flow milling plant.

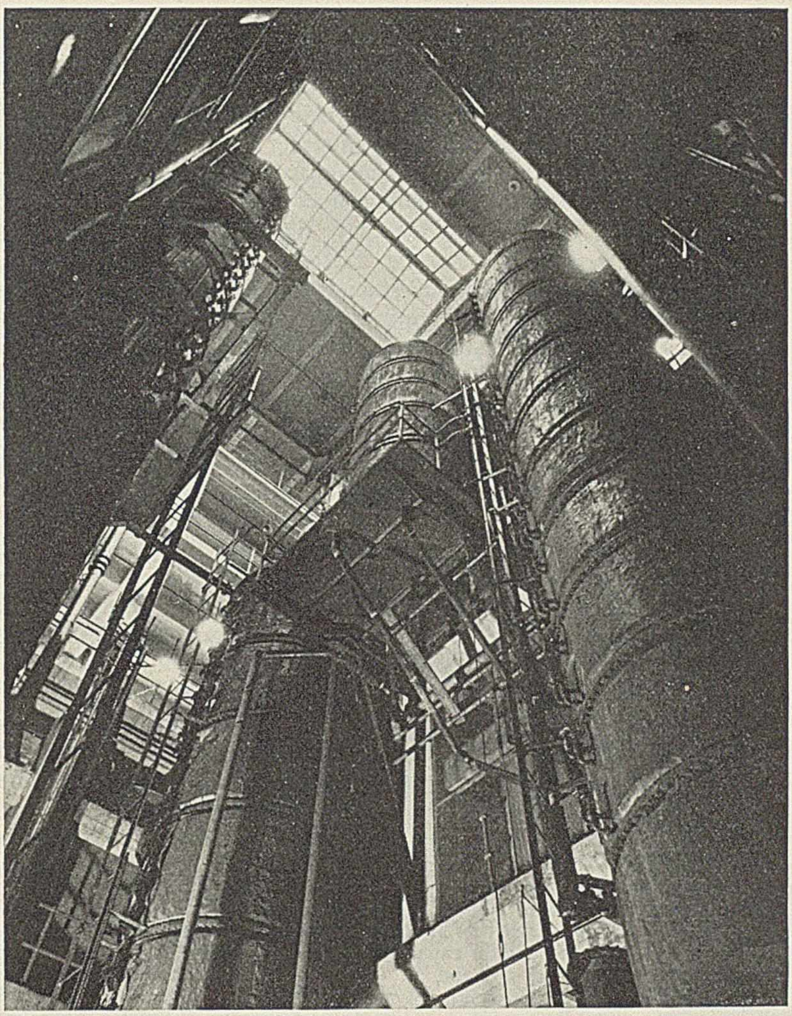


Fig. 1—Rectifying columns in a modern distillery

As there are several varieties of yeast, it is important to choose a type which is capable of producing the largest quantity of alcohol under desired conditions. We have high and low temperature yeasts, some for sour, sweet or hops mashes, while others are capable of being active in high density mashes. Regardless of which type of yeast is selected, it is of a prime importance to start only with pure culture yeast, which is used exclusively in the molasses distilleries in this country. Before Prohibition, the typical distiller considered the preparation of his yeast a great secret and attributed every conceivable result to the special method he used in its cultivation. The progressive distiller will start with a pure culture yeast and propagate it in the properly designed pure culture apparatus and acclimate it to the special type of mash he desires to ferment.

The yeast mash containing half rye meal and half malt is gelatinized and saccharified at a temperature of from 40 to 158 deg. F. First the rye is run into hot water slowly, stirring it vigorously and then the malt is added, watching carefully meanwhile, that the temperature shall not drop below 122 deg. F. While slowly stirring the mash is heated to 143 to 145 deg. F. within one hour and the sides and rakes are washed down with a little hot water. The mash stands at this temperature for approximately one hour to complete the saccharification. A density of 23 to 25 deg. Balling is desirable. At the end of the hour, the mash is prepared for the souring by inoculating it with lactic acid bacteria. It requires 24 to 36 hours to obtain an acidity of 1.8 deg. to 2.1 deg. normal, while a temperature of above 120 deg. F. is maintained. When the proper degree of acidity has been reached, rakes are started and the temperature raised to 170 deg. F. and held for about half an hour. Part of the hot mash is removed to be used as a starter for the next batch while the remainder is rapidly cooled, by passing cold water through the heating coils, to a temperature of 70 to 75 deg. F. and is inoculated with the pure culture yeast.

The pure culture yeast may be propagated either in suitably designed machines such as Magne's, or if carefully attended in wooden or iron yeast tubs. When the density of the first mash has dropped to 5 to 6 deg. Balling, it is transferred to a larger yeast tub stocked with a sterilized malt donna. After several hours working it is used in the fermenters. Its density is from 7 to 9 deg. Balling and acidity, 0.14-0.16 normal.

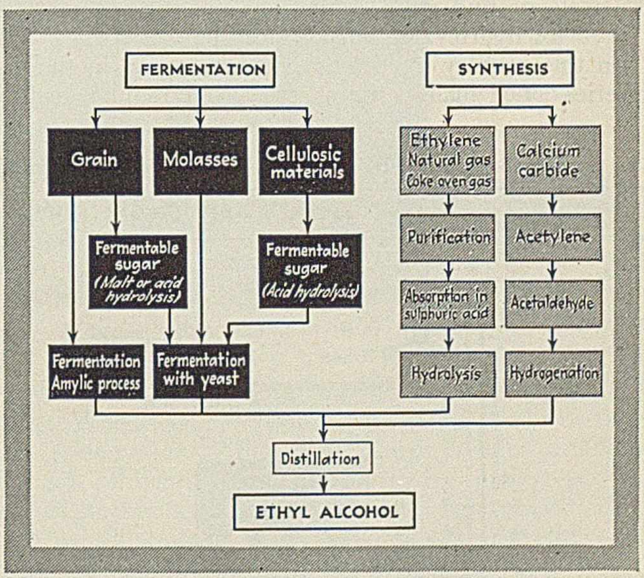


Fig. 2—Sources and processes for ethyl alcohol production

In the manufacture of grain alcohol, it is important to know whether the product is to be converted into whiskey or spirits; also the size of the distillery and raw materials used. Small distilleries will undoubtedly be equipped with open mash tubs while larger distilleries may operate pressure cookers exclusively. However open

Table I—Quantities of Grain Used in the Production of Alcohol and Other Distilled Spirits

Fiscal Years	Malt (Bu.)	Wheat (Bu.)	Barley (Bu.)	Rye (Bu.)	Corn (Bu.)	Oats (Bu.)	Others Materials (Bu.)
1910	3,704,740	10,316	2,733	5,042,741	20,547,427	11,502	8,248
1912	4,075,991	25,505	1.943	5,599,667	23,016,759	6,563	50,576
1914	3,938,715	10,582	2,072	5,341,931	21,315,699	5,654	64,896
1916	4,480,588	3,373	148	3,116,612	32.069,542	9,807	68,822
1918	1,689,677	......	....	248,864	14,544,545	.....	172,039
1920	215,072	......	....	50,077	1,057,519	.....	51,760
1922	679,697	......	....	84,876	3,093,065	.....	4,097,905
1924	1,059,985	......	....	91,065	4,835,139	.....	2,691,070
1926	641,032	......	....	12,678	7,948,184	.....	26,621
1928	385,238	......	....	6,579	6,189,264	.....	123,624
1930	646,574	11,990	21,320	208,209(1)	9,966,336	.....	19,144
1932(2)	505,613	3,311,441	....	217,934	4,848,133	.....	2,478

(1) 1931—6,385,365 bu. (2) Year 1932 figures include 211,675 lbs. of corn 19,865,419 lbs. of wheat, 150,619 lbs. of malt, and 20,103,526 lbs of hydrol acids used at chemical plants producing butyl alcohol, acetone, and ethyl alcohol.

mash tubs are sometimes preferred in distilleries mashing 1,000 to 2,000 bu. per day. Here we have two different opinions to consider: one claims that in order to make a good grade of whiskey open mash tubs should be used while others claim to get just as good results with pressure cookers. That a much better yield of alcohol is obtained from a vacuum cooker can not be doubted, but as to the quality of the final product, a great deal depends on the mode of cooking, the proportion of ingredients, the yeast, and the method of fermentation and still construction.

Cooking and mashing generally refer to the series of process steps in which the starch cells are ruptured to produce a perfect starch paste which through enzymatic action is converted into fermentable sugar. The rupture of the starch cells depends on the fineness of the grain, time and temperature. The more finely ground the grain, up to the point of becoming flour, the better will be the rupture of the starch and a perfect starch paste will be produced. The grain should be such that the recovery of the insoluble solids from the slop will be practicable without impairing the yield of alcohol. Another advantage of finely ground grain is that the quantity of malt required for hydrolyzing purposes can be reduced.

In this country malting is not carried out in the distilleries since malt is purchased from regular malting plants. While any grain can be used for the preparation of malt, from a practical standpoint barley is the most suitable for this purpose. A bushel of barley, which weighs 48 lb., yields 34 lb.—also a bushel—of dried malt. The value of malt from a distiller's standpoint is judged by its diastatic power and extract. The whole malting process aims to develop a malt of a very high diastatic value. The diastase is an enzyme and converts the starch of the grain, during the mashing into maltose and dextrin, which are fermentable and yield alcohol. In purchasing malt, a diastatic value of 1,350 to 1,450 is demanded on the Lintner's scale, i.e. 100 lb. of dry malt will invert 1,350 to 1,450 lb. of soluble starch.

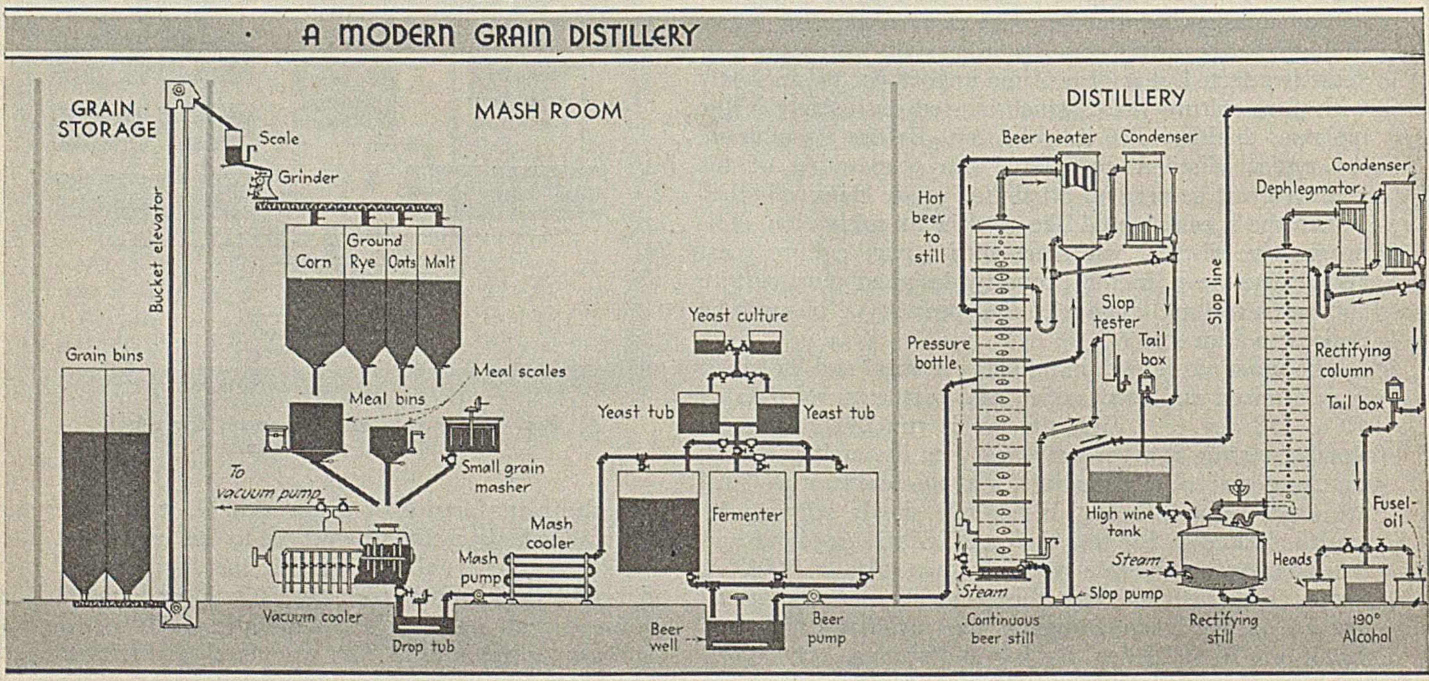
The function of the malt is to liquefy and saccharify the starch. Each action is influenced by the temperature. The diastase of the malt has the greatest saccharifying property between 118 deg. to 130 deg. F. and its strongest liquefying power, around 158 deg. F. The judicious use of these above temperature passages presages a good yield of alcohol.

The flow diagrams in Fig. 4 illustrate the way a typical grain distillery carries out these processes, depending largely on the type of equipment used.

The open mash tub is a cylindrical vertical copper or steel vessel with flat bottom and domed top. Usually it is provided with stirring rakes, copper coils, to be used for heating and cooking purposes, and vents for the escape of steam. Fig. 5 shows such a mash tub.

Hot water in the amount of 20 to 24 gal. per bu. of grain and at a temperature from 100 to 120 deg. F. is run into the tub. The addition of grain depends on whether a rye mash or corn mash is desired. If rye is mashed, the procedure must be adjusted according to whether it has a high gluten content or the rye malt has a low diastatic capacity and fluidity. Generally, half of the finely ground rye and all of the malt (approximately 15 to 25 per cent of the weight of rye) are mixed thoroughly and slowly run into the water. During the addition of the meal the rakes are speeded up to prevent the formation of lumps. After the addition of this mixture, the remainder of rye is added slowly so that all of the meal is run in within 30 to 45 minutes. Afterwards the temperature is held at 110 deg. F. for at least ten minutes with the rakes revolving slowly. The temperature of

Fig. 3—Complete flowsheet and equipment required for distilling beverages from grain in a modern plant



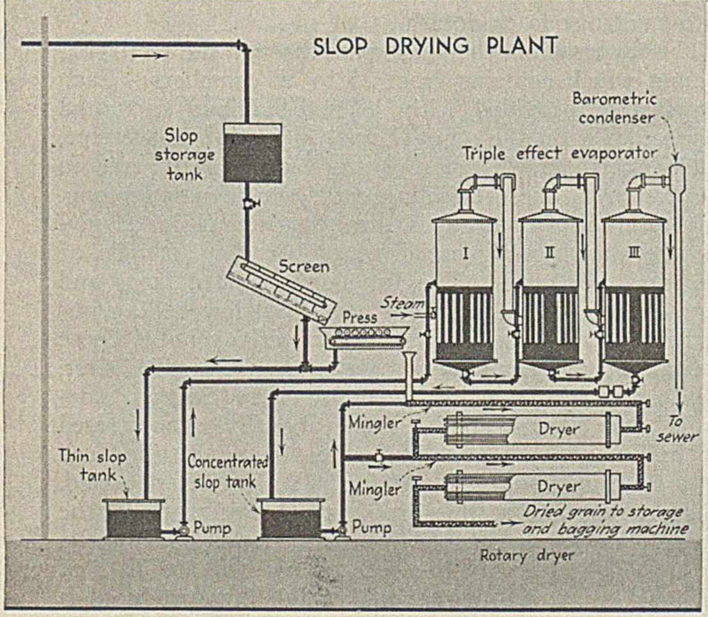
the mash is now raised by admitting steam to the coil until 145 deg. F. is reached. The mash is held at this temperature from 15 to 25 minutes and finally raised to 152 to 154 deg. F. and held there from 30 to 45 minutes. The saccharified mash is cooled to about 75 deg. F. and is pumped to the fermenters. Instead of adding all the rye meal at the beginning before the temperature is raised above 110 deg. F., we may also add half of the rye, after the mash reached a temperature of 152 deg. to 154 deg. F. and is cooled down to 150 deg. F. This procedure depends entirely on the quality of product desired.

Corn mash requires a much higher temperature since the gelatinization of its starch is much more difficult. In this case, 7 to 10 per cent of the total malt required, based upon the corn to be mashed, is added first to water at a temperature of 130 to 140 deg. F. and afterwards all the corn meal. While the rakes are in motion, the temperature is raised within 30 to 35 minutes to 200 deg. F. and is maintained there for 10 to 15 minutes. The gelatinized mass is cooled rapidly within 20 to 25 minutes, to 158 deg. F. As soon as this temperature is reached, the remainder of the malt is added slowly in order that the temperature shall not drop below 152 deg. F. If rye to the amount of 10 to 20 per cent of corn is used, it is added at a temperature of 156 deg. F. and precaution taken that the mash temperature shall not be below 150 deg. F. Where cold water is available, the mash is cooled to 100 to 110 deg. F. and when mixed with water will have the proper temperature for the fermenters.

While in the open mash tub, the cooking, saccharification and cooling is done under atmospheric pressure, in the vacuum cookers, cooking is carried on under pressure and the cooling effected under vacuum.

The vacuum cooker is a cylindrical tank supported on legs, provided with a shaft and stirrers. Capacity ranges from 2,000 to 10,000 gal. capable of processing 50 to 250 bu. of grain. They stand a pressure of 100 lb. and are provided with several live steam inlet pipes, vent and vacuum lines, also opening for the charging of dry grain and wet malt from the small grain masher. Customary pressure and vacuum relief valves and thermometers are also attached.

The cookers are charged with 20 gal. of water per bu. of grain. Then steam is applied and the temperature raised up to 300 deg. F., or 50 to 65 lb. pressure. During the heating a great deal of live steam is condensed so that at the end of the mashing, the original liquid volume has increased to 22 gal. per bu. After cooking, the blow out pipe is opened to reduce the pressure. Then the vacuum line is opened and by means of the vacuum pump, the mash temperature is reduced to 152 deg. F. when the malt mash in liquid form is added from the small grain masher. The amount of malt used to the grain is from 7 to 15 per cent. After allowing sufficient time for the saccharification, as has been described for the open mash tub, the thick gelatinized mass is dropped into the "drop tub" and from there is pumped through coolers into the fermenters. For the cooling of the mash the distiller employs either a double pipe cooler or a shell and tube cooler, the latter being used extensively abroad. For the dilution of the mash, water or a mixture of water and slop are used. The latter procedure is applied by Bourbon mashes or where the slop is to be concentrated and sold for feeding purposes. One cooker is capable of handling 8 to 10 charges per day.



PROPERLY gelatinized and hydrolyzed the grain will contain most of its starch in the form of maltose and dextrine which with the addition of yeast is easily fermentable. Wood, enamel-lined or steel tanks can be used for the fermentation of the mash. Small distilleries will use wooden fermenters but the progressive distiller prefers closed steel tanks, provided they have tapered bottom and top as illustrated. The advantage of the closed fermenters is the increase of the yield of alcohol from 1 to 2 per cent and the ease of the recovery of carbon dioxide for the manufacture of liquid and solid CO_2 as described by the author in *Chem. & Met.*, Vol. 38, 1931.

Table II—Distilled Spirits Produced During the Fiscal Years 1910 to 1932
(In Tax Gallons)

Fiscal Year	Whiskey	Rum	Gin	Brandy	Alcohol	Aggregate
1910	82,463,894	2,253,949	2,985,435	7,656,433	68,534,247	163,893,958
1912	98,209,574	2,577,861	3,577,861	9,321,823	73,630,032	187,571,805
1914	88,698,797	3,026,085	4,012,542	7,307,897	78,874,219	181,919,540
1916	59,240,671	2,986,940	4,118,064	4,159,351	182,778,245	253,283,273
1918	17,383,511	1,526,743	4,178,538	5,357,325	150,387,680	178,833,797
1920	234,705	944,916	....	1,649,445	98,436,170	101,265,236
1922	315,799	864,332	....	1,077,063	79,906,101	82,163,295
1924	....	784,698	....	847,104	135,897,725	137,529,527
1926	....	894,306	....	643,968	202,271,670	203,809,945
1928	....	953,350	....	*411,515	169,149,904	170,514,769
1930	1,998,947	982,781	....	416,043	191,859,342	195,257,113
1932	1,711,028	1,097,777	....	630,786	146,950,912	150,390,503

*Brandy manufactured in 1929—1,194.292 tax gal.

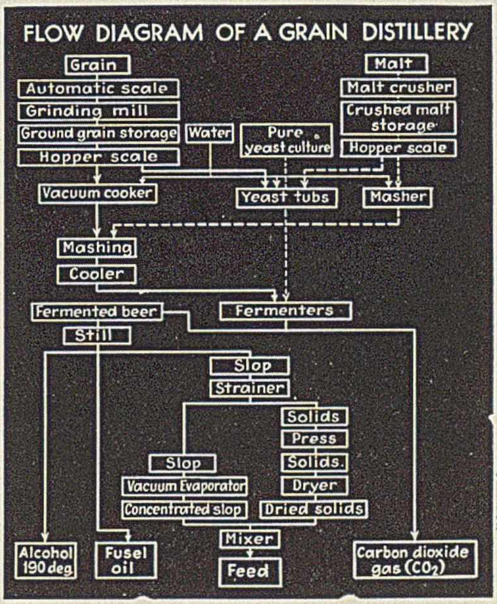


Fig. 4—Schematic diagram of distillery as shown in Fig. 3

The mash coming from the mash tub or cooker is too concentrated to be fermented easily. Therefore, it is diluted with water or water and a slop so that its fermentable sugar content varies from 7.5 to 11 per cent. This is equivalent to from 30 to 45 gal. of beer per bu. of grain. The concentration depends a great deal on

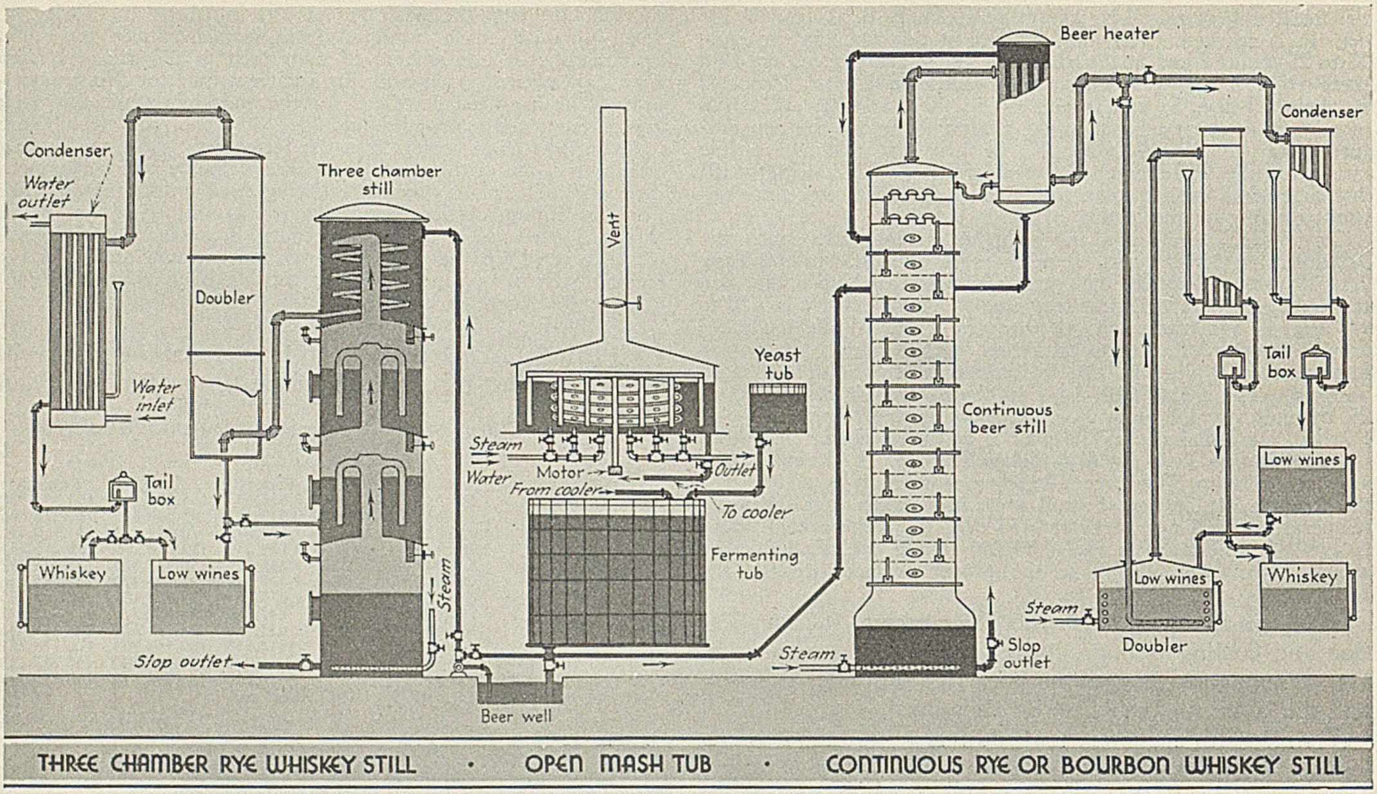


Fig. 5—Details of equipment featured in modern American distillery

whether or not the dealcoholized beer "slop" has to be recovered. The higher the dilution the less economical is the recovery of slop. An average mash will have a density of 15 to 18 deg. Balling and the temperature during the fermentation depends on the density of the mash, setting temperature and yeast. On an average, 56 to 65 hours are required to reduce the density from 10 or 12 deg. Balling to below 0.5 deg. and the acidity of a corn mash increases from 0.045 to 0.85 normal. To insure an even rate of fermentation, a temperature of approximately 70 deg. F. should be maintained in the fermenting room.

Large distilleries mashing from 2,000 to 20,000 bu. of grain per day will use only continuous stills or a combination of a continuous beer still and batch rectifying still. The latter combination is shown in Fig. 3 on a preceding page.

The operation of the continuous beer still is identical on either grain or molasses. The fermented mash is dropped into the beer well and from there pumped continuously at a uniform rate and delivered to the elevated beer feed tank. This tank is provided with an overflow pipe and is connected to the suction pipe of the beer pump.

The fermented mash flows continuously by gravity from the beer feed tank to the beer heater. A feed gage placed in the line provides means for observing and regulating the rate of flow of fermented mash to the beer column. The fermented mash passing through the beer heater is heated through the tubes of the reflux condenser by vapors passing through the inter-tubular space. The pre-heated beer is fed into the beer still, which is provided with a beer heater, condenser, live steam line, and is regulated by testing the alcoholic strength of liquid. A special "slop tester" connected to the base of the still serves to prevent the loss of alcohol in the "slop" discharged from the still.

The function of the beer still is to separate and concentrate the 5 to 8 per cent alcohol contained in the fermented mash. The distillate at from 100 to 140 deg. proof strength is condensed and stored and rectified in the intermittent rectifying still (*Chem. & Met.*, Vol. 36).

The rectifying still consists of the kettle, a rectifying column, dephlegmator and a condenser. The kettle, which may be horizontal or upright, is provided with closed steam coils, pressure and vacuum valves, and a glass gage. The still is charged with the distillate from the beer still, called "high wines" and, if necessary, its proof reduced to 100 deg., and in some instances treated with caustic soda or potash.

The vapors from the kettle pass through the rectifying column which contains from 25 to 50 chambers. Each chamber is provided with several bubbling caps and connected with the one above by a downtake pipe. Lately, considerable improvements have been made in the design of these bubbling caps, which may be long, trays with saw-tooth edges, straight slotted, slotted giving the vapors a zig-zag direction, or they may be of the small bell type. The function of the column and dephlegmator is to separate "heads" or low boiling impurities from the partially concentrated alcohol. These impurities, together with some alcohol, are distilled first, then cooled by the condenser and collected in the "aldehyde" or "heads" tank. The partially concentrated alcohol, freed from these impurities, is now distilled and vapors refluxed until a proof of 190 deg. is obtained. The pure alcohol at this proof is collected until all the alcohol has been recovered from the kettle. Ultimately, the high boiling impurities such as fusel oil are distilled off. The pure 190 deg. proof alcohol thus produced is sold as spirit to be used for cutting aged whiskey or applied for other industrial purposes.

Many experiments were made to supplant the three-chamber rye whiskey still illustrated in Fig. 5 with the continuous still also shown in Fig. 5 and known as the "Bourbon Still." So far, however, no conclusive results can be recorded, although the continuous still is finding more favor among the larger distilleries owing to its ease of operation.

As with all whiskies, the bouquet is the governing factor and several distilleries to be erected or under construction, favor the three-chamber still because it is claimed to produce a better grade of heavy bodied and highly flavored whiskey. Its operation will be described briefly.

The beer is pumped into the top chamber of the column, which acts as a beer heater and dephlegmator. Thence it is drawn periodically every 15 to 20 minutes, from chamber to chamber, until it is completely dealcoholized as it reaches the lower slop chamber. The slop is utilized for feed as will be described later.

The alcoholic vapors passing through the beer heater go into the doubler, boiling out the low wines, thence to the condenser and the distillate collected as "high wines" or whiskey.

From a fuel economy standpoint, this type of still is not very efficient, but the product is excellent. There is a recent tendency to use heat exchangers more liberally, resulting in a fuel economy of 20 to 30 per cent.

Fig. 5 shows a continuous still operated on the same principle as the continuous beer still shown in Fig. 3.

All the features of heat economy applied in the large continuous still are also applied here. The upper chambers of this column are provided with bubbling caps while the lower chambers containing perforated plates also have down pipes. The beer is pumped first through the tubular beer heater overflowing at the top and enters the column on the third or fourth plate. The alcohol vapors pass first into the beer heater and then they may either go to the doubler or to the low wine condenser. The doubler is either a horizontal tank or a vertical tank, crowned, provided with a perforated pipe reaching to its bottom through which the alcohol vapor coming from the still passes through the low wine, thus producing a very highly flavored, heavy bodied product. To prevent condensation, the doubler contains a heating coil, usually of the "scroll type" which is controlled to prevent excessive condensation of the distillate. The vapors from the doubler are condensed and collected in the "whiskey" storage tank.

Grains contain quite a high percentage of oil. Corn, which is used most extensively has an oil content of 4.5 to 5.5 per cent. Owing to the poor quality of its oil, corn is not generally degerminated but the oil is recovered in its dried slop. The processing of slop consists of the following steps: (1). Separation of the suspended solids from the liquids. (2). Removal of excess liquid from the solid in presses. (3). Concentrating the thin clear slop. (4). Drying the solid and mixing with the concentrated slop. (5). Bagging.

As the returns from the dried slop reduce considerably the cost of alcohol, a brief description follows:

The fermented beer, after passing through the still, is dealcoholized and is called "slop." This slop contains various amounts of solids in suspension and in solution depending on the kind of grain mashed, its quality and the concentration of the slop. A rye mash yields approximately 9-9.5 lb. of dried feed per bu. of grain; Bourbon mash from 11 to 11.5 lb. and spirit mash 11.2 to 11.5 lb. respectively.

The slop coming from the beer still, passes first into a traveling screen, a long inclined screen box, in which the suspended solids are separated from the liquid. The solids then pass into the filtering machine, where they are de-watered and ultimately put into the rotary dryer.

After the separation of the solid from the liquid, the distilleries usually run their thin slop to waste and recover the suspended solids in dried form except where the health authorities prohibit their doing so. The present tendency is to recover all the slop. The thin slop is concentrated in a triple or quadruple effect evaporator to a density of 25 to 30 per cent solids. This syrup is mixed with the solids and dried if necessary in several stages in rotary dryers. The dryers may be heated directly or by rotary steam tube dryers depending on the quality of feed desired and whether the thin slop is wasted or also recovered. In distilleries mashing corn, approximately 18 to 19 lb. of feed per bu. of grain is recovered provided all the slop is being processed.

Quite frequently distillery slop contains 35 to 37 per cent of protein while the fat runs from 10 to 13 per cent depending largely on the condition and moisture

Fig. 6—Ingot iron fermenters, of 100,000 gal. capacity, with closed tops for CO_2 recovery

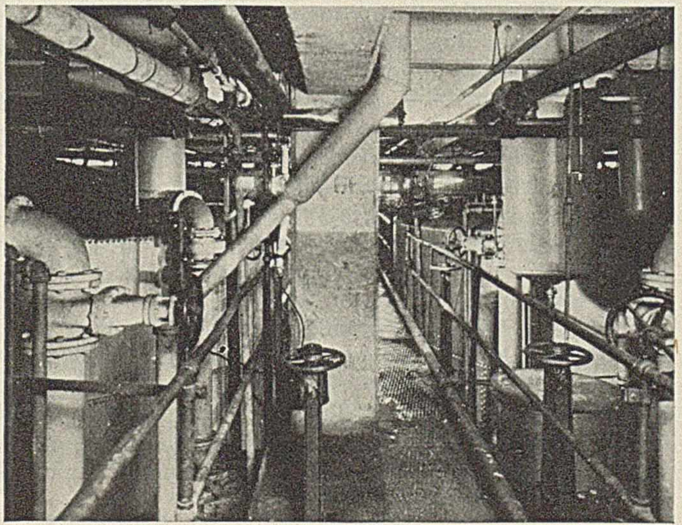
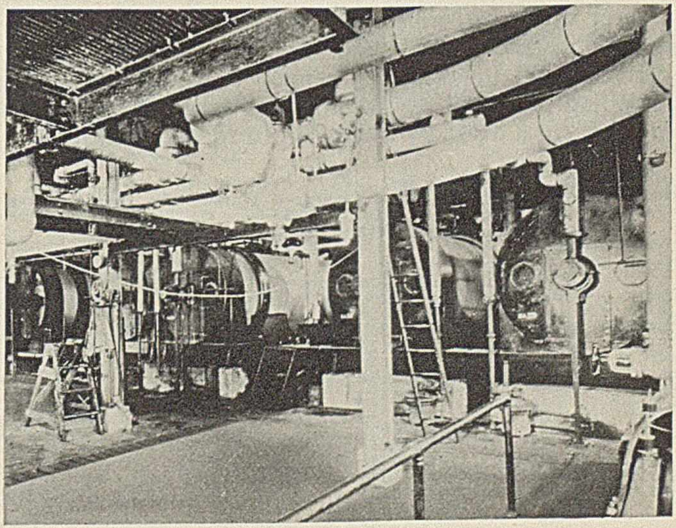


Fig. 7—Louisville slop dryers in plant of American Commercial Alcohol Co., Pekin, Ill.



of the grain. Fig. 7 shows six slop dryers built by the Louisville Drying Machinery Co. for the Pekin, Ill., plant of the American Commercial Alcohol Co. These handle slop from 6,000 bu. of grain daily. The value of the dried feed is approximately $21 per ton from a corn mash and $18 per ton from a rye mash.

ALCOHOL produced in distilleries is not considered whiskey, except after it has been stored and aged for at least four years, which is the minimum time required by the United States Pharmacopia. Its alcoholic content must be from 44 to 52 per cent or 88 to 104 proof. As to the aging, the exact reason for improvement in whiskey by maturing in casks is by no means clearly understood. It is usually ascribed to oxidation and the formation of ethers in the oak casks, which have been charred on the insides.

During maturing the alcohol acquires a mellow taste and its volume in the cask decreases from year to year. The Government takes cognizance of this by allowing the following "soakages" per year.

Distilling Beverages from Grain

Period of Absorption	Kind of cooperage: Plain	Kind of cooperage: Charred
First year	9 lb.	13 lb.
Second year	12½ lb.	14 lb.
Third, fourth & fifth year	13 lb.	14 lb.
After fifth year	14 lb.	14 lb.

The alcohol in oak barrels is stored in concrete or brick warehouses securely protected against theft. The average temperature maintained is 95 to 100 deg. F. and its humidity about 20 per cent.

In aging whiskey the manufacturer has to consider the cost of alcohol, oak barrels, loss of alcohol during storage, insurance, and also fuel for maintaining the proper temperature.

Anyone contemplating the erection of a distillery, must carefully consider the regulations issued by the United States Treasury Department. According to these regulations, the owners are compelled to adhere to very strict Government supervision. In Form 27a to be filled out by the owners, all the stockholders, their names and residences must be given; the name of the owner of the stills and other utensils, the kinds of stills and the cubic content of each; the mode of mashing and fermenting, the number of hours the distiller will ferment each tub of beer; the number of gallons of mash or beer which will represent a bushel of grain; and the kind of materials to be used.

It is highly important to employ only skilled help as according to the Government *"the true spirit producing capacity"* of a distillery is not limited to what the distiller may produce by following a particular course which he has marked but the amount which can be produced, using all the machinery and apparatus under competent and skillful management.

Table III—Denatured Alcohol Produced During the Fiscal Years 1910 to 1932
(In Wine Gallons)

Year	Denaturing Plants	Denatured Alcohol Produced: Completely	Denatured Alcohol Produced: Specially	Aggregate
1910	12	3,076,924	3,002,102	6,079,026
1912	14	4,161,268	3,933,246	8,094,514
1914	25	5,213,129	5,191,846	10,404,975
1916	33	7,871,952	38,807,153	46,679,105
1918	49	10,328,454	39,834,561	50,163,015
1920	52	13,528,402	15,307,947	28,836,349
1922	77	16,193,523	17,152,224	33,345,747
1924	83	34,602,003	33,085,292	67,687,295
1926	97	65,881,442	39,494,443	105,375,886
1928	82	46,966,601	45,451,424	92,418,025
1930	67	58,141,740	47,645,796	105,787,536
1932	49	34,298,235	44,031,281	78,329,516

The government has already established a certain limit of efficiency under which no distiller is permitted to operate a distillery without being penalized. In case of a grain or molasses distiller, the first point the Government determines is whether the distiller has accounted for all the grain or molasses used, and the spirits produced by him during the month. The assessment is based upon a production capacity of 80 per cent of the calculated capacity. If, for instance, a plant on a production capacity basis is 6,000 gal. and it produced 5,000 gal. only, the distiller would be assessed upon 1,000 gal. as a deficiency.

Because of the maze of contradictory figures that have been issued in recent months, it is desirable to scrutinize carefully those at variance with the following facts: According to the Treasury Department the United States used and produced the following amounts of grain and alcohol in 1917:

Grain Used (In bushels)		Alcohol Produced (In tax gallons)	
Corn	33,973,268	Whiskey	57,651,834
Rye	2,375,439	Rum	2,842,921
Malt	4,239,677	Gin	5,756,666
Oats	6,730	Brandy	8,251,097
Wheat	2,533		74,502,518
Other materials	72,039	Alcohol	211,582,744
	40,669,686	Total	286,085,262

Assuming that the distillers obtained 4.8 pr. gal. of alcohol per bu. of grain, then the total which could be produced from this grain amounted to 195,214,493 pr. gal. or based upon a 300-day year, the grain consumption was 135,565 bu. and the alcohol production 650,715 pr. gal. daily.

Since 1917 conditions in the alcohol industry have changed considerably. While the number of manufacturers, through mergers, decreased considerably, the total capacity of surviving plants increased to such an extent that distilleries mashing molasses now produce on the average, over 20,000 pr. gal. daily. All indications are that the new distilleries will produce beverage alcohol on a much larger scale than was ever attempted prior to Prohibition. A few distilleries under construction at present will be able to process more than 50 per cent of all the grain mashed in 1917. Whether there will be a remunerative field for small distilleries depends entirely upon their adaptability to modern chemical engineering methods.

When the enforcement of Prohibition restricted the supply of whiskey, the public acquired a taste for gin, of which the consumption in 1917 was less than 6,000,000 gal. Whether the demand for gin will prevail is problematical. It is anticipated that the public will gradually return to the use of whiskey, of which the consumption ratio to gin prior to Prohibition was ten to one. Not all pre-war whiskey was aged over four years in plain or charred white oak barrels as is required by the law for bonded whiskey, but was "blended," "rectified," or "cut" by the addition of high-proof spirits, flavoring, colorings, and sufficient distilled water to reduce the alcohol content to 50 per cent or less.