# MEETING OF THE LONDON SECTION HELD AT THE ENGINEERS' CLUB, COVENTRY STREET, ON MONDAY, 8TH FEBRUARY, 1926.

Mr. C. A. FINZEL, M.A., in the Chair.

THE CHAIRMAN said before he asked Mr. Hastie to read his paper, he wished to point out that after the last paper read before the Section an infringement of their rules had occurred, a copy being made of the paper, and also the figures on the blackboard, and sent for publication to a trade paper. In consequence of that he would read rule 15 to the meeting.

The following paper was read and discussed and a number of lantern slides were shown. Before reading the paper the author gave an outline of the different processes involved in the manufacture of pot still whisky.

## CHARACTER IN POT STILL WHISKY.

By S. H. HASTIE, O.B.E., B.Sc.

"CHARACTER" in whisky produced by the pot still process in the Highlands and Islands of Scotland is the term by which is designated the palate flavour experienced in tasting such whisky. It cannot be attributed entirely to the chemical substances found in whisky as reported in the conventional whisky analysis, nevertheless the distinctive difference between one pot still whisky and another is obvious to the consumer and is particularly definite to the expert.

Whiskies from different districts of Scotland and again from different distilleries in any one district of Scotland can be readily selected and their origin named with rapidity and precision by the individual who is accustomed to handle samples.

"Character" then may be defined as the palate flavour which each pot still whisky produces sufficiently definitely to permit of each whisky being differentiated from every other whisky. It is, further, the criterion of quality used regularly in the selection of whiskies for introduction to blends with the object of meeting the palate demands of the consumer.

The commercial importance of character is such that a whisky possessing a characteristic which is demanded by the consumer is in much greater demand and commands an enhanced price over less desirable products. So much is this the case that two given distilleries of identical material value as to quality of plant and buildings and facilities for transport may occupy relative positions varying from valueless to a very high value according to the character of the product. This factor of character is also a changing factor commercially. The character of the whisky itself may remain, and does remain indefinitely the same, but the taste of the consumer varies from time to time, so much so, that the chosen drink regarded by one generation as highly palatable may become almost the poison of the succeeding generation.

Campbeltown, the birthplace of the manufacture of pot still whisky, now finds its product shunned by the consumer, and this change in public demand is such that this once busy centre of production is now rapidly becoming a lifeless locality so far as whisky production is concerned.

Elsewhere, although public demand for whiskies with certain characteristics may not have reacted so drastically on the industry, in certain areas, there are still very material differences in market value between whiskies, entirely the result of the absence or presence of desirable characteristics.

Pot still, or "all malt" whiskies, may be divided into four great classes: North East of Scotland (including Speyside), Campbeltown, Lowlands and Islay. These classes are altogether distinct in characteristics, whilst there is a class resemblance between whiskies produced in each of these districts of Scotland. North country whiskies are notable for a comparatively light, clean flavour, Islay's are markedly heavy in character, Campbeltown's are known by a penetrating undesirable flavour, whilst Lowland malts are, compared with these others, comparatively featureless.

Indicative of the appeal to the public palate of Scotch whiskies from various districts of

Scotland the *Boston Daily Advertiser* of recent date contains the following :—

"A consignment of 400 gallons of 'Ilay' whisky from the Scottish Island of Islay was captured by the State Constabulary. The assistant analyst of the Health Department said, in the course of Court proceedings, that he had never heard of 'Ilay,' but that analysis showed this to be the best Scotch whisky out of 2,000 brands which he had sampled." It would be interesting to know exactly how the chemist in question drew his conclusions from chemical analysis, as he appears to have done, without the aid of the evidence of his palate.

The intention in these notes is to examine the factors, technical and non-technical, which determine or are supposed to determine the formation of the distinctive characters of these whiskies.

Even to the superficial observer there is an obvious geographical distribution of distilleries which suggests that in all probability certain factors in the natural surroundings of distilleries must be all important, for it may be taken as a fact that general technique does not vary essentially from one highland pot still distillery to another, or, alternatively, or in addition, this location may be the result of controlling circumstances during the production of whisky in the early history of the industry.

Two natural local factors must therefore be concerned, namely, the peat and the water supply, as no other essential natural factor locally existing is made use of in the industry. The bored well of the brewer, supplying water comparatively rich in inorganic substances and free from organic matter, is the exact opposite of the distillers' supply drawn from mountain or moorland loch, generally shallow and yielding surface water containing practically no inorganic matter but heavily laden with the vegetable organic matter derived from the peat and moss lands forming the catchment areas and the natural basins of such lochs. If the influence of the water used is a factor in the forming of character, then there must be fundamental differences either in the inorganic substances found in these waters or in the vegetable organic matter with which the water is so distinctly and so heavily charged.

There is a deep-rooted belief in the industry that all variations of character are due to the water, but explanation or proof does not seem to have been attempted, and if the facts are examined there is little real analytical evidence to support this belief. The following are compositions of typical distillery water supplies from distilleries producing the three classes of Highland whisky referred to :—

| — | Grains per gallon. | | |
|---|---|---|---|
| | Typical Speyside. | Typical Islay. | Typical Campbeltown. |
| *Inorganic*— | | | |
| Total saline residue | 6·84 | 5·32 | 6·86 |
| Calcium oxide .... | 0·49 | 0·42 | 0·60 |
| Magnesium oxide .... | 0·30 | 0·15 | 0·66 |
| Soda and potash .... | 2·04 | 1·69 | 1·51 |
| Sulphuric acid .... | 0·63 | 0·24 | 0·34 |
| Nitric acid .... .... | Nil | Nil | Nil |
| Nitrous acid .... | Nil | Nil | Nil |
| Chlorine .... .... | 1·07 | 1·99 | 1·75 |
| | Parts per million. | | |
| *Organic*— | | | |
| Free ammonia .... | 0·018 | 0·030 | 0·026 |
| Albumenoid ammonia | 0·081 | 0·186 | 0·150 |

If these figures are examined the outstanding facts are, first, that the inorganic composition is similar in total amount and varies but little in the relative proportions of the different inorganic salts present in the waters; secondly, it is obvious that a heavy content of vegetable organic matter is common to all three classes of water, and the reasonable deduction is that this vegetable matter is of paramount importance to the process since no group of these Highland distilleries employs a water which does not contain much vegetable matter while few of them employ water containing much inorganic matter. It must be concluded that this vegetable matter is the determining factor not only as to the suitability of a water for distillery purposes, but also as to the character of the whisky produced.

There is very great technical difficulty in the search for definite data. The total vegetable organic matter present in such a moor water, although large when tabulated amongst a series of water analyses, is very small indeed when it is desired to analyse and differentiate the nature of individual matters generally classed together as vegetable organic matter. Obviously this organic matter must consist of the extractives from the moor and peat lands, the decomposed and the partially decomposed materials which originally formed the sedges and other plants constituting the flora of the peat moss. The technical difficulty is to determine what these individual substances are, how they differ, and what the specific effect of each is on the product. Science has surely seldom been faced with such a problem. Nor is the matter ended when this tabulation has been completed, for the effects of the process upon these separate organic materials still have to be examined, which are so subject to change under the influences of temperature and bacterial action, the chief factors operating in the process. The effect of possible important differences in the bacteriological conditions obtaining in the different waters employed has been mentioned, but there is at present no evidence of any kind to support or oppose such a theory. It is difficult to believe that the races of predominant bacteria can vary to such an extent that organisms which have survived the mashing process still have such varied powers of altering the character of the product as to yield the different whiskies produced in practice. At the same time it is known that the moss and peat ground flora differ from the North to the South of Scotland, and differences in these plants and their by-products appear to provide a more logical explanation than the possibilities of bacterial differences.

It should be remembered, however, that different predominant bacterial conditions, although not obtaining possibly in the fermented wash, may exist in the loch water supply and in the catchment area where they could reasonably be supposed to produce different end-products in their work of disintegrating the sedges and mosses, and could in this way charge the water with different vegetable organic substances in different districts even from the same flora. In all probability the bacterial conditions and the flora vary from catchment area to catchment area and both factors are possibly instrumental in determining the composition of the vegetable organic matter with which the water is charged at the time of mashing.

The problem is still more complicated when the effects of these minute variables on the final product are considered, and can only be assayed, at present, by no more delicate a test than the palate of the expert taster of the whisky. Chemical analysis as at present employed is useless for the purpose.

Closely allied to this question of water supply is the use of peat in distillery practice.

Although it cannot be stated generally that the peat supply is usually obtained from the same ground which forms the catchment area for the water supply, still it may be taken as a fact that the area from which the peat is cut is distinctly similar botanically to that over which and through which the water supply is collected.

Peat is regarded as an essential to the production of character, and the peat is usually obtained locally. Whether this peat was originally obtained from the ground near a distillery already located by the water supply, or whether the water supply was sought for a distillery originally located by the peat moors available, it is not now possible to say. It may be that economical reasons determined the situation of the distillery adjacent to both peat and water, and that the probable effect on character had nothing whatever to do with the selection of the site originally.

The most reasonable explanation of the geographical distribution of pot still distilleries appears to be not the direct result of a definite choice for any technical or economical reason, but the result of a process of evolution. It may be safely presupposed that a natural desire for a fermented liquor made from a cereal has existed for centuries and its origin is lost in the mists of antiquity. From early times the production of whisky has been a hazardous enterprise as a result of the pressure of authority upon the producer, so much so that remote and inaccessible sites were perforce chosen for its production. These circumstances resulted in the industry such as it was in early times being situated in the Highlands and Islands. Otherwise, it is reasonable to suppose that the site of operations would have been in the barley-producing districts of the lower country, where all the raw materials, including fuel other than peat, were available. If it be admitted that the Highlands became the natural seat of operations of the smuggler and of the illicit distiller from whom the methods of production have descended, then the obvious solution of the all-important fuel question would be the naturally abundant peat, while the local water, whose character would undoubtedly be considered as of no consequence as a whisky character maker at that time, would certainly be employed, since the character desired consisted of a flavour of burnt peat and the bite resulting from an alcoholic strength well over proof.

From such methods the industry developed in response to the public demand for a beverage of this type. To produce such a beverage the primitive methods had to be followed to a certain extent, and so the original accidental circumstances surrounding the production of whisky determined that whisky of the type must be produced by employing the materials from the peat moors and mosses and with the moss water derived therefrom. By accident the local conditions round each distillery differed from these influencing neighbouring distillers, public taste favoured certain individual products and these survived. In this way it seems possible to explain the geographical distribution of distilleries.

Science cannot, however, bless the course of events which have led up to the accidental propounding of the difficult problem of solving the puzzle as to what substances influence character and how they individually and collectively operate. Nevertheless, the elucidation of this problem will be attended by such far-reaching commercial results that the reward of the fortunate investigator or team of investigators who solve it will be almost equal to the great scientific satisfaction of the achievement.

That the amount of peat extractives present in the mashing water has long been considered of great importance is further supported by the fact that some distillers have attempted to increase this peat extractive content by placing bags of more or less finely-divided peat into the liquor heater during heating of the mashing water prior to mashing. The investigation of the exact part played by peat in the practical process is further complicated by the fact that peat is introduced to the process *via* the malt, and in this case it is not the water soluble extractives alone which are employed, but the water soluble and mechanically-carried water insoluble products from the incomplete combustion of peat.

Distillers' malt is dried on the kiln over a peat fire, and during the early stages of drying, before the hand-dry stage is reached, the malt is subjected to a process of peat smoking, the intention being to impregnate the malt or at least to coat the exterior of the malt with the products of the incomplete combustion of the peat. These peat extractives thus introduced to the process are carried to the mash tun and are there, during mashing, subjected to a process of infusion with the malt. It will be seen, therefore, that the substances which originally were the components of the sedges and mosses of the peat moors arrive at the mash tun in the form of disintegrated and probably partially decomposed water-borne and water-soluble matters, and also as the water-borne and water-soluble matters derived from peat which has undergone partial combustion.

It may be of interest to indicate some of the time-honoured methods of introducing peat to the process other than what may be termed the normal methods outlined above. Various arrangements have been employed with the object of damping the draught in the malt kilns either throughout drying or more frequently during the early stages, such as the spreading of closely-woven material, usually haircloth, over the wire floor of the kiln before the kiln is loaded, the malt being spread on top of this haircloth. An open iron brazier is sometimes used in place of furnace and flues. This brazier, in which peat is used as the fuel, is situated in the centre of the floor below the kiln wire floor and has no flues or furnace doors or air control of any kind, unless the opening or closing of the outer door of the building can be regarded as an air control. The process thus becomes one of smoking analogous to that of smoking fish and is hardly a malt-drying process in the normally accepted sense of that term. Nevertheless, the operator succeeds in reducing the moisture content to around 4 per cent. in the finished malt.

Another interesting practice is that of introducing into the fermenting vessels, which have previously been thoroughly cleansed with steam and with lime, a brazier of glowing peats, which is allowed to remain in the fermenting vessel until the whole vessel is filled with peat smoke and peat soot, whereupon the brazier is withdrawn and the vessel filled with wort, pitching follows and fermentation is allowed to proceed.

It may be noted that "character" is not influenced by milling, or by mashing and draining of wort, and the next part of the process in which "character" formation occurs is fermentation. It must be remembered that no boiling of wort takes place as in brewing practice, and consequently at pitching in the fermenting vessels the liquor consists of wort, yeast, all the peat extractives referred to above, and also varying amounts of organisms of all kinds other than yeast. This liquor ferments naturally from an original gravity of about 1,048° to a content of around 10 to 12 per cent. of proof spirit. This original gravity permits of practically complete fermentation, inhibition of the yeast action by the increasing concentration of alcohol, and carbonic acid in the fermented liquor only becoming operative when there is practically no fermentable residue left unfermented. When fermentation is complete the fermented liquor is removed to a vessel commanding the first still, known as the wash charger, while awaiting its turn for introduction to the still, and in this vessel ultimate character must be influenced. The conditions obtaining in the wash charger may be considered. Yeast action has practically ceased, the liquor contains dead yeast, some live yeast, alcohol and acids, and the conditions become favourable for the action of those bacteria which have hitherto been suppressed by vigorous yeast action. Interaction between the alcohol and acids occurs, resulting in the production of secondary constituents, and there are also the final products of bacterial action. The extent of these actions will be functions of the time the wash remains in the wash charger before it is removed to the still, where the temperature conditions will cease the activities of the bacteria. When distillation commences the wash may vary from a fresh and still active yeast fermentation to an acid or even sour wash, in which yeast action has ceased for some time and bacterial action is proceeding rapidly and unchecked.

The ultimate composition of the whisky produced will therefore be modified to some extent by the time during which the wash remains in the wash charger, by the maintenance or otherwise of the temperature of the wash subsequent to transference from the wash back (at which point the temperature is around 90° F.) by the degree of fermentation attained by the wash prior to removal, and by the strength and virility of the ever-present bacterial contamination of vessels and materials consequent upon the employment of an unboiled wort. The bacterial contamination will also be influenced by the method of pitching, by the purity of the yeast supply, and by the duration of the "lag" phase in the process between pitching and full fermentation. It is most important that this "lag" phase should be strictly controlled and shortened as far as possible, and means should be devised to effect this in the method of storing of yeast between delivery and pitching, and also in the method of adding the yeast to the wort.

Up to this point in the process the various factors which determine the composition of the fully-fermented liquor or wash have been dealt with, and an attempt has been made to show the origin of what may be termed the raw materials from which the character-forming substances in the wash are produced. The next stage is the distillation process, by which these different substances are subjected to separation, the desirable constituents being collected in that fraction which eventually becomes potable spirit, after the necessary maturation, the undesirable constituents being returned to the process. Simultaneously with this separation, concentration of the potable alcohol is effected.

Distillation does not, however, consist entirely of separation and concentration, and the stills play a very important part in the production of character. In Highland pot still distilleries two distillations are usually carried out, first the distillation of the fermented wash in the wash still, the distillate being a weak colourless alcoholic liquid containing 17 to 19 per cent. by volume of absolute alcohol; secondly, distillation of this is effected in the second or spirit still. The distillate is collected in three fractions, the first and last fractions being returned to the process and the middle one collected and filled into casks for maturation.

For the first distillation carried out in the wash still, the fermented wash, a liquid containing about 10 per cent. of proof spirit, together with the by-products of fermentation, the exhausted yeast, etc., is run into the still, the yeast deposit being carried in suspension in the liquid, and as this suspension is considerable in amount, and the copper still is heated directly over the furnace a continuous scraping arrangement is employed to prevent burning of this deposit on the fire-heated plates. Distillation is continued until alcohol ceases to come over in the distillate, at which point the very considerable residue in the still is run off to the drains or purification plant. Considerable character formation takes place during this primary distillation, the wash containing ethyl alcohol, volatile and non-volatile, acids, esters, and higher alcohols, together with the exhausted yeast, and the mechanically carried peat extractives more or less disintegrated. The wash is thus a very complex liquid and during the period of distillation from the first application of heat to the still up to the time when all the alcohol has passed over, various interactions under the influence of increased temperature take place in the still. As previously shown (Hastie, this *Journ.*, 1925, **31**, 198), there is certainly interaction between acids, alcohol, and esters in the heated wash, with consequent modification of the relative amounts of each of these substances, resulting in an eventual difference in the composition and character of the potable spirit. In addition, there is the effect of heating the yeast residue, etc., over a direct fire, and this appears to be a matter of importance in character production. The use of a direct fire to heat the wash still has long been a subject of controversy, but it is the generally accepted belief that the employment of a steam jacket or steam coil without the open fire is undesirable, as character is thereby detrimentally affected. The question is in some ways analogous to the long-standing controversy regarding the same matter in relation to the brewer's copper.

It is sometimes affirmed that the use of a steam jacket or internal steam coil would be quite satisfactory and that no detrimental effects would follow. Few, however, have the courage of their convictions sufficiently strongly developed to make a radical change of this kind. Frequently internal coils are used in conjunction with open fires in order to hasten the heating process, but this of course is a different matter.

An interesting theory in connection with the question of the use of the open fire is that during heating of the still, local superheating of the more or less solid matter suspended in the wash occurs on the inner surface of the still at those points where the outside of the plates is in direct content with the fire, and that following upon the action of the mechanical rouser a large proportion of this material is superheated in this way before the distillate begins to pass over to the condensing worms. There is little satisfactory definite evidence as to any difference of composition of the Low Wines distillate from stills fire-heated and steam-heated, but it is known that furfurol, one of the more important constituents of potable spirit, is produced in the wash still, and further it has been shown that a larger furfurol content is obtained from the fire-heated than from the steam-heated still.

Certainly local superheating would be more probable in a fire-heated than in a steam-heated still, and, if and when, this theory of local superheating is eventually proved to be correct in so far as it influences character, then the logical succeeding step in the evolution of distilling is to use electricity for heating stills, the local superheating being obtained by employing a battery of "hot points" inside the still. If such a system is eventually employed, then its advent will mark one of the greatest advances ever made in the industry.

In a previous communication (*loc. cit.*) it was shown that in the spirit still there is interaction between acids, alcohol, esters and water, resulting in modification of the relative proportions of these secondary constituents in the liquor in the still and consequently in the fractions obtained on distillation. It is reasonable to suppose that modification also takes place in the two stills of the furfurol content of the whisky and of the proportions of the different higher alcohols in the whisky.

If definite data could be obtained regarding the history of furfurol and of the higher alcohols in the spirit something at least would be known of all the better-known constituents of whisky, embracing those constituents reported in the conventional analysis. When this point is reached an attempt may be made to elucidate the problems surrounding the other lesser known and hitherto uninvestigated constituents derived from malt, peat and yeast.

Following upon the work carried out on the effect of the heating of the still upon the acid, ester, alcohol content of the liquor, experiments have been commenced with the object of finding out what occurs in the still, with particular reference to furfurol. Furfurol, as is well known, is found in the distillate when pentoses, bran, carbohydrates or dried grains from the distillery or brewery are boiled with dilute hydrochloric or sulphuric acid. When pure, or freshly distilled, furfurol is colourless and has a strong empyreumatic smell, but it rapidly darkens in colour on standing and possesses markedly the characteristics of an aromatic aldehyde. It yields furfuralcohol on reduction and pyromucic acid on oxidation. Furfurol is understood to be produced in the wash still, but before proceeding to investigate this point the amount of furfurol, if any, must be determined in the wort and wash prior to distillation. According to Sykes and Ling there is a relatively small production of furfurol in the mash tun, and these authors explain that the free acids of the mash hydrolyse the galactoxylan and other carbohydrates of the mash containing a pentose complex and then act on the pentoses produced to form furfurol. If this occurs under distillery conditions of mashing it may be regarded as the first appearance of furfurol in the distillery process.

In numerous tests which have been carried out to decide this question, the writer has been unable to obtain any definite evidence of furfurol in the wort prepared by the methods employed in the distillery and if furfurol is actually produced it must be present in such negligible quantities as to have no appreciable influence on the amount of this substance eventually found in the whisky.

In the fermentation process furfurol is not formed, on the contrary it has been shown by Lintner (*Z. ges. Brauw.* 1910, **33**, 361–363) that furfurol, if present in wort, disappears during fermentation. This fact is of little importance to distillers, as no furfurol exists in the wort before fermentation, and the furfurol found in brewery worts is probably produced during boiling of the wort in the copper. It is, however, interesting to note the explanation of the disappearance of furfurol during fermentation. Windisch first showed that furfurol disappeared during the fermentation of brewery worts. Lintner also showed that sulphuretted hydrogen acts readily on furfurol in aqueous solution forming sulphur derivatives provided the degree of dilution is favourable. Will and Wanderscheck (this *Journ.* 1906, **12**, 478) also showed that sulphuretted hydrogen is formed during fermentation with yeast. It was therefore probable that the sulphuretted hydrogen thus formed combined with the furfurol, and hence sulphuretted hydrogen was considered to be the sole cause of the disappearance of furfurol in fermenting liquids and the sulphur derivatives found were considered to be probably of the nature of a mercaptan. It has since been shown, however, by Lintner and Liebig (*Z. Physiol. Chem.* 1911, **72**, 449–451; and this *Journ.* 1910, **16**, 688), that furfurol, which certainly disappears from fermenting sugar solutions originally containing it, after some days, is *not* converted into a sulphur derivative, but undergoes reduction to the corresponding alcohol-furyl alcohol, which substance these authors isolated from the products of fermentation.

To summarise, if any furfurol is produced in the mash tun of the distillery, and it is extremely unlikely in the writer's opinion based on the foregoing statements, then, as no increase, but rather a decrease in furfurol content is observed during fermentation of the wort, it is reasonable to suppose that the fermented wash enters the wash still free from appreciable amounts of furfurol, and that no furfurol is found in the pot still process prior to the removal of the wash to the wash still.

In the wash still the conditions in distilling become for the first time in the process favourable to the production of furfurol, the requisite conditions of acidity and termperature obtaining.

The substances from which the furfurol is produced are the pentosans of which, according to Tollens and Glabitz (*J. Landwirthschaft*, 1895, 106), from one-quarter to one-third pass to the wort during mashing either completely or partially converted into pentoses, and from these pentoses perfurol is produced during the heating in presence of acid in the still.

It has been found that from 100 parts of pentoses obtained by boiling brewer's grains with dilute sulphuric acid, although some 73 parts disappeared when fermented with ordinary yeast, only 17 parts of alcohol were found, together with much acid; acetic and lactic acids being identified. Where pure yeast was employed much less acid was obtained. It must be remembered, however, that pure yeast does not attack arabinose, but bacteria fermented 20·1 per cent. of this sugar, yielding 3·12 per cent. of alcohol, 4·23 per cent. of volatile acid (as acetic acid) and 1·10 per cent of non-volatile acid (as lactic acid). The furfurol yielding bodies of barley and malt other than those which yield arabinose and xylose on hydrolysis, apparently behave, to some extent, like the ordinary hexoses, and unlike the pentoses xylose and arabinose. Thus they are more susceptible to alcoholic fermentation. From the above it may be deduced that there is a considerable surplus of the original pentoses existing in the wort available at the commencement of distillation for the direct production of furfurol in the still.

If the operation of the factors of heat and acidity in the still are examined it will be desirable to ascertain the effect of such heating as occurs in the still upon the unfermented wort as it leaves the mash tun with and without the presence of acid.

To obtain some information on this point a wort was prepared from distillers malt of 1,047° sp. gr., filtered bright, and 100 c.c. portions of this wort were boiled under a reflux condenser for twenty minutes without the addition of acids. On cooling 50 c.c. of 50 per cent. alcohol (free from furfurol) were added and the mixture distilled. No furfurol was found in the distillate whether the liquid was boiled under the reflux condenser before distillation or was distilled without previous boiling. To confirm this result practical conditions were more closely imitated by using a wort from a mash strained through linen, and consequently carrying considerable matter in suspension, but again no furfurol could be detected in the distillate. When, however, acids were added to the wort prior to boiling, the remainder of the test being carried out as with the unacidified wort, considerable furfurol was obtained, both in the case of bright and cloudy wort.

| Acid. | Furfurol in mgm. per 100 c.c. original wort. |
|---|---|
| 1 c.c. acetic acid ... ... | 0·060 |
| 1 c.c. lactic acid ... ... | 0·144 |
| 0·5 c.c. hydrochloric acid | 0·090 |
| Nil ... ... ... ... | Nil. |

It is obvious, therefore, that no furfurol is produced by heating alone, no matter whether direct heating or indirect heating is employed, but that when acid is present direct heating produces furfurol. These are the conditions obtaining in the wash still, the degree of acidity varying somewhat from operation to operation.

The next step was obviously to ascertain whether furfurol was produced under the same conditions from fermented wort or wash. In this experiment the still was heated by a steam jet in the first case, and, using another portion of the same wash, by direct flame, distillation after addition of 50 per cent. alcohol being carried out as before.

A wort of 1,040° sp. gr. was fermented for 48 hours with 1 grm. of yeast per 100 c.c. wort at 86° F., but it was found that whether the wash was bright or cloudy, or whether the still was steam or fire heated, no furfurol appeared in the distillate; the important point must be observed, however, that the wash was fresh and still fermenting when heated and that no appreciable acidity had developed. When, however, acid was added to the wash in the still furfurol at once appeared in the distillate, and that when the acidity of the wash was developed sufficiently by allowing to stand at 86°–90° F. after fermentation was complete, as is done in practice, furfurol was obtained without the addition of acid employing a direct flame for heating the still. This work is still proceeding, and it would be unwise to deduce anything more definite from these few facts than the general inference that furfurol is absent from wash prior to distillation, but that it appears during distillation most probably as the result of acid action on the wash constituents governed by the method of heating the still.

To decide as far as possible what the influence of the system of heating amounts to in the production of furfurol an experiment was carried out in which distillery grains were boiled with acid under a reflux condenser and then distillled (after the addition of 50 per cent. alcohol to the cooled liquid from the reflux and before distillation).

| Acid. | Method of heating under reflux. | Method of heating during distillation. | Furfurol obtained in mgm. per 10 grm. grains. |
|---|---|---|---|
| 1 c.c. acetic acid.... .... .... .... | Steam jet .... .... .... | Steam jet .... .... .... | Trace. |
| ,, ,, .... .... .... .... | Direct flame .... .... | ,, .... .... .... | Slight trace. |
| ,, ,, .... .... .... .... | ,, .... .... .... | Direct flame .... .... | Trace. |
| ,, ,, .... .... .... .... | Steam jet .... .... .... | ,, .... .... .... | Nil. |
| 1 c.c. hydrochloric acid.... .... .... | ,, .... .... .... | Steam jet .... .... .... | Faint trace. |
| ,, ,, .... .... .... | Direct flame .... .... | ,, .... .... .... | 0·10. |
| ,, ,, .... .... .... | ,, .... .... | Direct flame .... .... | 0·70. |
| ,, ,, .... .... .... | Steam jet .... .... .... | ,, .... .... | Trace. |
| 1 c.c. lactic acid.... .... .... .... | ,, .... .... .... | Steam jet .... .... .... | Nil. |
| ,, ,, .... .... .... .... | Direct flame .... .... | ,, .... .... .... | 0·02. |
| ,, ,, .... .... .... .... | ,, .... .... | Direct flame .... .... | 0·08. |
| ,, ,, .... .... .... .... | Steam jet .... .... .... | ,, .... .... | Faint trace. |

The inferences are:—

(1) That by boiling dried grains with hydrochloric, acetic and lactic acids furfurol is produced in quantities varying with the method of heating, so much so, in fact, that a steam jet (and presumably a steam jacket) produces no furfurol, while a direct flame does produce furfurol.

(2) It may be reasonably accepted that the important character-producing substance furfurol in whisky is produced in the wash still, that the agents producing it are acids and pentoses, under the influence of heat, and that the system of heating is a very important factor.

The time taken to drive off the alcohol from a given charge of wash in the wash-still influences the content of character-producing substances in the distillate, as a rapid operation compared with a slow one will for a given form of still result in more of the less volatile substances passing to the distillate, and similarly the shape and dimensions of the head and neck of the still and the form of the lyne arm connecting the still head to the condensing worm will also control to a certain extent the degree of rectification obtained.

The point at which distillation is stopped for any given operation will also influence the character of the distillate, as where distillation is prolonged the less volatile acids, etc., will be carried over with the steam at the higher temperature reached in the still when the still contents no longer contain alcohol, and the boiling point consequently rises to 212° F.

In the second distillation, carried out in the second still, known as the spirit still, the process is a two-fold one. The distillate from the first still is concentrated during the second distillation from a strength of 66 U.P. to 11 O.P., at which strength the whisky is filled into casks and stored to mature. The second object of this distillation is to separate the potable whisky by fractionation. It will be obvious that in this distillation, carried out, as it is, with the distillate from the wash-still intermixed with the fractions not potable from the previous distillations of the spirit still, the interaction of acids, alcohols and ethers will occur as before, but in the absence of any solid or semi-solid matters in suspension such as exist in the wash still, no further formation of furfurol takes place.

Character is therefore influenced in the spirit still by the interaction of substances during heating and by the degree of separation obtained during fractionation. This degree of separation will be dependent upon, primarily, the form of the apparatus employed up to the point where the lyne arm dips downwards to the top of the condensing worm, and almost equally upon the methods of the operator, that is to say, upon the rapidity with which distillation is carried out and upon the decision of the operator as to when exactly to collect the potable fraction. The ultimate product as it leaves the spirit still condensing worm is a colourless alcoholic liquid of a strength about 11 O.P., possessing the distinctive characteristics of the distillery in which it has been produced, but also carrying undesirable flavours which render it quite unfit for drinking purposes.

The final process of maturation in cask is very imperfectly understood. Experience has shown that prolonged storage extending to ten or twelve years in casks which have previously contained sherry has the effect of removing the rank flavour of new whisky and of rendering it palatable, but although this is a necessary change it is not proposed to enlarge upon it, as the character of the whisky is not altered by storage to any appreciable extent. There is, however, some gain of desirable character in whiskies during maturation, and this improvement varies in amount with different makes of whisky, some becoming potable at a much earlier age than others and some improving more during maturation than others even granting the optimum period for maturation in each case. The changes which take place may be regarded as the result of a continuation of the interaction of acids, esters and alcohol similar to that taking place in the wash charger and in the two stills but naturally exceedingly slowly under the conditions obtaining in the cask. Precise explanation of the maturation changes is not a simple matter, complicated as they are by the presence of secondary constituents derived from the previous filling of the cask with wine and found in the pores of the wood when the cask comes to be used for filling with whisky. These secondary constituents absorbed by the wood are most important, as is also the fact that the wood is to a certain extent permeable and the importance of these two points is confirmed by the fact that in glass vessels no changes occur.

## DISCUSSION.

The Chairman said they had listened to a most instructive paper. He would like to ask Mr. Hastie how the Highland distilleries disposed of their grains.

The President (Mr. R. V. Reid) congratulated Mr. Hastie on his most instructive paper and assured him that the London Section appreciated his kindness in coming from Scotland to give them information on so interesting a subject. Was it the case that, irrespective of season, quality of barley, fuel, etc., the same character was always assured? Apparently distillers had the same difficulty as brewers in defining quality. Mr. Hastie had made it quite clear that in his branch of the fermentation industries there was a great field for scientific research.

Mr. H. L. Hind said he gathered from Mr. Hastie that character of whisky did not depend on mashing conditions. It seemed curious if that were so. In brewery practice they knew that character depended considerably on mash tun conditions and if it did not in the distillery whisky might be made equally well from any quality of malt or from materials other than barley. He was also surprised to learn that whilst flavour changed during storage character did not. He would have imagined that changes in some of the constituents during maturation would have a bearing on character. Was there any such thing as best character, or was the preference for certain characters the result of education of the palate? The taste for any particular spirit was more or less an acquired one. Given a preference for certain types of whisky, why did not other distillers, such as those of Campbeltown, who could not produce them, copy exactly the still heads of those who did, as character depended so greatly on the still construction?

Mr. A. C. Reavenall said that there were 36 distilleries in Campbeltown, but only about half a dozen were working, and having in mind Mr. Hastie's reference to the present-day unpopularity of Campbeltown whisky and the town's consequent decline in prosperity, the speaker wondered how far attempts had been carried to imitate in Campbeltown the character of the more popular blends.

Brewers had met with a certain success in their efforts to reproduce, for example, bitter beer of Burton character or Dublin stout in places other than Burton or Dublin, and a case was known in which Burton water was taken by rail to a North Country brewery where a very creditable imitation of Burton pale ale was produced. Was it not possible for Campbeltown to purchase malt or peat or whatever it was that determined the character of whisky from some district where popular spirit was produced? Mr. Hastie had not said where the distiller got his yeast supplies. Did he get frequent changes and did the whole of his out-crop eventually go to the sewer?

Mr. H. S. Bonner said he understood that the moisture in the malting process was reduced to 4 per cent. He believed it was customary in some of the distilleries in Scotland to use green malt, and he would like to ask Mr. Hastie what constituted green malt, the percentage of moisture present in such malt, and how it affected the character of the whisky?

Mr. L. C. Thompson asked the author to what extent the still and how far up the head of it was cleaned.

Mr. J. Auld asked if it was a fact that owing to the high price of old malt whisky that very little of it was used in the present-day blends.

Mr. Hastie said the reply to the question was in the negative.

Mr. W. E. Hornsey said the author had stated that local peat burnt on the malt-kiln fire had some influence on the flavour of the product of the distillery. He enquired if distillers made all their own malt, as it seemed to him that it was essential they should do so.

Mr. Hastie (in reply) said he would like to point out that distilleries were suffering, and suffering badly, from the absence of the application of scientific methods. Science stood to distilling to-day practically where it did to brewing 25 years ago. Regarding cleanliness, he feared his photographs had given an unfortunate picture of the outside of the vessels. The interiors, however, were very carefully cleansed, steamed and limed. Such treatment did not remove the possibilities of contamination from bacteria and dirt from the buildings. The insides of the mains and the stills were carefully cleaned. The still-head was clean up to the point when it turned to the lyne arm. From that point the deposit was not removed but was generally carried over to the distillate by the strong spirit of the next distillation. That went on continuously. The deposit was carried over to the receiver, and when a new worm was installed re-distillation was always carried out.

Concerning moisture in malt and the use of green malt, and whether green malt affected the character of the whisky, he would remind those present that no green malt was used in pot still distilleries. Green malt was used in the manufacture of grain spirit, which was the spirit which had to be blended with pot still whisky to give it a light enough character to suit the modern palate. Such spirit was made from materials other than malts, *e.g.*, maize. Green malt was used to effect the conversion of the starch which otherwise would not take place. It was used undried and ground between the plates of a mill in a stream of water, the water running right through the mill into the receiving vessel. Highland pot whisky was practically never drunk alone, but a large proportion of it was present in blended whiskies, especially in the higher grade whiskies.

He considered the shape of the still head and the lyne arm of a pot still were important matters. A standard shape of body and various heads would give different whiskies, but one standard shape of head and varied shapes of still body would give little difference in the character of the whisky. If the shape of the head was altered or the amount of the rectification by employing different temperatures, changes would follow.

There was no outcrop of yeast in a malt distillery. The yeast, which was for the most part dead, was passed into the still, for if the wash was filtered the effect was adverse on the character of the whisky. In grain distilleries yeast was produced and it was the source of the yeast supply used in bread-making. The type of yeast which came from the grain distillery was altogether different, so much so that grain distilleries did not normally use their grain yeast for pitching in their pot still distilleries.

The suggestion that "character" might be altered by changes of yeast did not really arise. It was found that by drawing yeast from various sources, there was no difference in character; as a matter of fact those conditions did not obtain nowadays, because the supply was controlled by a company who collected the yeast from various breweries in Scotland and possibly some in England, and then gave it out to distillers. They had to take it as they could get it, and it came from the Edinburgh district.

He did not know if the transport of water had been tried; but it was quite a common practice for distilleries whose maltings were restricted to buy large proportions of malt from maltsters; but he personally did not know of a case where whisky had been made from malt derived from outside sources. The distiller generally made some malt and went to the maltster to buy the remainder. At one time the distiller made all his malt, but this was not possible under modern conditions. Fifty per cent. of the distillers own malt, with 50 per cent. of purchased malt did not vary the character in any way.

Distillers' malt was dried to a moisture of about 4 per cent. and colour of $2\frac{1}{2}°$ to 3°. The diastatic power was generally about 50° Lintner, but the malt was not made with the idea of having excessive diastase. In a malt with colour of 3° there was ample diastase for conversion.

In answer to the question: "Was there a best whisky?" he could reply in the affirmative. If they took all the whiskies, the good pot still whiskies and the bad ones, and put them in glasses in a row, the ordinary individual who took any interest in the matter would certainly tell the good from the bad, and the goodness and badness was largely a question of public taste. At one time Campbeltown was proclaimed by public taste to be a good whisky, but now nobody would have it; so much so, that a small percentage of that whisky put into good whisky was sufficient to make people refuse to take it at all. Related to that was the question of duplicating plant. He had been asked why not duplicate the plant where there was good whisky? Take the details of it and duplicate it, say, in Campbeltown, where the whisky was not good. To do such a thing was very difficult, and it was not eliminating the influence of the peat in the water, and in the malt. When he had stated there was no difference in character produced up to the mash tun, he did not mean that in the absolute sense, because there were the differences due to the water and the peat. He had known of experiments entailing transportation of peat from the West Highlands. The result was a partial improvement.

Little was known of the effect of the differences in barley from year to year. A distiller using the same plant and operating it in the same way and using Scotch barley, or a mixture of Scotch barley and foreign barley, and carrying on thus year after year, would get essentially identical whiskies. There would be, however, slight variations, whether due to climatic variations in the growth of the barley, or the changes in the water, he could not say. But just as champagnes one year were better than another year, so were whiskies.

Changes in storage were very difficult to define. Each whisky had its own character, which was not altered by storage but the effect on the palate was different. There were no new characteristics acquired by storage and none definitely lost, but there was a modification of the amount and the relation of the characters one to another. That explanation he was afraid might be regarded as meaning that it was unknown what happened, and that was the truth. He had not referred to the effect of the higher alcohols on "character" but he hoped at some future date to work on that subject.

The grains in a distillery were dried on the spot and were conveyed by ship from time to time in the case of the Western Highlands and by train elsewhere. In some remote districts, when prices were so low that drying did not pay, the grains had been thrown into the sea.

A vote of thanks was accorded to the author for his interesting paper.

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## MEETING OF THE SCOTTISH SECTION HELD AT THE CALEDONIAN HOTEL, EDINBURGH, ON TUESDAY, NOVEMBER 24TH, 1925.

Mr. DAN ROBERTSON in the Chair.

The following papers were read and discussed:—

# NOTES ON THE NITROGEN CONTENT OF WORTS AND THEIR BEERS.

By L. G. SMITH, A.I.C.

To appreciate more readily the points about to be discussed it may be well to recall to mind the various modifications of the nitrogenous bodies of barley which take place from the malting floor to the copper.

The nitrogenous content of the barleys usually used in brewing varies with the type and source from 8 per cent. to 12 or 13 per cent. on the dry barley.*

These bodies are almost entirely insoluble, but when submitted to the malting process the proteolytic enzymes function, and according to the type of barley and the manner in which it is malted, varying proportions of the total nitrogenous bodies are rendered soluble. A small proportion (10 to 15 per cent.) of the soluble bodies is utilised by the growing rootlet, but the bulk is retained in the corn. When the malt is mashed, further proteolytic action takes place. Of the nitrogenous bodies rendered soluble in cold water during malting, about 15 to 22 per cent. are coagulable on boiling.

The effect of the proteolytic action in the mash tun is to increase the amount of non-coagulable nitrogenous bodies which are soluble in cold water by as much as 50 per cent., presumably by rendering the coagulable bodies permanently soluble and by the proteolysis of other insoluble proteins. Of the total nitrogen extracted in the mash tun a very small percentage is coagulable in the copper. From the copper then we get a wort with a permanently soluble nitrogen content varying according to the type of malt from 3·5 to 6·5 per cent. of total wort solids.

Expressed as a percentage of the total nitrogen content of a malt, the permanently soluble nitrogen content varies from approximately 24 to 42 per cent., superior malts yielding high extracts having the higher percentage.

Table I gives analyses of typical barleys and the malts made from them, from the nitrogen content standpoint. It gives:—

(1) Nitrogen per cent. in dry barley.
(2) Nitrogen per cent. in malt.
(3) Cold water soluble nitrogen per cent. in malt.
(4) Non-coagulable soluble nitrogen per cent. in malt.
(5) Percentage non-coagulable cold water soluble nitrogen of total cold water soluble nitrogen.
(6) Permanently soluble nitrogen per cent. in malt.
(7) Permanently soluble nitrogen per cent. of wort solids.
(8) Percentage permanently soluble nitrogen of total nitrogen in malt.
(9) Percentage permanently soluble nitrogen of wort solids non-eliminable by fermentation.
(10) Percentage eliminable permanently soluble nitrogen of total permanently soluble nitrogen.

* These figures and all others used represent nitrogen × 6·25.