Fig. 39.—Twin Column Barbet Rectifier.
where the alcohol is separated from the last runnings or fusel oil. In other words, the phlegm or impure raw alcohol is only raised to such a temperature in the first column as to drive off the very volatile constituents such as the ethers. These therefore pass off at the top of the first column into the condenser $C$, the retrogradation or condensed alcohol being returned to $A$, while the boiling phlegm taken from the middle of the column and still containing the aldehydes, oils, etc., is conducted by a pipe $E$ to the second column $B$ wherein the last runnings or amylic oils, etc., are separated from the purified spirits.

The vapors in this column are carried to the condensers $D$ and $F$ and from there to a refrigerator $G$. The fusel oils are extracted from the plates slightly below the center of the column and are carried to an oil concentrating apparatus $H$.

In the most complete forms of apparatus used to-day, there is a variation of this construction. The first runnings, middle runnings and the last runnings are each led off from the main column to separate coolers, condensers, etc., and the purified result from each of these columns is in turn led to a trunk rectifier common to all where the product is redistilled and entirely freed from impurities. This gives a very high grade of alcohol by a process practically continuous. At the same time the impurities are not returned to the first or main column to contaminate the vapors therein and add to the amount of fusel oils contained on
Fig. 40.—Gillaume's Rectifier and Inclined Still.
the lower plates. In construction of this character there is a very large saving in the cost of the fuel and the result is much better in every way.

**Fig. 40.—Guillaume's Direct Distillation-Rectification Apparatus for "Agricultural" Distillations.**

*A* Distilling Column.
*a* Tank for Wash to be Distilled.
*b* Cold Water Tank.
*C* Rectification Column.
*D* Final Purification Column.
*I* Wash Heater.
*K* Condenser.
*K'* Refrigerator of Ethers.
*O* Refrigerator for high-grade Alcohol and the First Runnings.
*Q* Refrigerator for the Products of the Last Runnings.
*R* Spent Wash Extractor.
*r* Siphon Carrying off Spent Wash.
*S* Steam Regulator.
*s* Tap and Pipe for Carrying Wash to Distilling Column.
*U* Water Regulator.
*u* Taps for the Extraction of Intermediate Impurities.
*V* Receiver Accumulator.
*v* Tap for the Extraction of the Last Runnings.
*X* Test Glass for the High-Grade Alcohol.
RECTIFICATION.

Y Test Glass for First Runnings.
Y' Test Glass for Last Runnings.
Z Test Glass for Determining Degree of Exhaustion of Spent Wash.

In this apparatus the still proper is of the form heretofore described on page 78. The liquid to be distilled enters at the top of the inclined column A and descends to the base thereof. The alcoholic vapor rises through the column and passes off from the head thereof into the rectifying column. At the head of the column A it has a strength of about 40° to 50° F. The column C is supported upon an accumulating reservoir V which acts to regulate the flow of the phlegm through the rectifying column and prevents too great an exhaustion of the plates of the column. It acts as a reservoir to contain any excess of phlegm or to supply an additional amount of phlegm to the plates when they have become nearly exhausted.

The oils or products of the last running accumulate at the base of the column, and are carried off to their special refrigerator Q. The alcoholic vapors concentrate while rising in the column and quickly attain a strength of 92° or 94° F. At a height within the column corresponding to the plates whereon alcohol of that strength is to be found, there are provided three taps u whereby the middle runnings or medium grade of alcohol may be drawn off, which have a maximum concentra-
tion of 92° and 94° F. Above these middle plates the alcohol vapors are completely separated from the products of the "tail" that is the aldehydes, amylic oils, etc., and at the upper portion of the column there is found the condenser K which separates the products of the head; that is the first runnings from the alcohol which has passed over with such products to the condenser. The alcohol so separated is completely rectified in the column of final purification D and the finished alcohol is cooled in the refrigerator O below the column of final condensation. In this apparatus the gauge glasses which regulate the exit of the various alcohols and mixtures are controlled by taps having verniers or scales whereby they may be very carefully adjusted, to regulate the relative proportion of the various products. This apparatus is able to produce about 75 or 80 per cent. of first-class alcohol, 10 to 15 per cent. of middle class alcohol, and 5 per cent. of ethers and 5 per cent. of fusel oils, the alcohol produced being about 96° Cartier.

The alcohol is thus obtained in one single operation and with, it is asserted, only a very small loss in rectification. The apparatus is claimed to be so simple that it may be operated even by unskilled farm labor. It is also claimed that purification by chemical treatment or filtration is unnecessary with the Guillaume apparatus. It may be stated, however, that the Guillaume system has many opponents.
The capacity of the rectifying apparatus has a good deal of influence upon both the quantity and the quality of the spirit obtained. Besides being much more difficult to manage, a small apparatus will not yield so large a proportion of spirit as a more capacious one, nor will its products be of equally good flavor. The proportion of alcohol which may be obtained from a successful rectification is very variable; it depends upon the nature of the spirit rectified, the method of extracting the sugar, and the manner of conducting the distillation; it will also be in inverse proportion to the quantity of fusel-oil contained in the raw spirit. The average loss of pure alcohol during the process of rectification is generally estimated at about five per cent.

In addition to the rectifying as above described, alcohol may be further purified by filtration through charcoal, by chemical means or by electrolysis. The last two methods have not so far been successful. The chemicals used merely act to disguise the disagreeable taste or smell of the spirit and do not really purify. They but substitute one impurity for another. The agents used are many—sulphuric and nitrate acids, soaps, oils and fats, soda, lime and potash have each and all been tried, but with no permanent success. As agents for disguising the taste of new and raw spirits, alcoholic extracts of fruits have also been used.

Purification and aging by electricity has been tried many times and in many different forms, but so far has not been commercially practicable.
Filtration still remains the best and simplest adjunct to the rectifier. In small plants, a filter bed several feet in thickness of bone black or beachwood or charcoal is used, laid upon a foundation of gravel in a filtering tank. In the larger plants a series of these vats is used, the charcoal being used in lumps varying from $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter. Two different views of the purification by charcoal are held—one that the charcoal purifies by chemical means, the other that it is purely a physical filtration agent. After filtration the charcoal must be steamed to recover the spirits retained therein and should be heated to a red heat every now and then to cleanse and regenerate it.
CHAPTER VI.

MALTING.

Wheat, oats, rye, potatoes, and other amylaceous or starchy materials contain starch insoluble in water and to render it soluble, and to change the starch to maltose they must be mashed with a certain small proportion of malt,—or grain in which germination has been artificially induced and then interrupted at a certain stage. This increases the diastase contained in the grain so germinated, and this diastase is able to transform starch into soluble form. Hence, malted grain gives lightness and liquidity to the wash, and prevents the starch falling to the bottom of the mash tub or "back," and also prevents the starch falling to the bottom of the still and consequent burning.

While all varieties of grain including rice are suitable for the preparation of malt, barley is preferred to all others, and is most commonly used.

The best barley for malting is that having the following characteristics; a thin skin; a mealy interior; grains of a uniform size; of the greatest weight; which has been stored for three months. Barley on harvesting has but slight germinating
power. The reason for the uniformity in the grains lies in necessity of a uniform steeping of the grain so that the period of germination shall be the same for the whole mass.

Like all materials for distillation, the barley should be thoroughly cleaned of impurities—not only dust, seeds and weeds, but fungi and bacteria.

This may be partly accomplished in the ordinary fanning mills, usual on farms, but a better machine would be a "tumbling box" of wire mesh. This is inclined, so that grain put in the upper end, will pass downward to the lower, being thrown about as the box or cylinder is rotated. The dust, seeds, etc., fall through the meshes of the wire as do the smaller grains. After this cleaning, the barley should be thoroughly washed. This may be either done in the steeping vat itself—and the water afterwards drawn off—or in special machines. If the barley be allowed to soak in water for a day or two, the later washing will completely cleanse it. This preliminary cleaning is most important as impurities reduce the germinating power of the grain, as well as introduce bacteria inimical to fermentation.

Washing in some instances is done by forcing compressed air into the steeping tub, thus violently agitating and swirling the water therein, and washing away the impurities. Another method is by passing the steeped grains along a trough supplied with moving water, the trough being provided with rotary agitators. Any fairly ingenious
mechanic could devise a capable cleansing machine. Care being taken that it shall not injure the grains.

After cleansing, the barley should be steeped. For this purpose tanks of metal or cement are to be preferred to wood. All vats should be kept thoroughly cleaned by frequent scrubbing with lime water.

The barley placed therein should at all times be entirely covered with fresh water to a depth of a few inches, and for the first few hours the grains should be carefully stirred in order that no grain should escape wetting. At the end of that time the still floating grains should be removed.

In 36 or 48 hours the grain will usually be sufficiently steeped,—but this varies with weather conditions. The warmer the water the quicker the steeping, and in winter proper steeping may not be accomplished before four or five days.

A simple test is to rub the grain strongly between the hands. If it is entirely crushed, and no solid matter is left it has been steeped sufficiently. Barley should be capable of compression lengthwise and the hull should become easily detached. It should be easily bitten, and not crack under the teeth. In order to prevent fermentation in summer, it is well to renew the water a few times during steeping. Over steeping is worse than under steeping.

After the barley is in proper condition the vat or tank is opened and the water drained away.
The draining should be complete, and therefore the grain should be left to drain about 12 hours.

**Germinating.** The grain is now taken to the malting floor. In practice it is well to locate the steeping vat above the malting floor, so that the steeped grain may be run down on to the floor without inconvenience.

It is best to first spread the grains out on the floor to a depth of a few inches in order that it may somewhat dry out. This is not necessary when it has not been steeped to a great extent.

After 10 or 12 hours of drying, the grain is placed in a heap until warm to the touch, which may occur in from 12 to 24 hours. It is then disposed in a layer from eight inches to 20 inches thick. This is called the "wet couch." The lower the temperature the thicker the couch should be. It should be turned every six or eight hours in this stage.

The heat so germinated after 25 or 30 hours produces at the end of each grain a small white rootlet. The grain in the middle of the layer is the first to sprout, as it is the warmest, hence the couched grain should be frequently turned so as to give all the grains a uniform heat, and a uniform germination. At this period the grains beneath the surface are dampish to the touch.

The height of the couch is now successively lessened to layers of from six to two inches called "floors," the height of each floor of course depending on the temperature, as before.
MALTING.

It is to be understood that the growing grain requires both dampness and air, hence the "floor" should not be thinned so rapidly as to deprive it of moisture, and the barley should be turned at least twice a day to give each grain a proper aeration. During this period the small white rootlets or radicals should be white and shiny. If they begin to fade, it is a sign that they lack water and the grain should be sprinkled. Germination usually requires from a week to ten days, or sometimes two weeks, depending on the previous steeping, the quality of the grain and the temperature. When the fibers or rootlets of the grain are about equal to the length of the grain, germination is complete.

It used to be considered that malt was in its best condition in eight or ten days. To-day, however, "long malt" is used,—requiring a germinating period of twenty days, being frequently moistened and turned during this time, and the temperature being kept at 65°F. This malt is very strong in diastase.

The effect of germination is to produce a change particularly favorable to mashing. The barley becomes sweetish, the gluten is partially destroyed and what is left is soluble. Thus the fepula or starch is set at liberty and free to be acted on by the yeast used in fermenting.

March is the best month in which to malt; and while the malt is best used immediately, it can not be kept in its green state and must be therefore dried for future use.
Drying. This is accomplished either in the air of a warm, dry room in hot weather, or by means of a drying kiln. In the first process the malt is spread in a thin layer and frequently turned. In the second the grain is spread out in a layer from eight inches to a foot thick on the grain floor of the kiln.

Beneath the grain floor a fire is maintained. In the beginning the temperature of the drying floor should be about 85° F., but this is increased gradually to about 104° F. until most of the moisture has been removed. The heat is then raised to from 120° F. to 130° F., thus completely drying the grain.

The germinated green or dried barley is called malt. It is of good quality when the grain is round and flowery; when it crumbles easily and when its taste is sweetish and agreeable. Pale malt or that which has been hardly altered from its original color is the best for distillation.

Before the malt can be used it should be screened so as to remove the rootlets.

Two hundred and twenty lbs. of barley should yield from 275 to 350 lbs. of green malt, about 200 lbs. of air dried malt, and from 175 to 190 lbs. of kiln dried malt.

In large plants malting is now so carried on that the steeping germination and drying are all accomplished in one vessel or container, by one continuous operation. This vessel is commonly in the form of a drum of sheet iron, revolving at a very slow speed. Moist air is introduced and the
carbonic acid laden air withdrawn. After germination the malt is dried by passing in dry air at the proper temperature.

As these systems are only adopted to large distilleries, using expensive machinery, further reference to them is not considered necessary in this volume.

Previous to use the malt must be finely ground or crushed either before or after mixing with the materials to be mashed. It is not necessary or advisable that the malt be reduced to flour. The use of malt with other materials in order to form a fermentible mash, will be considered in the chapters on specific mashes.
CHAPTER VII.

Alcohol from Potatoes.

In certain countries, as for instance Germany and France, potatoes form the greatest source of alcohol, particularly for industrial purposes. With the possible exception of corn and beets they will probably be most used in America.

The best potatoes for distilling are those which are most farinaceous when boiled. In other words, those which are "mealy" and most appetizing. These give the largest yield of alcohol per bushel. The best season of the year in which to use potatoes is from October to March, when they germinate.

The potatoes should be kept in dry cellars, and at even temperatures, warm enough to prevent freezing and yet not so warm that they will rot or sprout. Diseased potatoes may however be used, if they have not been attacked by dry rot, though they are not so easily worked. Frosted potatoes may be also used, but they must not have been completely frozen.

Before being steamed, the potatoes should be washed, either by hand or by a machine, care being taken to remove all stones, clods of earth,
and other foreign substances which might impede the subsequent operations.

There are three main methods of saccharifying the fecula or starch of the potato. The first and most important by reducing the tubers to a pulp, and malting the entire mass. The second and third, by rasping the potatoes and so separating the fecula or starch grains from the mass, and then making a thin liquor or wash containing this fecula.

Originally, in the first process, the washed potatoes were submitted to the action of boiling water, but later cooking by steam at a temperature of 212° F. was used, as being much more convenient to handle and more effective in action. The object of steaming is to break the coating and reduce the contents thereof to a pasty condition, wherein the starch is more effectively acted on by the malt and yeast. Ordinary steaming does not, however, render the pulp sufficiently pasty; some of the starch remains undissolved and is lost, hence in the modern practice, steam is turned into the steaming vat under a pressure of three or four atmosphere (45 to 60 lbs. to the square inch).

High pressure steaming will be later described but the simple and older method of mashing and apparatus therefor, used prior to 1870, was as follows:

Fig. 41 shows a section of a steaming vat. This consists of a conical wooden tub H provided at its top with a suitable cover O having a trap or door P for putting in the potatoes. This as shown, consists of a hinged lid, having a button
or other fastening means. This lid and cover should be of course steam tight, and it would be better to have it clamped down by a screw clamp than held by a button.

Somewhat above the bottom of the vat, a steam inlet pipe $I$ enters, connected at its other end by a coupling $i$ with a suitable steam generator (see Fig. 43). Preferably the outlet of this pipe is screened by a perforated plate $M$ so that it may not be clogged by the pulp. It is also best that a filling piece be placed at the junction of the bottom with the sides in order that there be no sharp corner from which the pulp may not be easily cleaned out.

The bottom of the vat may either have a discharge door at the side as in Fig. 44 or at the bottom, as in Fig. 41.
ALCOHOL FROM POTATOES.

An under side view of the latter construction is shown in Fig. 42. The bottom of the vat is made in two parts or doors $JK$. These are held closed by a transverse bar $L$ inserted at its end into a stirrup $l$ and supported at its other end by a button $l$, or other means.

While various forms of steam generators may be used, Fig. 43 shows a simple construction well adapted to the needs of a small distillery. $D$ designates the brick work of a furnace, and $A$ the boiler. This is so set that an annular space $E$ surrounds the sides of the boiler, through which the products of combustion must pass.

The head of the boiler is connected by a pipe $B$ and collar $b$ to the steam inlet pipe $I$ of the steaming vat, heretofore described, as by the collars $b i$.

A filling tube $C$ enters the boiler and projects nearly to the bottom, and the water outlet-pipe $F$
with cock \( f \) leads off from the upper water line. The tube \( C \) forms also a safety valve, for if the steam pressure becomes too great in the boiler and connected vat, it will force water up and out through the tube. If, however, the water falls below the level of the lower end of the tube, steam will issue and warn the attendant that water is too low. It would be best however, to provide a steam gauge, whereby the pressure of steam in the boiler and vat could be accurately indicated.

It is to be noted that when steamed the potatoes will swell and occupy more space and that the steam vat should therefore not be much more than two-thirds filled with potatoes.

With the steaming vat above shown, the potatoes are delivered mixed with a considerable quantity of water, but a better plan is to have a per-
forated false bottom to the tub, whereby the condensed water may be carried away, the steamed potatoes remaining behind.

Two hours of steaming should reduce the potatoes to proper condition, which may be tested by introducing a pointed iron rod through a suitable aperture; normally kept closed. If the rod passes freely inward, the potatoes are done and may be discharged into the crusher, shown in Fig. 44. In this Fig. the steaming vat A is shown mounted above the crusher. A pipe B with cock b leads to the steam generator. The steamed potatoes are shoveled out through the door a, which is usually held closed by means of the clamps or buttons a' a''.

The crusher consists of a hopper C whose bottom fits closely against two adjacent smooth faced rolls H I of iron. These are driven by gears D E. The shafts of these gears have cranks d d whereby it may be operated. These gears are unequal so that the rolls shall move at different speeds, and thus one will have a grinding action against the face of the other. A counter weighted scraper e bears against the face of the roll.

The crushed potato pulp passes between the rolls and into a bin beneath, having adjustable walls made of boards F, sliding in suitable guides f, from which the pulp may be shoveled into the mashing tank or "back." The crusher might, however, be arranged to deliver immediately into
Fig. 44.—Potato Steamer and Crusher.
the mashing tank, if the latter is provided with means for stirring the delivered pulp.

The pulp or paste thus made is now placed in a vat, holding about 650 to 850 gals., in which the saccharification takes place. About 2200 lbs. of the crushed potatoes and 155 lbs. of broken malt are introduced, and immediately afterwards water is run in at a temperature of about 97° F. to 104° F., the contents being well stirred with a fork meanwhile. The vat is then carefully closed for half an hour, after which boiling water is added until the temperature reaches 140° F., when the whole is left for three or four hours. The process of fermentation is conducted in the same vat. Alternate doses of cold and boiling water are run in upon the mixture, until the quantity is made up to 700 or 775 gallons, according to the size of the vat, and so as finally to bring the temperature to 75° F. or 79° F. Five and a half to six gallons of liquid brewer’s yeast are then added, and fermentation speedily sets in. This process complete, the fermented pulp is distilled in the apparatus devised by Cellier-Blumenthal (see Fig. 15) for distilling materials of a pasty nature; the product has a very unpleasant odor and taste.

The process above described is the old method of pulping the potatoes by using steam. Under the modern method, however, and with modern apparatus, in preparing potatoes for distillation in large quantities, the steaming of the material is accomplished at one time and under a high
steam pressure. The apparatus is also used for the preparation of corn, potatoes and other starch-containing substances.

There are many apparatuses which have been devised for the purpose, but the principle on which they work is practically the same in all cases. They comprise a closed tank, fitted with stirrers, agitators, or other means for mixing and comminuting the contents, means for admitting steam under pressure, means for cooling the mixture to the proper mashing temperatures, and means for forcing the steamed material out of the tank.

The Steamer. One of the earliest forms of steamer was that of Hallefreund devised in 1871,
and adapted for working on a large scale. A modified form of the apparatus known as Bohn's steamer and masher is illustrated in Fig. 45. This comprises a steaming cylinder A, having a securely closed opening D for the introduction of the potatoes. Centrally through the cylinder passes a hollow shaft B, which is rotated by the power pulley K. Hollow arms b project radially from the shaft B. These act as mixers of the mash and as coolers. The shaft B at one end is connected to a cold water supply pipe M as by a coupling C, the supply pipe being provided with a cock. E designates a discharge opening for the mash. A pipe F provides for the entrance of steam into the cylinder. G is a pipe through which malt is put in to be mixed with the pulp. L is a steam gauge and J a safety valve. H designates a water pipe. For the relation of the steamer to other apparatus, see Fig. 1.

In operation the potatoes are placed in the cylinder A and submitted to the action of steam at about 46 lbs. to the square inch, and at a temperature of from 266°F. to 275°F.

When disintegrated, the steam is blown off, and the potatoes crushed by rotating the stirring shaft. As the pulp must be reduced from 275°F. to 149°F., the mashing temperature, cold water is forced into the stirrer which chills the blades and quickly cools the mass.

In the vacuum mash cooker shown in Fig. 1, the steaming cylinder is partly filled with hot
water at 140° F. to 150° F. The potatoes to be mashed are fed into the cylinder whole. The steamer is then closed and steam admitted while the mash is stirred until a pressure of 65 pounds is reached, when the dissolution of the starch is complete. The steam is then exhausted and the temperature reduced to 212° F. To reduce this temperature to the proper saccharifying point of 145° F., the hot air is exhausted.

Barley malt meal in the proportion of 6 to 10 per cent. is used. This has been previously mixed with cold water in the small grain masher. The malt is admitted to the cylinder and thoroughly mixed with the potato, when the mixture is withdrawn into a drop tub, where it is still further stirred. It is then cooled as described on page 15 and then fermented.

While the crushed potatoes are being cooled and stirred, a mixture of green malt with water is prepared in an adjacent vat, and when the pulp in the cylinder has been reduced to 149° F. the malt mixture is introduced into the cylinder through the pipe G, and thoroughly mixed with the crushed potatoes. The mass is now left to saccharify; the stirrer being operated at intervals throughout this period. This machine might be readily modified so that the steam should enter through the stirrers, by tubes attached to the arms, then the steam may be shut off and cold water sent into the arms themselves to cool the mash.
A variety of steamer used in various forms and modifications in all the larger distilleries, is known as the Henze steamer, Fig. 2. In this, there are no stirrers. The cylinder is conical, and has steam pipes leading to the interior. At the end of its cone-shaped bottom it terminates in a blow-off tube, having in it a grate formed of sharp-edged bars. In operation, steam is introduced at a pressure of one to two atmospheres until the potatoes are cooked. More steam is then suddenly admitted at high pressure and the softened potatoes forced through the grating at the bottom and into the mashing apparatus in a finely divided state.

In steaming under pressure it is best that the safety valve be so regulated that the steam will constantly blow off as this action keeps the potatoes in motion and facilitates disintegration. Care should also be taken to see that everything about the apparatus is in good condition, as in working under the high pressures used in the last apparatus there is liability of explosion. Rust should be particularly guarded against.

With this apparatus a preparatory mash vat is used into which the contents of the steamers are blown out, malt and water to form milk having been previously let into the mash vat. Blowing out is accomplished in 45 or 50 minutes at 130° F. and about one-sixth of the charge in the steamer is retained in the steamer. The mash in the vat is stirred and cooled and the remainder of the mash blown in raising the tem-
perature to 145° F. when the mash is left to stand from half an hour to an hour. With heavy mashes, rich in sugar, even higher temperatures than 145° F. can be used for saccharifying.

The processes of crushing and saccharifying, above referred to, which are almost entirely used to-day, require steam. The following methods provide for the isolation of the fecula or starch, without steam and the production of a wash of a more watery consistency, therefore easier to handle in ordinary stills, and with less liability to burn.

Two operations are necessary by this method: First, rasping, or reducing the potatoes to a finely crushed and pulpy condition by means of a machine described in the chapter on Beet Mashing; and second, the separation of the fecula.

To this latter end the potato pulp is placed on a sieve, having side walls and net work of horse-hair, which is placed over a suitable tub. Water is run gradually through the pulp and sieve, while the pulp is rubbed up by hand. When the water comes through clear, then all the fecula of the pulp has been washed out, and the refuse left in the sieve can be thrown aside or used as a food for cattle.

For a mashing tub of say about 32 bushels capacity, the fecula from about 800 lbs. of potatoes is used. This is deposited in the mash tub with sufficient cold water to form a fairly clear paste. About twice as much water as fecula will bring
the paste to proper consistency. This mixture should be constantly stirred as otherwise the fecula will sink to the bottom. About 40 gallons of boiling water are then added gradually. The mixture has at first a milky appearance, but at the last becomes entirely clear.

This liquid is mashed with about 45 lbs. of malted barley or Indian corn, ground into coarse flour. In ten minutes the mixture will be completely fluidified. It is then left to subside for three or four hours when it will have acquired a sweetish taste and be what is termed as "sweet mash." The fluid is then further diluted by the addition of sufficient water to give about 290 gallons of wash. Two or three pints of good yeast will bring this mixture to a ferment.

A less laborious method of accomplishing the same result is that at one time used in English distilleries. In this a double bottom tub is used, something like that shown in Fig. 41, the upper bottom of which is perforated, and raised above the solid lower bottom. A draw-off cock opens out from the space between the two bottoms.

Assuming that the tub is of 220 gallons capacity, then from 2 to 20 lbs. of chaff are spread over the perforated bottom and pulp from 800 lbs. of raw potatoes placed on that. This is thoroughly drained for half an hour, through the draw-off cock. The pulp is then stirred while from 90 to 100 gallons of boiling water are added gradually. The mass then thickens into a paste. The paste is
mashed with about 65 lbs. of well steeped malt, and the liquid left to subside for three or four hours. It is then drained off through the perforated bottom into a fermenting back or tub. For this amount of material the back should be of about 300 gallons capacity.

The leavings left in the preparatory tub still contain considerable starch, and after they are well drained they should be mixed with from 50 to 55 gallons of boiling water. The mixture is then agitated and drained off into the fermenting back. The sediment left is again sprinkled with water, this time cold, which is drained off into the back. This completely exhausts the husks left on the upper bottom. By this process 200 lbs. of potatoes should produce something over 12½ gallons of spirit.

The objection to the last method described is that the spirit so obtained is unpleasant to taste and smell, but this would probably not be an objection for industrial uses.

The only means of obtaining alcohol of good quality from potatoes is to extract the starch separately and then convert it into sugar. This saccharification of the starch may be accomplished by sulphuric acid or by the action of diastase.

By the first of these methods the potatoes are disintegrated in such an apparatus as the Bohn steamer described on page 118. A mixture is made of one-third potatoes, two-thirds water, and one-
tenth part of sulphuric acid. The mixture is steamed for six or eight hours under pressure. The mash is then cooled and the acid neutralized by milk of lime. It is then fermented.

By the second and preferable method, dry or wet potato starch is used, which is malted, and the saccharine solution fermented with yeast. The proportions and method for a vat of say 800 gallons capacity are as follows:

Two hundred and sixty-five gallons of water are mixed with 1100 lbs. of dry or 1650 lbs. of moist starch. This mixture is well agitated, and 450 gallons of boiling water run in, together with 165 lbs. of malt. The whole is then stirred energetically and left to saccharify for three or four hours. The saccharine solution thus-formed must be brought to 6° or 7° Baume, at a temperature of from 71° to 75° F. To this is then added 1 1/3 lbs. of dry yeast for every 220 gallons of "must." Fermentation is soon established and usually occupies about 36 hours. After remaining at rest for 24 hours the "must" is distilled. From each 220 lbs. of starch there should be a yield of about nine gallons of alcohol, at 90° F.

The fermentation of the potato mash is carried on as described in Chapter II. For the preparation of malt see Chapter VI.
CHAPTER VIII.

ALCOHOL FROM GRAIN—CORN, WHEAT, RICE, AND OTHER CEREALS.

The different cereals constitute a very important source of alcohol in all countries, particularly of course for use in the manufacture of whiskey and gin.

All cereals contain an abundance of starchy substance which under the influence of diastase,—that is, malt,—is converted into fermentible sugar. The quantity of sugar and hence the yield of alcohol differs widely. The following table shows the results obtainable by good workmanship.

<table>
<thead>
<tr>
<th>220 lbs.</th>
<th>Wheat</th>
<th>gives 7.0 gallons pure alcohol</th>
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<tbody>
<tr>
<td></td>
<td>Rye</td>
<td>6.16</td>
</tr>
<tr>
<td></td>
<td>Barley</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Oats</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>Buckwheat</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Corn (Indian)</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Rice</td>
<td>7.7</td>
</tr>
</tbody>
</table>

In addition to these there are other raw materials containing starch which are sometimes used, as millet (55 per cent starch), chestnuts (28 per
cent.), and horse chestnuts (40 per cent.). The last is very difficult to work however.

Rice, wheat, rye, barley and corn are more frequently employed than other grains. Wheat gives a malt which is as rich in diastase as barley. Barley and buckwheat are added to these in some proportions. Oats, owing to their high price, are rarely used. Rice, of all the grain is the most productive to the distillers, but on account of its value as a food is not much used for the production of alcohol, unless damaged. Corn is the cereal most largely used for the production of industrial alcohol.

Great care should be exercised in making choice of grain for fermentation where the best results are desired. Wheat should be farinaceous, heavy and dry. Barley should be free from chaff, quite fresh and in large uniform grains of a bright color (see Malting, Chapter VI).

Rice should be dull white in color, slightly transparent, without odor, and of a fresh, farinaceous taste.

The flour or farinaceous part of grain is composed of starch, gluten, albumen, mucilage, and some sugar. The following table gives the proportions of these substances in the commonest grains.

Under certain conditions the albumen or gluten in the grain has the power of converting starch into saccharine matter. This is better effected by an acid such as sulphuric acid, or by a diastase. This latter substance is a principle developed during the germination of all cereals
but especially of barley. It has the property of reacting upon starchy matters, converting them first into a gummy substance called dextrine, and then into glucose or grape sugar, see Chapter II.

The action of diastase upon starch or flour made into a paste is remarkable, 50 grains of diastase being sufficient to convert 220 lbs. (100 kilograms) of starch into glucose. The rapidity of

<table>
<thead>
<tr>
<th>TABLE IV.</th>
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</thead>
<tbody>
<tr>
<td>PROPORTIONS OF STARCH, GLUTEN, ETC., IN PRINCIPAL GRAINS.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grains</th>
<th>Starch</th>
<th>Gluten and other Azotized Substances</th>
<th>Dextrine, Glucose, and similar Substances</th>
<th>Fatty Matter</th>
<th>Cellulose</th>
<th>Inorganic Salts (Silica, Phosphates, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat (average of five varieties)</td>
<td>65.99</td>
<td>18.08</td>
<td>7.68</td>
<td>2.16</td>
<td>3.50</td>
<td>2.69</td>
</tr>
<tr>
<td>Rye</td>
<td>65.65</td>
<td>18.50</td>
<td>12.00</td>
<td>2.15</td>
<td>4.10</td>
<td>2.60</td>
</tr>
<tr>
<td>Barley</td>
<td>65.43</td>
<td>13.96</td>
<td>10.00</td>
<td>2.76</td>
<td>4.75</td>
<td>3.10</td>
</tr>
<tr>
<td>Oats</td>
<td>60.59</td>
<td>14.39</td>
<td>9.25</td>
<td>5.50</td>
<td>7.06</td>
<td>3.25</td>
</tr>
<tr>
<td>Indian Corn</td>
<td>67.55</td>
<td>12.50</td>
<td>4.00</td>
<td>8.80</td>
<td>5.90</td>
<td>1.25</td>
</tr>
<tr>
<td>Rice</td>
<td>69.15</td>
<td>7.05</td>
<td>1.00</td>
<td>0.80</td>
<td>1.10</td>
<td>0.90</td>
</tr>
</tbody>
</table>

this change depends on the quantity of water employed, and the degree of heat adopted in the operation.

Inasmuch as barley germinates very readily, and develops a larger proportion of diastase than any other grain, except wheat, it is generally used as a producer of diastase. Barley germinated according to proper methods is called malt, and its preparation is fully described in Chapter VI.
There are many methods of preparing grain for fermentation, but all use at least two of the following operations:—grinding, gelatinizing, steeping, or steaming, mashing saccharifying.

Grinding. Where cookers or the Henze steamers are not used every form of grain should be crushed or ground into a coarse flour. This is in order that the starchy interior may be easily acted on by the diastase. If the grain is not to be mixed with malt later it must be ground more finely so that it may be thoroughly penetrated by the water. The grains should not be ground except as required, as ground grain is liable to heating and consequent loss of fermentability, and is also liable to become musty, in which condition it loses much of its fermentability.

Steeping. This operation is best carried on in vats or tanks of iron or cement, for the reason that wood absorbs impurities, which are communicated to the grain, thus lessening its germinative power. Wooden vats should be thoroughly scrubbed after use, and be kept continually whitewashed. The steeping tub should hold about two-thirds more than the amount of ground grain to be steeped.

Steeping is affected by pouring on to the crushed grain hot and cold water in such quantity that after 10 minutes or so of brewing the mixture will have a temperature of 75° to 95° F.
This warmth makes the water more penetrating. The water should not be poured in all at once, but a little at a time, until the grain is covered to a depth of three or four inches. Care should be taken not to let the temperature get too high, not above 95° F., as a temperature above that point kills the germinating power.

The mixture of crushed grain and water is now stirred for 10 minutes and then left to subside for half an hour. It is then stirred again and the mixture left to steep for 30 or 40 hours, depending on the temperature of the atmosphere, the dryness of the grain, and the character of the water. In very warm weather the water should be changed every few hours by running it off through a hole in the bottom of the tub and running in fresh at the top. This prevents fermentation setting in prematurely.

When the grain swells, and yields readily between the fingers it has been sufficiently steeped, and the water is run off. This is an old method of gelatinizing grain, but a better is by the use of cookers or high pressure steamers as described for potatoes.

**Mashing.** This consists in mixing the coarse flour with malt and then by means of certain operations and mechanisms bringing it to a condition most favorable to fermentation through the action of yeast. The mixing of the raw flour with barley or other malt effects the conversion of the starch of
the grain into maltose. The yeast afterwards converts this maltose into sugar.

Saccharifying. To effect the action of the diastase of the malt on the grain, in the old methods, boiling water must be poured into the vat until the temperature of the mass reaches about 140° to 168° F., the whole being well stirred meanwhile; when this temperature has been reached, the vat is again covered and left to stand for four hours, during which time the temperature should, if possible, be maintained at 140° F., and on no account suffered to fall below 122° F., in order to avoid the inevitable loss of alcohol consequent upon the acidity always produced by so low a temperature. In cold weather the heat should of course be considerably greater than in hot. It should be also remarked that the greater the quantity of water employed, the more complete will be the saccharification, and the shorter the time occupied by the process.

Having undergone all the above processes, the wash is next drawn from the mash tub into a cistern, and from this it is pumped into the coolers. When the wash has acquired the correct temperature, viz., from 68° to 78° F., according to the bulk operated upon, it is run down again into the fermenting vats situated on the floor beneath. Ten to twelve pints of liquid or 5½ to 6½ lbs. of dry brewer's yeast are then added for every 220 lbs. of grain; the vat is securely covered, and the contents are
left to ferment. The process is complete at the end of four or five days, and if conducted under favorable conditions there should be a yield of about $6\frac{1}{2}$ gallons of pure alcohol to every 220 lbs. of grain employed.

There are a number of different methods of mashing, having each its advantages, and applicable to particular varieties of grain.

We will first consider the mashing of the steeped grain in general by one of the older and simpler processes.

The grain to be mashed, which has been ground and steeped as before described, is mixed with malt in the proportion of four to one, or even eight to one. In addition, three or four pounds of chaff to every hundred or so pounds of steeped grain should be used.

**Mash.** Water is then run into the mash tub in the proportion of about 600 gallons to each 60 bushels of grain. Its temperature should be between 120° and 150° F. During the entrance of water, the mass is well stirred so as to cause the whole of the grain to be thoroughly soaked and to prevent the formation of lumps. It is best to add the grain to the water gradually and to stir thoroughly.

To this mass about 400 gallons of boiling water is gradually added to keep the temperature at about 145° F. During the addition of the boiling water the mash should be continually stirred so