THE THEORY AND PRACTICE OF MODERN BREWING.

SECOND EDITION

THE THEORY AND PRACTICE OF MODERN BREWING;

WITH FULLY-ILLUSTRATED APPENDIX.

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1888.

THE

THEORY AND PRACTICE

OF

MODERN BREWING.

A RE-WRITTEN AND MUCH ENLARGED EDITION OF "THE ART OF BREWING;"

WITH A COMPLETE AND FULLY ILLUSTRATED

APPENDIX,

SPECIALLY WRITTEN FOR THE PRESENT PERIOD.

BY

FRANK FAULKNER,

JOINT AUTHOR OF "STUDIES ON FERMENTATION," "NOTES ON THE POLARISCOPE," "NOTES ON BREWING, 1887."

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PREFACE TO APPENDIX.

ONCE more I am called upon to decide whether the "Theory and Practice of Modern Brewing," which, as my readers will remember, constituted an enlarged and almost entirely re-written edition of "The Art of Brewing," published originally many years ago, should itself be reissued without further correction, or, on the other hand, be so improved upon, as to place it in the position of a work dealing with all the more important modern methods of brewing, by the addition of an Appendix describing, in more or less detail, those particular points of existing practice which are deserving, more than ever, I think, of careful notice on the part of brewers generally.

After due consideration I have come to the conclusion that it would be far better to leave the original work intact, at the same time combining all special reference to new plant and the means of working it in a special Appendix to the original publication, so illustrating this, that readers may the more readily understand not only the working of the arrangements specified, but the improvements in general process that may be determined through their agency.

My idea will perhaps become more apparent if I specially refer at once to the new plant that I think of dealing with, making brief reference at the same time to the several objects for which it is used, since this will enable me to divide my subject into a series of chapters constituting the basis of the Appendix in question.

The general tendency of recent alterations in fiscal laws, taken in conjunction with the very pronounced preference on the part of the public during the last few years for weaker beers, has indeed rendered the adoption of certain plant appliances for determining the requisite alteration in character of a mere infusion wort an absolute necessity.

For instance, since the abandonment of the malt duty, types of grain have come into use and methods of malting have been carried out that have led insensibly to the production of infusion worts almost entirely destitute of dextrine, or, at any rate, of dextrine in sufficient quantity to determine that persistent palate of beer that is thought so necessary, while as public taste has been drifting in the direction of a decided preference for low gravity beers in place of those of extreme body and strength, that were indeed so diligently sought after a few years ago, this question of infusion extract and its general composition has of necessity become more and more important.

It is well known, I think, that the theoretical transformation products of malt starch (or rather of malt extract) contain, as a rule, about 60 or 62 per cent. of maltose and 20 or 22 per cent. of dextrine, while for reasons in connection with altered character of material, the adoption of low infusion heats, subdivision of mash wort, and stewing during collection process, this theoretically normal composition of wort extract is no longer very common, the ordinary dextrine constituent in the case of infusion worts having diminished to a proportion not exceeding, as a rule, some 10 or 12 per cent. upon total solids.

I am not saying or wishing my readers to infer for a moment that the dextrinous bodies are the sole constituents of wort capable of communicating body, viscidity, or foaming capacity to resulting beer; but they are, at any rate, of very great importance, the exact percentage in which they exist having much to do not only with the condition of beer, but the way in which it matures during lengthy storage.

In the production of weak beers again the dextrine percentage is constantly decreasing, not only as a result of dilution, but on account of the stewing method of wort collection previously mentioned.

In the next place, alterations in methods of agriculture, climatic changes, and the use of artificial chemical manures, have led, no doubt, singly or combinedly, to large increase in the particular proportion of alterable nitrogenous matters existing in malt and temporarily soluble in mash wort, though capable, on account of their alterable tendency, of subsiding from solution at different stages of the brewing process, frequently indeed, and in this case most unfortunately, after the finished beer has been placed in cask.

Now, as the transformation products of malt extract obtained under the influence of a mere infusion mashing process are no longer altogether recommendable in quality or proportion, English brewers have been strenuously advised to follow the lines of Continental working, foreign competitors being, indeed, exceedingly successful in producing beers exceptionally low in gravity, but, nevertheless, possessing the favouring qualifications of definite soundness, body, sparkling condition, and foaming tendency.

Such qualities are, of course, very significant to English brewers, since our weak beers of home production are not, as I think, characterised by any of the conditions named, light English beer being frequently flat, thin upon the palate, doubtful in point of brilliancy, while unfortunately exhibiting a great tendency to premature age.

I intend, therefore, devoting the second chapter of the Appendix to the subject of modern mashing, showing, both by text description and illustration, how the character of mash wort can be modified, not by the adoption of the German system in its entirety, but by certain modifications of existing process that determine percentage alteration in the component parts of malt extract, such modifications, I think, being very beneficial in influence.

I shall point out also how it is possible to eliminate certain alterable forms of nitrogenous matter by direct oxidation, without injury to the other constituents of malt wort, so long as such aëration method is carried out under stringent regulations that will be duly specified in detail.

In the next place, recognising that a tendency on the part of many English brewers has, during recent years more especially, been noticeable in the adoption of steam as a direct heating agency, while the majority, I fear, are more or less wofully ignorant of the reasons which determine occasional non-efficiency of steam heat, and the difference that exists between the influence of steam injected into wort under pressure, and the same vapour used indirectly through the agency of coils or steam jacket, I think it will be well to devote some of my remarks to this important subject, while, as it is neither safe nor advisable to employ naked steam unless it be pure, so in my chapter on the subject of boiling operations, I propose illustrating in detail a method of not only determining the full efficiency of steam boilers as the sources of steam under pressure, but describing how such steam can be obtained in a state of purity, illustrating also a form of water-softening plant of perfectly modern construction that is now being worked in many large English manufactories.

What difficulty, again, is more common than that of successful yeast reproduction? How many brewers, for instance, experience disaster through employing weak yeast, and how very few understand the various methods of reviving yeast when it has become definitely weak? Recognising, therefore, the importance of this subject, and the interesting nature of it to the large majority of English brewers, I have thought it advisable to write a chapter on fermentation as a whole.

How could I better explain modern ideas than by teaching the connection that exists between oxygen and yeast, while illustrating also the means of supplying oxygen in a state of purity, explaining the connection that exists between cold and purity of yeast, and the available means of determining the low temperature of atmosphere requisite in the case of a well-arranged fermenting room ?

Passing to the special subject of yeast revival, what course could be better than to describe how yeast can be fed and reinvigorated practically in a nutritive wort, and to explain how such wort can be prepared, while illustrating at the same time the plant used for this particular purpose ?

Finally, as the microscope has now come into general use in breweries, and as the old-fashioned methods of determining fitness of yeast for pitching purposes are no longer accepted as altogether reliable, the paragraphs on the subject of "The Microscope and How to use It" may not seem out of place, or prove uninteresting even to those readers who are expecting to find general information only on the subject of fermentation itself.

Other facts, indeed, are equally suggestive,—brewing firms, for instance, find it necessary each year to extend their trade, competition driving them to do this, while, in order to face competition, the brewer must be prepared to economise in cost price of beer production, definite increase in output of plant minimising very distinctly the working expenses, and, as a consequence of this, the actual cost of beer.

However advisable at first sight an agency trade may be, it invariably leads to one result that has to be considered by the brewer desiring to manage his business in a thoroughly satisfactory manner; for, while it is possible, when dealing with a merely local trade, to limit "returns" to a very small percentage upon output, this percentage runs up in a most alarming manner if the brewer embarks upon an agency trade, especially if such agencies are placed under the control of men who have no knowledge as to the character of beer, or the treatment that is requisite during prolonged periods of storage.

I intend, therefore, to devote a chapter to the question of storage as a whole, detailing various methods of effectually bringing "returns" into a condition that enables the brewer to gradually mix them off without detriment to the blend, while illustrating also the plant that is usually employed for this purpose.

Lastly, as laboratory teaching seems to be a necessity at the present day, and as chemical knowledge is certainly the basis of all success in practical brewing, I purpose devoting a chapter to a brief description of the various analytical processes that seem to me absolutely necessary as a part of the knowledge possessed by each brewer, referring also in my text to those biological and bacteriological processes that are at present carried out in determining the distinction that exists between mere quantity as compared with quality of extract, and in this way I hope to compile an Appendix that will cover all points of modern knowledge, and enable readers to thoroughly understand the many advanced theories that are continually being debated in the more scientific journals.

Frank Faulkner

THE LABORATORY,
LANGLEY, OLDBURY; AND

3, FURNIVAL'S INN,
LONDON, E.C.

December, 1887.

PREFACE TO FIRST EDITION.

It was in 1876 that I first published what must now seem a very elementary work on Brewing, since I may say, without any fear of contradiction, that brewing was then a very simple matter, as compared with the more complex process of the present time. Increasing competition, comparative inferiority of material, and a growing public taste for weaker beers, have certainly combined to render the manipulation of necessity more and more difficult, and to bring it into more perfect connection with theoretical teaching, while, if any proof were needed for the statement that greater skill and attention to detail has gradually been becoming more and more necessary, what better one could be urged than the rapidly increasing employment of chemical antiseptics and preservatives that were entirely unused, and, indeed, unthought of, a few years back?

In 1878 a second edition of the original work appeared, enlarged by an appendix, the chief feature being that the new subject matter gave brewers, at any rate, some scanty knowledge of the connection that necessarily existed between yeast as a plant, and wort as the field of growth, subject matter which was of course suggested by Pasteur's *Études sur la bière* which appeared about that time.

The following year, a third edition was asked for, but so loth was I to continue the publication of crude information, so anxious to explain the art of brewing in a practically simple, yet theoretically truthful manner, that I determined in my leisure to re-write the whole work, improving the theory, and largely extending the practical portion of the subject, all that follows being the result of the determination so formed.

It is difficult to please scientific and mere practical readers at the same time, and perhaps there is the less reason to gratify the former, as far more advanced works on the subject of modern brewing are constantly being published; but, at any rate, I may express the hope that even to scientific readers my theory may appear sound, and to the brewer interesting, as explanatory of the process that he has to conduct.

I have to tender my ready thanks to Mr. G. R. Wilson, of Frome, for the aid he has kindly given me in the matter of illustrations, which will, I think, prove serviceable to many of my readers, and to those in personal connection with myself who have rendered assistance in preparation of copy and revision of proofs. In conclusion, I venture to hope that "The Theory and Practice of Modern Brewing" will prove as interesting to brewers of the present day as "The Art of Brewing" seemed to be when it was first published.

Frank Faulkner

THE LABORATORY,
CROSSWELLS BREWERY, OLDBURY,
January, 1884.

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THE THEORY AND PRACTICE

OF

MODERN BREWING.

CHAPTER I.

INTRODUCTION.

On being asked to revise and issue a third edition of "The Art of Brewing," I thought it best to consider if some improvements could not be made, some additional subject matter added.

A second appendix was out of the question; while some of the chapters of the original work struck me as so crude and elementary in view of the new and increasing knowledge we have of theoretical brewing, and the freedom of choice in regard to material that new fiscal regulations practically allow brewers, that I finally came to the conclusion that the safest plan, so far as my own reputation was concerned, was to entirely re-write all chapters that I thought faulty, add one or two others likely to prove of special interest, and engraft the appendix to the second edition of "The Art of Brewing" into the body of a new work.

Thus the chapters on Water, Mashing, and Fermentation will be found much enlarged, the subject-matter brought into some sort of unison with modern knowledge; while the sections on Brewing Calculations and Applied Chemistry are entirely new. The latter chapter, however, is not very lengthy, for the simple reason that in response to urgent requests I have determined to publish as soon as possible, with the aid of my chemical assistant, a text-book on chemistry for brewery pupils—a book which will contain full information as to the *modus operandi* of the brewer's laboratory, in reference to the analysis of waters, malts, sugars, malt substitutes, and so forth. While doing all this, I have tried to keep to my original idea, and write a book more for the brewer than for the scientific student, sketching practically the simple principles, which, as I hold, explain so clearly the various stages of the brewer's art.

Peptonised albuminous matter.

If brewers will take a word of advice from me, they will study constantly and well the question of crude and peptonised albuminous matter and its vast direct and indirect influence; for I do not go too far in saying that sooner or later we shall have conclusive proof that, practically acting as the food of yeast, the nitrogenous bodies of grain centre as the turning-point upon which all success or disaster in brewing eventually hinges. This, be it understood, is no strictly modern view; it has existed in more or less definite shape for many years, from the time of the Liebig theory era to the present; but the more we work with the "microscope" and the "forcing tray," and carefully study the various systems of brewing practised in England and on the Continent, the more we learn how close the connection is between soluble albumen as the food of yeast, and this yeast as the motive agent of changes that lead to either improvement or deterioration in the quality of beer.

My firm hope is that my readers will understand, after mastering this work, why a certain extent of theoretical knowledge is required. Having it not alone but blended with practical experience, we may undoubtedly hope to succeed: while, without it, we can but follow the teaching of our practical instructor, and imitate his success only so long as the conditions influencing our work are similar to his own. In other words, proper theoretical knowledge enables us to brew anywhere more or less successfully, although this view is laughed to scorn by many who are older, and, may be, wiser than myself.

Theory and practice.

It is with confidence, however, that I advance such opinion; and the success which my former work met with—a success far exceeding all expectations—proves to me that the opinion is shared by a large number of the brewing world also.

CHAPTER II.

WATER.

I DO not overstep the mark in saying that the subject of water supply has a very great influence in regard to brewing. The purity of it alone is a matter of much importance, while its saline character practically demonstrates the type of beer that can successfully be produced by its use, most probably by determining the system of fermentation that must be followed if results are to prove successful. English brewers are too apt to regard fermentation as a matter of secondary importance, an action induced by the so-called bye-product yeast; too apt, I think, to ignore the fact that yeast varies in type, is a mixture of an almost endless variety of cells, and finally that the character of water determines altogether *the type* or kind of yeast we must employ, and the system of fermentation that must be followed, in order to render success uniformly possible! As to this we shall see more anon. No one can deny that purity of water is essential, since decided contamination at once induces impurity of yeast, and no sceptic even can think lightly of this or prevent the invariable result. The impurities of water are of two distinct kinds, both, so far as the brewer is concerned, organic in their origin—animal and vegetable—the former by far the more dangerous, since it is either putrescent, or enters into decomposition with the greatest ease, leading eventually to the presence of

Influence on type of yeast.

Impurities of water.

nitrites and *nitrates*, which are in themselves sufficient to render even passable purity of yeast or stability of beer altogether impossible. It is not often that the brewer has to contend with such defects, the generality of waters fortunately not being in any sense dilute sewage, and I need not pause to enlarge upon this part of my subject, since no amount of skill can enable a brewer to combat successfully with such forms of contamination or ward off the influences of any large proportion of nitrogen salts, unless he be prepared to employ expensive chemical agents and content himself with constant changes of yeast.

Nitrates.

Vegetable organic matter is of lesser influence, and waters containing it are nearly always free from the results of animal defilement, vegetable growth being, in reference to them, no doubt, more or less purifying, owing to deoxidising influences. Nevertheless, we do well to avoid the use of water that can be really classed as contaminated, although we need by no means adhere to the hard-and-fast lines laid down by Professor Wanklyn and other analysts, and discard a water even though it be but slightly impure. The brewer indeed is not always able to pick and choose, but has to content himself with that supply which is ready to hand; and so long as the water be free from animal excremental matters *or* the results of their original presence (nitrites and nitrates), and be not overburdened with vegetable impurities, he may employ it with a certain sense of security, boiling it, if he will, as an extra safeguard, while remembering that such ebullition leads to the precipitation of the saline matter temporary to the water—*the carbonates*—alone held in solution by the free carbonic acid, which rapidly escapes, of course, so soon as boiling commences.

Effect of boiling.

The ammonias.

I do not know whether brewers, by mere force of habit, have yet become accustomed to the analyst's expressions — "free or saline," and "albuminoid ammonia." They are, perhaps, technical terms, somewhat difficult to grasp in their meaning; but, fortunately, once mastered easy to remember. They are practically the indices of impurity, since no nitrogenous organic matter in solution remains for long in unaltered condition; it oxidises, and the nitrogen constituent passes through stages of oxidation—first to ammonia, then nitrous acid, and finally nitric acid. Thus, as a water percolates through an oxidising strata, the azotised impurities suffer oxidation, and the resulting ammonia becomes the index of the original organic matter: but as the oxidation of vegetable impurities under such influence is very slow, the "saline," or "free," ammonia in a water is held to be indicative of animal excremental matter, which either affords to the water direct the ammonia, or one of its salts (urea), which itself yields "free" ammonia under the slightest decomposing influence.

Oxidation influences.

Thus, when a measured bulk of water is boiled, the ammonia, either combined or uncombined, being volatile, comes off, and may be collected and estimated, constituting, in short, the free, or saline ammonia of the analyst. Exposing the same water to a powerful artificial oxidising influence—that of permanganate of potash—further ammonia is formed, and is held to be the index of those vegetable nitrogenous bodies that, existing in the water, partially resisted the oxidising tendencies of the strata through which the water percolated, *but are at once* changed under the more potent agency of the oxidising permanganate. So much for the two ammonia propor-

Method of estimation.

tions, one the index of animal, the other of vegetable organic matter.*

Strata influences.

If the contaminated water remain under strata influences, the first-formed ammonia does not continue for long as such, but gradually changes into what are practically higher oxides of nitrogen; so that we can have diminishing ammonia proportions, and in place of these, nitrates and nitrites, which are, as I have before observed, the index, not only of contamination of considerable standing, but, beyond this, fatal by their own individual properties to the purity of yeast, and the consequent colour, soundness, and stability of beer.

Organic purity.

There are other changes, more difficult perhaps for the beginner to grasp; we have oxidising and deoxidising strata influences at work, and a water containing merely the results of old contamination, salts of nitric acid, may pass through a strata and become entirely free from such bodies, yet contain "free ammonia" in place of them, *no longer, however*, an index of recent contamination, but an evidence only of the way in which chemical changes and actual purification can proceed under natural influences. Let my readers, then, remember that in glancing over one of those mystical reports of a water analyst that in so far as organic purity is concerned, they must study well the ammonia proportions, and see

* My meaning in the above remark must not be misunderstood. It is impossible to draw hard-and-fast lines as to the indication of the two ammonia proportions, but, generally speaking, they are as mentioned. At the same time it frequently happens that a water contaminated with sewage-matter contains not only "free," but "albuminoid" ammonia also, in large proportion; but in all such cases the "saline" percentage will be excessive. The reverse of this occurs in the presence of an excess of vegetable matter.

also if nitrites and nitrates are entirely absent; and while it is absolutely impossible to have perfect purity, the nearer we keep "free ammonia" to the smallest percentage possible, albuminoid ammonia under 1-10th part per million, and the higher oxides of nitrogen altogether absent, the more likely are we to be successful in our brewing operations.*

Saline bodies.

If the organic character of brewing waters be important in one direction, their saline nature is no less momentous in another. Waters, in reference to saline constituents, vary within very wide limits. We have the *Vartrey water* of Dublin, absolutely soft, at one end of the scale; the hard waters of Burton, Edinburgh, Great Yarmouth, and many other centres of brewing, at the other. Now, what is the influence of saline matter? It is pretty safe to predict that it has a double preservative tendency—preservative in itself, and indirectly so by altering the extractive nature of water, and equally safe to assert that its capacity in this dual direction varies according to the variety of saline bodies present.

Carbonates.

We have various classes of salts, carbonates of different bases, sulphates and chlorides. If we exempt carbonate of soda, which seldom exists in a brewing water (since gypsum is nearly always found as a constituent in varying quantity, and it is quite impossible that the two salts can be present together), but when

* It is as well perhaps to remark that many analysts do not hold mere *ammonia proportions* to be absolutely reliable as indices of impurity, and two other methods of working are more in favour with them, viz., that of Dr. Tidy, which turns upon the estimation of organic impurity by means of the oxygen process, and that of Dr. Frankland, which may be described as the combustion method, organic carbon and nitrogen being directly determined. These will be further explained in the chapter on Laboratory Work.

present is so permanently, that is, is not precipitated by boiling, and is a saline body, communicating great extractive capacity; the other carbonates—magnesic and calcic—have little or no influence, I think, except in the way of coating our boilers, liquor tanks, and pipes with scale, and neutralising the normal acidity of the malt—an action by no means constituting an advantage, in view of the fact that acid fluids are less prone to undergo deterioration than those which are almost or entirely neutral.

Sulphates and chlorides.

The other classes of salts—sulphates and chlorides—are much more potent, and as I have said, directly and indirectly preservative, apparently so indirectly by determining the type, if not the quantity, of nitrogen bodies which become extracted from our malt; a matter difficult to determine, since all modern methods of estimating albumen percentages fall short of perfect accuracy. Sulphate of lime, or gypsum, magnesium, calcium, and sodium chlorides are all powerful in this direction; and such fact accounts, perhaps, for the wonderful business done in so many hardening solutions of the nature indicated by the various advertising firms of the present day, although it by no means follows that artificial hardening is at all times advisable, or that by adopting it as a system we invariably arrive at the same result as if the saline bodies existed in similar proportions, or apparently similar proportions, naturally, in our water.

Sulphates as hardening agents.

We shall see, when we come to a discussion of the chemicals used in brewing, that of late years it has practically been discovered that certain sulphites—those of lime, magnesia, and soda more especially—seem to exercise very much the same influence in

Sulphites.

determining character of extract, as the sulphates and chlorides above mentioned, and in cases where a few years ago it was customary to utilise gypsum, common salt, and magnesic sulphate, as combined hardening materials, brewers are now far more in favour of sulphites, and for a reason not difficult to understand, since such bodies have a direct and powerful preservative influence quite distinct from their capacity of determining the type or variety of azotised matter taken into solution by mashing liquor containing these bodies.

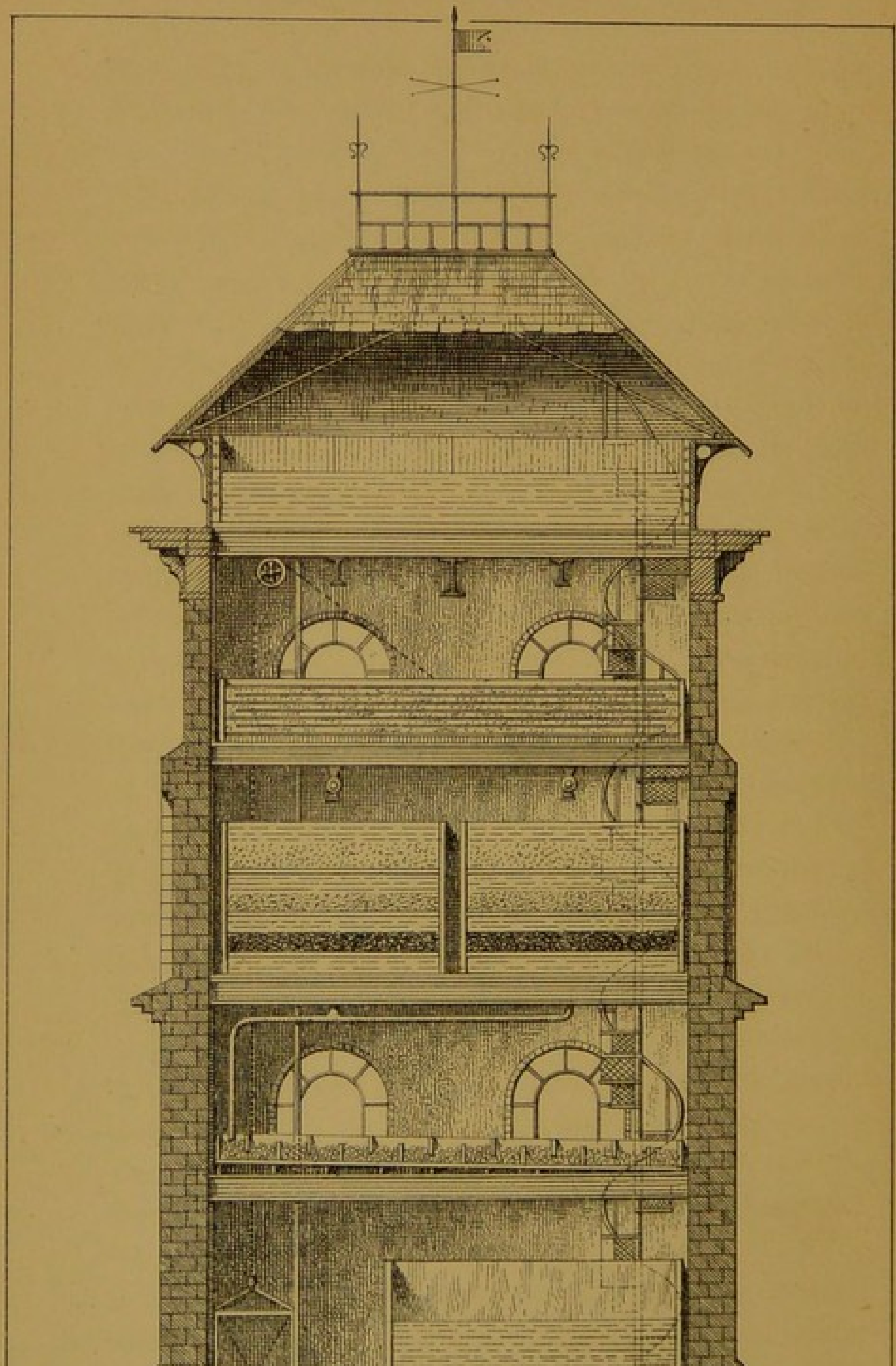
Excessively saline waters weaken yeast.

Of course, there is a limit to the quantity of saline matter that is useful in this special direction. The reproduction of yeast in healthy and vigorous form is a necessity, and we may diminish the "feeding" capacities of a wort too much. The excessive hardness of our water supply may limit the nitrogen percentage in the malt extract to such an extent that our yeast practically starves, and fails to induce proper normal results; and this, indeed, has been proved over and over again by the writer when attempting to employ water exceptionally saline in character. The extreme limit experimented with was in the case of water containing some 154 grains per gallon of saline bodies, largely composed of salts permanent to the water, and under otherwise most exceptionally favourable circumstances, the worts produced seemed incapable of facilitating the reproduction of yeast.

Water determines system of fermentation.

This, indeed, is a most important matter, and we shall see presently how the influence of saline bodies practically determines the kind of fermentation system that has to be adopted in various parts of the country, although we must remember that, within wide limits,

PLATE I.



HARDENING TOWER

we can alter the normal character of a soft-water wort by the use of glucose, saccharine, sugar, or other malt substitutes.

Stone square and other systems.

The influence of water, indeed, has practically decided the success of the stone square system practised in the North of England, and the equal success of the so-called fast system (so opposite in all respects to the other), carried out in Burton and other centres where the water in use is possessed of a strongly-marked saline character; while in many places—London and Edinburgh—we have a medium system in operation exactly in unison with the nature of the solvent employed. This influence will, I am sure, become plain as we proceed, and it is therefore unnecessary to refer at greater length to it under the present heading.

Water-tower.

Systems of manipulating water have recently been practised with more or less success. No doubt, by proper filtration we can reduce the organic matter proportion: by aëration we can oxidise out small quantities of iron, and by passing the water through tanks containing gypsum or other salts, we can increase its saline hardness. Our first illustration represents a "Water Tower," in which such processes are carried out. At the upper part the water is caused to flow through troughs filled with shingle, so that by exposure to the air the iron constituent becomes oxidised and insoluble; passing thence through tanks of slate filled with sand and animal charcoal, the iron is removed, as well as many of the albuminoid constituents; while finally, the purified water percolates through tanks (sectionally divided, so as to ensure alternate upward and downward flow, as indicated in sketch), filled with gypsum, so that it becomes considerably hardened. It will be noticed that the tower is provided with a lift and spiral staircase.

Calcic bisulphite.

Calcic bisulphite and ordinary salt are also commonly used; the former for its well-known antiseptic properties and possessing also a very similar influence to the sulphate; the latter for its power of determining flavour and yeast development; while it is not unusual to find our porter brewers using sodic or potassic carbonate, partly to soften the water, partly to exist as extractive saline matter, so determining increased fulness or "body" of their black beers.

Sodic carbonate and calcic sulphate reaction.

The mutual decomposition which results when sodic carbonate comes in contact with calcic sulphate is somewhat important. The water becomes, of course, softened, and no injury results so long as it is employed only in the brewing of porter or stout; but otherwise the system is not always successful, since the sodic sulphate, one of the resulting saline bodies, is known to interfere more or less with the development of yeast, and in this indirect manner affects, by retardation, the spontaneous clarification of beer.

In the brewing of ales, the presence of such a saline body would not by any means be advantageous—a fact that we must bear in mind if any one suggest that we should artificially harden a water naturally containing the sodic carbonate as one of its constituents, although, of course, by adding sulphurous acid in proper proportion we might easily convert the carbonate into sulphite prior to the addition of the gypsum, such conversion of carbonate being of necessity accomplished immediately before the employment of the liquor for mashing purposes in order to prevent all possible change of the sodic sulphite into cor-

Sulphurous acid.

responding sulphate, while with this *modus operandi* the gypsum in use would have to be mixed with the grist.

It would be well for brewers to study all these complex influences of water: for so long as the English brewer depends upon the attainment of stability by the removal from his worts during fermentation of any such excess of yeast-forming matter as could lead to fretful cask changes, the character of water, which governs, may be, the quantity, and most certainly the quality, of albuminous matter extracted from malt, must remain one of the most important questions in connection with the theory of brewing. Albuminous matter.

If we had in England the preservative influence of *extreme cold*, or could economically employ excessive quantities of agents with like preservative influence, exerted, however, in different ways, then, may be, we could, following the lead of our continental friends, regard water and its character as subsidiary considerations; but I contend that so long as we can only, unaided, attain stability of produce by a system of wort-purification, the varying aspects of the question now being discussed are of the deepest importance.

In regard to the analysis of water, under ordinary circumstances a very elementary process suffices. Let us ask of the analyst that he should determine with care the ammonia proportions, organic carbon and nitrogen, and the saline residue, splitting such saline residue up into its *soluble* and *insoluble* parts, practically determining by this means the sulphates and chlorides, as opposed to the insoluble carbonates. Let us be certain that the supply be free from iron, nitrates and nitrites, and we shall then be in a position to judge Water analysis.

of its fitness for brewing purposes, and to determine with ease that system of brewing most in unison with its character.

Analytical reports.

One can only feel amused at those complex and mysterious reports as to the quality of water which the owners of breweries are so careful to preserve, a report which generally contains a statement that the presence or absence of calcic sulphate determines the value of the water for brewing purposes, the ideas of many analysts being somewhat vague on the point. If brewers will but study the general principles of brewing, they will then be able to estimate aright the data of the analyst, and render such reports of the greatest possible value where hitherto they have been absolutely useless.

If I have not succeeded in saying much that is fresh in reference to this subject, I have, at least, dwelt upon it at sufficient length, and, as I trust, with such detail as to render any after references to it in no way confusing; and I may, therefore, at once proceed to consider the subject-matter of my next chapter.

CHAPTER III.

THE MATERIALS USED IN THE PRODUCTION OF BEER.

Grain, Malt, Sugar and Saccharines, Hops and Hop Substitutes.

A GLANCE at the heading of this chapter will at once disclose to the reader the reason for my entirely re-writing the original text, since the new fiscal regulations practically allow of the brewer utilising any material that he thinks proper in the production of beer; and he has, therefore, to extend his researches and experimental processes so as to determine the suitability of various raw grains for brewing purposes.

I shall be able, I think, in this chapter, to wipe away many cobwebs that at present render the English brewer so strictly conservative in his notions, and prevent his reaping in full those advantages as regards cheapness of production that the present Excise laws place within his grasp.

Choice of materials.

Now in determining the variety of materials that we can employ with any certain advantage, we have to keep two controlling influences constantly in mind. Not only have we to prepare a wort, normal in character, a wort suited by its constitution to the growth, in vigorous and healthy manner, of the ferment we cultivate, but we have also to study the palate-requirement of the public that consumes our produce; and while flavour depends, of course, in great measure, upon the variety of material we employ, we must by no means forget that influence of water I have so lately enlarged upon, or that much also depends upon the systems of mashing and fermentation adopted, and the variety of yeast cultivated.

From one point of view we are bound to select materials that will yield a suitable soil for the ferment to develop in. The statement I have made so frequently—often, perhaps, raising a smile, often the anger of my critics—is none the less true, and in choosing these materials we are kept within certain limits by this simple and all-important requirement.

Fiscal regulations.

Fiscal regulations also, while giving us a practically "free mash tun," handicap our selection by fixing a standard bushel and its possible extract, together with its equivalent in the form of sugar and saccharine; but these restrictions are not very harsh, for we can easily intermix a variety of grain that will yield us uniform results and subject us to no surcharges either upon material or fluid produced.

Varieties of barley.

Up to a very recent period the grain selected for use has been one that would submit itself readily to vegetation, and bring the greatest profit to the maltster. By universal testimony, barley has always been regarded as most practically useful, although very considerable selection has been possible as regards variety. The foreign barleys of late years have carried off the palm, partly on account of their vigorous vegetative capacity, and partly *because* their nitrogenous constituent has not apparently been altered in type by the over-use of artificial ammoniacal manures. The thinner descriptions have not been much in demand, the old duty-charge having handicapped them severely; but recently there has been

Diastatic descriptions.

some talk of a superior diastatic capacity attaching to such varieties as Chilian, Algerian, Egyptian, and Danubian—this, and their undoubted buoyancy leading to a very fair demand.

All these considerations are, to a certain extent, upset by the removal of duty from malt to finished beer, and we have now simply to concern ourselves with the varieties of grain that will yield us good malt, and the combinations that will exempt us from surcharges, and give us that description of wort that will not only undergo vigorous fermentation, but yield us a beer of desirable character.

We may firstly consider, then, the question of malting, and those cereals that submit themselves to vegetative influences with the greatest success. Malting.

Why do we subject grain to this artificial growth? I answer, without hesitation, in order to convert insoluble azotised matter into its soluble variety; in order to create that diastatic capacity upon which the brewer depends in his mashing operations; to bring the grain by kiln drying into a condition for storage, and communicate those empyreumatic bodies that are so influential in reference to the flavour and stability of the finished beer. At the same time that vegetation modifies the albuminous bodies, we have a partial change in those of starchy type (in the sense that no formation of sugar results), so that their after-hydration into "dextrin" and "maltose" during the mashing process is comparatively easy. Now, there is no doubt that diastatic capacity depends altogether upon the extent and perfection of growth, and, as a natural consequence, the better malts correspond with the barleys that are the more readily modified by vegetative influences, barleys that do credit to the maltster, and submit themselves as malt the more satisfactorily to our simple infusion method of mash.

English and foreign barley.

I am bound to say that English barleys are frequently heavily handicapped. Not only does much of it come off heavy land, leading to a thick exterior husk, and a kernel highly nitrogenous in constituent proportion, but so unfortunate have been the climatic conditions of late years, that much of the grain harvested has either never been stacked and sweated, or stacked in such faulty condition, that the after germination has been seriously impeded; and thus the Saale, Canadian, French, and Californian barleys grown upon lighter soils, favoured by more genial atmospheric conditions, and free from those peculiar nitrogenous bodies that are apparently allied, in the case of English-grown grain, with the use of excessive amounts of rich artificial manures, have been in favour with those brewers who select material, not so much in reference to price, as with a view to the character of malt it will give, and the quality of beer such malt will eventually produce.

Sweating.

The kind of artificial sweating on kiln, at a temperature of 100° to 120° Fah., has, no doubt, the capacity of rendering many barleys out of condition more suited for malting purposes; it takes the place, apparently, of the "sweat" in stack, enlivens the vital germ, ensures equal growth, vastly improves colour, and is a process that enables English barleys to compete more successfully with those grown under climatic conditions, not often so disastrous as those experienced by our English farmers.

Incentive to restriction of growth.

There is one point worthy of notice which is more or less in direct connection with the recent alteration in fiscal regulations, for while in the time of the old malt duty it was absolutely essential for a maltster to promote vegetation in order to obtain as large an *increase* percentage as possible, such inducement no longer exists, and as there is an absurd cry by brewers for malt naturally weighing 42 lbs. per bushel (the Excise standard), there is a positive incentive to maltsters to so restrict growth or intensity of kiln-drying temperature, as to arrive at the weight referred to.

Nothing, of course, could exceed the absurdity of such a cry, as it leads at once to inferior quality of material, since faulty growth is not only serious in reference to the resulting deficiency in diastatic capacity, but we fail to secure the removal of objectionable nitrogenous matters in the form of rootlet, or to render soluble those types that should afterwards act as the alimentary food of yeast; while the starchy bodies, unmodified, are so baked by the after kiln heats, as to be entirely untouched during any mere infusion method of mash. If we understand, then, the differences that distinguish diverse varieties of barley, and the way in which they influence our results during mashing and fermentation, we shall estimate aright the statements of those authorities who argue that percentages of raw grain may be used without addition to existing mashing plant! We know the result that has attended the employment of English barley malt with its 15 to 20, or even 30, per cent. of idle corns in our infusion mash tuns. If we cannot work such grain successfully with our present plant, how can we possibly introduce a percentage of raw meal? The statement is absurd on the face of it, although, as I shall prove presently, raw grain can be used,

Raw grain use.

and, indeed, is used, with profit and credit to the brewer.

Selection of grain for malting.

No matter, then, whether we are bent upon using an admixture of raw meal or no, we must still select those varieties for malting that, in so many words, vegetate successfully and yield a malt that will enable the brewer to steer clear of surcharges on material, and procure a wort that will ferment well and, as beer, satisfy his trade demands. I can thus ignore wheat, maize, rice, and oats, as cereals that could be advantageously malted, and say with certainty that barley of home or foreign growth yields us, without doubt, the more satisfactory results. The kind of barley is soon determined. We may use varieties to give us malt either diastatic or buoyant, but in view of fiscal regulations, in this sense alone, when intermixed with grain rich in extractive matter.

Stock beers.

For stock or keeping beers, we must malt those descriptions of barley which will vegetate well, and, when finished, prove rich in diastatic capacity, possessing also a well-balanced nitrogenous percentage in soluble form; finally, in reference to wheat, maize, rice, and oats, let us employ such materials, or their meal portion, *as meal*, under proper conditions of working, or leave them to the manufacturer of the saccharine substitutes for malt, who will determine their value in their extract-yielding capacity, remove their injurious constituents (if he does not stint his charcoal filtration), and supply us in result with a pure saccharine, which we can value from a strictly brewing point of view, a test which is sufficiently severe in reference to some of the specimens sold at the present time.

The maltster may now steep, couch, and vegetate his grain just as he thinks fit. There is no Excise officer to impede his operations; no longer any harsh Excise laws to hamper his system. He may now determine for himself the advantages of a long steep and the early aëration of young floor (the couch being a vessel of the past), so as to prevent that heating in the primary stage which invariably leads to a vitrified condition of constituents. He may supply sprinkling water when such is requisite, and he may now vegetate his floors upon sound theoretical principles, carefully carried out, without any fear of infringing fiscal regulations. We may, I think, look for general improvement in the character of malt—less mould, more perfect growth, and the employment of the better classes of barley—as one result of the abolition of the Malt Duty; since, if raw grain come into use, it is evident that the malt employed with it to supply the essential diastase must be of exceptionally superior quality; while the system of surcharges on malted grain yielding less than the standard extract of 82 saccharometer pounds per 336 lbs. practically handicaps the thinner varieties, excepting under the conditions previously named.

Restrictions on malting removed.

It is not my intention to enter into the practical details of malting. I leave that to others; but I fancy myself that much may be done in the way of aëration during germination at critical stages of the growth, as, for instance, after the grain has been drained for some twenty-four hours: that much of the moulding of cut and damaged corns—a mould which grows apace—may be prevented by the judicious use of calcic bisulphite: and that we may often arrive at friability and distinctiveness of flavour by skilful arrangement of temperature and "*withering*" during

Calcic bisulphite.

"Withering."

the later stages of the growth and systematic regularity of heats during "drying off." There is no doubt that a great change takes place during "kiln drying"—a change impossible to fathom, but one that gives a character to the grain that could never be acquired if the mere idea of the maltster was to evaporate the moisture, so putting an end to vegetation, at the same time bringing the grain into a condition for storing.

Kiln drying.

Kiln drying is a species of cooking. The heating rays of a coke or coal fire saturate our malt or drying grain with the products of their combustion, which are antiseptic and preservative, and directly give rise to those empyreumatic products which are of such importance in reference to the after palate flavour of beer.

Continental methods.

If we hear of Continental malt dried indirectly by hot air or steam heat, we must remember that the Continental brewer has a natural preservative influence in the shape of cold, which the English brewer lacks; and so long as we have to attain in England stability by the present means, we must not ignore the aid we receive when our malt has been carefully submitted to a somewhat prolonged, and finally intense, application of direct fire-heat.

Slackness.

Malt suffers much by exposure to atmospheric influences. Not only does it absorb moisture—one of its constituents never remaining inactive for long in the presence of such moisture—but our grain becomes coated with aërial dust, facts which, in great measure, account, I think, for some of the difficulties experienced by brewers during the spring, summer, and autumn months. Slack malt is indeed the cause of much unsound beer; this being often evidenced by a greyness of hue, apparently resulting from the stubborn suspension of a variety of small cell life. Slackness means, I presume, the presence of an excessive moisture percentage, and, under the influence of this, the azotised constituents soon drift into a very abnormal or diseased condition, and become unsuited to act as a support or aliment of the ferment we afterwards cultivate. Re-drying stops for a time the action specified, but does not restore the character of the nitrogenous bodies; and, in view of these possible changes in the constitution of malt, we should, at any rate, act wisely by paying more attention to storage and rapid transit of grain if shipped by rail, so as to keep down the moisture percentage to a normal standard. To sum up, then, we submit grain to the malting process, not because we are any longer obliged to do so by any fiscal law, but, firstly, to create that diastatic capacity we afterwards rely upon in our mashing operations—that is, to develop this capacity by converting one type of insoluble albuminous matter into its soluble form endowed with a new power—secondly, to render other types of nitrogen compounds suitable to act as yeast nutriment, to remove others in the form of rootlet —we know how advantageous a removal this is by our practical experience; and—by the influence of the growth leading to these results—to modify the other constituents of the grain, so as to render them easy of after conversion in the mash tun. By the after "drying off," we not only *fix*, as it may be expressed, the constitution of the grain, but bring it into storage condition, while forming those flavouring matters which are so influential as regards the after taste and stability of beer, in spite of the assertions

Objects of malting.

of M. Pasteur, to which I shall devote myself under the heading Fermentation.

Raw grain.

For some years raw grain has been indirectly used by brewers, not only when they have been employing so-called "malt," with a very large percentage of practically unmodified grain existing, but in the form of those saccharine and glucose compounds we are so accustomed to, the conversion of their starchy constituents being brought about under the influence of acid as distinct from the brewer's diastatic method; but I shall touch in detail upon this part of my subject, of course, in the chapter on Mashing.

Wheat.

There are many varieties of raw grain—wheat, maize, barley, and rice being quite commonly employed, the question of superiority turning more or less upon a consideration of the influence that each exerts upon the after-growth of yeast in a wort produced from a mixture of raw grain and malt. As is well known, maize in its crude condition yields a very considerable proportion of oil. Whether this is objectionable or no it is not easy to determine, since opinion varies very considerably, but there are many varieties of maize in the market entirely free from this defect, if it be one. It will astonish no one to hear that barley, properly kiln-dried, is about the most suitable description of raw material. A word of reference is due to those torrefied varieties of raw grain that are said to require no special treatment prior to mashing, the intense heat to which they have been subjected having practically modified the otherwise insoluble starch; but my opinion on the whole subject of raw grain use centres in a very simple observation. If it be merely a question of starch conversion, the use of 50 or 60 per cent. of raw material is perhaps possible, but so long as brewers have to study perfectly

Maize.

Barley.
Prepared meal.

healthy fermentation and yeast reproduction, its employment as a substitute for malt will be governed by our success as brewers, not only in the selection of the raw grain most advisable, but in the formation from that material of fermentable products, and of those digested types of nitrogen constituents that are absolutely essential to healthy yeast growth. If torrification of raw material practically peptonises the albuminous constituents, well and good, but I myself strongly adhere to the opinion that the formation of peptonic bodies is never brought about by such an agency. It is impossible to say much more cn this subject, for enlarge as much as we may we invariably come face to face with the two conditions enumerated. Peptones.

Methods of raw grain use.

My readers will remember that there are two distinct methods of raw grain use—the adoption by brewers of the saccharine manufacturers' process, that being indeed a suggestion of M. Manbré, and the diastatic process that the brewer relies upon when mashing malt alone, either employing the raw grain in a crude state, partially purified by removal of germ and husk, as by the process of Mr. Blair-Robertson, submitting such meal to a preparatory gelatinisation in a primary mashing vessel, or mixing the torrefied material, as supplied by Messrs. Gillman and Spencer and Messrs. Beanes, along with his malt.

Objections to raw grain use.

To sum up, then. Employed beyond a certain limit we commence, as I may say, a process of starvation, our yeast plant suffers, and, in result, the flavour and general character of our beer alters also. The old idea, that a bright wort could not be obtained, that the resulting beer would always be of milky hue, is a visionary defect, so long as the mashing system is perfect. The real danger of using raw grain, indeed, centres either in our overtaxing the diastatic capacity of our malt, or diminishing too much the nitrogenous percentage in our wort. If we want advice upon a subject of this kind, we may well ask it of our Continental friends, who have had for long the liberty of using unmalted material, and who have discovered by practical experience the thread of the theoretical conditions I have been enlarging upon. While I am personally certain that raw meal *will* come into use, *and may be employed successfully*, I am equally certain that its use will be strictly limited, and that if brewers wildly embark in the attempt to utilise it without proper knowledge of its influence and the necessary treatment to which it must be subjected, difficulty and disaster will alone follow. What this proper treatment is will appear in my chapter on Mashing; it would be premature to speak of it in greater detail here.

Sugar as a malt substitute.

I now come to sugars—crude and invert—and saccharines prepared from starch-yielding substances. They form a class of most interesting materials, and are used in enormous quantities at the present day, although their employment is regulated by one of the same considerations that I have enlarged upon in the previous paragraph, as controlling the use of raw meal; the necessity, in short, of not starving out in any degree the delicate yeast plant, that we have to cultivate in our operations.

Cane sugar.

The ordinary cane sugars, being very impure, are unfit for use in cases where we require stability of beer; while the refined descriptions are equally injurious in reference to yeast, in the sense that as cane sugar is entirely unfermentable, their inversion into a fermentable type invariably results at the expense of the yeast. This fact led to the artificial manufacture of invert sugar, in which acid takes the place of the soluble alterative plasma of the yeast cell, and the success which has followed such an attempt to render raw sugars fit for the brewer's purpose by simple artificial means is evidenced by the output of Messrs. Garton, Hill, and Co., and Messrs. Bostock and Co., of Liverpool, which amounts to many thousands of tons per annum; and I must say that for purity, perfection of inversion, and general flavour, this so-called "saccharum" is a most valuable malt substitute, a body of energetic fermentable capacity. Invert sugar.

The saccharines and glucose compounds are made from either starch-yielding substances—such as maize or rice—from dressed maize flour, or from potato starch. Sometimes the conversion of the starch is aided by pressure—that is, by elevation of the boiling point; but always under the influence of acid, and the exact type of saccharine substance resulting, depends, first, on the kind of material employed, whether whole grain, dressed meal, or extracted starch; secondly, on whether we induce hydration of the starch under the influence of acidulated liquor at a very high boiling temperature, or simply at that of a single atmosphere; thirdly, upon the consideration whether the influence of the acid be limited in point of time or no; fourthly, upon the perfection of the neutralisation, the removal of colour, final traces of saline matter and albuminous bodies by repeated charcoal filtration; and, finally, upon the success of the concentration process carried on either in vacuum pans or by passing the syrup over steam-heated cylinders. Saccharines and glucose compounds.

We thus have offered to us saccharines varying much in percentage composition, in flavour, colour, Varieties of saccharines.

and general value; some consisting almost entirely of glucose (grape sugar), ash and water; others, containing as well maltose (the sugar of malt), dextrin and albuminous matter. The reason for such variation is not difficult to explain, since my readers will remember that Mr. Cornelius O'Sullivan, in his paper on the "Manufacture of Dextrin-Maltose," clearly pointed out that the hydration influence of acid on starch varied in intensity according to pressure and time, and that we could, in short, convert starch completely into glucose, or, by limiting the action of the acid, into the so-called dextrin-maltose, closely resembling, by analysis, the combination of dextrin and maltose existing in brewers' wort. I am, I think, in no way unfair when I say that if we elect to employ a saccharine substitute for malt in preference to invert sugar, that which contains no free acid, albuminous matter, or excessive ash, is likely to prove the most profitable so long as its solution yield of extract is satisfactory. I do not care to say very much upon the dextrin constituent of these saccharines. Dextrin it may be, but whether it can take the place of the dextrin of malt extract is by no means a point easy of solution, and viewed in this special sense I do not think that any artificial combination of glucose, maltose, and dextrin can supplant, or yield a beer equalling that which contains alone the dry extract obtained from malt. These bodies are nevertheless of great service to the brewer in a variety of ways that we shall see more of as we progress, and it only remains now to refer for a moment to the moisture percentage. This, which often amounts to as much as 16 per cent., has *always* seriously handicapped these malt substitutes, when comparing the

Dextrin-Maltose.

Value of dextrin in saccharines.

Moisture percentages.

cost of saccharine extract with that of malt. Even more so, then, now, when the Excise deem that 28 lbs. will produce 0·5 barrel of standard beer. Such a yield is possible only in the case of a raw sugar, and no saccharine in the market is capable of giving it. I am therefore not surprised to hear that the Inland Revenue authorities have agreed to allow for moisture percentages in the saccharine compounds that are employed by brewers, in which case, so far as extract is concerned, they will run even good malt very close. The manufacturers of them are, again, very fond of asserting that, weight for weight, the extract obtained from a saccharine is more valuable than that of malt, as being capable of yielding *more alcohol*, since they are free from that 10 per cent. of albuminous matter normal to malt. I admit that when such substances are used for the purpose of *purifying* a wort, obtained through the extractive tendency of a soft water, the assertion has some weight, but not otherwise, since we should be rash to regard the nitrogenous constituents of our wort as in all cases useless or injurious; existing in excess they may be, but, if deficient, our yeast starves; while if in strictly normal quantity and quality, we secure, indirectly, by their aid, healthy fermentation and a beer that is stable in character, while full-bodied on the palate. I have never advised brewers to manufacture their own saccharines, the necessary plant being complex, and the absolute need for repeated charcoal filtration is an undoubted barrier; but I never could understand why they should not manufacture their own invert sugar, since they have done it often enough under the influence of their yeast plasma, and yet seem afraid of the far more efficient acid process which, put into operation with refined

Influence of albuminous matter.

sugar as a basis, would give them perfectly pure invert sugar without much trouble or additional plant. The special uses of these bodies will appear, as I have said, in subsequent chapters, as well as some directions for determining with ease not only their extract-yielding capacity, but their freedom from unconverted starch and other injurious or valueless constituents.

Hops.

My remarks, so far as hops are concerned, need not be lengthy. To the hop-flower we owe not only much of the flavour of beer, but also much of its stability and the tendency to spontaneous or artificial clarification, which favours such stability. We all know how hops vary in colour, condition and flavour, how much depends upon the exact constitution of the soil upon which they are grown, and upon the climatic influences that exist during their growth; and so important are these considerations that we see the prices of hops varying within very wide limits.

Valuable constituents.

Their value depends mainly upon their colour, freedom from leaf intermixture and mould, and their richness in that yellow powder (or technically, "condition") which covers the enclosed seeds, and contains the whole of the constituents which are of service to the brewer, and which, perfectly blended together, go far to constitute the distinctiveness of flavour spoken of. Herein we have the bitter principle, essential oil, resinous matter, and tannin, that become separated and dissolved in our wort, or its extract, during our boiling process, under the combined influence of the heat, and the solvent power of the extractive matter itself.

Proneness to oxidation.

Good, sound hops, cultivated on a rich soil, contain this (so-called) "condition," and consequently its component parts, in considerable quantity; but they are, unfortunately, most unstable in character, suffering readily from oxidation influences, so that it is no difficult matter to account for the depreciation that takes place in the value of hops by storage when exposed to air. We know how hop factors try and diminish this deterioration by pressing the hops; how others on the Continent pack them in air-tight cylinders (a very efficient but expensive method), and how the idea of extracting and packing the valuable constituents in the form of a thick syrup has found some favour in America—all this confirming the well-known fact that age in the case of the hop-flower means absolute worthlessness.

Packing in air-tight cylinders.

There are, of course, many degrees of value, a great deal depending upon variations in flavour, wide distinctions being apparent in this respect between hops cultivated in the Continental districts and those of home growth. The reason for this variation in value is evident to every brewer, and each has his own special view respecting the subject of flavour, some giving the preference to the mild Worcester hops, others to varieties of Farnhams, while many of our porter brewers are fond of the peculiar-flavoured Americans. If the blended oleaginous compound of bitter principles and resin constitutes in the case of hops a factor of importance, I can add that the tannic acid naturally yielded by hops to the solvent influence of wort, is one equally valuable, existing, indeed, in such exact proportion, that while aiding us, through its astringent and coagulating capacity in reference to nitrogen compounds, in bringing about the spontaneous and artificial clarification of beer, it does not, in the limited quantity stated, seriously interfere with the growth of the yeast cell, although, as can easily be imagined, such result would soon be seen if the proportion of hops used ever

Varieties of growth.

Tannic acid.

exceeded the normal quantity. The influence I speak of is apparent enough in the microscopical examination of yeast from heavily hopped beers, or those in which raw worts have been used, and if my readers wish for a striking example of the astringent and coagulating tendency of this acid, they cannot do better than add some in the form of solution (the dry acid itself is easily procured from any chemist) to a sample of bright beer. The result of such experiment would indicate to them the advantage of obtaining a tannic acid percentage in beer as resulting from the employment of hops, a percentage so suited to our requirement, and so short of the quantity that could damage our yeast or precipitate the nitrogenous constituents of wort.

Hop substitute.

It is, indeed, in the perfect blending of the component parts of hop extract as yielded by the hop-flower to worts during the boiling process, that we see its superiority over that obtained from the so-called substitutes, since they are utterly incapable of yielding that flavour which apparently only results from a perfect blending of oil, bitter principle, and resin. If there is nothing actually to condemn in the case of these substitutes, there is little to commend, and they can never take the place of hops to any serious extent. It is not difficult to understand this, for although there be many of them, artificial hop extracts, or the so-called substitutes, do not vary very much in composition. They one and all consist of a mere mixture of some bitter principle, such as that of quassia, chiretta, or gentian, mixed with resinous matter and a minute quantity of tannic acid.

Composition.

Before concluding my observations on this subject, I would ask brewers to keep the assertion made in my opening (viz., that the constituents of the *con-*

dition or lupulin give to hops their true value) constantly in mind, since it is on account of their being blended together in such perfect proportions that the use of hops is found to be so superior to that of substitutes, which, although nominally containing the same bodies, are but mere artificial imitations of a natural vegetable growth, and to remember that as one and all of these constituents suffer oxidation readily, so the hops laden with valuable "condition" deteriorate rapidly when exposed to air, and become, in the course of twelve or eighteen months, practically valueless. The chief defect of old hops is not only the disappearance of much of the volatile oil, but the conversion of a considerable quantity of it into a most unpleasant organic acid (valerianic), which, existing in beer, tends to communicate to it a flavour, *sui generis*, which can never be mistaken when once it has been tasted.

Deterioration by prolonged storage.

Valerianic acid.

It is of interest to note that the value of hops seemingly centres on percentage and condition of oleaginous constituent, and if this is so we can the more readily grasp why it is next to impossible to prepare any commendable artificial substitute. I am quite aware that lupulin has been manufactured, but in every case when such artificial material is exposed to the boiling temperature, it appears to undergo complete decomposition. To conclude these brief references to hops I may say that the "condition," or lupulin, constitutes something like 16 per cent. by weight of the entire bulk of hops, that something like 50 per cent. of the lupulin consists of resinous matter, and that it also contains 2 per cent. of volatile oil, 2 per cent. of tannin, and 10 per cent. of a bitter principle. I may refer my readers for much valuable information on the subject of narcotics

Composition of hops.

generally—a subject which embraces not only the question of hops, but that of tobacco, cocculus indicus, marsh ledum, clary, opium, hemp, betel-nut, coca and bearded darnel—to a most interesting and well-written work on "The Chemistry of Common Life," by Johnson, recently revised by Professor Church, and published by Blackwoods: this work not only including valuable essays on the subject of fermentation and distillation, starch conversion, and so forth, but dealing very fully with the one we are considering. Finally, good hops of any variety should have large cones, strobiles of a pale delicate yellow colour, slightly tinged at extremities, and when opened out the inclosed seeds should be found copiously covered with lupulin; there should be an entire absence of leaf, and the proportion of stem should be small, while this and the minute branches should be carefully examined microscopically for mould. Rubbed down between the hands, they should feel glutinous and oily, while the sample itself should appear tightly compressed. As for flavour, each judge has his own special proclivities, the majority preferring the "Goldings" of middle and East Kent; others the "white bines" from the Farnham district; while another section consider the finer descriptions of Worcester hops preferable for delicate-flavoured beers. The Mid-Kent and Sussex hops are by comparison altogether second rate, and even in the case of the better varieties of hop, their flavour depends very much upon exact character of soil and the skill of the hop farmer.

Characteristics of good hops.

CHAPTER IV.

THE CHEMICAL AGENTS USED IN MODERN BREWING, THEIR PRINCIPLES AND USES.

In coming to a consideration of this subject, I am anxious that what I write shall be so worded as to be easily understood by those who have but scanty knowledge of theoretical chemistry, and so explained as to diminish, if possible, the prejudice which undoubtedly prevails among a class, that may be described as old-fashioned brewers, against the use of any sort or kind of chemical agent in practical brewing. It is simply astonishing to think of the number of such bodies that have latterly come into use, and it is not very wide of the mark to say that two-thirds of them are employed directly or indirectly as preservative agents, a most striking fact, if we keep in mind the increasing difficulties in connection with brewing that have become more and more prominent the last few years.

Chemicals as preservatives.

Hostile critics would say that preservatives have spoiled the otherwise good beer; but in reality the objectionable saline bodies have been used to determine a certain stability of an otherwise rapidly deteriorating article, changeable in its nature on account of some mysterious alteration in the general character of its nitrogenous constituents.

I can easily run through the chemicals that are employed for mere cleaning purposes. I suppose they are known to almost every one; for instance, we have salt used to extract the sap of wood, ordinary calcic hydrate (*i.e.*, slaked lime) as a scouring agent, more frequently used, perhaps, in conjunction with chloride of lime, a body having distinct oxidation capacity, determining the destruction of moist impurities; potash, used either for the same purpose as salt or as a solvent for that deposit of azotised matter that collects in wort-mains, or, indeed, on any surface touched by wort or beer.

Cleansing agents.

Acids.

Then we have various acids, such as hydrochloric for dissolving saline deposits in mains, tannic acid for the prevention of hard saline scale in steam boilers, sulphuric for inducing sugar hydration if manufacturers of our own invert material, and tartaric, sulphurous, and commercial acetic acids for softening the gelatine we employ in artificial clarification of beer, technically termed "finings."

There is little or no difficulty in understanding the principles and uses of those enumerated; but it is altogether a different matter when we come to discuss the vast body of preservatives which are used in brewing. Let me see if I can make this subject perfectly plain. First of all, it has long been known that it is much easier to produce a stable beer with a hard water than with one deficient in definite well-known salts. Now the salts in question are certain sulphates and chlorides, and as the most efficient or influential of the sulphates—namely, gypsum—happens to be more or less insoluble, we have recently had soluble sulphates brought under our notice for water hardening, these being sulphates thrown out of solution, and existing, therefore, in moist condition. Such a process may be

Soluble sulphate of lime.

exampled thus: if we mix concentrated solutions of chloride of calcium and sulphate of soda together, we should have as result a precipitate of calcic sulphate and a supernatant fluid containing common salt. On the other hand, it is equally well known that it is impossible to produce full-palated black beer with hard waters, so it is quite a common practice at the present time to employ the much-maligned chemicals for hardening waters if deficient in saline character, for softening them if the reverse. This has been touched upon in my remarks on water, and I simply use it now as an opening to a very important point which immediately follows.

Sulphurous acid.

The use of sulphurous acid, free or combined, dates back for a great number of years, and it was employed by vintagers and sugar refiners for a very long time before it was ever thought of as a possible agent that might benefit the brewer. To Dr. Medlock belongs the honour, I believe, of first introducing the use of a sulphite as a preservative agent. Now the point I wish to impress upon my readers is that sulphites have two distinct actions. They directly prevent deterioration in wort or beer on account of their absolute poisonous influence on lactic ferments, while, what is of just as much importance, they indirectly facilitate stability by exercising apparently exactly the same power, possessed by the sulphates and chlorides referred to above, in the direction of determining the special kind or variety of nitrogen compounds extracted from the malt mashed. If this be understood, we can easily see why sulphurous acid and its varying compounds are suggested for use in mashing operations, why sulphurous acid is used by many people to transform the more or less valueless carbonate of lime existing in a brewing

Sulphites doubly preservative.

water into corresponding sulphite, and why the Edinburgh brewer, with a water laden with carbonates, finds it remarkably beneficial to add to it a proportion of Epsom salts or magnesic sulphate, which leads to the formation of gypsum and carbonate of magnesia. It will be understood that, so far, I am dealing with the sulphites as indirect agents of preservation, and I may point out that the state of combination of the sulphurous acid exercises, apparently, an enormous influence upon the efficacy of the compound. Let my readers think of the immense success that has hinged upon the use of the sulphite of soda that has been manufactured so long in an absolute state of purity by Messrs. Beanes and Co., and commonly called Beanes' "No. 1." Now, why should that have a superior influence to ordinary sulphite of lime? Simply and solely because its determining influence in the direction spoken of is more marked than in the case of the other sulphite.

Epsom salts.

Beanes' "No. 1" sulphite of soda.

So far, we see that if waters are deficient in gypsum, magnesium chloride, calcium chloride, or what not, it is not by adding these bodies that brewers always attempt to achieve the end in view, since artificial hardening of the kind named is by no means uniformly successful. On the other hand, brewers apparently are much more in favour of employing sulphurous acid, bisulphite of lime, "C. and D." solutions, Beanes' material, Powell's acid sulphite or hydrosulphite, as a simpler and far more efficient proceeding. Now, let me take up the direct preservative action of the sulphites, and let me refer, first of all, to the one that is most commonly known—viz., calcic bisulphite.

Sulphurous acid compounds.

It would clear away a great deal of misapprehension if I say at once what constitutes the exact physical

Bisulphite of lime.

difference between ordinary sulphites and what may be termed their acid or fluid varieties. The ordinary sulphites that brewers are accustomed to see, exist in the state of powder, but they are, one and all, soluble in an excess of acid, so that the *Bi*, or acid sulphites, are simply the ordinary sulphites of different bases, held in solution by the presence of an excess of acid. Every user, for instance, of the common bisulphite knows that if he paints it on woodwork, in a very short time a white deposit appears, that is, the excess of acid, being volatile, passes off, and leaves behind the insoluble neutral sulphite.

Now, the active poisonous principle is, no doubt, sulphurous acid, but it is most probable that a sulphite, even in direct preservative influence, exercises that capacity in a dual manner: first of all, it is a deoxidising agent, thereby preventing oxidation of beer constituents, and the revivification of inert yeast cells; and secondly, *per se*, it destroys lactic ferment. The reason that brewers employ it in basic combination seems to hinge upon the fact that, being volatile, there would constantly be danger of its escape from the beer; but fixed, on account of being in connection with lime, it always remains dormant until decomposed by any organic acid that may be forming; the liberated sulphurous acid at once destroying the organic ferment.

Destroys lactic ferments.

We naturally come next to the sulphite of magnesia —the "No. 2" of Beanes—which is a perfectly pure neutral compound, that can be used, in many instances, where an acid sulphite would undoubtedly lead to that *stink* of beer that is at certain times so prevalent, and which appears to depend upon the presence in beer of yeasty or crude albuminous matter, exercising a reducing action on free sulphurous acid. I may inci-

Sulphite of magnesia – Beanes' "No. 2."

dentally remark that I have recently been attacked for a suggestion made in an "Occasional Note," that the limited use of magnesia compounds in beer might be accounted for by the fact that magnesia salts generally led to certain unpleasant complications in the animal economy, and I am more than confirmed in this view by some very stringent remarks that have recently appeared in the *British Medical Journal* to the same effect.

Magnesic salts injurious.

We next have combinations of sulphites, such as the "C. and D." and the "*preservative*" of Messrs. Gillman and Spencer, the hydro-sulphite, and the so-called pure calcic-sulphite of other makers. Now, what are they? The "C. and D.," mentioned above, are simply two solutions of chloride of calcium and sulphite of soda, chloride of magnesium frequently being substituted for the lime salt, sulphite of potash for the soda one. On mixing these bodies a mutual decomposition takes place, and we have in result chloride of sodium (common salt) and the neutral sulphite of lime, previously spoken of. Now, sulphite of lime is a so-called insoluble salt, but the contention of the makers of these two solutions would be that by bringing a limited quantity of the fluids named into contact, spread throughout the whole bulk of beer, that is, a half-pint in a barrel, the sulphite formed exists, on account of the extreme dilution and the superior solubility of recently precipitated compounds more or less dissolved, so neither causing cloudiness nor sinking as a deposit to the bottom of the cask. "The *preservative*," manufactured by the same makers, is simply a combination of pure calcic sulphite with common salt and calcic hydrate, the latter being used to diminish to a slight extent the acidity of the beer to which it may be added;

"C and D" composition.

"The Preservative" composition.

for although acid in beer is useful and absolutely essential to good quality, any excess, over and above what is normal, is apt to cause stubborn clarification—a point I shall discuss in detail when we come to the subject of fermentation.

There is not so much to say about the so-called restorative or neutralising agents. They must of necessity be either alkalies, alkaline earth salts, or pure specimens of the hydrates of the bases; and to my knowledge almost all of them have been tried by different experimenters. They are used for neutralising the excess of acid in an old beer, so that it may be blended off; but, as must be perfectly apparent, the process is not to be commended, since it is in no sense restorative. Altogether, it appears far easier to produce a sound beer than to satisfactorily bring into a drinkable condition one that has deteriorated; but I could hardly leave these various neutralising fluids entirely unmentioned. The normal acid of beer is lactic, and this forms a series of salts of very pronounced flavour, so that from this we can see why it is so difficult to say which particular neutraliser is best; while, if we elect to use any of them, we must carefully ascertain that they are of absolute purity, and only use them to an extent that will leave the acidity of the beer normal.

Neutralising agents.

Their use.

I have mentioned once or twice the word purity, and this is of special significance in reference to chemicals; for while pure sulphites give to beer no harmful taste, it is an entirely different matter when they are mixed up with impurities, such as hyposulphites, or, what is far more common, ordinary magnesic or limestone hydrates, with accompanying iron. It is very curious that, while it is perfectly possible to manufacture a pure sulphite of soda or magnesia, it is very difficult

Their purity essential.

indeed to arrive at the pure neutral calcic salt; and, however useful such commercial preparations may be that pass under the names of hydro-sulphite and mono-sulphite, they present the defect of non-absolute purity, although we may in justice say that there is a considerable variation in their composition, and that those containing 85 per cent. and upwards of absolute sulphite may often be used with very considerable advantage.

Leaving the sulphites, we now come to another class of preservative bodies, which directly prevent the development of diseased ferments, either by acting as distinct poisons or by their astringent influence coagulating the delicate organism which leads to so much deterioration of beer. We have salicylic acid, borax and its compounds, creosote and sanitas as examples of this class; while quinine, the bitter of the hop, and an endless number of alkaloids might be described as preservative agents also. An astringent body, such as tannic acid, boracic acid, or mere alum, acts as a preservative, no doubt, by coagulating not only the albuminous matter of the fluid, but hindering the development of ferments that are almost entirely composed of nitrogenous bodies, and, so far as compounds of borax are in question, they might be used with great advantage if they could only be prepared in proper form; in fact, there is little doubt that glycerine and borax would constitute a very useful preservative combination.

Other preservative bodies.

Then, again, we have various types of yeast food prepared, and, perhaps, that which most successfully answers the purpose is the one introduced by Dr. Moritz, although it is pretty evident that, as yeast is a very cheap bye-product, it would be sufficiently easy to

Dr. Moritz's yeast food.

calcine it, and so arrive at its absolute ash, which might then be dissolved in a sulphurous acid solution, and be often used with advantage. The main constituents of yeast ash consist of phosphates of lime, magnesia, and potash, and the yeast food mentioned above is practically a combination of these bodies dissolved in sulphurous acid. I can refer to the various enamels that are employed when discussing the question of plant; but before closing this chapter I may give one example of the immense benefit that sometimes results when theory is applied to practical operations, and how chemical knowledge can sometimes determine success in a case that is directly in connection with our subject.

Its composition.

In the chapter on water I referred to the influence of nitrates, and explained how much salts came to be present in brewing waters. It is not too much to say that when nitrates—*i.e.*, combinations of nitric acid with bases—exist in solution in any excess, difficulties in brewing generally present themselves, the extent of which seems to depend very much on the basic constitution of the salt. There is no doubt that the influence of a nitrate is dual. It acts not only as an oxidising agent, but as a salt, directly facilitating the development of certain objectionable types of ferments, and it is only latterly that a method has been suggested for successfully removing the nitric acid by chemical means. Now, it is perfectly obvious that the process referred to must be one of reduction, and I have previously mentioned that sulphites, or, more strictly speaking, sulphurous acid, has this reducing or deoxidising capacity, and I have found (maybe some one else discovered the fact long before) that a pure sodic sulphite is far more efficient than any other sulphurous acid combination in

Reduction of nitric acid.

Influence of sodic sulphite.

this special direction. I know of many cases where success in brewing with a nitric acid water has been rendered possible by the use of the acid sulphite; and, in order that this information may be of some practical value, let me suggest that any brewers who are suffering from cloudiness or non-stability of beer, should refer for a moment to the analysis of their brewing water, and see whether, among the saline constituents, any considerable quantity of nitrates appear, and, if so, let me advise them to see what they can accomplish in the direction of removal by the means suggested, keeping in mind that, as these sulphites more or less interfere with the development of ferment life generally, we must not only concern ourselves with the reduction of nitrates by their aid, but see that in using them we do not interfere with the proper growth of yeast.

Antipathy to chemicals.

I have mentioned in my opening that a natural antipathy exists to the employment of chemicals, and that this antipathy is apparent among brewers quite as much as among the consumers of beer; but they have, as a body, had to choose between two evils—the use of a chemical compound to induce stability, or, in the absence of preservative energy, to rest content with an acid, or, at all events, deteriorating beer. It seems to me that the aim of all should be to use that form of direct or indirect preservative that is the least objectionable in palate flavour, and which constitutes the lesser evil from a medicinal point of view when existing as a component part of the beer produced.

CHAPTER V.

BREWERY BUILDINGS AND PLANT ARRANGEMENTS.

The little that has to be said about the site for a brewery may be summed up in a very few words. If we desire to produce beers of special character, the brewery must be within reach of the natural water that enables us to accomplish this, for I know of no instance of artificial modification of water, excepting, perhaps, that at Shepton Mallet, which enables the brewer to accomplish with a manipulated water what naturally results when using one of distinct saline nature. In confirmation of this view one need only point to Dublin, Burton, and London, as examples of my meaning, since it will hardly be contended that any great demand exists at Burton for the beer produced there, and brewers have undoubtedly gravitated to that district simply because the water found there determines a certain distinctive character of beer. So, also, in London and Dublin, we see a definite palate flavour of black beer, a fulness and softness resulting from the use of abnormally soft or extractive waters, and, although I am far from saying that material, plant arrangements, and skill of operators has not much to do with the result, the broad fact stands out that, in order to produce beer of the kind named, the breweries must be not where the demand, but where the necessary water,

Beers of distinctive character.

Fulness produced by soft waters.

exists. On the other hand, there is no doubt that modern taste is in the direction of a pale, sweet, clean, and brilliant beer, and as such beer can be produced without a distinctive water, on lines which embrace use of sugar and the adoption of a medium fermentation system, and as water suitable for such system can be obtained in most of the large towns, we are seeing a slow revolution going on; the country brewers adjacent to centres of population rapidly increasing their output, while the breweries producing the characteristic beers above mentioned, are more or less at a standstill. It is easy to see how the use of finings has facilitated this result, placing soft-water brewers of pale beers on a competing basis, and, since their premises are situate in the centre of demand, their operations are not handicapped by excessive carriage charges, which in many instances render profit on shipment of beer next to impossible.

Drainage.

It is not too much to say that the old absolute necessity for perfection of drainage, and the selection of a site for a brewery where such could be the more easily obtained, no longer exists, since few brewers outside the chief brewing centres obtain water supply from their own wells; but as the waste products in a brewery putrefy readily, it is quite as well to see that the drainage is perfectly arranged; and I am not far wrong in the opinion that gradually increasing impurity of well waters will invariably result if the boreholes be situate in populous districts, in spite of all the precautions that may be taken respecting the drainage system adopted by local authorities. The significance of this remark in reference to brewing operations in London and Burton should not be lost on those who have the management of them.

So far as the absolute arrangement of buildings is concerned, I think it would be well if the modern brewer's engineer or architect could be induced to pay some slight attention to convenience in place of grandeur of appearance. There is far too much of the so-called gravitating principle, too many stairs, and the malt and hop departments are not kept sufficiently distinct. Convenient arrangement.

The malt and hop stores should be, by rights, in a separate building, standing over cellars; the malt portion divided into bins constructed in brickwork, lined with wood covered with tin or zinc, or of wood with the metal covering alone, such bins to be in connection with worms and elevators, so that the malt shot down into them from hoisting stage may be conveyed to mill-room as required, without any exposure to the atmosphere. The immense difference that is seen in malt so stored is well known to those having malt-rooms so constructed. Malt stores.

The hop-room is of equal importance; it should be absolutely dry and dark, a lining of wood covering all brickwork, and so arranged that entry to it is through a passage with double doors. In place of a gravitating brewery, it would be much simpler and better to erect a series of buildings, with as much perfection of levels as possible, without going to any great height; and as regards absolute internal arrangements, we shall understand more as we discuss the question of plant. Hop store

At the outset, we naturally come to the material used for the construction of plant, and it is a subject little understood either by brewery engineers or the Material for plant.

great majority of brewers. First of all, what are the facts regarding metals? Many are easily oxidised and rendered soluble—iron, lead, zinc, and in certain instances copper, being acted upon in this way: zinc and lead being perfectly unfit for use, and the others necessitating some care to prevent the formation spoken of. Tin, at one time supposed to be insoluble and stable, has now a different character, since it has been found that all commercial tin is more or less impure, and that when in contact with beer galvanic action takes place, effecting solution of the tin, and decomposition of the fluid. This contact of dissimilar metals in the case of tin, leading to the results mentioned, should be a warning to brewers against adopting any of those absurd combinations so frequently seen—lead patches, for instance, with copper nails, copper pipe supported on iron brackets, copper coils in iron boiling pans; and although one does not desire to make too great a point of galvanic influences or results, there is no doubt that in many cases it is the cause of much inferiority of taste that attaches itself to certain beers.

Galvanism.

Iron.

There is, I think, a great antipathy to iron; the ease with which it oxidises and its disastrous influences when existing in solution are sufficient ground for the objections named; but many brewers succeed well enough with iron water-tanks, grist-bins, mash-tuns, wort-boilers, and coolers, while I myself have seen iron fermenting vessels in more than one Continental brewery—the great necessity in all cases being cleanliness of surface, and coating, as far as possible, with a film of tannate.

Cast and wrought.

There are two varieties of iron, cast and wrought; the cast, with its silicate surface, seeming to resist oxidising tendencies longer than the other, although facilitating that peculiar dirty frothiness of head that is constantly seen in breweries where iron plant is in use, the dark deposit probably consisting of humate or tannate of iron. Copper is easily kept clean, and there is no doubt that it is the most suitable metal for the construction of brewery plant. Copper.

On the other hand, what can be said about wood? Broadly speaking, it consists of cellulose and albuminous matter, and, when moist and unprotected by vitality, is about the most unstable organic combination possible to imagine, the albuminous constituent soon promoting decay. If we add to this the fact that it is porous, and a perfect harbour for the deposit of wort and beer, it is easy to see that wood is open to serious objections; but, with all its faults, it is still preferable to metals, and, in a certain sense, to stone, slate, or glass. Our chief care should be in securing the least porous varieties, oak being far superior in this direction to the various kinds of pine (the red and white deals that are so commonly used), to rid them as a next step of all sappy matter by the extractive power of salt and steam, and then to see that all woody surfaces be kept absolutely clean; and, what is of equal importance, dry when out of use, unless this means after-leakage. It is usual nowadays to supplement this treatment with the use of bisulphite, which destroys the growth of surface mould, and, penetrating into the pores of the wood, prevents therein the deteriorating influence of the albuminous constituent. Wood. Care in selection of timber.

Seeing what the tendency of wood is, how it can decay and influence thereby the flavour of beer, it is not wonderful that suggestions have been made for lining wooden vessels with sheet copper with brazed Copper lining.

joints, or coating them with one of the several enamels that are so freely advertised, but my own opinion is that if proper wood be selected, and be kept absolutely clean, there is no necessity for such precautions.

Settling tanks.

As regards stone and slate, they answer admirably as materials for settling tanks, and, in certain instances, perhaps, for fermenting vessels; but, as they both have powerful radiating capacities, they are apt to cause a most unpleasant chilling, which *may* have somewhat marked influence on the clarification of beer fermented in stone or slate squares.

Summary.

To sum up, then, we may well adhere to iron or steel for the construction of water-tanks and liquor-heating backs; copper for our wort-boiling vessels, the false bottoms of our mash tuns and hop backs, the piping of our attemperators, refrigerators, and wort mains; to brass and gun-metal for our pumps and sluices; to wood as a material for our mash tuns, coolers, hop backs, and fermenting tuns; and to slate for settling tanks and yeast backs, falling back upon iron, if we like to run the risk, for mash tuns, hop backs, and coolers, bearing in mind that it is easier to avoid trouble than to keep clear of it when once courted.

Having briefly run through the materials used in the construction of brewery plant, I may now, in detail, describe the different forms that are ordinarily met with in English and Continental breweries, and my readers will see from my description that we are very far behind our foreign competitors in the adoption of plant arrangements that determine good quality of extract, to say nothing of after quality of beer. With

Mill room machinery.

reference to mill-room plant, I may leave the matter of exact arrangement of rollers, whether linked or friction, smooth or grooved, to brewery engineers; but as malt stands at the present time, and as a brewer's mashing process is strictly an infusion one, I may point out that any extreme disintegration of such grain is certain to lead to unpleasant results in the direction of deadness of mash and after difficulties respecting clarification of beer. On the other hand, it would be well for brewers to pay far more attention than they do to the absolute cleanliness of the malt that they grind or crush—that is, taking more care respecting removal of rootlet, and brushing off dust and dirt that has accumulated on the husks.

Grist hoppers.

The arrangement of grist hoppers is also a matter of importance, since the regular flow of mash through a mashing machine depends upon the exact form of hopper, and there can be no two opinions as to that which is preferable. To my view a cone-shaped hopper, feeding into mixing-machine through short worm, would put an end to those flushing and irregular mashes that are so constantly seen, grist, especially that of slack malt, having a great tendency to compress, and become set in bin. As for mixing-machines, their name is almost legion, but I shall do no injustice if I remark that a good Steele's is about as perfect a form of mixer as a brewer can desire. In cases where steam power is not available, it is perfectly possible to work a small Steele by hand, but if a strictly automatic arrangement be preferred, I may simply say that there is little to choose between those that are so extensively advertised.

Mashing machines.

The next portion of plant that we come to is naturally the mash-tun, and on this point I must go into some detail. Up to a very recent period the mash-tun has been regarded as a mere filtration vessel—in fact, it is considered so still by the great majority of

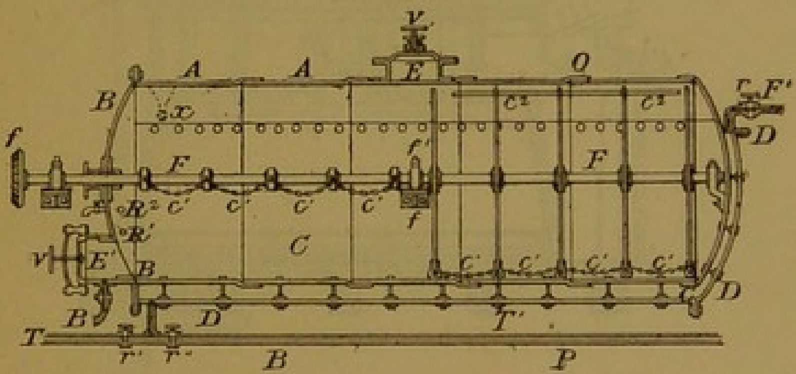
Mash-tuns.

English brewers. What a fallacy this is may be seen from the endless disasters that are experienced, and I may truly say that in place of being the mere filtration vessel, the mash-tun is the one in which the brewer has to complete the operations of the maltster, which, for well-known reasons, have been more or less inefficiently accomplished during the last few years. I do not wish to anticipate anything that I shall have to say on the subject of mashing, but I may remark that the simple mash-tun, without internal fittings of any kind, connected with an outside mixer, should be, in view of the general character of malt, a mere vessel of the past, and that English brewers should look a little abroad, and fit up such plant as might enable them the more successfully to combat with the imperfections of malt that I shall have to deal with presently.

Continental mash-tuns.

Now, what are the methods adopted on the Continent? In so many words, Continental brewers either carry on mashing in an infusion vessel, steam jacketed, and fitted with powerful internal machinery, a vessel so constructed that pressure can be applied at will, so that malt during the mashing process can be submitted to any range of temperature thought necessary, or in an ordinary open one fitted with rake machinery, and connected to centrifugal pumps, so that portions of the mash may be transferred to small coppers, boiled, and again brought back and intermixed with the remainder left behind, the idea in this instance being to arrive at all the benefits of stewing, while accomplishing complete starch conversion, without facilitating the creation of that extreme saccharine character that constitutes the great defect of English beers. In other words, no Continental brewer dreams of mixing grist and liquor to attain a standard initial heat, afterwards drawing off the resulting wort: he takes the malt for what it is, strives to gelatinise the whole of its starch, and by coaxing its low diastatic capacity, endeavours by certain variations of temperature, concerning which we English brewers know but little, to obtain a perfect extract.

The plant that he uses is simplicity itself, and an English brewer who would erect a mash tun fitted with water jacket, a good false bottom of the Cave or Lawrence pattern, simple rake or the plough rake machinery of Cave, and suitable underlet arrangements, would then have something more than a filtration vessel, one in which he could manipulate malt,



LACAMBRE CONVERTER.*

and arrive at all the results that a Continental brewer does with his Lacambre cylinder.

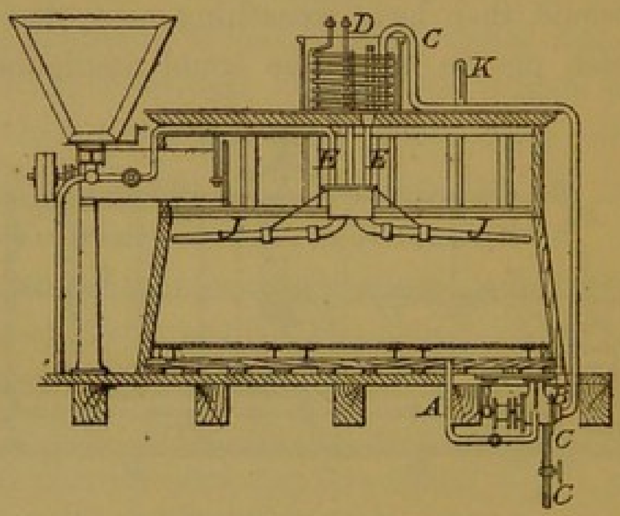
There are several modifications of the ordinary brewer's mashing process as facilitated by slight alteration in plant, worthy of notice, one being suggested by a Mr. Crockford some years ago, another by a Mr. Davenport quite recently, and a third by

Wort circulation.

* *AA*, cylindrical copper vessel; *BB*, end of same; *CC*, bottom of same; *DD*, iron steam jacket; *E*, manhole, with pressure valve *V*; *E'*, second manhole, and valve *V*; *F*, internal masher, with rakes and chains, *C*, to sweep the bottom; *R* & *R'*, racking taps; *T*, condensation pipe to boiler; *T'* & *T''*, pipe to hot water backs, for general purposes of brewery.

Messrs. Wilson, all depending upon the principle of wort circulation, and possible variation of mash temperature by means of this. As my readers will observe, such circulation amounts to motion without disturbance, motion undoubtedly having a very important bearing on chemical changes.

I give an illustration of a mash tun fitted according to Mr. Crockford's ideas, and by turning to the advertisement sheets of the *Brewers' Journal*, we shall find a drawing of the arrangement suggested



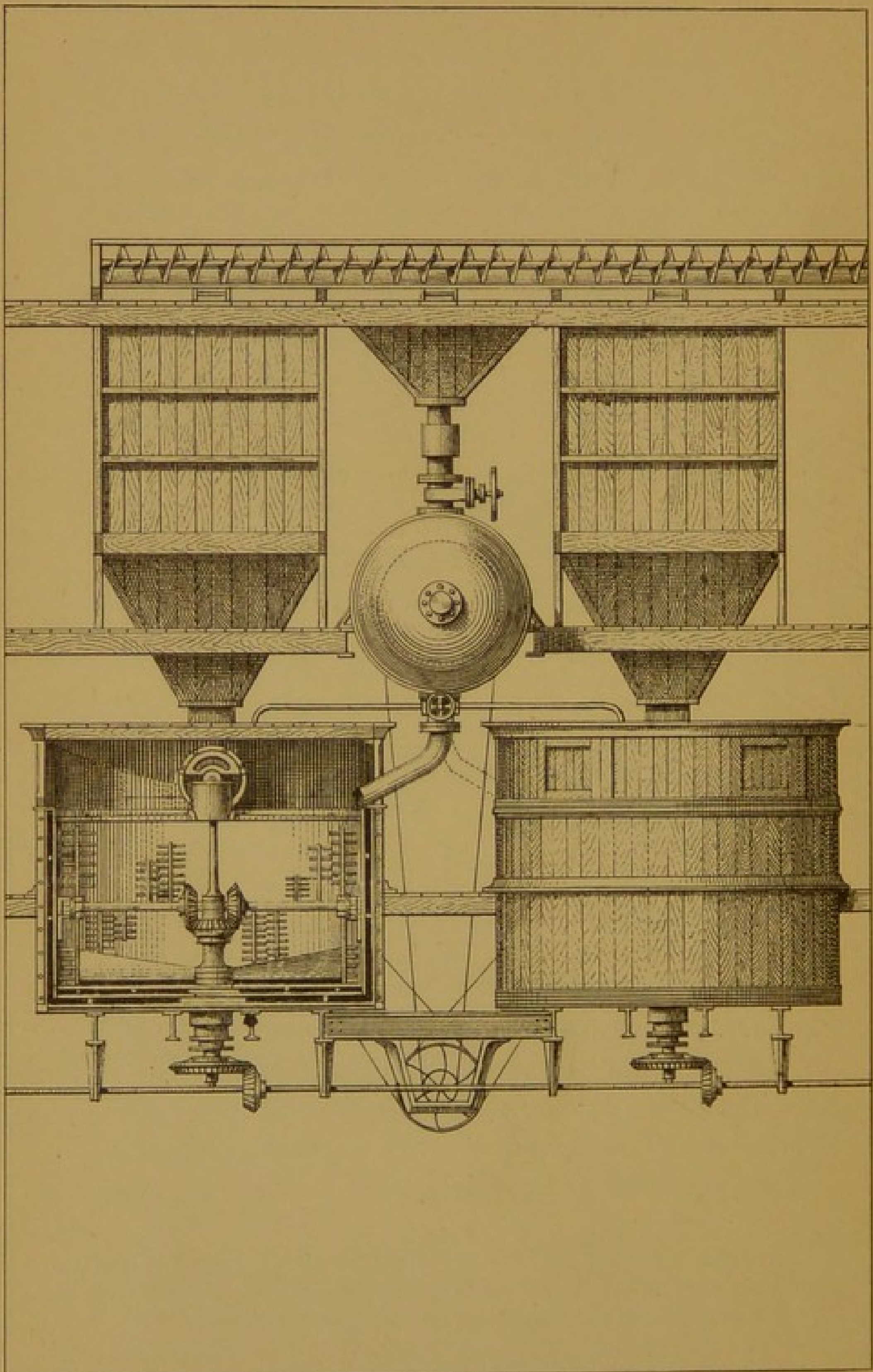
CROCKFORD'S CIRCULATING ARRANGEMENT.*

by Mr. Davenport, which hinges, as will be seen, on the principle of Hamper's fountain.

The interleaved plates will be readily understood, being almost self-descriptive. First we have front and side views of a mash tun room properly fitted, as I contend, for the treatment of inferior malt, or

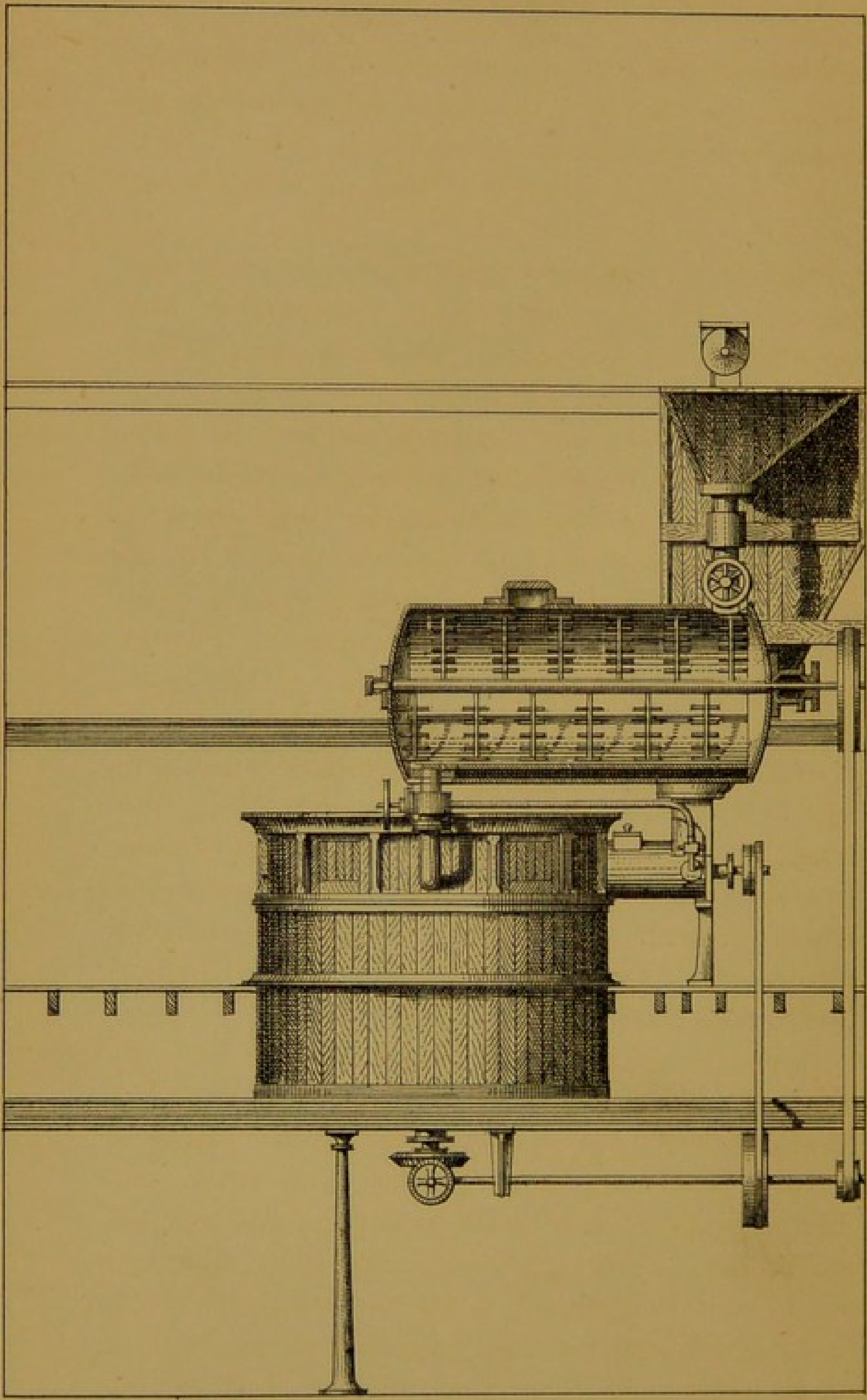
* *A*, pipe through which the wort is drawn by the action of pump *B*; *B*, centrifugal pump; *C*, pipe through which the wort is passed from *A* to *D*; *D*, receiver fitted with steam coil; *E*, pipe from *D* to sparger *JJ*; *F*, pipe for supplying hot water to sparger; *JJ*, sparger by which the heated wort from *D* is sparged over goods; *K*, thermometer.

PLATE II.



DECOCTION MASHING PLANT.

FRONT VIEW.



DECOCTION MASHING PLANT.
SIDE VIEW.

mixtures of raw and vegetated material. We see in plates ii. and iii. a Lacambre cylinder, fed by an automatic mixer, connected either to Steele's machine, commanding mash tun below, or to mash tun direct.

Plate No. iv. shows a mash tun room, fitted with decoction plant, *i.e.*, mash tuns in connection with centrifugal pump and coppers above, the boiled mash passing back through sluice main.

Intermediate between the mash tun and the vessel in which the wort is boiled we have the underback, and, what is of very considerable importance, a tank commanding coppers, generally termed a retention vessel, fitted like the underback with a steam coil, and used for the purpose of equalising gravities of different copper lengths, by means of the retention therein of a definite portion of strong runnings at such a temperature that their diastatic constituent may be kept in a state of activity; such strong wort being afterwards distributed over the several boiling lengths taken. This vessel is the more essential in English breweries where it is customary to deal with inferior malt, and divide the entire length obtained into several distinct worts. Retention vessel.

I now come to the boiling vessel, and have no word of commendation for that *abortion* termed a steam boiling back, such vessel generally being of circular wooden construction, fitted with steam coil. Let me settle off at once the problem of steam versus fire boiling. There is, I think, no particular difficulty; for it must be apparent to every one that the actual cooking and caramelising influences of steam heat must be very far below those of fire. I do not for a moment say that steam cannot prove effectual; but Steam boiling.

what I do assert is that we may have such a combination of circumstances—a variety of water, a faulty malt, a large and inferior extract, that requires far more extreme cooking to fit it for perfect fermentation than mere steam heat is ever able to accomplish. Then, again, steam heating arrangements are often badly fitted; the question of pressure is neglected, condensation in coils is allowed, and the coils themselves are frequently placed far above the bottom of the boiling vessel. It is not difficult to understand why no brewers ever experienced the slightest practical advantage from substituting steam for fire heat, while many have found for themselves that where success was unattainable with steam as the heating agency, it became possible at once on erecting an ordinary fire copper. If brewers *will* go in for steam, let them have jacketed coppers, and employ steam at a high pressure, taking steps for preventing the slightest condensation in jacket. That is all I can say; but, where possible, let them, by all means, adopt well-set 100-barrel fire coppers, if they be brewers of pale beers; as large and deep as they like, if they are producers of porter, giving room for that regular "roll" and "jump" of wort during ebullition that means so much.

Pressure and condensation in coils.

Domes and fountains.

I am often asked what my ideas are respecting domes, fountains, and so forth, and I confess that my old-fashioned opinion is that there is nothing so good as an open copper, with plenty of head room, and a man in charge with light mash oar to prevent any boiling over. Fountains and domes are all very well, but they frequently lead to over-aëration and excessive disintegration of hops, and as conditions of brewing vary so widely, it is quite as well in a treatise of this kind to advise brewers to keep on the safe side in matters of plant arrangement. Coppers are frequently much injured by the practice of dissolving in them solid saccharines, and by turning out wort while flues are still red-hot. Sugar cages should by rights be suspended over coppers in breweries where saccharines are employed, and it is a very good plan also to have steam coils fitted even to fire coppers, so that fires may be withdrawn thirty or forty minutes prior to turning out, ebullition being continued by steam heat. Sugar cages.

As regards open and closed coppers, with or without machinery arranged to prevent subsidence of hops, I think it is a question that merely concerns the large producers of black beer in London and Dublin, who employ immense boiling vessels, and who certainly attain a distinctiveness of flavour by boiling under pressure. In some instances, especially when dealing with saline waters, it is advisable, and perhaps economical, to boil hops a second time, in which case it facilitates matters to erect hop elevators between hop back and coppers; but this re-boiling of hops is only customary when making return worts or where the brewing water is of strictly saline character. A modern hop back should be a circular copper vessel, fitted with false bottom and sparger, with a central air shaft, to permit of the easy escape of air from under-side of false bottom on wort being "turned out." Of course, a square or round wooden vessel answers, from one point of view, just as well; but the one named is a modern improvement, that should attract notice. There has recently been a tendency to do away with coolers, and all I can say is that such an idea proves want of knowledge on the part of brewers abolishing a portion of plant that facilitates certain very beneficial alterations

Closed and open coppers.

Re-boiling of hops.

Hop backs and coolers.

in wort composition, alterations accomplished under the influence of oxygen, taken into combination with wort extract at a high temperature. There is no doubt whatever that an ordinary wort is much improved by exposure to the air in shallow bulk at high temperatures, ranging, say, from 212° downwards to 160°.

Refrigerators.

We next come to refrigerating machines, and I can divide them into two classes: the first, those in which we effect cooling by means of natural water; the second, those in which we bring about reduction of temperature by promoting physical alteration in the state of the cooling agent. As regards the ordinary refrigerators, the vertical cooling machines of Lawrence and Morton stand pre-eminently first as powerful and economical in reference to the consumption of water; they require keeping *internally* clean by occasional treatment with weak acid, and *externally* so by frequent scouring with dilute potash, clay, or, what is frequently a substitute, iron filings, or finely-sifted ashes.

Cleaning.

Continental cooling machines.

With reference to the second class of machines, they are more common in hot countries, or where cold is utilised as the preservative agency, than in England. This is not to be wondered at, since they are of necessity machines of complex arrangement, very costly as a first charge, and in after working even more so. They one and all depend upon the main principle that if the physical state or condition of a body be altered, heat is either liberated or rendered latent; that is, if we compress air heat is liberated; and if we cool it while compressed, and again allow it to expand, heat is rendered latent by the expanding air taking up the exact quantity which was set free on compression. This, for example, is the principle upon which the Windhausen cooling machines of Continental brewers are constructed. Again, if ether, which, as my readers know, is a very volatile liquid, be caused to evaporate under the influence of a vacuum, created by means of an air pump, heat is rendered latent to enable the fluid ether to exist as a vapour; and if warm liquor be passing through pipes arranged as a coil in the ether tank, the temperature of this liquor is, as a consequence, reduced. The ether is not wasted, of course, but condensed, and passed back again to the store tank. This principle is adopted in the machines of Siddeley and Co., of Liverpool; and Siebe and West, of London. The machine of Reece is equally simple in principle, and far more so in arrangement than the others, ammonia solution being boiled, and the pure ammonia condensed by its own pressure in a separate vessel. This concentrated ammonia, being extremely volatile, is then used exactly in the same way as the ether above mentioned, for reducing the temperature of water that may be required for cooling purposes; while it is perfectly evident that one and all may be employed in the manufacture of ice, if that be required. Quite recently M. Saladin, the inventor of one of the pneumatic methods of malting, which depend upon a supply of air artificially cooled, has brought out an apparatus for reducing the temperature of air under the influence of evaporation. So far as I can remember, the machine is of semi-cylindrical form, containing a revolving paddle, to which flannel or canvas is attached, a stream of cold water running under bottom side. As the paddle revolves the cloths dip into the water, and evaporation rapidly proceeding from their surface, such air as may be blown through the cylinder by means of a fan is cooled down considerably, and, at the same time, more or less saturated with moisture. The

Ether and ammonia machines.

M. Saladin's air cooling machine.

principle is sufficiently old, but the application of it is both novel and economically practical. M. Saladin employs it for his pneumatic malting, but it is easy to see that it might be applied to several uses in the brewery.

I now come to the fermenting portion of a brewer's plant, and must deal with collecting vessels, open and closed, stone squares, the question of shallow or deep skimming vessels, aëration, and rousing machinery, in some detail.

As far as the first-named vessels are concerned, the chief necessity, perhaps, is to see that they are well placed for drainage and accurately gauged, since it must be remembered that the collecting vessel dip is practically the basis for duty charge. At one time it was customary for brewers to be very much in favour of closed fermenting plant, the idea being that exposure of wort or beer to the atmosphere during or on completion of fermentation, rendered oxidation of alcohol possible if not altogether probable, and as a consequence of this brewers were in the habit of keeping an atmosphere highly charged with carbonic acid in contact with their worts during fermentation, by having fermenting vessels with a considerable amount of headroom above beer level, some, indeed, being entirely closed.

Old view respecting closed tuns.

Since Pasteur wrote his work on Fermentation, this view has altogether collapsed, and, if closed fermenting squares or rounds are used at all, brewers are very careful to pump in a sufficiency of air, and to expel carbonic acid at certain intervals. In a brewery where the union or puncheon system is in operation, we find simply collecting and cleansing plant; but in skimming breweries, on the other hand, we generally have three series—collecting, skimming, and settling vessels: and of late years I have noticed with pleasure that brewers

Collecting, skimming, and settling vessels.

have sensibly adopted the plan of avoiding all great depth of squares intended for skimming or settling in. There are two influences in operation towards the completion of fermentation—surface attraction and surface aëration,—and there is no doubt that a shallow vessel with a beer depth of some three feet brings into play both the influences named, and by their aid directly facilitates cleanness and spontaneous clarification of beer. As for the metal fittings in these vessels, I may remark that we are apt to have far too many, and the circular coils of attemperating piping in the centre of a tun, with brass parachute pipe passing down a centre line, forcibly reminds one of a Leyden jar arrangement, and in many instances seems to be one.*

Galvanic influences.

Stone squares.

The stone square, if not a vessel of the past, is still one that north-country brewers would gladly get rid of if they could. The original idea was remarkably good, stone was cheap, was easily kept clean, and there was no tendency towards surface acidity, while the water jacket arrangement enabled the brewer to regulate rise and reduction of temperature to a nicety. The upper back, with its manhole opening, not only prevented any exposure of beer to the air, but itself acted as a store for the yeast outcrops, and at the time when beers tended more than they do at present to spontaneous brightness, these vessels, which answered for collecting, fermenting,

Their bearing upon flavour of beer.

* LEYDEN JAR.

A thin glass jar, coated on both sides with tinfoil; a wire, terminating with a metallic knob, communicates with the internal coating. Charging the interior of the jar with positive electricity, a similar negative charge accumulates on outer coating, both being discharged by connecting inner and outer surfaces. In the parachute and attemperating arrangement spoken of, the parachute pipe would be the inner coat, the attemperating coils the outer, and the layer of beer between, the intervening glass.

cleansing, and settling purposes, gave a beer that had a full home-brewed flavour and an amount of condition that is never seen when beer has been over-flattened by exposure and lengthy settling. It is very curious that stone square brewers had, from the very first, to adopt rousing and aëration, but we shall no doubt see the reason of this when we come to discuss the subject of fermentation, while, if the truth be told, the stone square is no longer the vessel it used to be, since modern beers, those more especially of low gravity, require manipulation that can never be effected in one single deep and closed-up vessel, to say nothing of the ease with which a vessel of the kind named becomes mysteriously dirty on account of tendency to blister, and the rough jointing that is relied upon.

Rousing and aëration.

Difficulty of cleanliness.

Of unions, I can say this: they are an improvement on the old-fashioned puncheons, and may be employed in any brewery with success, if the principles of brewing be clearly understood by the brewer. In the case of slow fermentations, it is possible to work them with a bottom feed and rack direct from feed-pipe; while for quick fermentations, it is held that the feed should be at side to prevent a deposit of bottom yeast. Of late years, union casks have been fitted with attemperators, and there is no doubt that much of the character of Burton beer is due to the cleansing process being carried out in these vessels.

Union casks.

One or two well-known brewers, noted for their beer, still continue to favour the old principle of working out beers in carriage casks, this system giving to their beer a characteristic palate flavour; any excess of bottoms, of course, being withdrawn prior to its fining and shipment.

Working in carriage casks.

To sum up the subject of fermentation arrangements, I have no special predilection for either the skimming or cleansing system, but would strongly advise brewers adopting the former method to give attention to my hint respecting shallow skimming squares, so that, by attaining comparative brightness in these, no lengthy settling in racking vessel need be necessary; let them also avoid those complex metal arrangements that brewery engineers are so fond of; and, if attemperators and parachutes be fitted, let them be arranged as simply as possible. As for the cleansing method, I care little whether puncheons, unions, or pontoons be used, so long as due attention be given to aëration and the question of depth as influencing final brightening. An undoubted improvement has been made in one Burton brewery by connecting the unions to a bottom racking main, contents being drawn direct into trade casks without that frothing and aëration at a stage when both are injurious, to say nothing of the flatness resulting from exposure in racking tank.

Shallow skimming squares.

Cleansing system.

With reference to the subject of yeast storage, nothing can be better than backs constructed of slate, in which the pitching yeast can be stored perfectly quiescent in shallow bulk, while it is frequently an advantage to have these fitted with attemperators. Some good plan of drainage is always advisable, since different yeasts separate from fluid portion in distinct manner; in some we see yeast entirely floating on beer after a few hours' settling; with others we find a layer of bottom yeast, then a layer of fluid, and again a supernatant layer of yeast. It is evident from this that if we arrange a series of small draining holes up the side of slate store back, we can draw off the fluid wherever it may happen to exist, and so, the sooner arrive at a thick pitching store.

Yeast storage.

Slate backs.

Separation of fluid from solid yeast.

Filter presses.

Filter presses have now come into general use, and those constructed of metal of the Needham and Kite and Johnson pattern are, perhaps, most common. If actual pumping of yeast is carried out, care is necessary in order to see that the pressure be regular and not too great, and it is for this reason that the presses of Waller or of Ritchie sometimes answer best. The vacuum press of Ritchie, constructed of copper, would be very useful as a machine for draining store yeast under low suction power, and I have no hesitation in recommending them for this purpose, since much yeast is constantly wasted, never apparently getting sufficiently thick for pitching purposes, before commencing to deteriorate in an unpleasant manner. It was at one time considered advisable to leave yeast in contact with its fluid portion, and this is perfectly correct so long as the sample is not in matured state, but directly the cells are sufficiently developed, no advantage can result from leaving it in contact with a non-fermentable fluid, such as it must be, when attenuated to low gravity, and I prefer myself to keep yeast in thick condition in a perfectly clean slate back till required, while of course it should be used before the slightest deterioration commences.

Vacuum press.

Maturing of yeast.

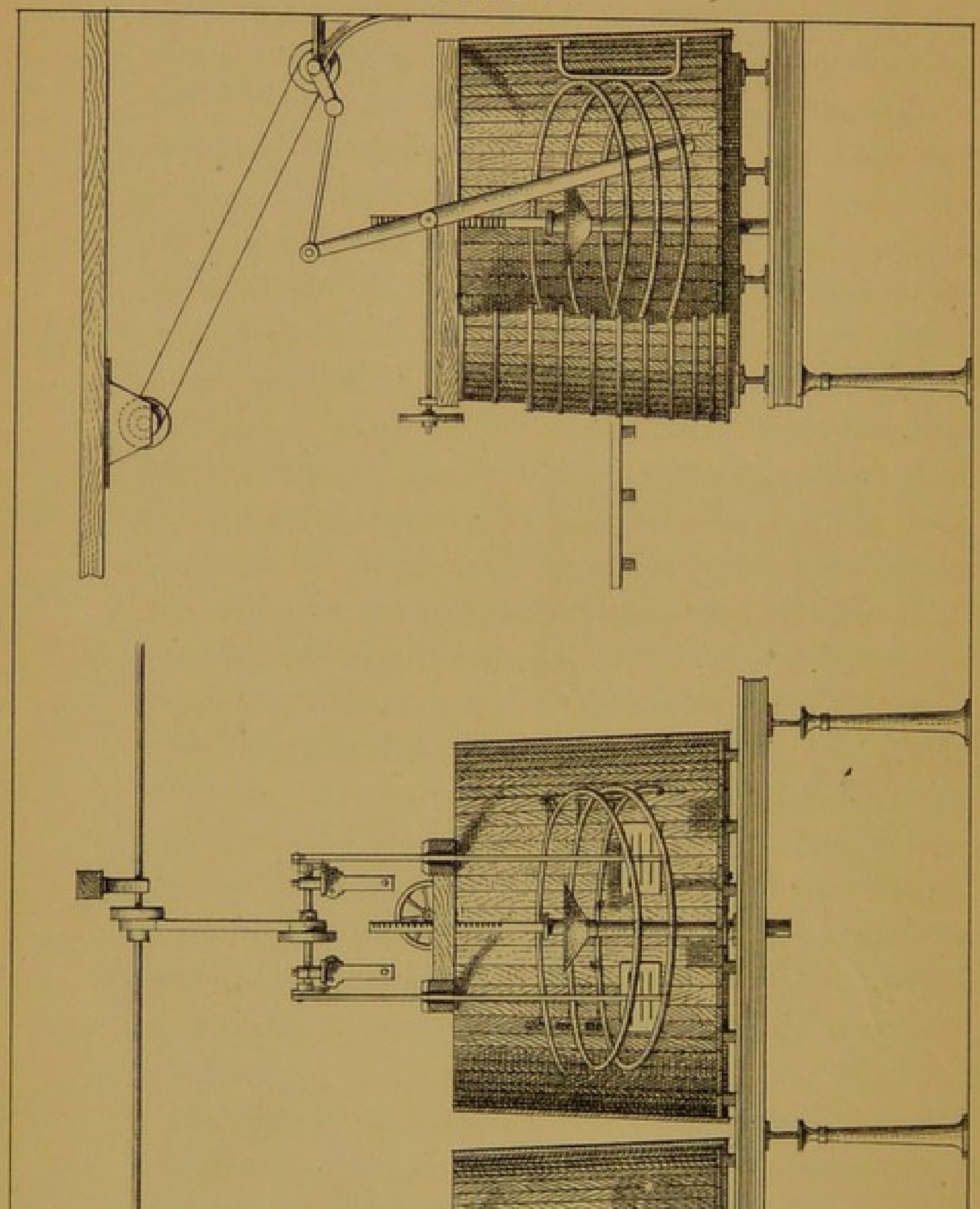
Cellarage.

As regards cellarage, I have little to say; cellars should be spacious, convenient for stacking, if possible lighted naturally, and in easy connection with racking-rooms and shipment exit—there is no doubt that bad storage causes endless disasters, and that half the complaints that arise in winter on account of flatness of mild beers might be entirely avoided if the brewer had sufficient storage-space; not to retain an abnormal stock, but to keep his freshly racked beers well rolled.

Rolling of beer.

It is a great point in a brewery to have a duplicate

PLATE V.



ROUSING MACHINERY

central motive power for machinery, and there should be duplicate driving-wheels throughout. Nothing is so objectionable as an endless number of small engines and steam-pumps; they are generally to be found in breweries that have seen rapid enlargement. One form of machinery that might be adopted with immense advantage is that patented by myself and Mr. Samuel Lees many years ago; simplicity itself, it enables us to communicate that oscillating motion to fermenting wort that is of such immense influence during fermentation. The question of motion in reference to vital action has never been clearly understood, but I have little doubt that the sway communicated to wort by the machinery spoken of promotes activity of growth of yeast-cells *per se*, and also by determining a certain escape of carbonic acid, and a corresponding aëration of wort. By glancing at interleaved illustration plate No. V. it will be seen how the perfectly regular oscillatory motion is arrived at by mechanical means, the paddle shafts oscillating on fulcrum, being connected to cranks driven from a central shaft carrying cone pulleys corresponding to similar pulleys on crank shafts, so as to obtain the varying rates of speed necessary.

Central motive power.

Rousing machinery.

Mechanical arrangements.

I need say little more about the endless mains, which I must include among brewery fittings. It would be preferable if we could do without them, but as that is impossible, I strongly advise brewers to go in entirely for copper, and have the mains in every direction so fitted that they can easily be taken down and cleaned internally with brushes; it is advisable, also, to have a steam connection to each series, so that steam may be blown through each day, following this with a flow of hot liquor.

Wort mains.

The connection between brewing system and plant.

The subject of brewery plant is no unimportant one, and I certainly think that it deserves more attention in this direction, that the exact plant arrangement should have some kind of connection with conditions of brewing and system carried out, and I am sorry to say it is a special point which brewery engineers sadly neglect. Before closing this chapter, I may say a few

Cask plant.

words on the subject of cask plant, for I have no hesitation in making the statement that a great many of the objectionable flavours that are common to beer—especially beers of low gravity—are due to the selection, in the first instance, of inferior timber for carriage casks, and inattention to their proper cleansing when in use. In speaking of timber in my opening, I men-

Porosity of wood.

tioned that it was chiefly the question of porosity that decided fitness ; the timbers that were the least porous, containing in result the smaller quantity of sap, and consequently being less capable of acting afterwards as a sponge, constantly absorbing and yielding up sedimentary matters, being most suitable for the brewer's

Price of timber.

purpose. At the present time timber is cheaper than it has been for years past, and it would be a wise step for brewers to buy up large quantities of best memel oak for future use in the construction of their cask-plant.*

* CASK TIMBER.

Best staves for casks, Crown Memel.

Best staves for thin varieties. Full-sized pipe, at about £24 per 120 staves ; or full-sized long barrel staves at £13 per 120.

Best staves for stouter stock and export casks—9¼ pipe, at about £19 per 120 staves ; or the long barrel 9¼ staves, at £10 per 120.

120 pieces of any sized stave = 1-10th of a mill.

CHAPTER VI.

BREWERY CALCULATIONS. ESTIMATES. COPPER CALCULATIONS. PARTY GYLES.

I now come to a subject that has not been touched upon in any very practical manner in previous works on brewing, and this is, perhaps, the more surprising since it appears to me that one of the most important points of knowledge for a brewer to have is that in connection with obtaining from the material he employs the full available extract, dividing this extract in varying proportions over varying bulks of fluid, so arriving at different gravities, or weights of dry matter per barrel. This knowledge necessitates, of course, the use of the ordinary weighing instruments employed by brewers, in many instances, no doubt, without the brewers themselves knowing anything about the meaning of their indications, and it will be, therefore, of the greater advantage that I should enter pretty fully, not only into the meaning of a saccharometer gravity, but explain how this knowledge can be practically applied in a variety of ways to render brewing operations the more certain and profitable.

Brewers' extract.

Saccharometer gravity.

To begin with, then, the instrument commonly employed by brewers is the pounds per barrel saccharometer, introduced by Richardson in 1784, its indications being simply based upon the principle of comparative weight—that is, it indicates the comparative weight

Richardson's instrument, 1784.

Principles of same.

existing between 36 gallons of water weighing 360 lbs. at a temperature of 60° and the weight of a corresponding bulk of any other fluid at the same temperature. Thus, when a brewer speaks of a 20 or 25-lb. beer, he simply means that a barrel of it weighs 20 or 25 lbs. more than the same bulk of water, and it is only a step beyond this to explain the indications of the Bates' saccharometer used by the Excise authorities.

Bates'.

Terms of weighing.

In the case of the brewers' instrument, the expressions are in terms of a barrel weight—*i.e.*, in terms of 360, the weight of a barrel of water; but as it is more scientific to express comparative weight in reference not to the weight of the brewer's barrel, but to a fixed standard number, called the specific weight of water, this number being 1 or 1,000, it is perfectly easy to see that if the comparative weight of a wort be 20 as compared with water in terms of 360 (its barrel weight), it would become 55·4 when compared with a fixed standard of 1,000, since $\frac{1000}{360} = 2·77$ and $20 \times 2·77 = 55·4$; or, to make the matter clearer, while the vessel holding 360 lbs. of water holds 380 lbs. of the wort specified, the one holding 1,000 lbs. of water would exactly contain 1,055·4 lbs. of wort.

Factor 2·77.

So far we have an explanation of the factor 2·77, so commonly in use to ascertain Excise gravities from mere brewers' saccharometer indications, and *vice versâ*. Now let us see what connection this has with the amount of solid extract represented by such indications. When solids undergo solution they lose apparently a portion of their weight, this portion being equal to the weight of the fluid which such solid displaces—that is, to the weight of its own bulk of the fluid, this, as it will be remembered, being the original theory of Archimedes. Upon this basis the specific gravity of all

Solid extract.

bodies is ascertained, since, by dividing their weight in air by the loss of weight in water, the resulting quotient will be the specific gravity—that is, the loss of weight when suspended in water indicates the weight of an exactly similar bulk of water, and by comparing this with their weight in air, we arrive at once at the comparative density of equal bulks of water, and the substance we may be experimenting upon. Specific weight.

Let me apply this practically to a brewer's case, taking ordinary sugar as an example. The specific gravity of sugar ascertained on the principle just mentioned is 1·6, as compared with water at 1—that is, the gallon which holds 10 lbs. of water, will hold exactly 16 lbs. of sugar; or, in other words, 1 gallon of sugar is represented by 16 lbs. in weight. Now, suppose we add 16 lbs. of sugar to a barrel exactly full of water, what results? The sugar displaces just 1 gallon, or 10 lbs. of water, there being no condensation of volume; we now have, then, 35 gallons of water at 10 lbs., and 1 gallon of sugar at 16 lbs., or 36 gallons of a solution weighing 366 lbs. as against 360 lbs., the weight of a barrel of water; so from this we see that the connection between real and solution weight of sugar is in the proportion of 16 to 6. Specific gravity of sugar. Gallon of sugar—weight.

This is entirely a rough practical experiment, that may be carried out by any one. I have referred to it very often, for it appeared originally in that useful little work on brewing by Booth, and always seemed to me a remarkably clear explanation of the entire subject. Recent investigations, however, especially those made by Mr. O'Sullivan, in connection with malt extract have resulted in the connection between actual and solution weight of such extract being placed thus:—Ten parts of malt extract equalling 2·59 when in Booth's work. Factor 2·6. Mr. O'Sullivan.

solution, or, roughly speaking, 2·6; while the proportion given above for the sugar experiment is, as will be seen, 2·66, since $\frac{16}{6} = 2{\cdot}66$. The meaning of this—and it is well that every one should master the point—is that as brewers' gravities indicate merely comparative or solution weight, it is necessary to have this factor constantly in mind when dealing with definite weights of material, whether raw, malted, or in the shape of sugars or saccharines. I have purposely kept my description free from all technicalities and complexities, and while it may be regarded as crude by those having scientific knowledge, it will, I trust, be the better understood by the larger class of readers for whom this work is written.

Comparative weight.

Available extract.

Let me now apply these principles to a brewer's daily work. Malt is supposed to yield, theoretically, an extract amounting to about 78 per cent. of its entire weight; raw material about 70; sugars according to their description, from 98 downwards to 85, or even less. Now this can all be put into practical shape by keeping in mind the exact meaning of the factor 2·6, so fully explained above. Let me take the case of malt. English brewers rarely obtain 70 per cent. of extract, since a considerable portion of the starch which should be converted is either unmodified or so vitrified as never to be touched during an infusion mashing process, and the average extract is about 68 per cent. A quarter of malt weighs 336 lbs., and since 100 yields 68, the 336 should yield 228·4 Of what? Solid matter, which, in solution, would equal 87·8, since $228{\cdot}4 \div 2{\cdot}6 = 87{\cdot}8$.

Percentage obtained.

Yield of solid matter.

Extract per qr.

My readers will thus see the connection between extract per cent. as expressed by an analyst, extract per quarter as understood by themselves, and the weight of solid matter actually yielded in dissolved condition. Again, we have a sugar offered that contains 16 per cent. of moisture, while its other constituents are entirely soluble, and we desire to know the extract it will yield. The first step is to ascertain the soluble solid matter contained in 1 cwt., the usual sale quantity, and as the moisture is at the rate of 16 per cent., this would equal 17·92, on 112 lbs. leaving 94·08 of solids, which $\div 2{\cdot}6^{*} = 36{\cdot}1$; that is, 1 cwt. of such a sugar, containing 94 lbs. of solids, is capable of giving a brewer's extract of 36 lbs. It is very different, of course, with some of the descriptions of refined cane sugar containing 98 per cent. of crystals, and which actually hydrate prior to fermentation—100 lbs. of the cane sugar becoming by hydration 105·25 lbs. of invert —but, as there are reasons why cane sugar cannot always be employed successfully, I prefer to give no tempting picture of the large extract they are capable of yielding, but can proceed at once with the question of estimate, remarking that English brewers universally deal with solution weights expressed either in terms of 360 or 1,000, and for purposes of convenience, I shall adhere to the former proportion.

Yield of saccharines.

Cane sugar hydration.

Speaking simply of barrel gravities, I have said that malt yields 68 per cent. of extract, which, as we have seen, corresponds to 87·8 lbs. per quarter, and it is pretty evident that, by dividing this by the gravity of the beer we wish to produce, we can tell at once the number of barrels per quarter that we can obtain of each specified beer from the malt employed. In practical calculations it is usual to decide upon a length at a stated gravity, dividing gross pounds required by

Barrel gravities.

Lengths.

* More correctly 2·597, but that used above is sufficiently accurate for ordinary calculations.

normal yield of extract per quarter, in order to arrive at the quantity of malt to be mashed. For instance, we require 100 barrels of a 22 lb. beer, and 50 barrels of a 15 lb. beer. The gross extract would equal 2,950 lbs., which, ÷ 87·8, the normal extract, would correspond to 33·5 quarters of malt, or if we were using a proportion of sugar, say, one-fourth, our extract would be composed of 2,213 lbs. malt extract, corresponding to 25·2 quarters of malt, and about 20·5 cwts. of the specified sugar, equalling 737 lbs., or one-fourth of total required. Of course it is easy, and in many places customary, to reverse operations, the brewer, starting with a definite quantity of malt and sugar, splitting the gross extract up into certain distinct lengths at different gravities, corresponding to his requirements, and to the capacity of the fermenting vessels which he may happen to have at liberty.

Brewing estimate.

Diminution in bulk.

He has next to concern himself with the diminution in bulk that takes place during his practical operations of boiling and cooling, since it is unnecessary, perhaps, to say that what little loss in extract takes place, represented by quantity absorbed and retained by hops, or left behind as a surface film on coolers, is duly taken account of, and is, in short, over and beyond the normal extract of which I have spoken, that being the nett yield obtained in gathering vessels. Now, these losses in bulk depend upon several considerations. The vessels of the brewer are somewhat roughly gauged; he dips wort hot in one set of vessels, cold in his gathering or collecting squares, so contraction in bulk accounts for one portion of the entire loss. Again, in his copper "length" hops are included, while these hops are separated prior to the wort passing on to coolers.

Loss of extract.

Contraction in bulk.

Then, again, while the wort is in copper, hop back and on coolers, rapid evaporation is taking place, the loss in bulk, from boiling alone, varying from 2 up to 15 or 20 per cent. of the entire bulk, according to the shape and size of copper and the system of boiling adopted, and, finally, wort flowing over dry surfaces leaves behind a film of its own bulk, and thus the length gathered in collecting vessel is altogether different in volume from the quantity pumped to coppers. Evaporation.

It is quite impossible for me to fix any percentage that would be of any particular value for individual cases, since losses in bulk vary immensely; but, as a rough guide, I may say that diminution by boiling averages about 11 per cent., while loss between coppers and fermenting tuns would run to about 9 or 10. The next series of brewers' figures are termed copper calculations, and they are carried out in two distinct ways, some taking the lengths and gravities of each copper, deducting from the lengths the known losses in bulk, adding to the gravities the average increment, multiplying the corrected quantities together, comparing nett extract with original calculated requirement, any deficiency being made good by the addition of sugar, so that, to keep within the strict letter of the law, the time entered on Excise paper for solution of sugar should be late enough to cover the time usual for making copper gravities up to requirement; otherwise, if prohibited from adding sugar, the wort would have to be concentrated, this method practically giving a shorter length at required gravity. Others take the gross lengths in copper at the standing gravities, and deduct from the multiplied product the average loss in the extract which *apparently* results, as calculated

Percentage losses.

Copper calculation,

Entry of sugar.

Correction of copper gravity.

from a series of prior brewings, a loss which practically runs to about 8 per cent., this calculation showing them at once whether their copper gravities are sufficient to give them required extract; if in excess, bulk is increased by the addition of liquor; if deficient, sugar is added, or the length concentrated.

I claim for this work that it is entirely practical, and I therefore give an actual example of a brewing calculated out from first to last; and, in order to render it of the greater service, I purposely take a party gyle, and will say that it is a brewing in which sugar forms a considerable portion of entire extract. We are brewing as follows: Equal lengths of a 22, 20, and 18 lbs. beer, 110 barrels of each, the sugar proportion to be one-fifth, the saccharine in use yielding 36 lbs. per cwt., the malt being reckoned at 87·0 per qr., the wort to be boiled off in two lengths in four separate coppers of varying size. The figures below will, I think, explain themselves, at any rate, with the aid of the few side remarks appended:—

Example of party gyle.

EXAMPLE OF BREWING ESTIMATE, COPPER, AND SUB-DIVISION OF WORT CALCULATIONS.

		lbs. extract.	
110 barrels, at	22·0 =	2420	
110 barrels, at	20·0 =	2200	
110 barrels beer, at	18·0 =	1980	$\frac{1320}{36}$ sugar extract = 37 cwts.
		——	
Saccharine proportion	$\frac{1}{5}$)	6600(	
		1320	
		——	
Malt extract, at 87 per qr.)		5280(	60 qrs. 4 bush.
		522	
		——	
		60	

That is, we mash 60 qrs. 4 bush. malt, and dissolve 37 cwts. of sugar to produce quantity required.

The next step is to ascertain copper lengths, in order to obtain 330 nett barrels in collecting vessels.

Barrels in collecting squares	330
Losses—	
Evaporation by boiling off 4 distinct lengths— 12 + 12 + 10 + 12 =	46
Hop retention and bulk contraction— 14 + 24 =	38
	414 barrels.

This length we distribute as follows :—

No. I.	Copper,	125	First wort.
II.	,,	125	Blend as second wort.
III.	,,	72	
IV.	,,	92	
		414	

On the coppers being charged, gravities were found as under, and it is as well to remark that the strong runnings had been more or less divided over entire length :—

First wort,	125	barrels	at 32·0 gravity.	
Second wort,	125	,,	at 15·3	Or, 289 at 11·1.
,, ,,	72	,,	at 8·5	
,, ,,	92	,,	at 7·2	

By referring to *losses*, we see that the first wort evaporates 12 barrels, and diminishes in bulk 14 by hop retention, contraction in bulk, and cooler evaporation. The second blended lengths lose 34 barrels by boiling, and 24 by hop retention, &c., so the nett gathering quantities would be 99 first wort, 231 second wort, making up the 330 barrels required ; while at the same time the gravities would increase as under. First wort, 2·5 per barrel ; second wort, 1·7 per barrel. At making up of coppers our calculation stands thus—

Nett result—

First wort . . .	99 barrels	at 34·5 =	3415
Second wort . .	231 ,,	at 12·8 =	2956
			6371

that is, as against 6,600 lbs. required; so that in order to make gravity good, we either add 6 cwt. of sugar to make up deficiency, or as the mean gravity of beers is 20·0, turn out 11 barrels less length, cutting each of the beers $3\frac{3}{4}$ barrels short in gathering vessels.

Sub-division of wort.

Before describing the actual subdivision of these worts let me say that if we are merely dividing different lengths of separate worts for a single beer into gathering vessels of various dimensions, there is no difficulty in the matter, since all is accomplished by a simple proportion sum. For instance, taking the brewing in question, as all one beer distributed over vessels, such as the following series: 50, 45, 82, 95, and 58, the proportional division for first wort would be as follows:—

Total length.		First vessel.		First length.		
330	:	50	::	99	=	15 barrels,

that is, 15 barrels of the first wort would be placed in the fifty-barrel collecting vessel, the proportion for the other vessels being ascertained in the same way.

Unequal sub-division for party gyles.

Now, in the case of a "party gyle" a combination of beers of unequal gravities, the varying "strength" is arrived at, of course, by the unequal intermixture of the several worts, and the problem to be solved is what this unequal mixture must be. In the case above we know that we have sufficient wort and extract to give required gravity and length of each beer calculated for. How, then, are we to subdivide 99 barrels at 34·5, and 231 at 12·8 to give in collecting vessels 110 at 22·0, and similar quantities at 20 and 18?

The simplest plan is to deal with each beer separately, seeing what excess of extract we shall have if taking all first wort to such beer, and then ascertaining

Displacement of extract.

how any excess can be displaced by substituting second wort for first. Thus in the example above it is apparent that by substituting second wort for first, for every barrel of second wort used we displace 21·6 lbs., the difference between 12·8 and 34·5.

We require 110 barrels at 22·0 = 2,420 lbs. Now 110 barrels × 34·5 = 3,795, showing an excess of 1,375 lbs. over required quantity; and if this be divided by difference between gravity of first and second wort, which, as seen above, is 21·6, we find that it will require the substitution of 63·6 barrels of second wort for corresponding first wort, in order to displace the excess lbs. in question. In other words, our beer of 22 lbs. gravity would be made up of 46·4 barrels at 34·5, and 63·6 barrels at 12·8, equalling 110 barrels at 22·0.

Rule for division.

The other beers are calculated for in the same manner, and it will be seen that the results come out with perfect accuracy. The rule for division of worts in party gyles may be thus expressed. Multiply each length by gravity of first wort; deduct from result the lbs. extract required, and divide excess by difference between gravity of first and second worts; the quotient will be the barrels of second wort required, which, subtracted from total, gives barrels of first wort.

Usefulness of calculation.

It will be perfectly evident that the two calculations I have last given suffice for many purposes in the brewery, such as the proportional distribution of certain bulks into vessels of dissimilar size, the blending of different lengths of a single beer existing at varying final attenuation into separate racking tanks, so that a mean gravity is attained, and also constitute a means of readily calculating the proportional intermixture of two or more beers at dissimilar original gravity, to produce a beer of any mean strength required.

For instance, we have plenty of beer in stock at a gravity of 30 and 18, and a necessity arises to produce some at 20: putting on one side for a moment the question as to advisability of blending beers, even those produced in one plant, it is sufficiently easy to calculate the required intermixture, treating gallons as barrels, since we find that 30 gallons of the 18 lb. beer mixed with 6 gallons of the 30 lb. would give a mean gravity of 20 lbs. per barrel. Thus, the apparent extract required is 720 (36 × 20), while 36 × 30 = 1,080, or an excess of 360: difference between gravity of 18 and 30 = 12, and 360 ÷ 12 = 30. Therefore, 30 × 18 + 6 × 30 = 36 × 20·0.

Application to barrel admixtures.

All these matters are easily described in algebraic formula, but it would be useless in a work of this description putting anything in a very advanced manner, and I believe that the figures given almost explain themselves.

Algebraic formula.

As soon as fermentation commences another loss in bulk begins through *the elimination of yeast-forming matter*, there being slight difference in volume between fermentable matter and the transformation products. This loss varies in amount according to the system of fermentation, the extent of yeast outcrop, and whether such yeast be pressed or no, and its filtrate returned to bulk. I mention this here as it concerns calculating nett extract, since many brewers are in the habit of stating gross extract on gathered length, in place of nett yield in cask, the difference between the two varying, as above stated. There is one more point to deal with in connection with this subject when using mixed grists of pale, brown, and black malts, the general rule being somewhat absurd, since brewers are apt to express extract on pale and brown after deducting the caramel-

Diminution in bulk by fermentation.

Extract from mixed black beer grists.

ised material. I think it preferable to calculate the brown or blown at 60 per qr., the black at 40, taking the difference for the pale.

Cost price of beer.

We now come to the question of cost price of beer—a subject that has been very much neglected, but which, in these days of competition, is of the most extreme importance. Now, the cost price of beer is not difficult to ascertain if we keep a proper account of each brewing in an ordinary brewing journal of the malt, sugar, hops, and chemicals used, the number of barrels of beer obtained and racked into trade casks. To the cost of the absolute materials we have to add duty and the proportional amount chargeable to the specified brew for such items as finings, coal, labour, and salaries for brewhouse, crediting Dr. side with amount derived from sale of grains and yeast, and finally dividing nett total cost of all the above-named items by the actual number of barrels racked.

Distribution of cost in party gyles.

In the case of a party gyle, where several beers are produced, the relative sum chargeable to each distinct beer is arrived at by a proportion sum, comparing the pounds extract in entire brew with the proportion of that total in the specified beer, the third term of our sum being the gross money charge, and the fourth the proportion of it standing against the beer we are calculating the cost price of. I give below an example, taken from an actual cost-price book, and may simply say that in the brewery to which it belongs the average cost of production, including all the items above named, is under 50 per cent. of invoice price.

Omissions in cost price book.

Of course it must be clearly understood that this account leaves out of question such items as rent, taxes, gas, water, depreciation in value of plant, carriage charges, office, commission, and general outside expenditures; but each brewer can easily determine these for himself, and it is better, in calculating the absolute cost of beer, to state it in the way described.

Excise charges. Standard bushel and its equivalent in sugar.

In conclusion, I may briefly refer to Excise charges, and the method of calculating them. As is well known, under the terms of the new Beer Act 42 lbs. of malt is taken as the standard bushel, while 32 lbs. of glucose, or 28 lbs. of cane sugar, is supposed to be equivalent in extract yield to the standard bushel named. The regulation respecting the 32 lbs. of saccharine has only recently come into force, brewers previously themselves making the correction for moisture percentage, while at the present time the gross weight used is entered in special column, the Excise officers being authorised to deduct one-eighth. I have heard it stated, however, that some brewers prefer to make an accurate deduction themselves, to make sure of getting it, since the one-eighth only corresponds to about 12½ per cent. of moisture, while many saccharines contain as much as 16; but, at the same time, this modified rate is a decided step in the right direction, and does credit to the justice of the Inland Revenue authorities.

Allowance for moisture.

Now, there are two systems of levying duty, the charge being either made on material employed or on the produce yielded, and the reason for this is as follows:—The Inland Revenue authorities assume that a standard bushel of malt, 28 lbs. of crystallised sugar, or 32 lbs. of saccharine, is capable of producing 0·5 barrel of standard beer—*i.e.*, beer of a gravity of 1,057 or 20·5; and if the unfortunate brewer does not succeed in obtaining it, or, at least, within a margin of

The standard bushel.

Presumptive yield.

4 per cent., the duty charge is not made on length collected in fermenting vessel, but, in other words, upon the presumptive quantity that should have been obtained.

First of all, the brewer enters his material on the above-named basis—malt at 42 lbs. per bushel, and sugar in specified column—and on brew being collected, the charge is at once calculated by taking the quantities as obtained from dip-book, multiplying these into their respective gravities, and dividing by either 57°, or 20·5, according to whether densities are expressed in terms of 1,000 or 360, in order to arrive at the corresponding number of standard barrels. Off this number 6 per cent. is deducted, this representing, according to Inland Revenue notions, the average loss in bulk that takes place between the gathering of the wort and the racking of fermented beer, a duty charge of 6s. 3d. attaching to each of the nett number of standard barrels.

Entry of material.

Allowance for loss.

The Excise officer, in order to check the result, then deals with the materials on the basis above described, and if the charge work out to a less number of standard gallons than the actual yield, the gathering charge stands; while if a deficiency of standard barrels exists in gathering squares, when this comparison is made between presumptive and actual yield, after a further allowance of 4 per cent., the charge shifts from the one to the other; although, as is well known, the results are averaged for each month, the duty being payable within about fifteen days of the Excise-book being made up.

Correction of charge.

It is necessary to remark here that the presumptive yield of material is not excessive, since it only amounts to 82 lbs. extract per quarter on malt, and a similar

Fairness of presumptive yield.

quantity from 2 cwt. of cane sugar; and although saccharines fall short of yielding this, it is rare that more than one-third of sugar be used; and the statement made is not, therefore, wide of the mark, since malts made up to weight should at least yield 85, a sufficient counterbalance for any slight deficiency of sugar extract.

Excise officer's diary.

The Excise officers are bound to keep a journal or diary open at all times to inspection, and it is an easy matter for the brewer in charge to see for himself whether his own calculations of duty agree with those of the officer; while my own experience is that courteous Inland Revenue officials invariably call attention to abnormal results in either direction, for although charges on material are quite common in small breweries, they are very rare in large plants; indeed, there is generally an excessive yield of something like 10 per cent. over presumptive quantity; the Excise taking no notice of this unless the excess runs higher than 12.

Dilution of caramel.

Entry of same.

I now come to a very simple calculation that often puzzles both Excise officers and brewers, and I specially mention it as it will familiarise many readers with the factors and divisors previously explained. I refer to the question of caramel, either supplied by sugar dealers or made on the spot, the Excise insisting that this shall be diluted to a gravity of 1,150, and entered as a solution of dry sugar, as well as *declared* at its standing-gravity. I prefer, for the reasons stated, to work out solid contents on the elementary principles explained, for the specified purpose, and I will suppose that in our caramel tub we have 52·5 gallons of solution, at a gravity of 1,105, the query being what amount of dry sugar must be entered on notice paper.

Calculation of solids in solution.

The gravity of 1,105 corresponds to 37·9 per barrel, or 1.05 per gallon, which multiplied by the factor 2·6 = 2·73 lbs. dry matter per gallon; and as there is a bulk of 52·5 gallons, we have consequently 143·3 lbs. of dry matter in the caramel tub. The same result may be arrived at in many different ways, but I have repeated a familiar example, with the intention of over and over again exemplifying factors little understood.

It is a most difficult matter in brief space, or without endless examples, to make the subject of brewery calculations perfectly plain; I have now run through those that are commonly employed, and hope that the subject-matter of this chapter will induce many who have hitherto worked by mere rule-of-thumb to organise, according to the data given, their extraction process, so that they may really know how they stand as regards possible profits.

EXAMPLE OF COST-PRICE BOOK.

Cost price example.

Beers of following saccharometer gravities, 36, 33, 30, and 15 lbs. per barrel, described as K K A, K A, X X X X X, and Beer.

Dr.		
Malt—	£ s. d.	£ s. d.
40 quarters, at 42s. 6d.	85 0 0	
25 ,, 41s.	51 5 0	
		136 5 0
Saccharines—		
42 cwt., White, at 18s. 3d.	38 6 6	
16 ,, Brown, at 17s.	13 12 0	
		51 18 6
Hops—		
458 lbs. East Kent "Gaunt," 1883, £8 8s.	34 7 0	
232 lbs. Bavarians, 1878, 36s. 6d.	3 15 7	
110 lbs. East Kent [racking], 1883, £8 8s.	8 5 0	
		46 7 7
16 lbs. Beane's, No. 1	1 4 0	
60 gallons Foreign Yeast, at 1s. 6d.	4 10 0	
Duty	115 6 11	
Wages	7 4 3	
Finings	0 17 3	
Coal	1 11 6	
Salaries	3 4 3	
		133 18 2
		£368 9 3
Cr.		
Grains	8 13 4	
Yeast	1 0 0	
		9 13 4
		£358 15 11

Cr.

Extract per quarter	84·0
Cost per lb. of Extract	0/6
Cost per Barrel Racked, K K A	$34/6\frac{3}{4}$
,, ,, K A	31/0
,, ,, X X X X X	$28/9\frac{3}{4}$
,, ,, Beer	$15/5\frac{1}{2}$
K K A, Barrels Brewed	54
,, ,, Racked	$52\frac{3}{4}$
,, ,, Waste	$1\frac{1}{4}$
K A, Barrels Brewed	65
,, Racked	65
,, Waste	Nil.
X X X X X, Barrels Brewed	67
,, ,, Racked	65
,, ,, Waste	2
Beer, Barrels Brewed	101
,, ,, Racked	94
,, ,, Waste	7

Distribution of Nett Cost—

	lbs.				
K K A,	1954 cost		91	17	0
K A,	2145 ,,		100	16	7
X X X X X,	1548 ,,		72	15	4
Beer,	1990 ,,		93	7	0
Total lbs.	7637	Total cost	£358	15	11

CHAPTER VII.

CHEMICAL ANALYSIS—ELEMENTARY BIOLOGY IN REFERENCE TO BREWING.

Extent of chemical knowledge necessary.

THE present chapter treats of subjects that have only been of interest to brewers within the last few years, and both necessitate somewhat lengthy description, although it is not my intention to enter deeply into analytical detail, but merely to describe the extent of chemical knowledge requisite, and the point to which analytical experiment should be carried; but as regards biology, it embraces the whole subject of ferment life, the stability and deterioration of beer, and is one deserving the attention of both writer and reader more, perhaps, than any other I can call to mind.

Biology.

As brewing happens to be, in all its preliminary processes, a strictly chemical one, it is only right that students should understand something about the interesting change that takes place in the mash-tun, during which nearly the whole starch of malt becomes transformed into fermentable sugars, and nothing perhaps conduces to more practical experience on this and similar points than to run through a course of elementary analysis in the laboratory, not only determining the fitness of water for use, and its saline character, but the value of the various malted and raw materials that are employed together with sugar and saccharines, the composition of our worts when ob-

Elementary analysis.

tained, and the character of the finished beers as existing in cask.

Unfortunately, I can in these pages offer but a very poor substitute for such a course, confining myself of necessity to a brief reference to those analytical processes that are of the greatest service, leaving to my future text-book on Brewing Analysis the duty of putting in full form the actual details of proceeding.* Text-book on brewing analysis.

I propose, then, without employing figures at all, to touch upon the question of water, malt, raw grain, saccharine, raw wort, boiled wort, collected wort, finished beer, and yeast analysis, following this with a brief reference to that of the various chemical bodies that are now used for the several purposes in brewing enumerated in Chapter IV.

As regards water analysis, constant dispute is proceeding among analysts, but it will be found that the process of Professor Wanklyn generally answers every purpose, if the brewer pays special attention to the quantity of iron and nitric acid present, as well as to those points to which Wanklyn attaches so much importance—namely, "the ammonias," as representing organic impurity. Iron is a grave defect as a constituent of brewing water, while nitric acid is in many instances disastrous, although I have previously shown how its influence may be minimised. Wanklyn's ammonias. Iron and nitric acid.

The special point for the student to master is the one in connection with the meaning of ammonia proportions in conjunction with chlorine and nitric acid, and the general rule may be thus explained: chlorides alone are no proof of impurity, while, on the other hand, all contaminated waters are heavily charged with soda salts, Indices of impurity.

* "Laboratory Text Book," by Lawrence Briant and Frank Faulkner.

not only in the form of chlorides, but frequently also as carbonates; the presence of the latter salts being easily detected by the fusing of the residue on ignition. Again, "free ammonia," in excess in certain rare instances, as explained in the chapter on Waters, is no index of impurity, but when we have large quantities of both "free" and albuminoid ammonia, chlorine, and nitric acid appearing side by side, then the water is not only defiled, but has been so for a long period.

Dr. Frankland's theory.

The contention of other water analysts, notably Dr. Frankland, a great authority on the subject, is that some types of nitrogenous matter fail to yield the whole of their nitrogen in the form of ammonia, when submitted to the permanganate process, and that in working according to the lines laid down by Professor Wanklyn, it is impossible to say whether certain waters are actually contaminated or no, this being notably the

Deep London well waters.

case with the deep-well waters of the London basin, which yield, on analysis, large quantities of chlorine and the two ammonias, but are not regarded as contaminated supply. Dr. Frankland's method is based

The organic carbon method of analysis.

upon the principle of submitting the saline residue of a water that has been evaporated to dryness with great care, to actual combustion, so determining the organic carbon and nitrogen, while from the proportion that exists between the carbon and nitrogen so estimated, the analyst is able to decide whether the organic constituent results from sewage contamination or no—*i.e.*, if the proportion of nitrogen is in any way similar to that of the carbon, defilement of the water with excremental matter has undoubtedly taken place; while if the carbon constituent largely predominates, the organic body yielding it is held to be of vegetable origin.

Dr. Tidy's process.

Dr. Tidy's process also finds much favour at the present day, although, in principle, it is not exactly novel. Dr. Tidy holds that the exact organic condition of a water can be readily determined by ascertaining the quantity of oxygen required to counterbalance its deoxidising capacity, or, in other words, to completely burn up such organic matter at the ordinary temperature of water.

Standard permanganate solution.

The test solution is simply permanganate of potash of standard strength, each cubic centimetre corresponding to a definite measure or weight of oxygen; and in determining the organic constituent of the water, a measured bulk is carefully titrated with the permanganate until the violet colour becomes permanent, showing that the potash salt added is no longer being deoxidised. There is no doubt that in the vast majority of cases the ammonia process first described answers every purpose; but it is only fair to say, that in certain instances confirmatory evidence is necessary, and it is well for every one engaged in the occasional analysis of water to know how the three methods of determination stand in relation to each other. A far more accurate method of conducting Tidy's process consists in the addition of an excess of permanganate of potash to the water under examination. After allowing the whole to stand three or four hours, the residual permanganate is citrated by the addition of a few drops of potassic iodide, and the iodine thus liberated is determined with sodic hyposulphite solution, using starch solution as an indicator. If readers wish to go into the subject generally, they can easily refer to the works of the three professors mentioned.

The practical usefulness of Wanklyn's method.

Difficult chemical problems.

As a point in connection with the general subject of the chemistry of water analysis, I may mention the vexed question as to whether carbonate of soda and sulphate of lime can exist side by side in solution, and whether calcium chloride added to a water containing carbonate of soda would decompose the soda salt. According to the ordinary law of affinities a mutual decomposition should result in each case, and endless experiments may be made in a laboratory to prove that it is so; why, then, should there be any doubt on the subject? Well, first of all, I often see the reports of analysts with such an apparent erroneous arrangement of saline constituents, expressed in figures; secondly, we must remember that, in ordinary waters, the state of dilution is extreme, and the saline bodies exist in the presence of carbonic acid, which undoubtedly exercises a determining influence; and thirdly, I have heard of the most disastrous results from the use of chloride of calcium for the purpose named, which certainly would not have followed if the mutual decomposition had taken place. Unfortunately, there is no method of proving whether the affinity reaction in either case results or no, excepting by very indirect means; but, at any rate, I have never seen a water containing any considerable quantity of the two salts.

Inaccurate calculation of results.

Chloride of calcium.

Danger in using same.

Sugar test.

I am no great believer in the sugar test, which depends upon the kind of action which goes on, when we add, to a small quantity of the water under trial, a portion of pure loaf sugar, the idea being that if it contain developed ferments, these will soon cause, in the presence of fermentable and ferment-forming matter, turbidity, followed by a deposit that can be microscopically examined. On the other hand, Dr. Tidy's process, which hinges upon the use of a standard solution of dilute permanganate, should be understood and practised by every brewer, since it is simplicity itself, and the slightest change in the organic constitution of a water can be discovered in a moment by its aid.

Soap test.

The soap test was at one time in high favour, but the results are so deceptive if the water contain any quantity of magnesia, and the soap solution itself is so apt to alter, that the test has, to a certain extent, become unpopular, and the plan of separating the salts that are soluble after ignition of residue from those no longer soluble in the absence of the necessary excess of carbonic acid (driven off by ignition) is now considered a ready and reliable means of speedily ascertaining the general characteristics of the saline constituents.

Separation of saline residue into soluble and insoluble portions.

Necessary connection between character of water and system of brewing.

This question of water analysis seems to be the more important as the influence of water in determining system of brewing is beyond all question, and it is by ignoring this that so many young and inexperienced brewers get into serious difficulty; I have seen, indeed, many old-established firms drift into hopeless muddles on account of a prized well-water mysteriously becoming impregnated with nitrates, while, at the same time, within ready reach, there has existed a pure river or company supply that they have not attempted to use, in face of the absurd old-fashioned antipathy to waters of this kind.

The analysis of malt and raw grain.

In coming to malt and raw grain analysis, there is this difference between them; as regards raw grain, the important point to determine is the quantity of starch that a certain weight is capable of yielding; while, in reference to malt, it is a question entirely of perfect and healthy growth, and the absence of mildew and excess of acidity. The starch percentage in a raw grain is determined by an ordinary saccharification process, using acid to induce hydration, the resulting sugar being determined by "Fehling solution," calcu-

Starch percentage.

lating such result back into corresponding starch. I am of opinion myself that the estimation of albuminous matter in raw grain is of no great service, since it is not likely that in a mere infusion method of mashing the crude azotised bodies will ever be sufficiently peptonised to act as yeast aliment; while as this term "peptonise" may be frequently used, it may not be out of place to explain at the outset what it really means.

Albuminous matter in raw grain.

Peptones and para-peptones.

Practically expressed, a *peptone* is a digested form of otherwise insoluble albumen, a *para-peptone*, a more completely soluble and digested variety of the same matter. This digestion proceeds under various influences, such as that of the gastric juice, which converts albumen, fibrin, casein, legumin, and gluten into as many different peptones. Again, the diastatic albuminoids of malt undoubtedly lead to the same result by acting on the albumens, modified, to a certain extent, during malting; this activity of diastatic bodies being, no doubt, promoted by variations in temperature of mash and the prolonged stewing of wort obtained therefrom.

Digested albuminous matter.

The manipulation of low diastatic malts.

If crude albuminous matter submit itself to this kind of digestion process, it is evident that the power of low diastatic varieties of malt must be *coaxed* by extreme duration of action, and strict attention to such influences as temperature, motion, and pressure, while, if raw grain be used, the greater the necessity that the malt employed in conjunction with it is highly diastatic.

The fatality that so many brewers suffer from is simply the use of material of such imperfect growth that it seems incapable of peptonising its own albuminoids that happen to be soluble; and, in analysing malt therefore, the main point is the extent of diastatic energy, which varies with the original percentage of albumen and the perfection of vegetation which has led to its modification. This determination of diastatic capacity is easily accomplished by operating with a weighed portion of the malt we are experimenting with, upon a standard quantity of some starchy body for a definite period (ten or fifteen minutes), finally estimating the quantity of sugar that has been formed under its influence. Each analyst fixes a standard for himself by working with the very finest malt he can procure, comparing afterwards all succeeding results with the standard so arrived at.

Determination of diastatic capacity.

Fixing standard of same.

As a general rule, I may say that the malt possessed of high power in this direction is free from such faults as excessive percentage of sinking corns and low extract, although if thin foreign barley malts are being experimented with, the connection between high diastatic power and tempting extract percentage does not hold good. One of the chief points to look after is the moisture constituent. We all know, I suppose, how rapidly malt absorbs moisture, and, unfortunately, such absorption sets in motion a train of evils that I have previously described, as corresponding to a degradation of albuminous bodies, with increased catalytic formation of lactic acid, and a seeming incapability of the abnormal albumens to act in any sense as healthy nutriment of yeast. This is just where analysis stops short, and where biological knowledge stands us in good stead. We find by analysis that a malt is capable of yielding a large extract; that 55 per cent. of the nitrogen compounds are soluble, that the sample contains no abnormal percentage of unmalted grain, and we might consequently conclude that it was in every way a satisfactory specimen. Tested by a method that

Characteristics of good malt.

Moisture percentage.

Formation of lactic acid.

Short-comings of analysis.

will follow in next section, it will be seen that a malt may pass through the ordeal of analytical examination, and yet be incapable of giving a mash that will remain moderately sterile for a single day; in other words, the miniature mash, with its supernatant layer of bright wort, will become cloudy, gas will escape, and the preliminary signs of putrefaction will at once set in. Why? Simply because moisture has been absorbed, the otherwise inert nitrogenous bodies have been set in motion, and we have a specimen of malt perfectly good and sound, to begin with, that is now alone capable of yielding a grey wort, and a beer swarming with small cells, that remain persistently in suspension, giving it a cloudy appearance; and yet, in face of this fact, it has been asserted that slack malt could be cured by redrying. I confess myself that I never heard of diseased matter being rendered healthy by cooking, and yet that is what such a statement means.

Biological determination of soundness of malt.

Monads in wort.

To give some idea of the figures obtained in analysis, I append the actual results arrived at when operating upon two samples—No. 1 a good, No. 2 a bad malt:—

Analytical figures.

	No. 1.	No. 2.
Extract per 336 lbs.	88·00 %	77·7 %
Acidity	·18 %	·35 %
Moisture	2·20 %	4·20 %
Soluble Albumen	4·30 %	3·20 %
Insoluble ,,	3·60 %	5·10 %
Diastatic Capacity (Standard 100)	98·00 %	72·00 %
Sinking Corns	nil.	18 %

Acidity, moisture, soluble and insoluble albumen.

The acidity is determined in a cold mash by means of normal* alkali, the moisture by drying a weighed portion on watch-glass in water-oven, till the sample ceases to lose weight, the soluble albumen by the soda-lime process dealing with a portion of the mash

* "*Decinormal.*"

wort, the insoluble albumen by difference, and the sinkers by throwing 100 corns into cold water, examining the sinking percentage as to extent of growth. This is a very old-fashioned method, much to be commended, the more especially as maltsters don't like it at all. I have heard that a practical plan has been devised for separating the sinking corn on a large scale from samples of malt, and if this can be done without injury to the floating portion, it cannot but be successful, for English brewers have neither the plant nor the experience to enable them to cope successfully with material called malt, but which contains, in reality, some 15 to 20 per cent. of actual raw grain.

Sinkers.

Their separation by mechanical means.

There are two other points respecting malt-analysis that are worthy of mention. It does the student good to determine the ash percentage and the proportion of phosphoric acid in the ash, since that will tell him pretty clearly why sugars and some varieties of raw grain so upset regularity of fermentation; in other words, let him compare the ash of yeast and the ash of malt, and he will then see why an entire malt brewing spells good yeast and why the introduction of mere starch or sugar-yielding substances seriously interferes with its development. Lastly, it should be apparent to the analyst that good malt is one simply requiring the mash-tun process, since, if the wort obtained renders prolonged stewing necessary, in order to complete at the high temperature what the maltster should have accomplished at the low, the fatality is that while keeping up the energy of the diastatic constituent, we are seriously diminishing that most important dextrin percentage that is so marked a feature in the case of beers produced from good material.

Ash percentage.

Phosphoric acid.

Ashes of yeast and malt.

Influence of stewing.

In coming to the different varieties of sugars, I may thus review them analytically:—The value of raw sugars as brewing material, turns upon two simple experiments: the determination of the percentage of crystallisable sugar by means of the polariscope—I think all information on this point is to be found in Landolt's work—(see footnote)—and a microscopical examination, in order to prove the absence of developed ferments. I need not here go into the question of whether the use of such unfermentable sugar is advisable in brewing, but can at once consider the class passing under the names of saccharums and invert sugars. These are specimens of inverted cane sugars, and it is sufficiently easy to explain their analytical variation. If we deal with refined cane sugar, and use for its hydration pure sulphuric, tartaric, or phosphoric acids, which happen to form insoluble lime salts, we naturally arrive at perfectly pure invert sugar and equally pure sulphate, tartrate, or phosphate of lime, if we employ selected lime to neutralise the acid. A manufacturer of invert sugar is differently placed. He cannot afford to employ, in the first instance, refined sugar, so has to content himself with low-class varieties, and even then he has to separate as a refiner 10 or 15 per cent. of the more crystallisable sugars before dealing with the remainder as a basis for the brewer's "invert" or saccharum, and thus we find considerable difference between these invert sugars, due to the class of raw material primarily acted upon, the percentage of crystals separated for the refiner, the care expended in the

Raw sugar.

Landolt on the polariscope.

Invert sugars.

Acids used for inversion.

The separation of better crystals by manufacturers of invert sugars.

"Landolt on The Polariscope." Translated by Robb and Veley. Macmillan & Co., Bedford Street, London, W.C.

direction of charcoal filtration to remove the last traces of insoluble lime salts, and the original albuminous impurities of the raw material, that have been in no way improved by the action of acid at a high temperature.

Charcoal filtration.

Thus, when analysing these sugars, we make a point of determining the extent of inversion accomplished, and freedom from albuminous matter and ash, for it will be seen that the chief difference between the saccharums and invert sugars in the market is exemplified by variation in these respects, and how very difficult it is for the manufacturers to successfully invert common material from which they remove large percentages of the better crystals. It does not do for me to exhibit the least bias, but the "No. 1" of Messrs. Garton and the "No. 1" of Messrs. Bostock are certainly equally good. I confess I do not quite understand the actual meaning of the flowery descriptions sheltered under the prefixes Lævo and Dextro, although, as is well known, saccharose, when hydrated by inversive ferment or acid, splits up into equal proportions of Dextrose and Lævulose. I recognise, of course, a right-handed as distinct from a left-handed sugar; but, from a brewing point of view, I do not suppose there is very much to investigate, and in dealing with these mystical bodies we shall much simplify the analysis if we acidulate a weighed portion and boil for five minutes before settling down to the actual determination of the sugar.

Determination of value.

Messrs. Garton and Bostock's saccharums.

Some makers have devised the very happy notion of intermixing a percentage of invert sugar with their starch saccharines, this fulfilling a double purpose—it baffles the analyst, and takes away from the other-

The presence of invert sugar in dry saccharines.

wise entire starch-saccharine its tendency to produce a distinct dryness of flavour.

Analysis of saccharines.

Coming to the analysis of saccharines, it seems to me that the chief points to be determined are the sugar and dextrine, the quantity of extract of useful type that each cwt. is capable of yielding, and the perfection of charcoal filtration that has left them free from any objectionable albuminous and excessive ash-percentages, since it unfortunately happens that the ash of a saccharine is by no means that of the grain intact, but is chiefly composed of lime salt, formed in the process, that has not been successfully removed.

Sugar, dextrin.

Albuminous matter.

Ash and moisture percentages.

The sugar and dextrin percentages are determined by the combined use of the polariscope and Fehling solution, the dextrin being converted into sugar by the acid process, the albuminous matter estimated by the soda-lime method, the ash by burning off a portion of the sample, and the moisture by dissolving a known weight of the substance in a certain bulk of water, say, 10 grammes to 100 cubic centimetres, then testing its specific gravity. The dextrin percentage is a somewhat important one, for although I do not suppose for a moment it is anything more than merely isomeric (identical composition, differing properties) with the dextrin of malt, yet it would certainly exist in beer as a constituent, increasing the palate fulness.

Continental saccharines.

Their colour.

The Continental and American saccharines, manufactured as they are from pure extracted starch, are far superior, analytically, to specimens made direct from a starch-yielding body, since they are almost free of necessity from the albuminous and inert constituents, which figure somewhat largely in other forms of saccharine. The colour is mainly a question of filtration, but diminution in this respect runs hand in hand with corresponding freedom from excessive ash and nitrogenous matter, and although I am far from saying that the dark and ill-flavoured qualities may not answer for black and common running beers, purity from the analytical point of view is more exemplified in those perfectly white specimens that are imported into England. Quite latterly, it is only fair to say, that a point has been made by Mr. Hooper in his book on Brewing in favour of inert bodies as constituents determining much of the palate fulness of beer, as opposed to the older view, that such character depended specially upon azotised matter and dextrin. I expect, myself, that fulness depends more upon the particular combination of several bodies than upon any special constituent; but as inferior malts yield excessive percentages of inert matter, and as saccharines are principally employed to purify malt extract, it seems to me that it is preferable to use those consisting of fermentable matter and dextrin alone.

Inert matters in regard to fulness on palate of beer.

The so-called dextrin-maltose of Valentin and O'Sullivan, isomeric, undoubtedly, with the dextrin and maltose of malt-wort in chemical composition, is a capital laboratory specimen of what I mean by this statement. It can be used with perfect success so long as the people employing it rank it as a saccharine, and keep clear of the supposition that it is actually artificial malt extract.

Dextrin-maltose

Altogether, in a strictly analytical sense, there is a fair field for capital, energy, and knowledge in the manufacture of English saccharines to compete with Continental and American brands. I object myself to

The influence of competition.

monopolies, and the guarantee of extract, amounting to 37·5 to 38·5 per cwt., is a decided step in the right direction, for in most cases the higher the extract yield the lower the percentage of impurities. It is analytical energy and discrimination that has led to this result—stirring up, as I may say, competition in directions where monopoly had created carelessness.

Concentrated syrups or extracts.

The analyst frequently has to deal with concentrated syrups, prepared from raw grain under diastatic influences. He submits them to analysis exactly as he would do a wort, and is only surprised to find that firms still persist in bottling up fermentable mixtures without regard to length of transit or conditions of storage to which such syrups are exposed. Used direct, they simply comport themselves as a raw grain wort; stored, they frequently enter into so-called spontaneous fermentation, and if afterwards used occasion unpleasant upsets.

Beanes' brewing material.

I next come to the case of so-called brewing materials, such as that of Messrs. Beanes' gelatinised rice, and what the laboratory student has to determine is whether these materials *do* convert readily in the presence of diatase, without preparatory gelatinisation in distinct vessels. I am quite aware that there is a vast difference between the operations of a brewer, the intensity of diastatic influence in his mash-tun, and the corresponding manipulation of a chemist in a laboratory beaker; but, at the same time, I hold that if I come across a material that brews well in a miniature mash—experiment without preparatory treatment, it is preferable to another that does not, and very considerable difference will be found in this respect between the varied materials offered.

Difference between laboratory and practical results.

With reference to the case of worts, it will be remembered that I specially divided them into three distinct classes: the raw worts from mash-tun, the same after boiling, and lastly, the wort gathered; and I did so for this reason, that careful analysis made of worts so collected will give the student a very important insight into the influence of his boiling and cooling arrangements. Let me explain this. The strong wort from the first mash has a totally different composition to that of the weaker runnings, in reference to the percentage of malt-sugar dextrin and inert matters; and yet the analytical composition of the gathered wort corresponds very closely with the character of the strong runnings, this being explained very easily if we keep in mind that during the collecting process of the brewer diastase is constantly kept in a state of activity, so that while the intermixture of weaker wort with its lesser fermentable matter is tending to diminish the maltose percentage in mixed bulk, the activity of the diastatic albuminoids is incessantly exemplified in a contrary direction. Again, wort running from the mash-tun contains a certain percentage of nitrogenous matters—some varieties being precipitated by ordinary ebullition heat, and others thrown out of solution by oxidation, as brought about by aëration—so that a complete investigation of the actual azotised proportion in the gathered wort is a matter of the most extreme importance, since if it sinks as low as 6 per cent. on dry extract of the blended bulk, then we shall begin to experience difficulties during fermentation in reference to yeast reproduction, and consequent vigour of action.

The analysis of worts.

Variation in composition.

The prolonged action of diastase.

Deficient percentages of albumen.

Let the student determine first, then, whether the strong wort, as obtained from his malt, is sufficiently rich in albuminoids, and then, after boiling, let him ascertain once more whether, with the removal of the

The importance of this determination.

coagulable varieties, his cooler wort is still left sufficiently rich in those likely to comport themselves as peptones; if not, let him see if some slight alteration in length boiled, extent of evaporation, or mechanical fixture of dome or fountain, suffice to give results more in accordance with requirement; if not, he may at once know that the malt in use is in itself faulty, or that his mashing system requires reorganisation, while he may be absolutely certain that the introduction of sugar into such a wort can but still further diminish the proportion of those bodies that are so important in one special sense.

The aim of analysis.

Analysis, to be of any service, must have some distinct practical aim. It is never more useful than when investigating a question of this nature.

Method of analysis.

The method of wort-analysis is very similar to that of a raw grain, malt, or saccharine. A known quantity of the wort is taken diluted, and the maltose, dextrin, and albuminous constituents determined by the usual methods; while if the wort contains added saccharine, the polariscope is brought into play, so that the analyst may determine the proportional intermixture. The variation in percentage composition of different worts is very great, good malts yielding high proportions of albumen and dextrin, while those from poor malt are characterised by the extreme lowness of both; and just for comparison I give two examples, the figures being very striking.

Initial heat 150°: mash standing in each case 1½ hours.

Example of results.

	No. 1 Good Malt Wort.	No. 2 Inferior Malt Wort.
Maltose	65·0	72·7
Dextrine	17·5	9·5
Albuminous Matter	8·7	5·4
Inert Carbo-hydrate Matter	8·8	12·4
	100·0	100·0

The curious point is that with inferior malts we always obtain worts with high maltose and inert carbohydrate percentages, while being at the same time deficient in dextrin and albuminous bodies. Practice in such analysis is most essential, and even the much-dreaded soda-lime process for the determination of nitrogen becomes sufficiently easy when the operator employs an iron combustion-tube.

Results with inferior malts.

The analysis of finished beer is an equally important matter, since in many cases it enables us to pick out faults, and glean some knowledge of the proceedings of brewers more fortunate than ourselves, and, at any rate, we are able to ascertain the gravity at which they produce beers of distinct brand. Speaking of gravity leads one to refer to the method which the Excise authorities adopt for checking charges made by their officers. If there be any discrepancy between the declared gravity of worts and the weight as taken by the officer, and the brewer protest against the excess charge, the custom is to wait until fermentation is finished. The officer then collects samples in the presence of the brewer, puts in some antiseptic, and forwards the specimens to Somerset House, where, I presume, an original gravity determination is made. There are so many sources of error in the process that it is not to be wondered at that brewers are somewhat sceptical as to the fairness of checking an Excise officer's gravity by determining the original weight of the beer by such a method; but as the usual errors are in favour of the brewer, excepting the one that allows for any excess of acid over the 1-10th per cent. as if it resulted from the oxidation of alcohol, there is not, perhaps, very much ground for the scepticism spoken of; while the process itself, which consists in deter-

The analysis of finished beer.

Original gravities.

Confirmation of excise charges.

Usefulness of original gravity method.

mining the quantity of alcohol present, converting this into its corresponding extract gravity, and adding this to the unattenuated matter, is so useful that every student of brewing should render himself familiar with it.

Different methods.

Roberts' original gravity process.

There are several methods for determining original gravity, the one just mentioned being perhaps the best. The others are, first that mentioned by Roberts in his book on Brewing, which depends upon weighing a sample of the beer with and without its alcoholic constituent, since readers will, no doubt, remember that the gravity of an attenuated beer is apparent, and not real; in other words, the alcohol it contains being lighter than water, hides a portion, and no small portion either, of the extract. In the case of an ordinary mild beer the increase in standing gravity by driving off the spirit will be as much as eight or nine degrees, and this difference in gravity so ascertained is the so-called spirit indicator in this method of Roberts. Secondly, we have a method based upon an accurate determination of the temperature at which the alcoholic fluid boils, this, of course, being influenced by its spirituous constituent.

Filtration of samples for analysis.

I have often been asked whether samples for analysis should be filtered or no, and I have no hesitation in replying in the affirmative, since filtration removes suspended particles of yeast without in any sense altering the gravity, at the same time efficiently flattening it.

Weight of filtered and unfiltered beer.

It may astonish many to know that the scale weight of the filtered is, if anything, slightly more than the weight of the unfiltered beer, for the simple reason that the suspended particles causing turbidity displace more than their own weight of wort, so that in every case when we are determining specific gravity by means of the bottle, it is necessary to carefully filter the sample, or the indication may be deceptive.

Analysis of unattenuated extract.

Before determining the composition of the unattenuated extract, it is necessary to remove the yeasty and modified albuminous matters which interfere with the Fehling reaction for maltose, this being done by the use of special subacetate of lead solution.

Albumen estimation.

The albuminous matter is determined by the soda-lime process in iron tube.

Antiseptics.

In these days of antiseptics and preservatives, it is essential to test for them somewhat carefully, and if we know the quantity and composition of an ordinary ash of beer, it is not difficult to determine when any foreign substances have been employed. After all is said, however, the mere chemical analysis of beer fails to tell us anything concerning its stability; in other words, a beer may analyse out sufficiently well and yet be on the point of acetification; but in the system for forcing on a secondary fermentation under stated conditions, as described in the next section, we have a ready means of determining the actual state of the nitrogenous portion of remaining extract, a more advanced step in the analysis of beer than would have been thought possible a few years ago.

Biological experiment.

So far, I have touched upon steps in organic analysis that certainly ought to be mastered by those having anything to do with operations on a large scale at the present time; and it remains for me now to make brief reference to the necessity that exists for brewers making themselves acquainted with such ordinary inorganic analysis as is practised in determining the value of specimens of pure carbonates of potash and soda employed for water softening, the composition of the endless neutralising agents sold, and those many com-

Inorganic analysis.

binations of sulphites that are palmed off upon brewers under high-sounding titles. This latter knowledge, above all the iodine method for the determination of sulphurous acid, will be fully described in the coming "Laboratory Text-Book," and I am convinced that much practical benefit will result, when the young generation of brewers make themselves masters of all the many processes sketched strictly from a brewer's point of view that will appear in that much-needed volume.

Laboratory text-book.

The connection between laboratory and brewery.

I am quite aware that a laboratory ought to be entirely distinct from a brewery, that miniature operations must not tempt us too often to imitation on a large scale; that chemicals in any shape or form are best away from the brewery, and absent as constituents of our beer; but, at the same time, as brewing in itself is a strictly chemical process, there is every reason for those connected with the management of operations gaining a very liberal insight into all the circumstances that are directly or indirectly in connection with it, and there is no doubt that a well-grounded analytical knowledge of the composition of materials, worts, and beers will prove of the greatest service to the operator, and invariably tend to the improvement of the produce he is responsible for.

Biology in reference to brewing.

In coming to biology in its connection with beer, or more strictly speaking in connection with brewing as a whole, I am touching upon a subject that almost anticipates that of fermentation generally, but as it is a complex one, and will certainly bear a good deal of repetition, it is only my object in this chapter to dwell lightly upon some of its more salient features and upon that practical exemplification of it which is in strict accord with ordinary laboratory work, leaving the full explanation of the theory of the subject until I come to discuss fermentation generally. It is, I may almost say, a complete novelty for brewers to be told that they have to deal with animal and vegetable life, that their wort and beer contains nutritive matter for types of cellular organisms the germs of which exist all around us, very unequally spread without doubt, but still present, that the difference between a sound and unsound beer chiefly depends upon variations in condition of the constituents of beer, mainly, if not entirely, to variations in actual state of nitrogen compounds, and that the chief reason for the gradually increasing use of antiseptics and preservatives corresponds exactly with the increasing production of weaker beers, containing, as such beers do, inferior extract and lesser alcohol, and the bad quality of malt that has been characteristic of recent seasons.

Animal and vegetable life in beer.

Cause of variation in stability

Now, what does all this mean? Simply this, that beer has its possible diseases; that the old-fashioned college ales were free from them, not only because material was better, but that such beers were highly alcoholic; that, do what we will, abhor chemicals, sulphites, salicylic acid, and all the rest of them, just as we may, we are still bound to employ them if a combination of circumstances such as inferior malt, or at any rate inferior as compared with the malts of bygone years, mildewed hops, low gravities necessitated by increased competition, and trying sultry weather determine a certain changeable condition of wort or beer.

Disease of beer.

Necessity for use of antiseptics.

Liebig was very fond of saying that, according to the condition of albuminous matter, so we had the formation of lactic acid, starch hydration, vinous fermentation, acetous fermentation, or absolute putrefaction, but at

Liebig's view.

The modern view.

the present time we have advanced far beyond this, and know as an absolute fact that just according to the state of the azotised constituents of malt, and the resulting peptonic plasma in wort, so will be the tendency of that wort in the direction of normal vinous fermentation, or abnormal development of viscous lactic acid, or putrid ferments. This is so entirely beyond dispute, so easily proved, so useful a point of knowledge, that I may describe the connection of biology with brewing as of the greatest interest and importance. All the intricate proofs—all the necessary explanations—will naturally come in their proper place, since biology constitutes the groundwork of fermentation; but as the laboratory is the true position for the forcing tray, and as by its indirect aid we determine quality of malt, stability of beer, and comparative value of different antiseptic agents, I prefer to describe here the practical manipulation necessary.

Condition of azotised matter.

The forcing tray.

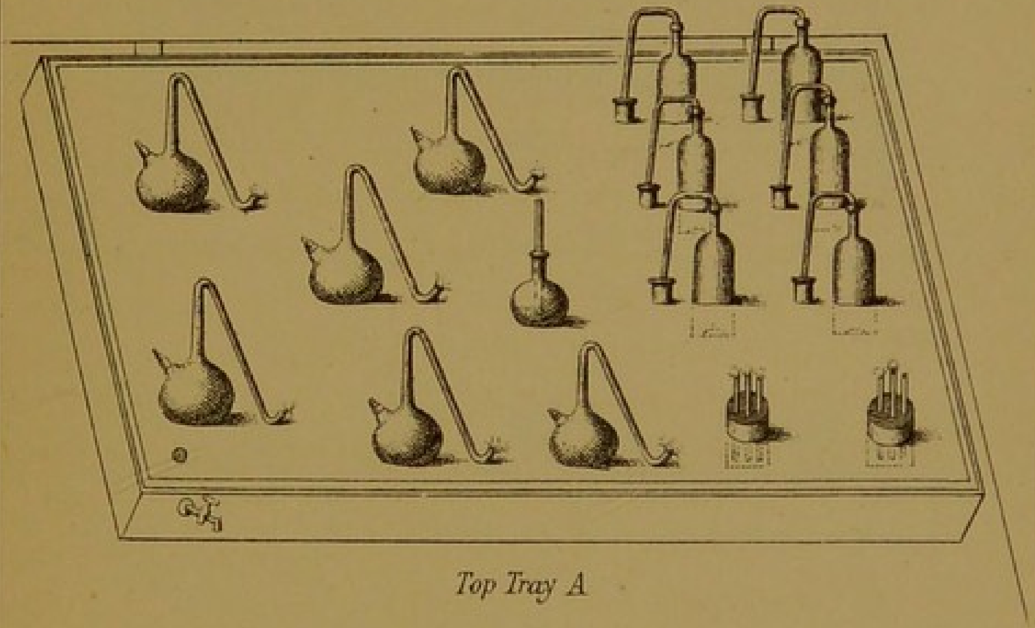
Description of illustrations.

If my readers will refer to illustrations they will see a detailed arrangement of such a tray—what are termed forcing trays—each tray constructed of copper, properly supported and containing water, which is kept at a suitable temperature by a single gas jet, as shown in sketch. On the top tray (A) we see, first, small bottles, termed growing flasks, the outlet end of long-bent neck being closed with a plug of lightly-inserted cotton-wool, the inlet by an india-rubber stopper; secondly, ordinary beer bottles, standing in pockets, and connected by means of bent-glass tubing with a mercurial trough, or dipping simply into a small beaker of mercury; while, thirdly, at the right-hand corner of tray we note another pocket arrangement for test tubes, which, as will be seen, are similarly lightly plugged with cotton-wool. On the lower tray (B) are placed ordinary forcing flasks,

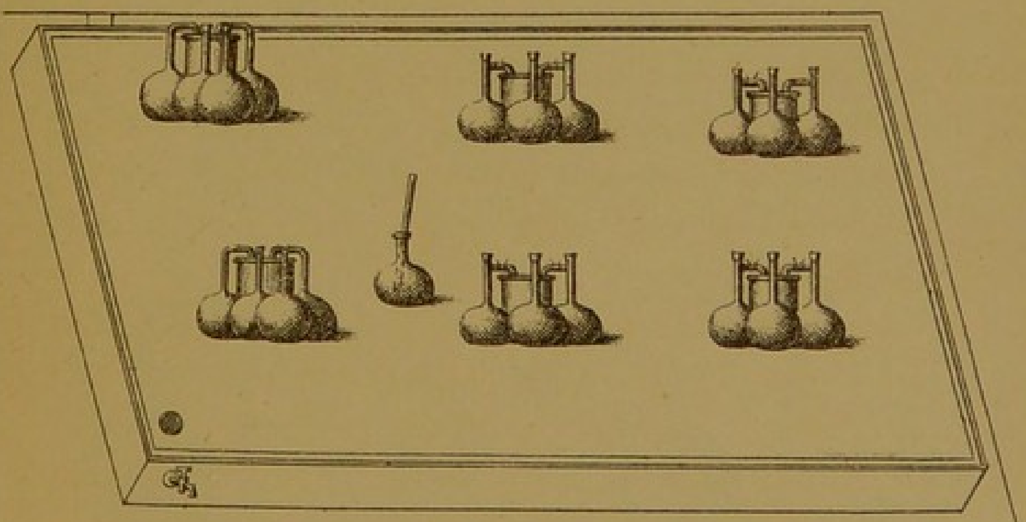
Details of tray arrangement.

FERMENTATION SECTION.

PLATE IV.



Top Tray A



Bottom Tray B

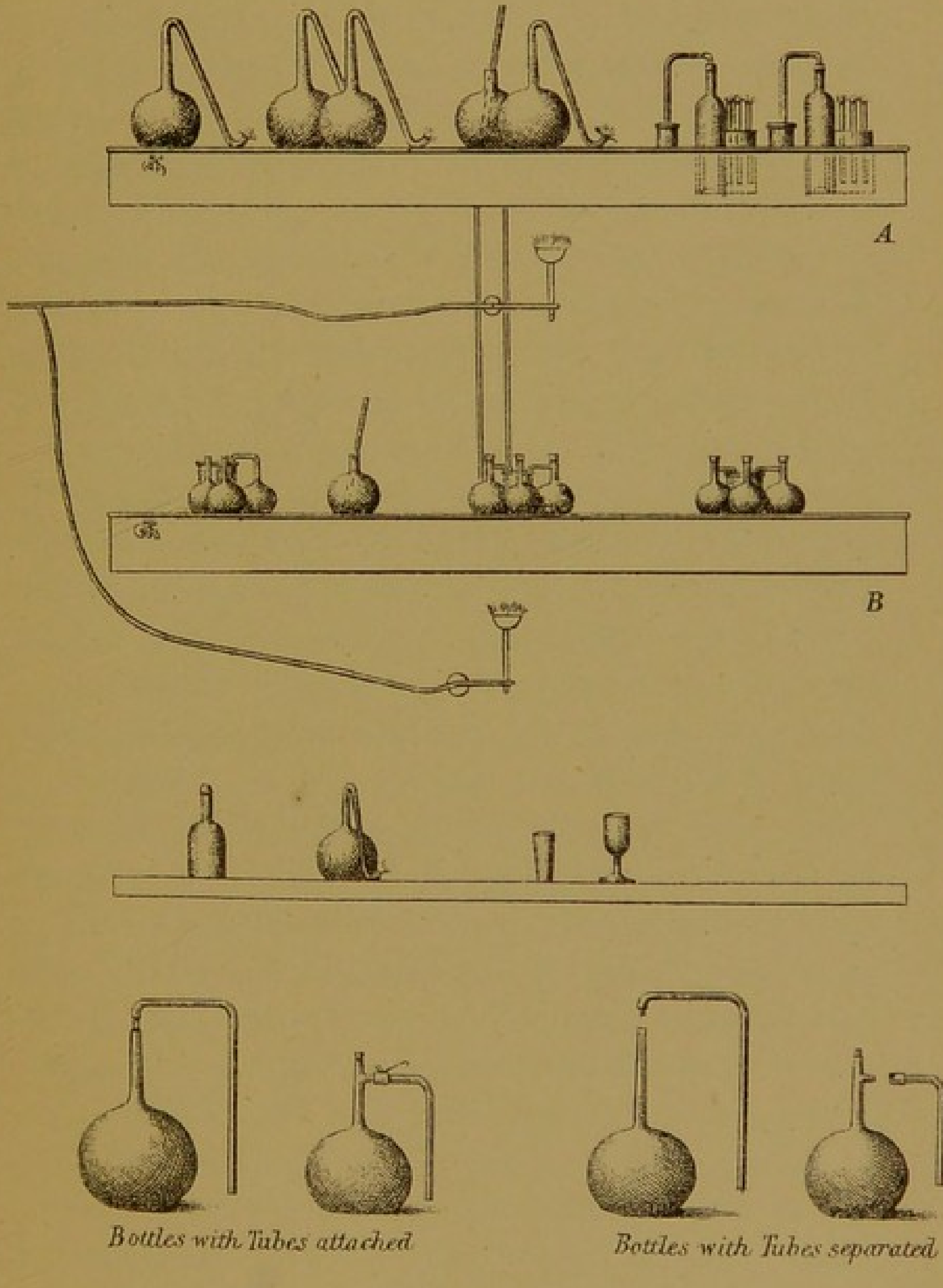
"FORCING TRAY" ARRANGEMENT

FRONT VIEW.

Sprague & Co Photo-litho London

FERMENTATION SECTION.

PLATE V.



"FORCING TRAY" ARRANGEMENT

(DETAILS)

Sprague & Co Photo-litho. London

ranged in series round a central reservoir of mercury, the outlet pipe of each flask being connected to an angular tube, dipping into it, while the next plate shows us a front view of the same trays (A and B), with gas arrangement. Below and following this we have an enlarged representation of the forcing flasks and connections, indicating the way in which the bent tube is attached. On each tray a thermometer is placed, to indicate temperature; and if a small flask of water be inverted, with its neck dipping into fluid contents of tray, we shall always see by the level of water in flask when our trays require replenishing. The usual forcing temperature is 75°; and it is, of course, of importance that there should be no variation, this being sufficiently easy to arrange if the trays be enclosed, the gas supply regular, and if we employ a delicate Bunsen burner. Forcing temperature.

The *modus operandi* is simplicity itself; but the manipulation requires practice, and absolute cleanliness is necessary. I will explain two forcing-tray uses: first, the determination of the character of a malt; secondly, the stability of a beer. Let us take one or two large test tubes, of 200 c.c. capacity, boil in them about 100 c.c. of distilled water, plugging up the ends lightly with cotton-wool; on ebullition resulting, the steam blows through wool, practically sterilizing it, and the test tubes, with their fluid contents, are then placed in a beaker of cold water, and in a few minutes we introduce a tea-spoonful of the crushed malt we are experimenting upon into our tubes, the beaker being then placed over gas, and the temperature of the whole arrangement raised to 150° or 155°. We have, in fact, in our test tubes miniature mashes, and by occasionally shaking up contents we promote saccharification, and in the course of a couple of hours the supernatant wort

Forcing tray manipulation.

Testing stability of malt.

Miniature mash tubes.

brightens. The tubes containing the mashes are now cooled down, and placed in pockets of forcing-trays, the wort in each being examined at the end of every twelve hours. A good malt will give a solution remaining absolutely unaltered at the forcing-tray temperature for twenty-four hours, or, at a temperature of 60°, for even thirty-six to forty-eight hours, while inferior malts comport themselves quite differently.

Determination of beer stability.

I now come to the question of determining stability of beer, and value of preservative agents; they are processes that naturally run hand in hand. It is not usual to deal with beer that is turbid, nor to filter a beer to obtain it bright. In other words, our object is not to discover the type of ferments that have existed, but those that will come into existence if we promote secondary changes. We operate, therefore, on beers that have dropped spontaneously bright in cask, collecting them in sterilised vessels, *i.e.*, in ordinary open beakers, that have been rinsed out with boiling water; and we draw the beer, not through taps that are most likely dirty and plugged up with mould, but through freshly-bored peg-holes, immediately covering down beakers with glass plates, to keep out all dust and dirt. In the same way we sterilise everything used in these experiments by means of boiling water, or by holding such as can be so treated in the clear flame of a Bunsen burner.

Sterilised vessels.

Method of sterilisation.

Filling of flasks under pressure.

Extreme care and delicacy is necessary in filling the forcing flasks themselves, since this is accomplished under the influence of suction, both sudden and strong. Each little flask is taken and half filled with distilled water, an india-rubber cork is inserted tightly in upper outlet, the small side outlet pipe being connected to a short 50 c.c. pipette by means of an india-rubber tube.

Details of manipulation.

This arrangement complete, the flask, clipped by a proper holder, is placed over a clear Bunsen flame. Ebullition quickly results, while the steam rushes out of flask down india-rubber connecting link, making its exit through attached pipette. This, of course, is effectual sterilisation, and, by a sudden twist of the hand, we at once invert the flask, so that the whole of fluid contents are ejected, partly forced out by the internal steam pressure. At this moment the india-rubber connecting link is clipped tightly between finger and thumb, while we plunge the free end of pipette into the beaker of beer. Instantaneous condensation of steam in flask and pipette results, the latter fills with beer, and by employing the fingers as a clip on tube, we can regulate to a nicety the entry of fluid into flask—sucked there, of course, under the influence of the vacuum that exists. If the beer be very gaseous it is possible that the small flask may not be completely filled; but in this case it is only necessary to withdraw suction tube, utilising it as a fountain supply to the flask itself, which speedily fills, if we slightly ease the india-rubber stopper. When properly charged, we again pinch the india-rubber connecting link, disconnect it from pipette, and attach it at once to the slip of glass tube, bent at right angles (as shown in illustration), which itself passes through cork, with its open end immersed in the mercury contained in small phial.

Regulation of suction.

Great care is, of course, necessary in all this, since after sterilising the forcing bottle, and creating strong suction by the very means adopted for sterilisation, we must see that we do not allow air to enter as well as beer; but a very little practice makes any one an adept at the manipulation, when their fingers once become

Prevention of air entry.

accustomed to the somewhat trying heat of the entire apparatus and connections. It is customary to arrange the flasks in series of four, each set having its own little mercurial reservoir, so that we do not place reliance upon one result, but filling each bottle of the series with the same beer, we eventually have four distinct deposits to examine.

Arrangement of flask series.

Placing the whole arrangement on forcing tray, it is labelled with the number of the brewing we are experimenting upon, and the date from which the test commences ; and it is very evident that our tray may soon be filled with samples of various stock-brewings, of which we desire to know, what I may rightly describe as their future history. Under the influence of the forcing temperature we distinctly bring on a secondary or tertiary fermentation, under a definite pressure and out of contact with air, any excess of gas produced bubbling through mercury in reservoir. It sometimes happens that the beer experimented upon, being exceptionally clear, remains quiescent for a considerable period, and if the forcing bottles have been placed on tray somewhat too warm an actual vacuum results as contents cool down to the tray temperature, and mercury is sucked back into bottles. I mention this since any such result not only spoils the experiment, but exhibits to us the influence of metals upon beer; the mercury, of course, being anything but absolutely pure, galvanic action takes place, the beer is decomposed, a heavy deposit is thrown down, and, if air has been sucked in as well as mercury, putrescent change eventually takes place.

Results of forcing.

Vacuum in bottle.

Galvanic action.

Beers, when submitted to this severe test, soon exhibit their differences of constitution ; the mild varieties left at high gravities become immediately turbid, throw

Non-stability of mild beers.

down a heavy deposit, mainly consisting of normal yeast cells, but fail to resist for any length of time the influence of high temperature—in other words, rapid acetification results; while, if the beers have been produced from inferior material, absolute deterioration corresponds with the preliminary turbidity—*i.e.*, the fermentation forced on is distinctly unsound. On the other hand, clean beers—those produced with excessively saline waters, or brewed upon definite lines, covering the use of sugar as a partial malt substitute, fully attenuated, and heavily hopped, both in copper and cask—comport themselves very differently, no violent fret takes place, the fluid remains moderately bright, and the small quantity of deposit that accumulates is almost of itself sufficient proof of the widely differing composition of the two classes of beer described. Microscopically, its character is equally marked: we see no normal yeast, but a mixture of granular and elongated cells, if the deposit be pure; but if the beer, in spite of all the different conditions of production described, have an unsound tendency, then mixed with this abnormal physical appearance of vinous yeast, we shall see the ferments corresponding with acidity and putrefaction as pictured in the "*microscopical aspect of a Turned Beer.*" There is no doubt upon this point; in every case the deposit is the key to the question of stability, and personally I have never known the test to fail. True, you may have many beers that will not bear a forcing-tray test, and that yet will remain sound in store so long as they are quiescent and the temperature of the cellar is sufficiently low, but agitate them and expose the cask or bottle to the same heat as exists on the tray, and a similar result will invariably show itself.

The keeping quality of well brewed beer.

Microscopical aspect of deposit.

Forcing tray.

Its application to stock beers.

From this it is easy to see that the test, as a practical one is more applicable to stock beers, and those intended for export or lengthy home-transit than for the great bulk which is consumed before it has time to "go off." It may be supposed that such a fact limits the usefulness of the forcing-tray experiment; but although mild running beers constitute the bulk of the entire produce, still all brewers store a very considerable quantity of pale and strong ales, that require age for the development of distinctive flavours, and it is certainly a point of great moment for them to determine if such beers can be safely stored or no.

As a test for preservatives.

It is but another step to test the respective value of different preservatives, since we can treat a beer of known want of stability with definite quantities of calcic bi and mono sulphites, sanitas, hydro-sulphite, Beanes' No. 2, Gillman and Spencer's C. and D., and salicylic acid. Place a series of each on forcing-trays and make careful examination of the deposits at the end of a fortnight, using the following quantities of the various preservatives for the experiments: 1 c. c. of all the fluids to 500 c. c. of the beer, and ·05 gramme of the solids; a quantity largely in excess, as it will be seen, of the practical proportions employed.

Quantities employed.

Some very useful information may be obtained by experiments in this special direction, not only as regards antiseptic capacity, but also suitability in direction of neutral influence in respect to flavour. For instance, sanitas will appear as a somewhat objectionable body, with powerful oxidising tendency and a capacity of communicating a distinct flavour of turpentine. The acid sulphite will occasionally cause a stink when added in the proportion named to soft water or yeasty beer, while the dry sulphites are more or less free from

Sanitas.

Acid and dry sulphites.

this defect, their state of purity corresponding also with the absence of rough harsh palate taste of the beer to which they have been added.

If the brewer does not care to dip deeply into experiments of this kind without proof of their value, the following simple operation may induce him to modify his crude sceptical views. All stock beers undergo frets in cask, and if the fret be persistent, it is termed absolute sickness. Let him collect, periodically, a small quantity of the fretting beer in a 200 c. c. test tube, plug with cotton wool, and allow a deposit to subside, which will be a matter of a few hours if the fret be what I may describe as healthy or nearly complete, leaving supernatant beer bright, while, if otherwise, the beer itself will remain more or less cloudy. Without any forcing temperature the microscopical aspect of the deposit indicates, with absolute certainty, the results that the brewer may expect, and gives him also a pretty clear idea of any faults or mistakes that may have been made during the process of production. If the deposit is one largely composed of vigorous alcoholic yeast cells, he has evidently produced a very heavy albuminous wort, insufficiently attenuated his beer, or racked it with a large quantity of yeast in suspension, while if there be an intermixture of lactic ferments and acid filaments, he may rest assured that, on the fret terminating, the beer will be more or less unsound.

Forcing tray applied to a fretting beer.

Indications of the deposit.

These facts are beyond dispute; they are the practical outcome of what Pasteur taught us in his studies on Wine and Beer; but it may not be known that the entire honour of working out the practical manipulation properly belongs to Mr. Horace Brown, of Messrs. Worthington's, who was the first to erect a forcing-

Mr. Horace Brown.

tray and select his stock and export beers according to its indications.

If I am not clearly understood, I would remind readers that they have yet to come to the explanation of the theory and practice of fermentation, which will undoubtedly clear away clouds that may at the present moment exist, and it now only remains for me to describe the working of the wonderful instrument that we employ for investigating the actual character of deposits, or the cause of turbidity in beer. It is very unfortunate that ordinary vision is not capable of giving the required knowledge, since the microscope is a delicate and complex arrangement of lenses that require very nice adjustment in themselves, while the specimens for examination have to be prepared with more care than many brewers have time or inclination to bestow.

The microscope.

A necessary addendum to a brewer's office

The chief practical point centres in obtaining an instrument possessing what is termed a high power of definition—*i.e.*, a lens power showing only mere outline of ferments is worse than useless, while any distortion is an equally grave fault. I do not suggest that any expensive instrument should be secured, but great care is necessary in selecting the magnifying lenses and corresponding eye-pieces, and it will be found that even the best makers are not always successful in turning out lenses of equal power in the special direction spoken of.

Choice of an instrument.

The next point is to obtain a site for the microscope that will prevent any quivering and secure a powerful reflected ray of light to illuminate field of view, which, of course, should be absolutely free from specks of dust and dirt. It is best to have the instrument constantly ready for use, standing under a glass shade, in some

Its position.

out-of-the-way corner of brewer's office that can be conveniently set apart for it, since moving from place to place is apt to cover the field of view with little particles shaken from the sides of lens cases.

Preparation of samples.

The preparation of samples for examination is equally important, the glass slides should be perfectly free from scratches and any greasy film, and it is customary to wash them in soda-water or with soap, finally polishing them off with silk or wash-leather wiper ; the covering slips should be of very thin clear glass, not so thin as to lead to constant breakage, but sufficiently so as not to diminish magnifying power of object glass, and these also require to be kept scrupulously clean.

Covering slips.

It is usual to employ a pair of clips for placing these slips, the fingers being always more or less greasy. Yeast for examination is mixed with distilled water always at one temperature, since if it be employed warm one day and cold the next it is apt to lead to very erroneous ideas respecting size of cell life. The dilution should be such as to give 50 or 75 cells in a field of average size, the mere appearance of such fluid being no particular guide, as different yeasts require varying degrees of apparent dilution to give the number of cells specified.

Dilution of sample.

Deposits are usually collected by means of a pipette from the bottom of flasks or beakers, or the clear contents may be partly poured off and the deposit shaken up in the residuum so as to give the necessary dilution. A single spot of the liquid for examination is placed on centre of slide and immediately covered down with glass slip in such a way as to prevent any of the fluid attaching to upper side, this being easily accomplished if the operator place the slip at an angle touching the glass before allowing it to drop on the bead of fluid.

Practical details.

Removal of excess of fluid.

Sometimes there may be an excess of liquid which oozes out round covering slip, and may be removed by blotting-paper. It is hardly necessary to observe that no sort of pressure must be applied to the slip itself, its own weight being quite sufficient to spread out the bead of fluid into a film, while if pressure be applied, the yeast cells are distorted and more or less ruptured.

Young beginners.

It is a very common occurrence for tyros in yeast examination to get fluid on the upper side of slip, which eventually attaches to outer glass of object lens in their vain efforts to obtain proper focus, while if the bead of fluid they place on slip be not a perfect mixture, or if allowed to remain too long before compressing it with slip, so that suspended solids commence to subside, a *double* field results—*i.e.*, it is impossible to get all the cells into perfect focus at the same time.

Double fields.

Common instruments.

I have spoken of the defining power of a lens, and what I mean by this will now be evident. The commonest instruments may give us a beautiful field of yeast-cells; we may be delighted with their regularity of shape and distinctness of outline, but of what use is this if they do not indicate the interior physical construction of the cell itself? This is of the most extreme importance as far as store yeast is concerned, and in reference to the meaning of microscopical deposits. I can example the special significance of this remark by saying that the frothy head of a common table beer of 8 or 9lbs. gravity, would give a field in many instances of beautiful globules that many might mistake for perfect yeast, but which, in the absence of plasma or interior nutritive matter, would prove utterly useless for any practical purpose, so that microscopes capable of indicating mere perfection of contour without any power of exhibiting prominently the interior physical

Definition of lens.

De eptive indication of poor instruments.

development, are something worse than useless, they are absolutely dangerous in the deceptiveness of their indications.

For the same reason over-enlargement under magnifying influences is not advisable, since we are deceived by what amounts to absolute distortion, and if we secure an enlargement of 400 diameters, which corresponds to the illustrations of ferments in Pasteur's work, as obtained by the use of a 1-6th objective in conjunction with A eye-piece, I think it suffices for all practical purposes. 1-6th objective and A eye-piece.

It is no small matter to become a good microscopist, but I have touched upon the points that require special practice, and the only necessity is that a really good working instrument should in the first instance be secured. This chapter, I confess, covers a variety of subjects. It may for that very reason prove to be of the greater practical interest, and it leaves me now clear to come at once to the everyday operations of the Brewery.

CHAPTER VIII.

MASHING.

Mashing determines character of wort.

It has always been supposed that fermentation was the most important stage of a Brewer's process, but I incline, myself, to the opinion that the preliminary operations of malting and wort extraction are equally important, since we are practically engaged in preparing a variety of soil in which we afterwards cultivate a vegetable organism.

It is all very well for people to smile at such a description of the Brewer's mashing operations. No amount of scepticism can upset the broad fact that character of wort entirely determines quality of beer in so far as such wort constitution has to do with the healthy or diseased reproduction of vegetable ferment life, and as this is so, the subject of mashing merits a great deal more attention than has hitherto been bestowed upon it.

Character of wort influences flavour of beer.

Previous writers have devoted a great deal of time to an explanation of the importance of stated percentage proportions of malt sugar and dextrin as constituents of wort; others have spoken of the quantity of nitrogenous matters and inert bodies that are useful for one purpose or another; but few if any have concerned themselves about *Peptonic* constituents, *i.e.*,

Peptones.

the exact condition of the yeast-forming bodies that their wort contains, and it is in reference to this special subject that I desire to make the chapter on mashing more than usually interesting. Prior to this operation the malt is crushed or ground, and I have previously described how the extent of disintegration should vary according to the character of the grain and the saline nature of the water in use. I also mentioned that crushed material should not be exposed to the air or left too long to heat, compress, and set.

The olden idea respecting mashing was a very simple one, and may be summed up thus—malting led to saccharification of barley, and during the infusion mash the brewer simply dissolved the sugar formed, and writers were apt to refer to the sweet taste of malt as proving the saccharification, although it is doubtful whether it does anything of the kind. Old idea of mashing.

The saliva of the mouth contains, as is well known, a body of albuminous nature named ptyalin, which has a wonderful capacity of effecting starch hydration, and is utilised for this purpose in the preparation of chica beer, the maize being chewed in the mouth and then ejected into a vessel, where the mixture, unpleasant as it is, undergoes saccharification and so-called spontaneous fermentation, ending in the intoxicating chica. Ptyalin. Chica beer.

It is perfectly easy to understand from this why a malt containing a quantity of modified and semi-soluble starch should taste sweet when chewed, since the above-named ptyalin is actively employed in forming sugar, the malt containing starch the more perfectly modified, tasting far sweeter than semi-vegetated material. It will thus be seen that the mashing process is not merely the solution of ready-formed sugar, since, as a matter of fact, the best malt contains but a very small percentage. To put it plainly, mashing has two main offices, the formation of fermentable products from starch under the influence of modified albuminous matter, nitrogenous bodies that have been modified by vegetation; and, secondly, the conversion of other soluble albuminoids into digested form by diastase, aided in marvellous manner by temperature and pressure.

Object of mashing.

Aim of malting.

The main object of malting, then, is the creation of diastatic energy. I have insisted upon this over and over again in the chapters on materials used in brewing and the chemical examination of malt, the succeeding mashing process hinging for success upon utilising to its full and in a dual direction this diastatic power—hydrating starch into dextrin-maltose and digesting by its aid ordinary soluble albuminoids capable of peptonic modification. From this it will appear why the infusion method is frequently so unsuccessful. Malts in recent years have had low diastatic powers, and the problem for the brewer has been, in so many words, coaxing a small quantity of active diastase to accomplish a great deal of work.

Low diastatic power of malts of the present day.

Infusion mash and inferior material.

Starting with perfectly vegetated grain, the infusion method gives a temperature and period of action that suffices for this purpose, but under other circumstances it is a pitfall for the unwary, and boiling and sluggish fermentations, cloudy and unsatisfactory beer prove how ineffectual the process has been in the direction of providing a wort in which yeast, no longer to be considered the mere by-product of the brewer, can reproduce itself in perfectly healthy form. The infusion mash tun is to my mind a vessel of the past, and the clumsy means we take at present for neutralising its deficiencies in the way of non-intermixed underlets, naked steam on surface of mash, and prolonged stewing of wort in copper, while accomplishing, perhaps, as much as is possible, would be entirely unnecessary if we took a leaf out of Continental books and erected a preliminary cooking vessel of the kind pictured in my description of brewery plant.

Continental cooking vessel.

I will start at the beginning and gradually wade through the entire question, so that there may be no sort or kind of misunderstanding, and try and explain how it is that by the use of Continental forms of mashing plant brewers might succeed far better with inferior descriptions of grain than they do at the present time. Malt, as we have seen, contains a great deal of starch, and by comparison a small quantity of what analyses out as the so-called diastase—a portion of the soluble albuminous constituents—the exact diastatic capacity of this portion depending upon the perfection of vegetation that has taken place. The chief difference between good and faulty material turns upon the extent of diastatic capacity. Brewers bring this diastase into action by making their mash at what is termed a correct saccharification temperature, and this is limited in two ways, since below a mixture heat of 140° acidity would most likely develop, while above 165° the diastase itself, or active principle, would be destroyed. It is a common point of knowledge that cold malt extract, *i.e.*, the filtrate from a mixture of malt and cold water, which contains only, of course, the soluble albuminoids, acts quite as energetically on gelatinised starch at the temperature of 60° as at the higher range common with the brewer; but brewers, unfortunately, are not dealing with gelatinised starch, and, besides this, acidity is with them a question of much moment. Employing as they do

Malt contains a great deal of starch.

Mashing temperatures.

Necessity of initial heat being over 140°.

Cold malt extract.

malt, which yields a considerable quantity of acid, any increase would assuredly prove an uncomfortable factor towards the completion of their operations, nothing, to my mind, interfering so much with spontaneous clarification of beer.

Fluidity of mash.

With the initial heat of mixture fixed between the two extremes mentioned, the next question that presents itself is in connection with degree of fluidity, since it is pretty evident that by employing large quantities of liquor we can very considerably lower the temperature that would be necessary with a smaller quantity to give the exact initial selected. I give, as a footnote,* a formula for calculating out the necessary temperature of liquor to arrive at required mixture heats for any degree of fluidity selected, and this will prove very useful to those who suddenly change from a small plant fitted with outside mixer to mash tun, into a large concern with immense tuns fitted with rakes only.

Calculation of striking heat necessary.

* It is very necessary for a brewer to have at hand a formula for calculating the initial temperature of certain proportional mixtures of malt, in its crushed condition, and liquor.

The following figures and explanation of same will perhaps render the matter clear :—

Specific heat of malt	...	0·4
Temperature of malt	...	12° Centigrade.
,, mash liquor		55° ,,

Relative proportion between malt (weight) and liquor 3 to 1.

$$\frac{0{\cdot}4 \times 12^\circ + 3 \times 55^\circ}{3{\cdot}4} = \frac{4{\cdot}8 + 165}{3{\cdot}4} = 49{\cdot}9^\circ\text{C}.$$

Thermal unit, or the unit for the quantity, is the amount of heat—obtained, we will presume, by burning coal—required to raise a given quantity of a standard substance—say 1 lb.—through 1° of temperature, water being generally taken for the purpose as the standard substance.

The specific heat of another substance is merely the number

Practically the degree of dilution is fixed for us in one direction by the limit to mixing power of ordinary machines driven by belts, and in the other by the fact that dilute mashes mean, as a rule, very saccharine forms of extract with diminished sparging length and consequent loss. The outcrop of all this is that some two to two and a-half barrels of liquor are employed from first to last in the mashing of every quarter of malt, the comparative weights being 720 to 900 lbs. water to 336 lbs. malt, and these figures are useful as explanatory of the terms of footnote formula.

2 to 2½ barrels of liquor per qr.

As malt contains an agent of great importance, and as this is undoubtedly crippled and eventually destroyed by high temperature, it is customary for all brewers to employ the lowest heats compatible with attaining the requisite mixture initial spoken of, since

A set mash.

of units which it takes to raise 1 lb. of it through 1° of temperature.

The easiest way to proceed is to imagine everything to start from zero temperature, and then ask the following questions:—

I. How many thermal units will be used in raising 3 lbs. of water from 0° to 55° and 1 lb. of malt from 0° to 12°?

II. Through how many degrees—*i.e.*, to what temperature will this same amount of thermal units raise a mixture of 3 lbs. of water and 1 lb. of malt?

Number of thermal units to raise 3 lbs. of water from 0° to 55°... ... ... $= 3 \times 55 \times 1$

Number of thermal units to raise 1 lb. of malt from 0° to 12° .. .. $= 12 \times 0{\cdot}4$

Therefore, the total number of thermal units existing in these two bodies while separate equals

$$(3 \times 55 \times 1) + (12 \times 0{\cdot}4)$$

Now the number of thermal units to be applied for raising 3 lbs. of water and 1 lb. of malt to a common temperature equals $(3 \times t^\circ \times 1) + (1 \times t^\circ \times 0{\cdot}4) = 3{\cdot}4\, t^\circ$.

But this number of thermal units is the same, *i.e.*,

$$3{\cdot}4\, t^\circ = (3 \times 55) + (12 \times 0{\cdot}4)$$

$$\text{Therefore } t^\circ = \frac{(3 \times 55) + (12 \times 0{\cdot}4)}{3{\cdot}4}$$

the old-fashioned term *scalding of the mash* merely referred to the result that was experienced when using liquor at a temperature sufficient to gelatinise the starch granules, destroying at the same time the converting principle, this being practically a *set mash.*

Keeping up heat of mash tun.

The means taken by the brewer are in the direction of thoroughly heating the mash tun with steam or hot liquor, and by so enclosing the vessel as to prevent excessive radiation and consequent cooling of mash tun contents. By care in these several points, it appears that by mixing ordinary crushed malt and liquor at 165° in the proportions stated, the primary initial heat is closely approaching to 150°.

Ordinary striking and initial heats.

I prefer to put the case in this way, as older writers referred to this stated temperature as one of great importance, being to their view necessary in order to attain brightness, creaminess, and sparkling character of resulting wort. Although it is quite true that worts should come off eventually at this temperature, it is, nevertheless, far too high as a preliminary one, which, to my mind, should be as low as 140°.

Preliminary initial of 140°.

It will be remembered that in the olden days when mashes were made by hand, the intermixture heats were much lower than at present, and it was only towards the end of the mash-tun work, quite forty minutes from the commencement, that the temperature of goods was raised to the 150 or 152° now customary, while, besides this, the malts at that time were unundoubtedly more fitted to resist, satisfactorily, the influence of what may be termed excessive heat. It is not usual to notice the development of heat during intermixture, and yet, in some mash-tuns it is a very prominent feature. All chemical changes give rise to heat, and it is obvious that during the hydration of so

Rise of temperature during stand of mash.

large a starch percentage the temperature of mixture must rise considerably, but this, in the majority of cases, perhaps, is neutralised or counterbalanced by the radiation going on.

The increase in acidity of mash also escapes notice, this increment being due to the formation of peptones which have an acid reaction. It is well to state these facts even if they be but of theoretical importance. Increase of acidity in mash.

Such, then, are the ordinary considerations governing the infusion mash; let us now inquire in what direction improvement is possible.

If the brewer have but a mash-tun of modern fittings, the matter is a very simple one; hitherto, improvements have been in the wrong direction,—for example: the mashing machine of Tizard was most commendable in principle, but failed utterly in practice; the mixing machine of Sorrel was another attempt to obtain a low first mixture heat with after increase to the recognised finishing temperature, while the circulating methods of Crockford and Davenport are simply steps in the same direction. Tizard. Sorrel. Crockford. Davenport.

The only disadvantage of such processes is their lengthy nature, *i.e.*, it takes a very long time to raise the heat of a large bulk of grist by the constant circulation of its own wort, if this wort be circulated at a temperature leaving its diastatic constituent in a state of activity.

The adoption of steam coils under false bottoms is thoroughly wrong, since there is constant danger of over-heating the wort under the plates and the mash in contact with them, and the system of blowing in naked steam is objectionable, as leading to a certain destruction of some diastase, and frequently occasioning a most unpleasant kind of contamination. Steam coils under false bottoms.

Underlets.

There is only one defect, perhaps, in the system of underlets intermixed with powerful machinery, and that is that in arranging for an underflow the primary mixture is made so stiff as to necessitate a degree of liquor temperature far too high, since it should never be over 158°, and with a stiff mash it frequently has to be ten degrees higher to give the most moderate initial.

Water and steam jackets.

The case then to me seems simple; there is no objection that I know of to a water jacket, and very little to the steam jacket of Continental mash-tuns, except that, in using these for the purpose of raising temperatures, the mashes have to be kept in constant motion by machinery, which leads to a certain deadness and settling of goods.

Pressure and filtration.

On the Continent such disadvantage does not amount to much, since pressure is applied where ordinary gravity fails, but in England, where we have not at present pressure filtration vessels, we should have to overcome any tendency to settling by the use of a percentage of buoyant material or by increasing our drainage area so as to facilitate the percolation of the fluid.

The question of pressure is not altogether novel; it is undoubtedly both interesting and important, and there is no doubt that combined pressure and motion exercise an immense influence on chemical changes of the kind we are dealing with when considering mashing. If any example be needed, what better one can be given than that of starch hydration under the influence of acid?—this corresponding very well with starch modification by diastatic agency.

Pressure and starch hydration.

Before pressure was adopted by saccharine manufacturers as a detail of their process several hours were required for the conversion, the same change resulting at the present time under a pressure of three or four atmospheres (say 60lbs.) in so many minutes, so that putting on one side the benefits of pressure, as facilitating filtration, the brewer could but derive advantage from its other influence, and I do not wonder that it has been adopted as a method for facilitating saccharification in many North German breweries.

It will be pretty evident so far that there is little to say in favour of the infusion vessel, but as this happens to exist in two-thirds of the English breweries, it must be utilised in such a way as to make the results as perfect as possible. The general outline of the process is to mash through external mixer with some two barrels per qr. at 160°, so as to give first initial of 142°, raising this after an interval of one hour to the final heat of 152°, by the use of some further half barrel per qr. at 185° to 190° slowly run under false bottom, with internal rakes revolving or mash oars and hand rakes vigorously applied, the idea being to prevent any section of the mash unduly heating.

Mashing with 1st initial of 142°.

This is certainly within the capacity of every plant, and the knowledge and power of every brewer, and the benefits arrived at are simply as follows:—The comparatively low temperature of intermixture keeps the diastatic constituents, few or many, in active condition; they are thus energetic in several directions, bringing about, first, the solution; secondly, the hydration of starch into proportions of dextrin and maltose constantly assuming a more saccharine nature, and also peptonising other nitrogenous bodies, rendering these capable of acting eventually as the plasma or aliment of yeast.

Advantage of low initial.

The process has justly been described as a *coaxing*

Coaxing process

one, *i.e.*, we induce diastase to accomplish much more than it would do if its power were crippled by a first application of a high temperature, and no words of mine are necessary to prove that the process is specially adapted to that class of material which has never been efficiently vegetated on the malting floor. The users of raw grain are very sensible of the limit to diastatic power, since the first step in their process is the complete gelatinisation of the starch, for, as they know that the diastase of malt has sufficient work to accomplish as regards starch solution in the case of malt extract itself, they deem it wise to submit extra quantities of starch in the condition which the more readily admits of speedy and complete hydration.

Gelatinisation of raw grain prior to use.

Rise of temperature in mash induces a bright wort.

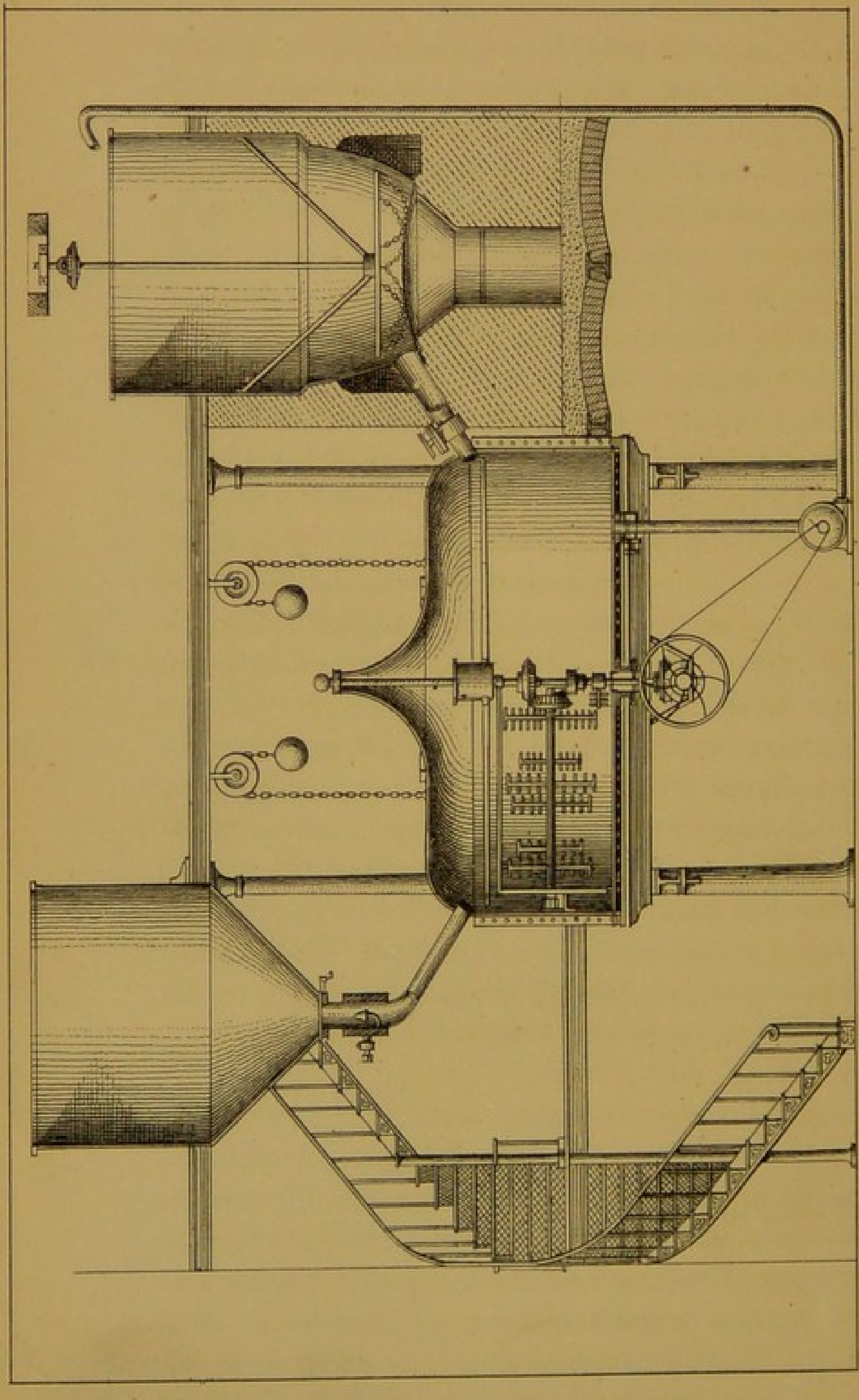
The full benefit attained by the process of coaxing, explained, seems to end at the expiration of 40 to 50 minutes; it might do so in a much shorter time if pressure were applied, and it then becomes necessary to raise the mash to the temperature which facilitates the flow of a bright wort. Strange as it may appear, this very time was not only adopted by practical brewers in the days of open tubs and mash oars, but is also adhered to by scientific brewers, working on a system entirely different, and is only another example of how practice sometimes precedes the theoretical explanation of its utility.

How practice has preceded theory.

The infusion method, whether carried out on the principle of a simple mixture or the improved plan of two distinct heats, yields a wort of pretty steady composition, the only difference resulting from the use of very inferior material, although the *coaxing* spoken of tends to prevent the variation being so apparent, and the main difference between mashing in an English and Continental brewery is that abroad every brewer

Difference between English and Continental systems.

PLATE IV.



DICK-MAISCH MASHING PLANT

proceeds with a definite idea of stewing the malt, while he carries out the further idea of obtaining a higher dextrin percentage than is possible on the English plan—*i.e.*, he commences to destroy the diastase at the very moment that his mash begins to rise in temperature to the true saccharification point, 150°.

Thus, whether a Continental brewer be working on the infusion or decoction systems, he starts, invariably, with a low heat; he knows how important it is to dissolve albumenoids first, starch next, and induce the influence of one type of nitrogenous matter on other types. He secures the range of temperature by working with a Lacambre saccharification vessel, using the mash tun below as a filter, so long as the process is infusion; while the decoction brewer raises the temperature by his own peculiar process, which it is now necessary to explain, since hitherto I have enlarged entirely on the question of peptonic improvement as influenced by temperature range, while the decoction process refers to the problem of increased dextrin percentage, this consideration cropping up directly the temperature of the mixture is raised from the lower preliminary standing heat suggested as so advisable. I have constantly come across people who could not grasp the meaning of the German Dickmaisch or thick wort mash method. I confess that I do not see any difficulty.

Increased dextrin per cent.

German Dickmaisch.

A German brewer says to himself: "Can I devise any method which will enable me to obtain a complete extract of malt, at the same time avoiding all increase in the normal sugar percentage? Can I, in other words, destroy a portion of the diastase and bring the whole quantity of starch of the grain into soluble form, after I have utilised the entire diastatic influence in the direction of creating yeast aliment?" I must say that he has answered this question in a manner theoretically and practically accurate. What simpler plan than to infuse the malt at the usual low temperature, then raising the heat, not by means of steam or water jackets, underlets, or naked steam, but by heating portions of the mash *seriatim* to a temperature that will lead to dual result, the gelatinisation of starch granules in the portion so heated with corresponding destruction of diastase? By re-mixing the portion so treated with remaining bulk the temperature is raised, the activity of the lesser quantity of diastase is increased, while it finds itself in contact with gelatinised starch.

Starch gelatinisation and destruction of diastase.

The word *seriatim*, introduced above, means that successive portions of the mash are so treated, and it is perfectly evident with what result. At every successive re-intermixture there is increase of temperature, less diastase, and more soluble starch, and analysis confirms what a single thought would suggest—there is less sugar and more dextrin, forming the so-called fermentable portion of a decoction brewer's wort, while the ferment-forming bodies are certainly as high as in the most perfect infusion mash wort that could be obtained with similar material. It is not necessary for me to explain the exact temperature at which the heated mash is returned to bulk left in mashing vessel, or the temperature to which the heated portion is exposed; but I may say that it is seldom boiled, merely being run to 176° to 185° for the double purpose named.

Decrease of sugar and increase of dextrin.

Temperatures.

If this plan is understood it will sweep away many of the absurd ideas that have hitherto existed, and render easy the explanation of English methods of so-called boiled mashes, whether these be devised to merely obtain large extracts or to facilitate the use of

Boiled mashes.

raw material in the brewer's mash tun. If we make a mash at an ordinary temperature, or better still, at the much lower than ordinary temperature suggested, stand for the mystical 40 minutes, and then draw off from the mash tun two-thirds of the strong wort, we secure the dissolved albuminoids with diastatic capacity that have, during the time stated, been fulfilling a very important office in the direction so frequently insisted upon; and if we then apply steam and boil the goods we gelatinise the vitrified starch that has so far defied the influence of the diastase. Cooling down the boiled mash, and bringing back the strong wort, we effect the complete conversion of the gelatinised starch; and although we do not accomplish, in any sense, the increased dextrin formation, we obtain at any rate the larger extract.

Raw grain use without additional plant.

It is easy to see how raw grain can be used under such circumstances, without the erection of preparatory gelatinisation plant, since, after the withdrawal of the strong wort and prior to the boiling of the goods remaining in the tun, the proportion of raw grain for use may be run through mixing machine and intermixed with goods, where it comes in contact with a certain amount of diastase, which exerts activity until its power is crippled by the rising temperature of mash after steam is turned in. It is customary to add a small percentage of very buoyant malt at the stage when the strong wort is returned and intermixed to effect starch hydration, the object being to facilitate filtration at tap setting.

Buoyant malt. Objection to boiled mashes.

All these processes have been practically carried out, I must say, with very great success by Mr. Arthur Mure, of Hampstead, who has vastly improved in detail on the sketch given, while still adhering to it in principle. Certain objections have been raised to the *modus operandi* described, since the constant intermixing of material and the use of naked steam lead to such disintegration of material as to convert it into a pulpy mass, to say nothing of the flavour of wort resulting from the actual boiling of the entire grist.

Cleaning malt before grinding.

This gives point to what I said respecting the necessity of improving our mill room arrangements, so that all extraneous dust and dirt are removed from husk of grain that is to be employed in the production of beer. German brewers are very careful in this matter, since their mashes are exposed to high temperatures, and it is not too much to say that English brewers, employing mere infusion heats, would experience much improvement in flavour of beer if they would expend a little more care in this direction.

The objections just mentioned are not without warrant, since, although the process brings the whole available extract of material into soluble form, it is not, as a matter of fact, obtained in view of the viscid condition of the goods, but all such objections would disappear if the filtration vessels of Messrs. Wurtz, of Breslau, could be employed in conjunction with the ordinary mash tun, or as mash tun and filtration vessel combined.

"Wurtz" filtration vessels.

Their construction.

This machine may be described as cone shaped, possessing side and bottom drainage area easy of regulation, and fitted with an air pump to give the necessary surface pressure, while inside there exists a very simple rake arrangement, and, finally, they have gearing for throwing out grains and self-cleaning. Messrs. Flower & Son, of Stratford-on-Avon, were the first, I believe, to introduce these novelties into this country.

It may well be asked why all this care and complexity of manipulation is necessary; why, in short, the wort, a much simpler fluid to deal with, cannot be efficiently modified at varying temperatures so as to give the same result? The answer is clear. When once the temperature of the mixture has been raised above the limit spoken of, 142°, the diastatic bodies of wort seem to lose their capacity of acting upon albuminous matter in the peptone direction, and simply exercise the well-known power of sugar formation. I do not mean to say that albuminous matter is not modified in the copper, since much benefit sometimes results from prolonged stewing; but I have never yet seen a wort from inferior malt converted by stewing into one of good character to anything like the same extent as if the malt itself had been so manipulated as to obtain to its full the distinct dual influence of its soluble albuminous constituents.

Results of stewing in copper.

Now, what shall I say of those cumbersome processes described in certain books as second and third mashing methods? They are clearly useless, if not absolutely injurious, for I fail to see the benefit of continually stirring up a mash after the soluble bodies have been drawn off, or after their dual capacity is no longer in existence. Certainly, the brewer may obtain a larger apparent extract. He may sweep it through the plates by india-rubber scrapers fixed to the ends of rake arms, but what kind of extract is it? Simply crude raw material that would be better left behind. There is no doubt on the subject, as any one accustomed to brewing operations in London, where this process is still in vogue, can testify. It is not only theoretically but practically wrong, and those conducting it certainly do not understand the true object of mashing.

No necessity for 2nd and 3rd mashes.

To sum up, then, the following appear as the salient

Well-heated mash tuns.

features of all that has so far been said. There should be two distinct heats arrived at in making a perfect mash, and the temperature of the liquor employed should be as low as possible, in view of arriving at the fixed heats necessary. No great range of fluidity being possible, much may be done in this direction by thoroughly heating the vessels and preventing radiation; much more may be accomplished by water and steam jackets. The two heats are 142° as a preliminary mixing and standing temperature, and 152° to 155° as the final saccharification heat, while the liquor employed to arrive at all this should not be more in the first instance than 160°, and in the second 185°.

The adoption of water and steam jackets does away with the necessity of any sudden application of high ranges of heat, and are certainly much better as agencies for effecting variation in temperature than underflows. After the mash is once made, it really matters very little how the heat ranges, so long as we keep within reasonable limits, although with infusion mashes it is safer to adhere to temperatures which leave diastase in some sense active.

Ranges of heats.

Thus I may easily fix a mash-tun range of 152° to 160° after setting tap as strictly within reason; and I need hardly point out that mere tap heats are altogether deceptive, and we ought invariably to be guided by the exact temperature of the mash itself; and a word of caution is necessary, as it is by no means a simple matter to obtain a correct mash heat, and the varying temperatures existing in a mash made by an automatic machine or by a badly-fed Steele is enough to raise a doubt as to the efficiency of existing methods of intermixture. I believe myself that a Stopes' mash-tun thermometer, or a hard German glass thermometer

How to take the heat of mash.

without covering of any kind fixed on a metal stick is about the most accurate appliance. Once enclose the bulb of a thermometer, and it is next to impossible to arrive at the temperature of a semi-fluid mixture into which it may be inserted.

So far, then, I have tried to paint the happy process of the future, but what can I say about present methods of procedure. It is useless expecting brewery firms to make extensive alterations in plant. Disaster, so far, has not taught them that alterations have taken place in conditions of brewing; so, to be quite practical, it is as well that I should suggest methods of improvement in present working that may be possible with existing plant.

Rake machinery.

To those who have mash-tuns fitted with rake machinery and underlet pipes, the heats I have mentioned will appear as in no way strange or novel, but to those who have mash-tuns so exposed as to permit of great radiation without interior fittings of any kind, and supplied by some simple exterior mixer, I may suggest improved protection of vessel, underlet pipes, naked steam inlet above surface of goods, a diminution of mixing temperature by some ten degrees, and to counterbalance this a combined application of slow underlet, top sparge, and naked steam atmosphere. Much may be done in these several directions if the principle of the suggestions be clearly understood.

Then again, on setting tap, if the wort be in any sense crude or inferior, what can be more dangerous than to distribute it into a number of lengths without regard to conversion or modification necessities? What is more common than to find brewers boiling off the strong primary extract and the weak crude starchy runnings in two different and distinct lengths, mixing them together in gathering vessels? Who has not experienced the better fermentation results when dealing with beers of comparatively high gravity, naturally containing none of the inferior runnings spoken of? How comes it that these weaker worts are so inferior?

It would not be so if we were all decoction brewers. Is it not clear that barley malt contains a large quantity of starch that is never acted upon in the first instance by the diastase, that this same vitrified starch under the combined influence of contact with diastase, temperature, and friction gradually becomes disintegrated and carried forward in suspension, if not in solution, that it becomes soluble at the boiling temperature of wort, but at a time when there is no chance of its hydration? What is true of starch is equally true of many other crude constituents of malt, and if we fail to modify them during the primary standing of the mash we are certainly not likely to do so, at any rate in complete manner, during extraction process.

What, then, is the inference of this, if we cannot accomplish in the copper all that we can arrive at in the mash tun? Let us, at any rate, be sensible, and so collect our worts as to avoid the evil of having present in them dissolved starch and bodies that have never been efficiently modified by diastase during the mashing process. Let us give up that very absurd plan of boiling off lengths at gravities of 35, 10, and 3 lbs., and in place of this let us collect the whole of our wort in one length, or distribute the stronger portion over the several lengths, so as to introduce into each a distinct proportion of that active principle, which, at any rate during the collection of the wort

Equalization of copper gravities.

for boiling, may exercise its ameliorating energy on the crude matters in contact with it.

It must be borne in mind that such activity is crippled to a serious extent at temperatures over 160°, so that, when carrying out the idea in question, it is necessary to collect the several lengths, not allowing them to exceed the stated heat till quantity is secured, this rule not applying to the stronger wort that may perhaps have a gravity of 28 to 30 lbs., and which is collected as a first copper charge.

Retention vessels.

In the chapter on brewery plant, I specially referred to retention vessels, and the use of them will now be apparent; but they are not required if our plant consist of several coppers, over which the wort may be proportionally divided from an extract point of view, or one sufficiently large to contain the whole length at once. The objection that loss of extract occurs through boiling off in one length on account of diminution in evaporation bulk, and much extract being retained by hops, falls to the ground, if the brewer adopt the principle of taking a liquor length over the hops to wash out the strong wort retained therein: and although this process is apt to give us, perhaps, too much tannin, it is, at any rate, superior to the plan of extreme washing of malt, sometimes followed by abnormal and distinct boiling lengths, which may give a larger percentage of extract, but are not commendable in any other sense.

Objection to a single boil length.

Distribution of strong wort among several coppers.

Where party gyles are taken, it is essential to have two lengths of a varying gravity; but even then the difference should not be extreme, and I think a much better plan is to make a careful calculation in the original estimate for the distribution of the entire malt and sugar extract over several coppers, in order to give the varying lengths and gravities required—*i.e.*, brew, if you will, several classes of beer on one day from a single mash, but, in place of doing it in the simpler way, let it be done as now suggested. There is nothing difficult, if we only have the retention vessel or roomy copper plant referred to.

I have said sufficient to prove, I think, that the old views respecting mashing are no longer tenable, and while the mere practical test of throwing 200 grains of malt into a tumbler of water may be useful as proving its fitness or unfitness for use, I should strongly advise brewers to make a dead set against much of the malt that they at present purchase without any knowledge of its real character. I contend that a malt yielding wort with less than 5 per cent. of nitrogenous matter in the dry extract is entirely unfit for the purposes of the brewer, unless he is prepared to work, like the distiller, with constant changes of yeast, while, if obliged to use such material, his ordinary infusion method of mashing is absurdly incomplete, and much of the difficulty at present experienced would be avoided if brewers could make a preliminary analysis of every sample of malt offered to them, and determine its bearing with the polariscope.

Water test for malt.

Nitrogenous per cent. of malt.

Testing malt by the polariscope.

The uses of this instrument are many. Not one is more important than the power that it gives of enabling us to ascertain beyond doubt the actual brewing value of malt. How malts vary in quality I have already said; it is their variation in one special direction that is of the greater importance.

A great talk is made of large and deficient extracts. The brewer's extract is a somewhat mysterious figure, depending upon accuracy of dip and gravity, and

The brewers' extract.

includes, of course, the extract yielded by hops. I have said that that available from malt is about 78 per cent., and that the infusion brewer obtains about 70 per cent., if his malt be perfectly made, this corresponding to over 90 lbs. per quarter, while practical results vary between 78·0 lbs. and 90·0 lbs., much of this variation depending on inefficient growth.

Practical results.

A good malt mashed with two barrels of liquor to 336 lbs., or one standard quarter, will yield a mash wort weighing 36 lbs., or containing in each barrel 93·6 lbs. of solids. That is, in the first mixture some 187 lbs. of solid matter is taken into solution from 336 lbs. malt—in other words, 55·6 per cent., although, of course, half this is held back by the goods if the wort be drawn off. The true mission of sparging is to wash out a perfect extract already formed; many brewers utilise it for obtaining crude extract at a time when no modification or alteration is possible.

Sparging.

From what I have said there appears little doubt that improvements in practical brewing will of necessity turn upon improved methods of effectually obtaining malt extract in suitable form, and the reason for this will appear more prominently as we progress with our subject.

CHAPTER IX.

BOILING AND COOLING.

Boiling and cooling.

THE chapter that I devote to the consideration of the two operations of boiling and cooling must, of necessity, be brief, since what there is to say on this dual question, although important, cannot be by any possibility lengthened out into treatise form.

Instability of unboiled wort.

It has long been known that an unboiled wort exhibits a great lack of stability; that even if submitted to induced vinous fermentation the results would still be unsatisfactory, and nothing has been more common among practical brewers than a perfect belief in the influence of an extended and vigorous boil.

Folly of steam boiling.

With this lesson before them it is somewhat curious to observe how many have introduced steam as the agency for effecting ebullition. Whatever its economy may be, no one, I suppose, would contend that steam heat corresponding to 230° or 240° Fahrenheit could, in any sense, have the same power of caramelising and cooking as a direct fire temperature three or four times as high.

Object of boiling.

Now, what is it that we attempt to accomplish by boiling? First of all, we concentrate wort; secondly,

Coagulation of albuminous matter.

a considerable quantity of nitrogen compounds, coagulable below the boiling point of water, are thrown out of solution in flocculent shape, while a further quantity are precipitated by oxidation, which takes place at the high temperature if oxygen be present, and this is always so if the boil be at all violent so as to cause breaking of the head, to say nothing of the influence of the several forms of dome and fountain arrangements spoken of; lastly, hop extract is split up into its several constituents—bitter principle, oil, and resinous matter, these being more or less taken into complete solution by the malt extract.

Oxidation.

Splitting up of hop extract.

This question of hop extract is no unimportant one, since the solution of it is no easy matter, as manufacturers of the natural concentrated extract of hops can testify, and it will be found that somewhat prolonged ebullition is necessary, in order to accomplish, first, the splitting up of the extract, secondly, its solution. As is well known, the brewer does not succeed in attaining complete solution, since his wort, as it cools, carries upon it a film of resinous matter and oil, this being more than usually apparent when new hops are in use, which are, of course, excessively rich in oleaginous matters.

Over and beyond influences of this kind, prolonged boiling induces partial caramelisation of wort extract, and not only gives flavour to it, but undoubtedly fits the ferment forming portion of it for the after office that it has to fulfil. It will thus be seen why no mere simmering answers, and why, in order to attain full benefit, the ebullition must not only be prolonged, but kept as vigorous as possible short of leading to any unpleasant disintegration of the hop leaf.

Prolonged boiling.

It is probable that without hops wort might be boiled for very lengthy periods and suffer no injury, but as it is usual to introduce nearly the whole of the hops before commencing to boil, a limit is fixed, since,

Effect on hops.

Duration of boiling.

if prolonged, we not only lose too large a quantity of the aromatic constituents, intensify hop flavour, rank and bitter by comparison, but disintegrate the useless principles of the entire hop-flower, leading to unpleasant turbidity of wort, and eventual excessive deposit with corresponding impurity of yeast during fermentation.

Evaporation.

The usual boiling period is some $2\frac{1}{4}$ hours, and in every case a vigorous boil, without reference to extent of evaporation, should take place. As remarked in dealing with plant arrangements, diminution in bulk by evaporation varies within wide limits, and I do not like to suggest it as an evidence of vigorous boiling, as I am by no means certain that it is always advisable to facilitate it, and in those instances where extreme evaporation results, I am nearly sure that it is under the influence of a lessened surface pressure caused by the peculiar top arrangement of boiling back or closed pan.

Influence of pressure.

It is most unfortunate that pressure cannot be employed without increase of boiling temperature, since there is no doubt that its influence during ebullition, as during other processes of more complex nature, would be sensibly felt by the brewer. It is a mechanical question, which some day may be solved in a satisfactory manner. As the case now stands, pressure prevents ready convexion, leads to increased boiling temperature, and practical burning of wort, so that closed coppers, and, as a matter of fact, deep coppers of small diameter are no longer to be found in pale ale breweries, although their usefulness in communicating flavour during the boiling off of black beers is very marked, and I have heard it stated that the whole secret of the original flavour of London porter turned

Closed coppers for black beers.

London flavour.

upon the almost accidental use of very deep domed coppers working under pressure.

If there be truth in this, it only enhances what I have said respecting the ineffectual influences of ebullition promoted by steam, and, as I personally know that many serious disasters have been entirely due to this fact, I cannot too strenuously urge brewers to look upon boiling as one of the most important stages of their process, leading to those results that I have described, only when the temperature promoting ebullition is sufficiently intense.

Hop-back deposit.

The well-boiled wort filtered from hops and coagulated precipitate—and what this amounts to is seen under the false-bottom plates of hop-back—left on cooler-floor exposed at shallow depth to the air, undergoes not only evaporation, but various other mechanical and chemical changes: the former, represented by its increasing cloudiness, due to much of the solid matter appearing in a state of semi, as opposed to complete, solution, and the precipitation of some portions of it as sedimentary deposit; the latter, a change promoted by the fact that at high temperatures wort is capable of absorbing oxygen, not holding it in solution, but actually taking it into combination with certain of its oxidisable constituents.

Oxidation of wort at high temperatures.

There can be no doubt about the advantage of this, and I think it is Pasteur who proves that a wort will filter perfectly bright when cold if it has been cooled in contact with air, while it strenuously refuses to do so if reduced in temperature out of contact with the atmosphere—*i.e.*, the oxygen taken into combination at the high temperature of the cooling-floor throws out of solution matter of nitrogenous type, that otherwise interferes with mechanical filtration, and experience

Pasteur on oxidation.

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shows us that bodies of this type impede the eventual clarification of beer.

Coolers a necessity.

There can be no question, then, that coolers, even in these days of economical and powerful refrigerators, are of great utility, and there is only one statement to make in reference to them from the biological point of view. We are taught in studies on fermentation that as long as wort is at a high temperature it will remain sound, but when under 158°, and particularly when between 77° and 99°, it is open to the ravages of aerial ferments of the lactic and butyric types. This will explain the meaning of the old term foxy fermentation, the peculiar white creamy froth starting generally from the sides of the cooler and the wort itself appearing red in colour, being the practical signs. It is probable that, as a matter of fact, foxy fermentation was due to the development of aerial ferments in the pores of the wood of the cooler so soon as the temperature of the wort sank sufficiently low, so long as its higher temperature had not in any way crippled their activity, which it would not do by mere contact with the wood surface.

Foxy fermentation.

There is no danger of any such result if coolers be kept thoroughly clean, occasionally scoured with equal mixtures of lime and chloride of lime, and if the wort itself be quickly refrigerated after it has once dropped to the higher temperature of 150° mentioned. Besides this, there is practically very little danger involved in exposing worts for a reasonable time at very moderate temperature, and as a matter of fact a useful action goes on, since oxygen, no longer taken into combination, is just as readily dissolved, and what this means will appear as we proceed with the next chapter.

Refrigerator aëration.

Those who have watched wort rippling over refrigerator surfaces cannot fail to have been struck with the film of solid matter which adheres to the corrugated sheet of metal; it is one of the useful offices of the cooler to facilitate collection of a deposit of a like nature, since passing forward to the fermenting tun, it can but lead, not to the nutriment, but to the impurity of yeast.

It is the sudden drop in temperature on surface of refrigerators that throws the last remaining portions of this oxidised matter out of solution, and identically the same kind of action is proceeding from the moment that the wort leaves the copper. It is hardly necessary to speak of the old-fashioned fans, although they were abolished without good reason, and from what I have said it is evident that a constant change of atmosphere over and above the cooling wort cannot but be of considerable advantage, causing a ripple of the fluid, increased evaporation, and a greater combination with oxygen.

CHAPTER X.

FERMENTATION.

Fermentation.

It is in this chapter that I shall have to dip at once into advanced theories, and it would, I think, be absurd on the face of it to attempt any brief description of a subject that is of vital importance from every point of view, for by fermentation we attain results that have long been known as giving to beer its flavour, stability, and characteristic quality, and this by a means too little studied, too little thought of in the rough daily work of the brew-house. Long before Pasteur wrote on the subject of fermentation, Continental brewers, always in the van, as it appears, had devised a method of fermentation that is, as a matter of fact, the very system that is so rapidly displacing the old-fashioned schemes that previously held ground, although it is only recently that true light has been thrown upon the subject. I purpose explaining, first of all, the theory of fermentation, applying this theory to all the practical operations that take place in our fermenting vessels, and to all the changes that beer is subject to during storage in cask or vat.

Its object.

The theory.

Up to within very recent years the term fermentation was applied in chemistry to a peculiar metamorphosis of a complex organic substance by a transposition of its elements under the agency of an external disturbing force, resembling those obscure phenomena of contact action to which the term "*catalysis*" has been applied. The theory of Liebig on the subject was very popular, not only among brewers, but among chemists; and although strictly hypothetical, it seemed, at any rate, to be confirmed both by facts and apparent results.

Catalysis.

Liebig.

It had for years been noticed that the fluids which underwent spontaneous change the most readily were those that contained azotised or nitrogenous constituent bodies, which, in a moist condition, were known to putrefy with great ease. Liebig's idea was that when such bodies happened to exist in contact with air, that they underwent oxidation—chemical change—and induced a similar state of change in other bodies of low stability, such as sugar, present, the sugar splitting up into simpler and more permanent form. In other words, azotised matter, in a state of change, undergoing what was termed a *molecular disturbance*, induced a similar action in bodies of the tertiary series, so that Liebig's view of fermentation was strictly a chemico-physical one, and, as such, it served to explain theoretically one and all of the many changes that take place after wort is "*set on*" for fermentation.

Spontaneous change.

Molecular disturbance.

Ferments, then, according to Liebig's view, were simply nitrogenous matter in different states of change, varying degrees of molecular disturbance, at one time acting as vinous ferment, at another as lactic, acetic, viscous, putrid, and so forth; and it was this eminent chemist who undoubtedly suggested that method of fermentation which is practised at the present day abroad, and which turned then, as now, upon lowness of temperature and free exposure of the fermenting wort to air, so that azotised matters would suffer

Continental system.

oxidation and be thrown out of solution, as so-called yeast, without any danger of such matter acting as acetous acid, ferment, or direct oxidation of alcohol taking place.

Dread of surface exposure.

This theory was kept prominently before the brewing world; it was the cause of closed fermenting vessels being adopted, and the dread of all surface exposure, so long as the existing temperature was such as to permit of the alcoholic oxidation change. Fermentation was induced by the addition of so-called ferment so as to determine its character, lest, if spontaneous formation of ferment were awaited for, the extent of molecular disturbance might perchance be active in a wrong direction; and it was dangerous, for this reason, to leave any excess of nitrogen compounds unremoved.

Oxidation of alcohol.

Liebig made a point of this in his suggestions to the Bavarian brewers, showing how they could carry on prolonged fermentation at the low temperature, in order to remove albuminous matter by oxidation, while steering clear of the other unpleasant result that would have been possible in the azotised alcoholic fluid at a higher temperature.

Acidity again, according to this view, resulted from the catalytic oxidised nitrogenous constituent of beer attacking the alcohol itself as soon as the larger proportion of sugar had disappeared, and from first to last Liebig's theory, hypothetical as it was, sufficiently answered the brewers' purpose, and it is only giving honour where honour is due in distinctly naming him as the first to attempt a chemical explanation of fermentation, and then to show how his theory might be turned to practical usefulness.

Liebig's theory exploded and out of date.

One is almost sorry to say that such theory is an exploded fallacy, that it is at the present time almost forgotten, or at any rate hardly ever referred to in books on the subject of brewing, while in its place we have the far more interesting, complex, and important theory of M. Pasteur, which may be described as *vital* as opposed to the mere chemico-physical idea of Liebig.

No one supposes for a moment that all the honour belongs to Pasteur. He grouped, as I may express it, the ideas of several microscopical observers, and came to a certain clear and definite opinion as to their meaning; or, in other words, seeing that fermentable fluids threw down during their fermentation an organised as distinct from a mere non-organised deposit, he traced the true connection between cause and effect, and proved, by a series of brilliant experiments, that fermentation was due to the development of actual cell life, of which the deposit in wort and beer was found largely to consist.

Pasteur.

Fermentation due to cell life.

It is necessary at the outset to put an end at once to any doubt or scepticism on the subject of these two theories, and there is, perhaps, no simpler experiment than the one adopted to prove the untenable nature of the older view.

Liebig's theory untenable.

If fermentation be due to oxidising azotised matter acting by catalytic influence on the tertiary sugar, such action should result in a boiled fluid of this complex nature exposed to an atmosphere of pure oxygen or air. It is hardly needful for me to say that it does not.

The most putrescent fluids known boiled for a moment and cooled in a pure atmosphere would remain under such conditions unchanged, no matter how rich they might be in Liebig's basis of ferments, and this expression—pure atmosphere—will be seen to have no unimportant bearing upon the subject we are about to discuss; for if fermentation be due, as it most assuredly is, to the development of cell life, we may well ask ourselves from whence does this life appear, and how can we prove that it is not of spontaneous development.

The means adopted for arriving at a pure atmosphere almost solve the problem. There are two methods commonly employed for purifying the air we breathe without actually destroying the aerial dust it contains. We may either filter the air through cotton wool or by arranging absolute quiescence allow of the aerial dust depositing by reason of its own preponderance, while an equally simple method is to pass the air through tubes at such a temperature as merely to leave undestroyed the saline portion.

Filtration of air through cotton wool.

Aerial dust.

It is this aerial dust—which every one some time or other has seen when standing in a room where the direct sunrays are penetrating—that carries in dormant, dry, and even microscopically minute form the germs of these ferments that cause not only vinous fermentation, but lactic, viscous, and other more advanced putrefactive changes.

It is this one fact that troubles the mind, perhaps, of the young beginner. He is apt to smile at the statement that the ordinary aerial dust is absolutely the basis of that thick viscid yeast he is in the habit of seeing, and yet nothing is simpler to prove, nothing so confirmatory of Pasteur's theory when once practical evidences are secured.

The atmosphere teeming with germ life.

Now, I do not wish to imply that the atmosphere is teeming with germs of ferment life; nothing of the kind. They are, indeed, very unequally distributed, so much so that it would be possible to expose fermentable fluids in certain districts where the air is naturally very pure, or on the other hand absolutely quiescent, without fermentation taking place. As a matter of fact the germ of vinous ferment seems to be less equally spread than others, to judge by the result when exposing azotised albuminous substances to the air, although this statement is somewhat handicapped by one in connection with the spontaneous fermentation of grape juice which I shall almost immediately discuss.

We have thus, in a few words, arrived at the origin of ferment cell life; and I may now ask, What are the conditions of development? in other words, What causes these dormant germs to develop into actual cells? the cells we are accustomed to see by the aid of the microscope? Briefly put, warmth, moisture, and the presence of azotised and carbohydrate nutriment suffice to at once facilitate actual fermentation. Conditions of development.

So far I have been digressing somewhat, but my contention is that the actual quiescence of a fermentable fluid, if itself sterilised by boiling, when placed in an atmosphere from which the organic dust has been removed by one of the three methods named, suffices to show that azotised and carbohydrate fluids have no fermentable capacity *per se*, but simply comport themselves as suitable soil for the development of ferments, the seed of which exists in the atmosphere prior to its purification. Sterilisation.

The confirming experiment is simply to introduce some of the dust collected by filtration into an azotised wort that has remained quiescent, proving its sterility, for a considerable period. In a very short time, if the fluid be aërated and kept moderately warm, turbidity will result, a deposit will be thrown down, and if we examine this we shall find it composed of a mixture of ferments, that predominating depending upon the exact conditions of development. Now, what does this all Convincing proof.

mean, in reference to the old phrase—spontaneous fermentation?

Liebig *versus* Pasteur.

The popular idea was, and we have seen how it was theoretically explained by Liebig, that azotised fluids spontaneously underwent alcoholic fermentation without the intervention of any outside agency; and, if people knew a little chemistry, an addendum was tacked on to the effect that the actual cause of this depended upon one of those mysterious chemical catalytic influences, of which previous examples were known; or, in other words, azotised matter undergoing oxidation induced, by mere contact action, a disturbance in the equilibrium of sugar, so that, according to this view, fermentable substances were those having a low degree of stability, which could be put an end to by mere contact influence.

The experiment mentioned above proves the untenability of such theory; and there is another more convincing one, perhaps, that will be explained later on, so that the term spontaneous fermentation at the present time refers to changes which are not directly induced by what may be termed the art of man—*i.e.*, not brought about by the direct introduction of developed ferment life.

The followers of Liebig, loath to give up the old physico-chemical theory, seemed inclined for a time to fall back upon what is termed the idea of hemi-organism. It was quite evident that, as the deposit in azotised fluids consisted of apparently organised cells, some modification of the original crude idea of oxidised albumen exercising ferment power was absolutely necessary, and they suggested that such matter had a power of self-organisation; in other words, life could result without the intervention of vitality.

Artificial growth of yeast.

This, like the more crude view, was easily disproved by that convincing experiment made by Pasteur, wherein he shows that yeast could actually develop in the entire absence of nitrogenous food, so long as we supplied the necessary nitrogen in mineral form. Looking at the subject as a whole, it is perfectly easy to see that the only meaning of spontaneous change at the present time is change induced under the influence of aerial ferments not introduced in developed form, but naturally subsiding as a component part of aerial dust into fluids left exposed to the air. If the fluid be a non-fermentable one, no change takes place, while rapidity of change hinges upon the conditions before-named.

Why, then, cannot brewers rely upon spontaneous fermentation? Why have they, too, so carefully cultivated and selected their pitching yeast? I simply answer, because a brewer's wort is unfortunately a fertile field, not only for vinous, but other forms of ferment life; on the other hand, successful spontaneous fermentation is practically accomplished, nay, *has* been accomplished, even in the case of wort itself, but the more common example of it is seen in the case of grape juice, which is always fermented spontaneously.

Grape juice.

The juice of grapes, as is well known, is exceedingly rich in fermentable sugar, and contains besides a considerable quantity of acid tartrate of potash, which is known to exercise a very powerful influence in facilitating fermentation. Exposed to the air without the slightest care fermentation results, and if we collect the deposit and submit it to microscopical examination we shall find it to consist entirely of vinous ferments.

Tartrate of potash.

Aerial dust.

Let me be clearly understood on this point, as it will save a good deal of trouble hereafter. Ordinary aërial dust has deposited in the grape juice, and we cannot for a moment suppose that germs of alcoholic ferment have alone found entry. What then is the inference? The juice of the grape, by its ready fermentability, richness in sugar, poverty in low types of nitrogenous matter, and richness in tartrates, exercises an actual determining influence as to the variety of ferment life that develops, so one type of ferment alone finds itself existing in a nutritive medium.

Tartrates preservative.

On the other hand, the brewer's wort exhibits no such capacity; rich in sugar it may be, but it also contains much albuminous matter and no tartrates, and, exposed like grape juice to the air, we should in the majority of cases find a deposit of a totally different nature. At the same time, brewers' yeast of the present day is simply the cultivated outcrop from an original spontaneous development of ferment life, its origin, the germs of ferments, existing in the atmosphere combined with aërial dust, an outcrop which in a long series of years has been modified and purified under different controlling influences, by cultivation in varying worts at different temperatures in different forms of plant, until at last it has arrived at the endless kinds of store or pitching yeast, not only to be found in the great brewing centres of England, but also in those of the Continent and America.

Origin of brewers' yeast.

I have purposely said that the necessary aliment of cell-life may be classed as carbo-hydrate, nitrogenous, and saline, for I was anxious to leave, till the present moment, a consideration of the exact connection that exists between oxygen, or air containing oxygen, as a controlling influence in reference to fermentation, since it is not only of deep importance as regards a theo-

Necessary aliment of yeast.

Oxygen essential.

retical explanation of the subject, but is practically most interesting in a variety of ways.

The fact that vegetable life requires the presence of air is so popularly known that there is nothing strange in the assertion that even minute cellular plants live only in its presence, but so far as fermentation is concerned, the power of the small cell to act as a ferment essentially depends upon its capacity of living for a time out of contact with air, securing its necessary supply of oxygen from some carbo-hydrate body, such as sugar, that contains it; thus the fermentable body is the one capable of yielding its oxygen, the ferment is the cell endowed with the power of seizing upon it, and the true alcoholic ferment is that special form of cell that in seizing upon the oxygen of sugar splits that sugar up into definite proportions of alcohol and carbonic acid (180 parts by weight of sugar yielding 92 parts of alcohol and 88 of carbonic acid).

Yeast seizes the oxygen of sugar.

It is in this special direction that the power of yeast seems so extraordinary, since in ordinary vegetable growths there is a distinct connection between the food assimilated and the bulk of resulting plant, while in the case of this minute cellular body there appears to be the greatest disproportion, for what is more practically striking than the result of introducing 200lbs. of fluid yeast into 100 barrels of a 30lb. beer? During the fermentation of such a beer some 52lbs. of solid matter would be split up in the case of each barrel bulk, while the 2lbs. of fluid yeast might, if reproduction were satisfactory, become 16, or even more.

Weight of solids split up during fermentation.

There thus seems little connection between solids decomposed and resulting yeast reproduction, and, so far as vegetable life is concerned, it is quite abnormal. It is, indeed, in considering the subject of air in reference to cell life that we master the whole secret of different forms or systems of fermentation.

We need not trouble ourselves with the fact that the power of seizing upon combined oxygen cannot be ascribed alone to the variety of cells we brewers are accustomed to cultivate. It is perfectly true that many cellular organisms, suddenly cut off from free air supply, exhibit a similar capacity, at any rate for a time—the experiment of hanging grapes in an atmosphere of carbonic acid being the ordinary method of determining such action, but we can leave such questions for the scientist, simply remembering that when sugar is decomposed under such circumstances, the proportion of alcohol formed is distinctly different from that normal to true fermentation.

Grapes in an atmosphere of carbonic acid.

Now let me refer again to the important question of oxygen. I have said that a true alcoholic ferment has the power of obtaining its necessary oxygen from sugar, and it is for this reason that it passes under the name of an anaërobian ferment as distinct from aërobian cells, *i.e.*, its normal condition of development is out of contact with air, but it must not be understood that constant development can take place under such circumstances. At certain stages contact with free oxygen is absolutely requisite, notably in the earlier stage of development, whether it be when the germ is enlarging to cell, or when the bud of the mother cell first detaches itself.

Anaërobian ferment.

Necessity for free oxygen.

If my meaning be grasped so far, what result would follow if free oxygen or air were continually supplied? The developing cells would simply reproduce themselves with greater rapidity on the carbo-hydrate, azotised, and saline food present, but as no seizure of combined oxygen would take place in the true sense of seizure,

Its effect on fermentation.

the action would be one of vegetable respiration without formation of alcohol, without, in short, fermentation.

Effect of aëration on yeast.

Let us go a step further. The nutriment of yeast developed as we have seen from original germ life is largely nitrogenous in nature, so that if we increase the development of yeast by supplying air, we naturally enable it to remove, in the shape of nutriment, larger proportions of azotised matter, and cannot my readers at this point see the practical meaning of such a statement? that by supplying air to yeast, even beyond what is absolutely necessary for its life, its power as an alcoholic ferment is diminished, its property, of self-reproduction and by such development, of removing albuminous matter by assimilation vastly increased.

Now, for a moment, let me retrace my steps, and let me ask how we describe fermentation. Does not this passage, the wording almost of Pasteur himself, explain it?

Fermentation described.

Fermentation, by means of yeast, is essentially connected with the property possessed by minute cellular plants of performing respiratory functions, with oxygen existing as combined in sugar, and that its power, as a ferment, is not to be gauged by the quantity of sugar decomposed in a given time, but by the degree of capacity it has of living out of contact with free oxygen, the power of yeast being entirely independent of the time during which it performs its functions.

How can we apply this theory, so novel, so accurate in all its complex details, so easy of proof, to all the ordinary processes of the brewer? If nitrogenous matter be necessary to the development of yeast, has not its quality or condition something to do with the variety of ferment that will develop? Can we suppose that the atmosphere of the brewery—nay, the very

Atmospheric germs.

pitching yeast the brewer employs—is conveniently free from the germs, if not the developed ferments, corresponding to lactic acid and putrid changes? Nothing of the kind. They, at any rate, are always present, and it needs but the necessary condition of azotised matter to promote their appearance.

Character of albuminous matter determines variety of ferment.

Take some cold water malt extract, the albuminous matter of which has never been peptonised or cooked in the moist condition, see what form of ferment life will appear, even if we directly impregnate such a fluid with our so-called alcoholic yeast. Verily, it will be a mixture largely consisting of lactic and acid ferments, simply because the conditions of development oppose the growth of the added yeast, so far as its alcoholic cells are concerned, and aid that of the acid filaments. For this reason, the absolute condition of azotised matter is of immense importance.

Influence of temperature.

What influence has temperature? Below 50° Fht. it is very rare that we find ready growth of any but true alcoholic cells, below 40° never, while at high temperatures, over 70°, the conditions of heat are more favourable to the growth of acid ferments than alcoholic cells, and they increase accordingly.

Object of attenuation.

Why do we attenuate beer? Simply because the unattenuated wort is rich in nitrogenous matter, consequently unstable, not so much in the direction of determining alcoholic character of fluid as acidity and putrefaction.

We remove such excess—how? By determining vigorous alcoholic change, and continue it till we have removed, under the influence of the developing yeast, the excess of azotised matter, diminished fermentability by sugar transformation, and added a further stability by arriving at the usual alcoholic percentage.

Why do hops, or their extract, add to the keeping properties of such a fluid? Hop extract is astringent, retards by such astringency the development of a delicate albuminous organism, while the bitter principle is altogether opposed to its growth. Why is dirt, the albuminous deposit in mains, in the pores of wood, and on the surface of plant, so injurious? Merely because in such a state it is no nutriment for an alcoholic yeast cell, but simply for ferments that develop freely on degraded forms of azotised matter.

Preservative tendency of hops.

Injurious effect of dirt.

Why do we have reproduction of yeast, and why does such reproduction vary 5, 6, 8, or 10 times? Because yeast exhibits an exceptional plant action, assimilates nitrogenous matter as nutriment, and respires on combined oxygen, the maltose of our wort robbed of its oxygen splitting up into alcohol and carbonic acid. The outcrop of yeast consequently is largely in excess of the ingoing store, the exact extent of reproduction turning upon the quantity of free air supply, the incentive to growth, but not always to alcoholic action.

Variation in quantity of yeast reproduction.

Why do Continental brewers seek safety in cold as a preservative? Because low temperature keeps lactic acid and putrid ferments inert. Why can meat be preserved by mere hanging in a dry atmosphere? Because moisture is necessary to the development of vegetable organisms.

Moisture encourages growth of vegetable organisms.

What practical bearing has this? Yeast may be dried, reduced to dust, and kept in such condition for six or seven months without losing its capacity of revival. Why does the draff thrown from the brewer's mash tun putrefy so readily? On account of the moisture present. Dry the grains and they will remain sweet and unchanged for any length of time.

What, lastly, do we employ chemical preservatives

Object of preservatives.

for? To stamp out the possible development of diseased ferments that have been rendered more probable as constituents of our beer by the gradually increasing deterioration in quality of malt that has been apparent the last few years.

Varieties of ferment.

I have spoken of many varieties of ferment, their microscopical appearance, as will be seen by reference to plates, being widely different, but is it possible for one ferment to change into another? It is not, but it is possible for the physical form of yeast to undergo strange modifications, almost deceptive to the young brewer, and I know of no branch of semi-scientific work that requires so much practice as yeast examination.

Each type distinct and immutable.

There are types of mould, for instance, that develop in branch-like form when in contact with air, that assume globular shape when submerged; on the other hand, yeast cells may and do elongate in many ways when conditions of growth are changed, but no actual transmutation of one form of ferment-life to another ever results. It is simply impossible, as Pasteur shows in an almost endless number of experiments.

Effect of starvation on yeast.

We can see now why it is that yeast—not the mere non-organised oxidised nitrogenous matter—suffers so terribly when starvation conditions alone exist. So long as fermentation was due to a mere chemical principle it was difficult to account for the endless varieties of fermentation, the great care necessary to prevent sudden check in heat; to assure vigorous aëration at setting on, the action of flour and salt dressing, and so forth; but as fermentation is promoted by a delicate globular organism, the starvation of such means the absolute collapse of its vitality, and as the organism is simply a cell full of liquid nitrogenous nutriment, we can easily see why, when its growth is checked or rendered altogether impossible, it loses its expanded form, becomes specifically heavier, and no longer possesses the power of holding the fluid contents inside the porous cell; turbidity due to the increase in specific gravity of yeast results and in some cases followed by turbidity and putrefaction together. Cause of turbidity.

Why? It is well known that the nutriment of vital organisms protected by vitality is absolutely pure and sweet, but no less certain when once escaping from this controlling influence it rapidly becomes putrefactive.

Look, for instance, at the fluid excrements of animals, the blood of the vein. See how readily they putrefy, and we shall understand the better how it is that, when once by imperfect yeast cultivation we practically facilitate the escape of liquid plasma from the cell, we determine sooner or later something beyond the turbidity created by the semi-soluble azotised matter; we determine, in short, putrid fermentation. This may be staved off by absence of free air, lowness of temperature, or presence of most unpleasant doses of sulphites, but sooner or later we arrive at the bad or ropy beer, and yet feel or pretend to feel surprised at a result that might have been predicted. Putrid fermentation. How to stave it off.

It is easy to see, again, why good malt facilitates such ready cell development; I hope we understand by this time why the perfect development is necessary. It is a combination of nutriment that yeast requires; poor malt yields a deficiency of the necessary azotised matter; and my readers will please remember that it is not all descriptions of albuminous matter that act as yeast food. For instance, you may examine a beer some years old; it is capable of fermenting, yet its extract is rich in nitrogen compounds, but they are not the digested variety. They are, as I may put it, similar to Yeast food.

the azotised extract of a bad malt of low diastatic power that has never suffered modification in mash-tun or copper.

Saline yeast food.

On the other hand, saline nutriment is necessary to the structure of yeast, and when we begin to employ large quantities of sugar we seriously diminish the amount requisite. It is all very well to talk of some form of saline matter said to be identical with the ash of yeast. We do not know much about this; what we do know is eminently practical, and shows that the saline matter yielded by malt coming in contact with the saline matter of our brewing waters gives a combination of salts that favours yeast growth.

Influence of hard water on yeast.

We have always supposed that hard waters were preferable for brewing on account of a determining influence respecting quality of nitrogen extract. I, for one, should not be at all surprised to find that the saline matter of such a water in combination with the salts existing in malt led to more perfect yeast development. We know how Burton brewers pride themselves on their entire malt brew yeasts, how strong and well developed it appears to be microscopically; is it difficult to explain after seeing the care they bestow on the selection of malting barley and how they look with disdain on the process of the brewer who employs sugar in some shape or form to increase the output of his plant or purify his otherwise highly albuminous wort?

Sugar use.

It is all perfectly clear; however successful we may be in ameliorating the character of a heavy malt wort by the use of sugar, however skilfully we may add flour, salt, and saline yeast food, it is impossible to say that a combination of artificial circumstances can ever attain to the perfection of influence exercised by the combined constituents of malt wort. It wants merely the case of grape juice to prove to us in a practical way what the meaning of wort character really is.

Let me now attack in detail the practical bearing of aëration. Theoretically it means, as I have proved, greater yeast development, lesser alcoholic ferment capacity. What, may I ask, are the several methods of dealing with soft extractive water worts, or how do soft-water brewers proceed to attain stability of beer? There are three methods—water hardening, sugar use, slow aëration fermentation—all different in principle, all ending in same result as regards stability; different result, as regards flavour and general character of beer.

The meaning of aëration.

Treatment of soft water worts.

The water hardening determines the variety of azotised bodies extracted or variety of saline yeast nutriment existing; secondly, by partially substituting sugar for malt extract we displace a certain quantity of azotised matter. Finally, by adopting the slow system of fermentation.

Water hardening.

Sugar use.

Slow fermentation.

Now, practically speaking, what does this latter process mean? What is slow yeast? It must be perfectly evident from what has gone before, even to the least scientific reader, that directly we commence to supply definite quantities of air during fermentation by deliberate pumping, plunging, or oscillating movement of head in closed vessel, that we advance in the direction of modifying the life action of yeast; in other words, we diminish its power of acting as an alcoholic ferment, and form what is termed slow yeast.

Slow yeast.

I have said previously that no transformation of ferment life is possible; but this does not mean that the ordinary ferment of the brewer may not be slightly modified in a dual direction. Aërate a fast yeast, cultivate it in a wort not too fermentable, and it will gradually become *slow* in action. Take the slow yeast,

Transformation of yeast.

cultivate it in a highly nutritive wort without aëration, and it will in a series of reproductions become similar in every way to that of a Burton brewer.

This naturally follows from all that has been said on the subject of brewers' yeast, endless in variety, as produced from a stock common to all, and the slow yeast of the stone square brewer is simply an example of cell life, the growth of which corresponds with the exact conditions of nutriment normal, and the degree of aëration carried on.

What does the propagation of such a yeast mean? I have said that it is less powerful as an alcoholic ferment than other varieties. Its natural growth is accompanied by great reproduction and corresponding assimilation of azotised matter, and in result the wort of heavy albuminous character becomes purified, as I may express it, under the influence of this slow working species of yeast, which seems to depend almost entirely on mechanical motion, over and above aëration, for a great deal of its energy. I say this since, in rousing systems where there is mere oscillation of the yeasty head, there can be but little introduction of air, and the revived energy of the ferment under such an influence must be due more to the displacement of carbonic acid and direct motion than to anything else.

Oscillation of yeasty head.

It is not to be wondered, then, that the principle of utilising such a form of ferment life, a description of yeast undoubtedly produced by the art of man, has found favour in many districts where softness of water and heavy character of malt in use has practically given a wort of highly azotised nature, and besides this one can call to mind many systems of fermentation wherein a partially modified aëration ferment is employed; indeed, directly rousing is adopted as a definite prin-

Modified aëration by rousing.

ciple, the yeast in use becomes slowly changed in the direction spoken of, and there can be no two opinions of the benefit of this if the wort requires more than ordinary purification under the influence of yeast growth.

Fermentation systems.

In all systems of fermentation there is partial aëration—this being uniformly necessary—since, as I have said, yeast at different stages of its growth requires to come in contact with the oxygen of air. I may divide English fermentation systems into three divisions, the first including the ordinary quick attenuation method of Burton and other hard water centres; the second embracing the system turning upon the use of malt and sugar, with limited displacement of carbonic acid and aëration by motion during attenuation; and the third referring simply to the stone square method which is the most advanced example of aëration fermentation known.

Oxygen.

It will be well, indeed, if all brewers can grasp the exact practical meaning of the term oxygen in reference to fermentation, since it is the mainspring of Pasteur's theory and of many practical brewers' processes. At one time boiling was supposed to be advantageous, because it was said to dispel any air that the wort might contain; it was usual to prevent frothing by every conceivable means, since in those days the formation of acetic acid by oxidation was dreaded, and it was concluded that if the wort introduced into the fermenting tun contained air, and the temperature of fermenting liquid once rose to 70°, acetic acid would at once be formed.

Old idea of boiling.

Intermixture of air.

I may safely say that at the present time such view has entirely collapsed, and brewers energetically pursue direct intermixture of air with wort, *i.e.*, they whisk up their pitching yeast, employ refrigerators so constructed that there is a constant rippling over corrugated surface, aërate even during boiling by means of fountains and domes, never, in short, taking a single step to dispel air, so that at the time of collecting wort it contains a considerable quantity, some naturally absorbed, some directly introduced, and yet a few hours after gathering it has all disappeared. Where? It has been assimilated by the yeast, thereby bringing it into a more vigorous state as an anaërobian ferment.

Sluggish fermentation.

Again, if fermentation be sluggish, and if this condition of things arise from weakness of yeast as distinct from "slowness of fermentative character," what sooner puts an end to it than direct introduction of air? and during storage period, what sooner leads to the fretfulness of beer than the introduction of air at the racking stage? The more we examine the subject the more we shall find that aëration, as a distinct principle, is worthy of study, and so far we have gone through the conditions of yeast nutriment, accepting fully the undoubted truth that the yeast cultivated is a vegetable organism, depending for its growth upon certain fixed conditions, the supply of soluble azotised matter, a definite quantity of carbo-hydrates in the form of sugar and dextrin, and air free or as oxygen combined.

Aëration.

Determination of ferment life.

We have seen that the character of the azotised matter present, the temperature, and, I may add, the degree of acidity of the fermentable fluid determines the variety of ferment life that would preponderate, and to this I may now append the statement that the quantity of free air supplied decides the manner in which the alcoholic ferment will develop. So much for theory. Let me now turn to practical operations, which will be the more readily understood now that something is known of the principles upon which they depend.

Pitching yeast.

The cooled wort gathered at the temperature normal to the distinct system in operation is impregnated without delay with vigorous yeast, and a method which has led to much improvement in results, turns upon the cultivation of pitching yeast to be used, in a strong concentrated unhopped malt wort some hour or so before setting on. The purity of pitching yeast is of the utmost importance. It is generally selected for its physical fitness, sweetness, and solidity (every brewer knowing the necessity of perfect maturity of yeast), and for its microscopical purity.

Its purity.

Maturity.

Now, what do I mean by maturity? There is a wide difference in this respect between special varieties of yeast; for instance, it is perfectly easy to understand that in the case of slow fermentations, where the reproduced yeast exists for days on the surface of the wort while slow attenuation is going on, that such yeast matures before removal, and is consequently fit for use soon after skimming takes place; while, on the other hand, in the case of rapid attenuations, the yeast crops are secured almost as soon as the yeast rises to the surface; it is, in short, quite young, and consequently unfit for use until it has been stored for some length of time, thirty-six or forty-eight hours at least, since if such yeast were employed for pitching, its want of maturity would exhibit itself in a faulty attenuation, not resulting, as attenuation should, in spontaneous clarification.

Difference between young and matured yeast.

Microscopically speaking, the difference between young and matured yeast is equally marked; the young and newly-formed cells which constitute the light yeasty heads exhibit a beautifully clear outline, but no interior physical development, while the matured yeast shows each cell with a distinct vacuole with one or more young cells included; in short, a yeast of suitable age for pitching presents microscopically much the same appearance as the full moon does with its shaded undulations. I know of no more practical example.

Purification in a sugar solution.

Next I come to the purity question. It is practically impossible to purify yeast successfully by artificial means, since the several processes suggested by Pasteur, viz., cultivation in pure sugar solution, and treatment with preservative agents of various kinds, not only stamp out impurities, but injuriously influence alcoholic yeast; so that purity from a brewer's point of view must be attained by cleanliness of plant, use of good material, the removal of all cooler deposit by skimming off first cream thrown up during fermentation, the selection of middle skimmings, when there are a series, for pitching, and the storage of the collected yeast in shallow slate backs where it can be efficiently drained.

Skimming off first-head collection for pitching store.

The general principle of purification should not be left unnoticed. Take, for instance, the cultivation of yeast in a pure sugar solution; it is perfectly evident that it finds therein no sufficient nutriment, but it happens that alcoholic yeast, being more robust than other forms of ferment life, resists the practical starvation influences of sugar longer than false ferments can; and thus, by repeated cultivation of an impure yeast in pure cane sugar solutions, it will be found that each succeeding cultivation will leave yeast purer, and yet itself more aged and worn out.

Starvation in sugar solution.

Revivification in strong unhopped wort.

Certainly, such yeast can be revived by cultivation in a strong unhopped wort with vigorous aëration, but such a process is by no means advantageous in a brewing sense. Take, again, treatment of yeast or wort with strong doses of salicylic acid; this is potent and absolutely fatal to lactic ferments, but at the same time it weakens and eventually destroys alcoholic yeast; so, while arriving at purity by its use, we are left face to face with weak yeast, and there is perhaps nothing more dangerous in a brewing sense.

There is one practical method employed on the Continent which merits passing notice. As a rule all diseased ferments are small, fragile, and buoyant, passing off with the more fluid portions of yeast; so German brewers, who work with bottom ferment, first drain it, then cover with ice cold water, decanting this after short periods of standing once or twice. The yeast is much purified by this process, but it is easy to see how even this may lead to weakness of store, the interior constituents of yeast being soluble in water; so that if excessive washing is carried on we remove some of the soluble plasma. I think that I explained the term yeast water when speaking of cane sugar inversion, and the process adopted for securing this proves the danger of overwashing yeast.

Decantation of yeast.

Purification.

Yeast water.

The wort once pitched, fermentation, evidenced by attenuation, *i.e.*, thinning down and diminution of gravity and evolution of gas, soon sets in, and we have at once a series of head changes which have not hitherto been satisfactorily explained. Let me see if I can throw some light on this subject. Wort has what is termed a certain viscidity, due to its gummy and albuminous nature, this viscidity giving it the capacity of holding more or less gas in solution, and a great deal more in semi-solution and suspension. I

Head changes due to viscidity.

Champagne *v.* stout.

can illustrate my meaning by pointing to champagne and stout, as two fluids of pretty equal dry extract proportions, the one having no viscidity on account of its extract being entirely composed of saccharine, the other capable of creaming and foaming in a very marked manner on account of its gummy, azotised, and viscid nature.

Directly fermentation commences this viscid influence comes into play, and a first cream is formed, which, as escaping gas becomes greater in volume and upheaving power, is driven up into peaky form, the lighter portions of first cream being forced up highest.

Sugar wort head changes.

This becomes more prominent as gas power becomes greater, and we soon have a series of practical hills and valleys, the valleys being the heavier portions of cream containing hop extract and dirt, the hills being the pure white froth driven up to a great height. That this is so is easily proved by diminishing viscid character of wort by use of sugar or some chemical that cuts down proportion of albuminous matter; the ordinary head changes at once being correspondingly modified.

To proceed, viscidity *versus* gas power continues in operation, and the light head is forced up to a level surface, which entirely collapses as soon as the escaping gas gets sufficiently powerful to break through the light head, so soon as its viscidity is no longer capable of controlling it. This collapse is soon followed by an absolute rise, viscidity once more increasing under the influence of yeast reproduction, and the rise of head continues so long as yeast increases in bulk and there be sufficient gas liberated to buoy it up.

Yeasty heads.

If the quantity of yeast be very large, as in the case of slow fermentations, very little gas escapes, but, on the other hand, is taken into solution; and if the beer be not exposed until cooled down this dissolved gas exhibits itself, when set free by any mechanical agitation, and accounts for the throwing up of the yeasty head by slow fermented beers when passed to settlers, while those rapidly attenuated, carrying little or no head and much exposed during a series of skimmings while existing at a high temperature, lose the greater part of their carbonic acid and pass to settling tanks absolutely flat; so that if containing any yeast this subsides on the bottom, in place of being thrown to the top.

Results of fermentation.

If I make a point of carbonic acid and its influences, it is not to be wondered when we bear in mind that 100 parts of fermentable matter yield forty-nine of carbonic acid when splitting up; so that in a 30 lb. beer, which loses, as we have seen, 52 lbs. of solid matter per barrel during fermentation, some 25 lbs. of carbonic acid per barrel will be liberated. We know the main results in other senses of attenuation. Sugar disappears, and we have in place of it alcohol, carbonic acid, and a proportion of succinic acid and glycerine, and, besides this, the reproduced yeast which comes in for after-pitching purposes.

Rise of temperature during fermentation.

The increase of heat varies according to the character of beer and system of fermentation adopted, but so far as English systems are concerned, the increment corresponds closely with one degree per pound of gravity; and as by practice the temperature of 70° Fah. has come to be regarded as a fixed limit for pale beers, it is easy to see that the two rules mentioned, stated increment and stated limit, account for much that we notice practically; thus, in setting on a 20 lb. beer, which skims, say on the average, at an

Skimming gravity.

apparent gravity of 8·0, corresponding to about 10·0 if the spirit were driven off, the brewer would start with a gathering temperature of 59°; so that by allowing the gradual rise specified the temperature would naturally be about 69° by the time the skimming or cleansing stage is arrived at; and so with stronger beers, the gathering heat is put lower, so as to allow of the natural increment without exceeding the standard limit.

Cleansing stage.

Strong beers.

With very strong beers the case is different, since with a top system it would be impossible to pitch below 57°, while in order to allow the normal increase of heat we reach 72° or 73° before full attenuation is secured; but this matters the less, as beers so highly alcoholic are not so subject to the ravages of inferior ferments at the higher temperatures as some of the weaker varieties.

Speed of attenuation.

Speed of attenuation is also very dissimilar, for in some breweries two saccharometer pounds in twelve hours is considered quite sufficient, while in others it runs as high as four or five. On this one matter a word of advice may be offered. If the character of brewing water is such that spontaneous clarification easily results, no great harm comes of rapid attenuation, but if difficulties are experienced as regards brightening, then comparative slowness of attenuation is a positive advantage; and, besides this, it is probable that rapid splitting up of sugar with the high temperature leads to the formation of inferior varieties of alcohol. On the other hand, the higher temperatures are said to determine a distinct peculiarity of flavour, due, no doubt, to the induced development of some special ferment that otherwise would be dormant in the yeast.

Formation of inferior alcohol.

I next come to the extent of attenuation prior to skimming or cleansing and when finally complete. It has been found practically that attenuation to an apparent one-fourth of original gravity gives necessary quiescence and stability, and the skimming or cleansing point is fixed for rapid attenuations some 3 lbs. or 4 lbs. above this, while in slow fermentations, where the power of yeast seems to hinge entirely on mechanical motion, it is quite common to find this continued till the beer has nearly come down to the one-fourth specified, attenuation seeming to cease directly mechanical motion terminates. Final attenuation.

Thus no general rule can be laid down, even extent of attenuation being varied according to whether beer is naturally fretful or no, intended for immediate consumption or for lengthy storage, or if the wort has been practically purified prior to fermentation by the saline nature of water or use of sugar. Still, the one-fourth rule holds good in the majority of cases, and it may be varied according to the discretion of the brewer.

Next comes the vexed question as to cleansing *versus* skimming. It is most difficult to convince a Burton brewer that a good stock beer could be secured by skimming in place of cleansing to unions, while the brewers accustomed only to skimming methods see nothing particularly beneficial in the working of unions. There is, however, something in both systems worthy of notice. Cleansing *versus* skimming.

In working with union casks we have undoubtedly distinct aëration at a most critical stage of the fermentation, *i.e.*, when the beer has attenuated to about one-half of its gravity, this aëration being very limited in amount and pretty constant, as each bead of yeast drops Union casks.

from the swan-neck and the settled beer from it passes back into unions. Besides this there is the distribution of beer at height of fermentation into comparatively small bulk, which, without checking heat, or, more strictly speaking, without cooling down, renders attemperation unnecessary at the point when it would be most productive of mischief, while, finally, the beer in the union casks with their swan-necks exists under a slight pressure, which is also of some influence, the beer never being exposed in bulk to the air till ready for racking.

Attemperation avoided.

On the other hand, when skimming is adopted, the more especially in fast fermentation systems, the bulks are generally large; much attemperation is necessary towards latter stage of fermentation to keep heat under control, and there is excessive exposure of beer while existing at high temperatures, to the air without that gradual aëration spoken of, and in result the skimmed beer is abnormally flattened, and by comparison is apt to taste coarse on palate.

Cleanness of a skimmed beer.

There can be no opinion about the superior cleanness of a skimmed beer, and the lesser amount of labour involved in keeping a simple skimming plant clean; but, speaking candidly, my opinion is that it is not a question of exact goodness of beer that is affected by the adoption of one system or the other, but exact flavour at time of racking, and in this, I believe, there is a marked difference, although the varying palate characters tone down and become more and more similar as the beers attain age.

Spontaneous clarification.

I now come to a point that is of extreme importance and in direct connection with the variation in result that is often seen, when working a combined skimming and union plant, in the direction of spontaneous brightening of beer, the assertion frequently being made that while a stated beer clarifies perfectly in unions, it exhibits a certain stubbornness when merely skimmed.

Now, to consider such a question as this properly, one must leave for a moment the practical details of the process and discuss the whole question of "surface aëration" and "surface attraction" theoretically, for it is in reference to these two influences that one may fairly describe the variation in results spoken of as being of special significance, and by means of which I may perhaps open up a new field for thought and inquiry.

Surface aëration and attraction.

The term surface aëration refers to the capacity of any fluid, whether water or beer, of dissolving, when in contact with air, a certain proportion of its oxygen constituent, and it is on account of this oxygen combining with a certain portion of wort extract of a nitrogenous character, and of its being assimilated also by yeast, that brightening of the beer is immensely facilitated. Why? The oxidation of the nitrogenous matter renders it insoluble, the assimilation of oxygen by yeast revives it, and renders each cell more buoyant, giving it a capacity of rising to the surface instead of remaining in persistent suspension.

Oxidation of nitrogenous matter.

The meaning of surface attraction is entirely different. I expect that most of my readers have noticed that when a lot of chips are thrown into a vessel of water they invariably tend to conglomerate together at side or centre, each slip seeming to have an attractive influence for its neighbour. In the same sense the surface of a brewing vessel, whether it be of wood, metal, stone, or slate, has a certain definite attractive influence for all suspended matter that may exist in the fluid contained therein.

Surface attraction applied to attemperating and steam coils.

If a practical proof of this be needed let any one examine the attemperating coils in a fermenting vessel or the steam coils for boiling back in which a carbonated water is heated. Such coils, upon examination, will be found pretty evenly covered with a deposit of yeast or saline matter. Yet one would suppose that as sedimentary matter falls it would adhere or deposit only on the upper side of such piping, but this is not the case.

Wood shavings.

So well defined is the principle, that Continental brewers actually employ wood shavings, which, exerting the "surface attraction" spoken of, remove from the settling beer the grosser particles of suspended yeast, aided, perhaps, by the astringent nature of the wood employed. Let us apply this knowledge to the problem referred to above.

It is perfectly clear that in the case of a union cask there is far more surface attraction at work than when the same bulk of beer is placed at a depth of four or five feet in a fermenting vessel or skimming back, and unless the skimming beer is far more exposed to aëration influences than is usual, the union beer gets also much the most indirect surface aëration, not only at the cleansing stage, but during the whole process of working-off, as before mentioned, when each bead of yeast and the accompanying fluid is freely exposed to air as it drops from "swan neck."

Swan neck aëration.

Do I go too far when I assert that it is frequently a combination of the two influences named that gives to the union beer a tendency to clarification, which it does not present if skimmed in a deep vessel without any defined surface aëration? I think not, and I am confident that the well-known superiority of shallow skimming squares is a direct confirmation of this view; but

Shallow skimming squares.

while sure of this I must not forget to point out that we always stand in face of another influence that has hitherto been much neglected.

I refer to the fact that many brewers, employing very perfect malt and apparently working on the most correct lines, still have to contend with turbid racking samples, which involve the necessity of some fining method being adopted to accomplish a degree of clarification which should have resulted spontaneously. These brewers may aërate beer as they please, move it from vessel to vessel, and yet the turbidity is a prominent feature, and one has to offer some explanation of what appears, at first sight, totally inexplicable.

It is probable, if not certain, that the use of exceptionally good malt under some conditions of brewing, such as are customary when soft water is in use, often facilitates turbidity, for a very simple reason, the wort yielded being, in so many words, too nutritive, so that by the time ordinary attenuation is accomplished no sufficient diminution of fermentative character has been brought about, and there are still in existence influences that keep the few, *or comparatively* few, yeast cells, fully expanded, sufficiently buoyant to remain suspended without exhibiting the slightest tendency to rise to the surface.*

Turbidity.

If such be a correct explanation, then the practical proof of it should be remarkably easy, and a simple increase in the saline nature of the water employed, the proportion of sugar customary, or the use of a yeast less vigorous in the direction of alcoholic fermentation,

Alteration of system.

* I refer my readers to my occasional notes in November, 1883, issue, which explain pretty fully the subject of racking condition as influenced by opacity of wort at time of gathering.

should, either separately or combined, lead at once to no uncertain improvement, and this, I am prepared to say, is invariably experienced practically.

In making a statement of this kind it is quite as well to attach this rider :—Exact lines of working require varying according to local circumstances, so it is difficult, if not impossible, to name any hard and fast line of proceeding when we are once beyond the range of main principles. I mention this as there are so many systems of hardening, some answering better in one special plant than the others.

Water hardening.

Different sugar percentages likewise exhibit varying influence in distinct plants, although the main conditions of brewing may appear identical, and nothing is more common than to find a yeast answering in one brewery that goes altogether wrong in another where the same conditions and lines of working are in force. So that in dealing with the question described above, one has to be very cautious in demonstrating the actual cause of the difficulty and suggesting means for overcoming it.

Again, one of the most prominent features of turbidity is the persistency that is frequently common to it, *i.e.*, artificial filtration methods, such as the employment of filter paper or finings, do not overcome it, this form of turbidity turning upon a very different principle, viz., the affinity which a fluid like beer has for its *suspended* extract or developing yeast.

Affinity.

Influence of acidity.

Now, acidity directly aids such affinity, and thus, if our beer contain yeast having no special tendency to rise or sink, and different varieties of mere amorphous matter lacking the same tendency, it may happen that the affinity of the fluid is sufficient to persistently hold in suspension matters that should rise to the surface or subside to the bottom. The obvious method for avoiding such result is to prevent any weakening of yeast that would at once lead to the presence of endless cells, lacking either necessary buoyancy, or, on the other hand, requisite gravity, and to keep out of our worts semi-oxidised amorphous bodies that remain unassimilated and in merely partially dissolved condition.

Weak yeast.

One of the commonest little experiments, to prove the correctness of fermentation lines, is the filtration of beer at the skimming stage through ordinary filter paper, the brightness of the filtrate proving that up to that stage such affinity as the fluid has for suspended particles is incapable of preventing their removal by mechanical filtration; in other words, it shows that the wort fermented does not contain semi-dissolved matter, nor has the yeast, employed for inducing fermentation, become worn out and weakened in accomplishing it.

Filtration of beer at skimming stage.

It would have been absurd for me to have spoken of turbidity of beer as resulting from variation in surface attraction and aëration influences without reference to this latter point, which constitutes a factor that brewers have quite as constantly to face.

The meaning of all this is sufficiently simple. When brewers begin to talk about comparative merits of the union as compared with the skimming system of cleansing, they must, one and all, take into consideration the influences that I have just been describing, and it is not difficult to see that the subject of fermentation is hedged about, as I may say, with a number of petty theoretical details which require carrying out practically if we expect to be uniformly successful.

To return again to practical working, one naturally reverts to a consideration of skimming *versus* cleansing,

Aëration in *jack-back*.

and I would strongly advise brewers, when passing their beer to union casks, to do so through an intermediate vessel or jack-back, in which it will naturally undergo a thorough aëration, while, in adopting the skimming process, let the vessel employed be sufficiently shallow in order to give high surface attraction, and at the same time a large area for surface exposure.

Carbonic acid injurious.

There is no doubt that carbonic acid is very injurious to the development of yeast, many brewers dispelling such acid by some method of plunging or arranging a series of openings in sides of fermenting vessel, some few inches above beer line, so that the carbonic acid atmosphere may flow out, simply by reason of its own gravity.

It is probable that a good deal of the influence commonly ascribed to aëration may be indirectly due to prior removal of carbonic acid, this removal bringing a fresh atmosphere in contact with the fermenting fluid, and there can be no question about the superiority of the fermentation that results when the supernatant atmosphere in fermenting tuns is kept moderately free from the gas produced by the splitting up of sugar, a gas which every one knows is altogether opposed to vegetable growth.

I cannot do better than set out now, in tabular form, a sketch of a normal fermentation, first, of a saline water beer cleansed into unions; secondly, the same beer as progressing when skimmed; thirdly, the medium fermentation of a beer produced with moderately soft water, added sugar forming a definite portion of the extract; and, lastly, a soft water beer produced entirely from malt, and worked in stone squares or in closed rounds, with rousing machinery as depicted in illustration.

No. I.

Saline Water Beer, no Sugar, Burton Yeast.

Hard water and unions.

Gravity, 23·0 } Cleansing Method.

2 lbs. Yeast per Barrel.

Monday	6 p.m.	58°	......	23·0
Tuesday	6 a.m.	59°	......	21·5
,,	6 p.m.	62°	......	18·0
Wednesday	6 a.m.	65°	......	14·5
,,	6 p.m.	68°	......	11·2
Cleansed to Unions through intermediate aëration back.				
Thursday	6 a.m.	69°	......	8·0
,,	6 p.m.	68½°	......	7·0
Friday	6 a.m.	68°	......	6·0

Rapid formation of yeast after cleansing, attenuation stopping on Friday, and heat gradually decreasing naturally.

On Saturday, the heat being 65°, attemperation commences, and on Sunday, at 6 p.m., at 59° 6·0, the beer passes to racking-square for drawing off on Monday.

No. II.

Saline Water Beer, no Sugar, Burton Yeast.

Hard water skimming.

Gravity, 23·0 } Skimming system.

2 lbs. Yeast per Barrel.

Monday	6 p.m.	58°	......	23·0
Tuesday	6 a.m.	59°	......	21·5
,,	6 p.m.	62°	......	18·0
Wednesday	6 a.m.	65°	......	14·5
,,	6 p.m.	68°	......	11·2
Thursday	6 a.m.	70°	......	8·5
Skimmed and continued doing so every three hours.				
Thursday	6 p.m.	71°	......	7·0
Friday	6 a.m.	71°	......	6·0
,,	6 p.m.	69°	......	5·9
Saturday	6 a.m.	67°	......	5·9
,,	6 p.m.	64°	......	6·0
Sunday	6 a.m.	62°	......	6·0
Passed to racking-tank at 6 p.m.,		59°	......	6.0

24 hours settling.

The first three heads skimmed were rejected, the remainder stored for pitching.

No. III.

Corporation water. Sugar.

Medium Fermentation, Corporation Water, $\frac{1}{3}$ to $\frac{1}{6}$ Sugar.
Medium **Burton Yeast.**

Skimming.

Gravity, 23·0 } Skimming in Shallow Settlers.

1½ lb. Yeast per barrel.

Monday	6 p.m.	59°	23·0
Tuesday	6 a.m.	60°	22·0
,,	6 p.m.	62°	20·0
Wednesday	6 a.m.	65°	17·0

Occasional plunging was adopted to dispel carbonic acid.

Wednesday	6 p.m.	67°	13·5

Dressed with flour and salt and ran to shallow skimming vessel.

Thursday	6 a.m.	69°	10·0
,,	6 p.m.	70½°	8·5

First head skimmed off.

Friday	6 a.m.	71°	7·0

Skimming continuous, the beer being occasionally *pulled up* from bottom.

Friday	6 p.m.	71°	6·0
Saturday	6 a.m.	70½°	5·8
,,	6 p.m.	69°	5·8

Beer clean and falling bright, so attemperated rapidly and passed to racking vessel, also shallow.

Monday	6 a.m.	59°	6·0

Racking immediately.

No. IV.

Yorkshire System.

Stone square.

Gravity, 23·0 } Skimming in gathering vessel, stone square, or round.

1 lb. yeast per barrel.

Monday	6 p.m.	59°	23·0
Tuesday	6 a.m.	60°	22·5
,,	6 p.m.	61°	21·5
Wednesday	6 a.m.	63°	19·0

Started pumping with alternate rouse and increased number of plunges progressively.

Wednesday	6 p.m.	65°	16·5
Thursday	6 a.m.	67°	14·0*
,,	6 p.m.	68°	11·7

* Dressed with flour and salt.

Friday	6 a.m.	68¾°	9·0
,,	6 p.m.	69½°	7·5
Saturday	6 a.m.	70°	6·0

Skimmed to finish.

Saturday	6 p.m.	70°	5·5
Sunday	6 a.m.	69°	5·5
,,	6 p.m.	68½°	5·3

Gradual attemperation from this time till Monday, when the beer showed signs of brightening, and attemperation was carried on quickly, the beer being racked on Tuesday eve for working out, 61° 5·3.

Differences in speed of attenuation.

Now what are the distinctive differences between the fermentations above sketched? The most striking seem to be difference in speed of attenuation and varying gravity at which removal of yeast is commenced, while if the yeast outcrop could be estimated it would be found enormously large by comparison in the case of example IV., for although in No. III. we have partial aëration at different stages, and although such aëration tends to increase the yeast crop, increase from this cause is perhaps more than counterbalanced by the fact that sugar largely enters into the composition of the dry extract.

Nos. I. and II., no dressing.

In the case of examples Nos. I. and II., no artificial aid to yeast formation, such as dressing, is employed. The beer being produced entirely from malt of exceptionally good quality, and thoroughly vegetated, the added yeast, being of a vigorous type, induces rapid alcoholic change with but slight reproduction, till towards the termination of attenuation, *i.e.*, some few hours after distinct aëration commences, while in example II. yeast formation corresponds with commencement of skimming, a certain amount of surface aëration then resulting.

Fast fermentations.

I do not, of course, mean to assert that in these quick systems reproduction of yeast entirely depends upon a distinct aëration influence, but, at any rate, it is curious to observe how closely it corresponds with such aëration, and there is no doubt that in the case of rapid attenuation the splitting up of sugar is entirely accomplished by the added as distinct from the reproduced yeast.

Now, the saline water beers exhibit so much tendency to facilitate aggregation of yeast, and a corresponding spontaneous brightening of beer, that the cooling down of the attenuated beer may apparently be carried on somewhat quickly and without that extreme attention to detail that is necessary in example III.

Cooling down may be more rapid.

In this instance we are brewing altogether on artificial lines, using sugar as a substitute for malt; endeavouring, in short, to modify a comparatively soft water wort so that we may cultivate in it successfully a practically speaking hard water yeast, and my experience is that success in such a process hinges very much upon frequently dispelling carbonic acid, occasionally inducing direct aëration, and towards the latter stages encouraging the development, and what I may express as the buoyancy of yeast by preventing the slightest check in temperature till all yeast is eliminated, and, by mechanical *pulling up*, stirring up any sedimentary yeast there may be, giving it by contact with air the capacity of rising to the surface.

Pulling up.

I am quite aware that according to one system of aëration an actual drop in temperature is advised, but if we are to accept Pasteur's view, and if we are, as brewers, dealing with plant life, the development of which depends so much upon temperature, then I assert

Rise and fall of heat unadvisable.

that alternate rapid rise and diminution in heat of fermenting wort is altogether opposed to healthy yeast growth, although I am ready to admit that such fall in temperature would be far more serious at the yeast elimination period than during the preliminary stages of attenuation.

These remarks apply more to examples I., II., and III. than to systems of fermentation that are carried on by means of a slow yeast—often developing at much lower temperatures than those specified in example, and if any special significance attaches to the old good quality of Puncheon beer, of which the modern union beer is simply a copy, I should say it is because such good quality coincided with distinct aëration, and no possible rapidity of cooling down.

Puncheon beer.

In the case of No. IV. we come to an example of fermentation widely different, a system that admits of certain variation, for I am bound to state that such slow system is far more satisfactory in an open round or a square, practically termed closed, but yet admitting of constant contact of air with yeast, than with the original closed box, denominated a Yorkshire stone square; in short, if the matter be investigated, it will be found that no stone square brewer is now brewing upon the original lines.

Stone square brewers.

One and all carry on a modified system necessitated by altered conditions of brewing, and the observation at bottom of example IV., that beer is racked for working out, is significant as proving that with all the modifications they have made they still have to rely upon artificial methods of clarification to give them the necessary absence of suspended yeast in the beer shipped to customers.

The subject is worthy of full explanation. Stone square brewers, in the majority of instances, employ malt of heavy nitrogenous character, and the brewing waters being more or less extractive, the entire malt worts are correspondingly heavy, or, what is more suggestive, yeasty in nature.

Aëration to remove excess of yeast forming matter.

I am quite aware that the original stone square worker knew nothing of aëration; he thought of it quite by accident, since he found that fermentation in the closed vessel was remarkably sluggish without it, and it was the adoption of distinct and constant aëration by pumping and plunging that led to the modification of yeast, giving it that capacity of self-reproduction that enabled him to remove from his heavy wort the large excess of yeast-forming bodies that it contained, bringing it thereby into a condition of stability.

Low temperature.

The lower temperature usual in such systems is perfectly natural: the fermentation was slow, and there was no incentive to rapid increase of heat, and the brewers too were constantly in dread of alcoholic oxidation, since in those days Liebig's views on fermentation were more or less popular; and I believe it was quite as common for a stone square brewer to employ warm liquor for preventing a drop in temperature as it is for the brewer on other systems to use cold to ensure it, this proving that in the old stone square method there was no great tendency for the contents of the stone to rise in heat.

This means that with slow systems it is quite common to find the usual range between 59° and 65°, and the curious difference in result that I myself have noticed is that the reproduction of yeast at this comparatively low temperature puts an end to much of the danger attaching to quick attemperation. I have seen endless

Rapid attemperation possible.

quantities of beer cooled rapidly from 65° to 58°, the reduction commencing at the skimming point without seeming to interfere in any way with the spontaneous clarification of the beer. This was, however, under exceptional circumstances, and is not the present experience of stone square brewers, who suffer far more than others from the altered conditions of brewing that are now so prominent.

It will be noted that in example IV. the removal of yeast does not commence till attenuation is practically complete, this showing how much this description of ferment depends upon combined motion and aëration for its vigorous development. This fact is, perhaps, in a certain sense disadvantageous, putting an end to all chance of yeast selection, the whole of the very large crop coming off practically in a single skimming, and being, as I have before pointed out, more or less matured in character.

There is another point about such beers worthy of notice, since, as they are fermented at low temperatures and constantly capped with a dense head of yeast, much carbonic acid that would otherwise escape is held in complete solution, exhibiting its influence in two distinct ways—thus, when in solution it gives to beer a hot stinging palate character, and, secondly, when the beer is agitated by passage from one vessel to another, portions of it are set free, exhibiting itself by the appearance of a film of yeast on surface, thrown up there by the supporting agency of the liberated gas in place of depositing itself on the bottom. Carbonic acid.

I ask any of my readers knowing the details of such a system if I am not corrcct in my statement. Are not such beers, whatever their defects may be, of extreme palate warmth and fulness? And do they Redeeming points of stone square beers.

ever exhibit that abominable flatness by settling which is so characteristic of beers fermented quickly at high temperatures and much exposed during skimming? Certainly not; they always appear charged with carbonic acid, and it is there as the result of low temperature and the deep head of yeast that prevents its escape.

It is quite common to see a light held directly over one of the deep, thick heads of yeast without being in the slightest degree affected; in other words, attenuation is going on, sugar is splitting up, carbonic acid is being liberated, and yet none, or next to none, is being set free, and it reminds me in modified degree of much that is common in the case of a Lager beer.

This is painting a picture that may be too tempting for, as I have said, spontaneous clarification is one of the main principles of fermentation; and I fear it is no longer normal in the case of a stone square beer produced on the old lines.

Necessary alterations to process.

I have not time, nor is it necessary, to enter deeply into the reasons of this. Let it suffice that the vast alteration in general character of malt, the altered condition of its albuminous constituents, even after the most perfect vegetation that is now possible, leaves the stone square brewer with an entire malt wort that no longer spontaneously brightens on completion of attenuation, so he seeks relief by modifying the crude nature of wort by the very means that others adopt—partial hardening of water, use of sugar, and so forth, the stone square ferment, in result, being, in consequence, very different from what it was a few years ago.

It will be noticed that in examples III. and IV., mention is made of *dressing*, this being composed usually of flour, wheaten or malt, and salt, and it is employed for a very definite purpose; in example III., for directly nourishing the yeast; in example IV., for effecting by such nutriment the greater elimination of gas to support the dense head of yeast which usually exists. It is at first sight difficult, perhaps, to understand how crude starch and albumen can act as the nutriment of cell life that feeds itself by absorbing soluble nutriment only through the pores of the cell wall. Dressing.

That such assimilation does take place is, I think, self-evident, although certain observers describe the action of dressing as a determining cause or catalytic agency, facilitating the splitting up of some partially fermentable compounds; but the majority conclude that the crude albuminous matter, in contact with salt and developing yeast, immediately digests, while the starch either sinks insoluble to the bottom of the vessel or gradually splits up, as it is known to do during prolonged fermentation. Its assimilation.

It must be remembered that the quantity of flour so added is very minute, and it is quite evident that any large proportion would lead to the most disastrous results, as many have experienced. The usual quantity employed is 1, or, as an extreme, 2 oz. flour per barrel, and ½ to 1 oz. salt; these being thoroughly *whisked* up in a tub with some of the fermenting beer, so that all lumps are perfectly broken, the mixture being then scattered over bulk with a good rouse. Quantities employed.

It may be advisable to mention here the subject of added salt, there being an impression that such addition is illegal. The only law on the subject is specified in one of the clauses of the Food Adulteration Act, and Addition of common salt.

if county analysts find an excessive quantity of salt in beer, they can proceed against the producer of it. We doubt very much if 50 grs. per gall. would be considered an excess, as many beers naturally contain much more.

On the other hand, the addition of flour is opposed to excise regulations; but I have never found difficulty in obtaining the necessary permit, Inland Revenue officials being very liberal-minded on such matters if they recognise the fact that brewers intend no sort or kind of fraud.

Racking brightness.

I naturally come now to discuss the question of racking brightness. What is meant by this term? It would, I think, be absurd to lay down a general rule; a degree of brightness that answers in one brewery may be altogether unsuitable, or short of what is necessary, in another.

London trade conditions.

Let me illustrate this practically. A large quantity of the London public-house beer is delivered with a considerable proportion of suspended yeast present, and with a certain amount of fermentative energy still existing; the beer being immediately fined by the publican, the fining material and collected impurities rising to the surface and passing out through bunghole. It is quite evident that such a degree of racking brightness would not answer under a different system of sale, but even with similar shipment conditions varying degrees of brightness become necessary, this being necessitated almost entirely by the differing character of water in use.

Burton.

For instance, a Burton brewer, up to recent times at any rate, paid but scanty attention to racking brightness, the sulphates and chlorides of his brewing water determining an undoubted conglomerating tendency of yeast with a lesser fermentative character of wort, so that the racked beer, even not pleasingly bright, rapidly became so in cask, without the least danger of a practical *kick up* or *fret*.

On the other hand, the brewer who, in spite of all his knowledge and care, finds that his original soft, or, perhaps, artificially-hardened, water still gives a beer in which this ready conglomeration of yeast is not seen, and which itself exhibits a strange tendency to rapid secondary fermentation, finds it of the utmost importance to obtain a racking sample as bright as possible, absolutely brilliant in a tin taster and pleasingly bright even in a tumbler.

Hindrances to bright racking samples.

If the necessity is allowed, let us examine for a moment the influences that prevent it, since I have mentioned some that directly aid it, and very briefly, one or two that explained a certain difference experienced in working a combined union and skimming plant. I am quite ready to admit that there is such a thing as over-stewing of wort; nay, I believe that it is an actually injurious proceeding if the wort does not contain starch; but in many instances stubborn attenuation and sluggish clarification coincide with non-attention to the necessity for completing in copper what should have resulted in mash tun.

Slack malt.

Again, a large number of brewers are in the habit of exposing malt to the atmosphere in sacks: it absorbs moisture, becomes slack, and a degraded condition of nitrogenous matter results. Unfortunately, the evil does not end here, since in every case such a malt yields a wort that, during fermentation, becomes charged with a minute variety of cell life, directly caused by the modified condition of original albumen; and the brewer experiences what he terms greyness,

Greyness.

supposing that greyness is the direct result of dissolving the extract from slack malt.

He generally notices that the wort is also more or less cloudy; but the persistent dulness even of his fine beer is due to actual suspended yeast cells of minute size, which pass easily through filter paper and the gelatinous membrane of added finings; and this can be readily proved by simply neutralising the acidity of such a beer. In a short time the sample will become brilliant, or it will filter at once, for reasons I explained when dealing with the subject of affinity a few pages back.

Neutralisation.

How to secure spontaneous brightening.

Thus, as regards spontaneous brightening, the sum total of influences seems to hinge on combined surface aëration, surface attraction, effectual diminution of fermentative capacity, the use of perfect malt, or, when employing imperfect material, the careful manipulation of such in mash tun and of its wort in copper. To these we may add temperature as a question of moment, while the influences named above cover, of course, considerations of depth.

Necessity for unison between yeast and wort.

Before proceeding to the subject of settling, we must look for a moment at what is meant by the necessity for exact unison between yeast employed and wort fermented. It may be explained practically in this way—If yeast, cultivated in wort of one standard character, and under certain conditions of motion and distinct aëration, be transplanted into an entirely different wort, with the absence of such conditions, its growth naturally suffers; and we find that diminutive forms of cell life appear as the result.

We have, in fact, a repetition of the evils experienced when using slack malt, and this explains why a very general principle of yeast use may be laid down; for it is mere absurdity, as any tyro can see, to expect perfect fermentation if we attempt to cultivate yeast under diametrically opposite conditions to those that the mother crop was accustomed to.

A Burton yeast in a stone square.

For instance, the introduction of a powerful Burton yeast into a stone square placed in a wort usually found in such vessels would find the brewer, at the close of fermentation, with a heavy crop of bottom yeast, and a beer persistently turbid; and much the same result would follow if a slow stone square yeast were used to induce fermentation in a wort normal to the union system of Burton.

Modification of yeast.

These, of course, are extreme examples of my meaning, but they are not the less suggestive for being so. I admit that modification of yeast is possible. I have said this in so many words when discussing the theory of fermentation, and I could, no doubt, in a series of growths, modify a stone square yeast into Burton barm, and *vice versâ*, but brewers cannot afford to carry out theoretical views of this kind, since the beer during these series of growths effecting modification would probably be unsaleable. We all understand that the yeast of the present day has been produced from an original common stock, but do not let any one delude himself that it is either wise or profitable to attempt modification in our daily operations.

Source of yeast supplies.

Enquiries are endless as to suitable sources of yeast supply. There is perhaps no more important question in practical brewing, no question more hedged about with difficulties when one seeks to give definite reply. Broad lines of selection may be laid down, and it devolves upon each brewer to so watch his fermentation process that the yeast, selected for qualities most in unison with his wort conditions, should reproduce itself efficiently, and give that spontaneous clarification that is invariably a sure sign of success.

Soft water yeast supply.

If I am fermenting a strictly soft water wort, I should naturally go for a yeast supply to Yorkshire or Lancashire, where such worts are usually to be found, and which yield, as I have explained, a definite yeast.

On the other hand, if I am dealing with a saline water wort, I should seek a yeast supply from well-known brewing centres where hard waters are used. Lastly, if I am a user of saccharine as a substitute for malt, if I partially harden my brewing water and produce an artificial kind of wort somewhat resembling that naturally resulting when using medium waters, I go to a centre of yeast supply, to a brewery carrying out operations on this exact principle, or to one that has a natural wort somewhat resembling the strictly artificial one referred to.

Broad lines of yeast selection.

These are what I term the broad lines of yeast selection; it would be unfair to name the individual yeasts I refer to, but I know a large number, and there is not the slightest doubt that this question alone lies at the bottom of many noted examples of success, and quite as many unfortunate evidences of disaster.

Period of settling.

It will have been noticed, in the examples of fermentation given, that some beers are settled for a very short period, others for a longer time, and this brings us to the subject of settling, The racking tank of years ago was, generally speaking, a deep square vessel, in which beer cooled down to the racking temperature, and became moderately free from yeast. Beer was allowed to settle for 24, 36, or 48 hours, to attain the degree of brightness thought necessary; this, of course, being facilitated by the combined influence of the clean surface attraction and surface exposure to air.

In some cases the beer would carry a distinct layer of yeast on surface, in others none at all, this turning principally on the question whether the beer had been fermented on a slow or fast system, and the degree of cleanness that had been arrived at prior to its removal from cleansing casks or squares. This lengthy settling in a clean vessel led almost invariably to great flatness, and, of course, in a certain sense, to possible oxidation of alcohol by the direct intervention of a surface ferment. Deposit in settling tanks.

The tendency of modern thought has been in the direction of so improving fermentation systems generally that no necessity should exist for the prolonged settlement of finished beer in contact with air.

In many breweries the settling vessel has become merely the racking-tank, the beer passing into it almost sufficiently bright for immediate racking, and this has chiefly been accomplished by the introduction, in many plants, of the intermediate shallow skimming-square, a vessel admirably adapted for facilitating clarification, even while yeast elimination is in full progress. Shallow skimming vessels.

The brewers working with unions have, by attention to small details, succeeded in getting the beer bright therein, so as to render after-settling a matter of small moment. A few weeks ago, at Burton, I had direct confirmation of this view in seeing beer racked direct from union casks, an undoubted novelty in that well-known centre of brewing. Union breweries now racking direct.

The use of preservatives has been of immense service to the brewers using settling-tanks on the old-fashioned plan, since, in adding some quarter-pint of calcic bisulphite to each barrel of beer in tank, very little harm could result from the prolonged exposure; while, on the other hand, I have frequently seen beer left in settling- Preservatives added in tanks.

vessels without covers or attemperators rising in temperature and entering into a distinct secondary fermentation prior to racking.

Covers and attemperators to settling tanks.

If settling-vessels are to be used for the old purpose, they should, undoubtedly, have proper covers to keep out dust and dirt, and attemperators sufficiently powerful to control temperature; while the beer should be passed to them in such a condition as to allow of a protecting film of yeast being thrown to the surface, although such film puts an end, of course, to the surface aëration influence; but in some cases we have to ignore this to prevent undue flattening.

Home-brewed flavour.

It has often been remarked that the shifting of beer from one vessel to another with final lengthy settling, has been the main cause of brewers' beer losing the old-fashioned home-brewed flavour so much prized by many consumers. Of course, competition has given rise to many changes in the general character of beer, but there is no doubt that there is a considerable amount of truth in the argument above referred to, as can be readily ascertained if we taste a beer as it exists in a cleansing-vessel, and the same beer after it has been finally placed in the trade cask.

All the older beers were most probably stored in the casks in which working off had taken place; this, in great measure, being the basis of the peculiar flavour attaching to good public-house beer, and thus we find several very extensive brewers carrying out a system oi cleansing directly based upon the principle of retaining the old-fashioned flavour in preference to the cleaner palate taste of the beer finally racked into clean casks for shipment.

Cleansing direct into trade casks.

The system I refer to is that of simply working the beer in gathering square till two-thirds attenuated, and then cleansing it direct into carriage-casks placed in tiers; some brewers going so far as to have a series of rooms in which such casks are placed, kept at different temperatures suited to the stage of fermentation then progressing, their main object being to prevent cooling down until yeast is fully eliminated.

May not we suppose also that they have experienced benefit in pulling down tiers of casks filled with cleansing beer, and restacking these in a room below at a different temperature, this removal leading to that kind of aëration that is so useful in aiding the elimination of the last portions of yeast of practically poor buoyancy. In this system the trade cask cleansing-vessels are topped over just as puncheons were, any excess of bottoms being eventually drawn out by means of suction tubes, a few finings being introduced after hopping prior to shipment.

Suction tubes for withdrawing excess of bottoms.

The subject is worth mention, as the beer so worked seems specially fitted for private trade consumption, since beers racked clean into very small casks are apt to be exceptionally flat, and those worked in these small casks have always sufficient sedimentary matter present to keep them more or less lively; so however beneficial the system may be in one way, it would hardly answer for stock or export beers.

Uniform brilliancy of Lager beer.

It will be convenient, in discussing the question of temperature as affecting fermentation, to explain, also very briefly, the subject of attaining those special qualifications of Lager beer that are so much admired by English consumers—viz., uniform brilliancy and condition. It is a point of popular knowledge in England that high temperatures communicate a distinctive flavour of beer that is much sought after, but high temperatures are not always safe, and having vegetable life of different varieties to deal with we have to steer clear of aiding too much the development of such forms as induce premature acidity.

Influences on temperature of fermentation.

Now, the two conditions which enable the brewer to adopt a high range of temperature with impunity seem to be the use of caramelised malt, as in porter brewing, or the employment of a water excessively salt (chloride of sodium). Under such circumstances a successful range of from 60° to 80°, and in some instances to 90°, is possible and advantageous, the special benefit arising from the increased development of some distinct yeast corresponding to the high range of temperature.

Do not let me be misunderstood: I cannot and do not advise such high temperatures, and the majority of brewers have found, and will continue to find, that a range under 70°, although, perhaps, giving the colder palate taste, is by far the safest in view of the practical impurity of commercial yeast.

Bottom fermentation principle.

I have before explained the main principle of fermentation under a temperature of 50°; it precludes the development of any species of diseased ferment, and facilitates the solution of much carbonic acid, while as the yeast is of bottom variety the wort during fermentation is constantly in contact with the air, which undoubtedly exercises its usual influence.

Lager beer production.

The succeeding steps in the production of a Lager beer are sufficiently simple. The beer, attenuated at the low temperature in open vats of small size placed in rooms constantly kept at about 45°, or ranging down from this, is removed into vessels somewhat resembling union casks, where subsidence of bottoms takes place, and where, in many cases, actual brilliancy is enforced by the use of a few finings.

It is next moved to a similar series of vessels in complete connection, not only for direct racking, but also with an automatic pump for a purpose afterwards to be named. In this series of vessels, still kept at the low temperature named, the bright beer is treated with a minute quantity of fermenting wort, sufficient to communicate fermentative action to the whole bulk, without being in such excess as to cause turbidity.

Addition of fermenting wort.

Those who have had practical experience of bottom fermentations will remember that even when in full progress the beer looks remarkably clear, the aggregation of yeast seeming the special feature, so that there is nothing very strange in bringing about an incipient fermentation without turbidity, this being induced to counterbalance such flattening as may have been occasioned by artificial fining.

In this last set of vessels duly fitted with pressure-gauge the beer becomes perfectly brilliant, and at the same time charged with more gas, so that actual pressure in cask results, and the use of the automatic pump is seen at racking stage when the beer is drawn off into shipment casks of small size, the exact pressure in clearing cask being kept actually steady during the racking process, so that no disturbance of any possible sediment results, the beer being forced into trade casks, not only bright, but under a slight pressure, which even increases the condition that the fluid would otherwise have.

Automatic pump.

This turns upon a very nice principle. From first to last the beer during its fermentation, cleansing, racking, and storage exists at a temperature between 45° and 40°, it is racked perfectly bright, and if trade casks are quickly shived up it exists therein under a certain pressure. Now, what happens when such beer is removed into the warmer cellars of the consumer?

The immense importance of pressure and temperature.

It rises in temperature, gas is liberated, the pressure in cask is increased, and on drawing off it foams as if a violent fermentation were in progress, and yet there is none at all, while the beer, bright at the low temperature named, is superlatively brilliant at the higher one of consumption, and thus we see that much of the mystery of Continental beer depends upon the very simple influence of temperature, although I am leaving out of question peculiarities of palate taste that are mainly due to the distinct mashing system, and the practice that Continental brewers have of tarring the interior of their casks.

Palate flavour.

Beers of this description are frequently seen in bottle without deposit, and yet in brisk condition. Such samples have merely been sterilised after bottling, a process that has destroyed all false ferments, while the beer, coming into warmer climates than correspond to the exceedingly low temperature of fermentation, sparkles and creams as a high fermentation beer does when distinct attenuation has resulted in cask or bottle.

Sterilisation.

These matters are sufficiently interesting, and could hardly be left unnoticed when dealing with temperature as an influence on fermentation; and although it is absurd to suppose that English brewers could not produce a Lager beer, it is positively insane to expect them to do so with present plant arrangements and existing cellarage.

Plant arrangements and cellarage.

Low-fermented beer.

If the English people exhibit a disposition to prefer a bottom fermentation beer to a high fermented article, then it will be easy for capitalists to supply it; but it is well to remark that the stability of such beers, if not induced by sterilisation, entirely depends upon the lowness of temperature during storage and up to period of consumption.

This, at any rate, is the rule with the vast bulk of Lager, although qualities of bottom fermented beer are produced that, with a considerable percentage of alcohol present, exhibit a character of stability, even when removed into warm cellars some 10 or 15 degrees higher than the temperature of the store from whence they came. Before entering upon a general recapitulation of the subject of fermentation, let me turn attention to the matter of yeast storage and treatment.

Yeast storage.

Weak yeast.

I have observed more than once that weak yeast is at the root of many disasters, such weakness resulting from insufficient nutritive character of wort, and there may be found even yet a possible system of successfully feeding yeast before introducing it into bulks of wort. Unfortunately we do not appear to have any very ready source of digested albuminoids, so we fall back, as I have said, on crude flour.

Saline artificial yeast food.

We have, at any rate, artificial supplies of saline nutriment, and the use of these often leads to considerable advantage, while too much could not be said on the subject of feeding with a concentrated malt wort, as briefly referred to before, such strong wort containing all the essential elements of yeast, so that by planting in it the "store" to be employed for pitching, each cell soon exhibits the influence of the food, they expand, vacuoles become clearly marked, buds detach themselves, and the yeast becomes capable of starting in vigorous in place of weakly condition, to accomplish the office for which it is employed.

Growth in a strong wort.

If aids of this kind are necessary, steps should also be taken to prevent deterioration of barm after it is removed from the beer; and I have previously noticed that yeasts differ materially in the degree of maturity that they have attained at the period of removal. This is of importance, in so far as beer should always be left in contact with yeast till maturity is attained, and when once this stage is reached the fluid portion should be drawn away.

Draining after collection.

From this we shall see that the outcrop from a slow fermentation may be drained with advantage sooner after collection than that from a rapid fermentation, and after draining is complete the yeast should be carefully watched, so that it is used before any actual deterioration sets in.

Practical indications.

The majority of brewers would judge of this fitness for use by mere practical indications—its colour, smell, and degree of solidity, while the microscope, of course, is of service at this stage in demonstrating its purity and absolute physical vigour; but in my experience there is one very common form of deterioration that becomes practically evident some considerable time before the microscope indicates that anything is wrong.

Tendency to fluidify.

I refer to the change from solid to fluid condition, invariably, I should say, the forerunner of actual putrefaction, this generally resulting from the use in excess of some chemical agent that has crippled, in no uncertain manner, the actual vitality of the yeast, and which, in a very short time, evidences itself also microscopically by the peculiar granular appearance and general visionary look of each cell, which, undoubtedly, means percolation of plasma outwards.

Sluggishness in separation.

Many varieties of yeast exhibit a certain sluggishness in the direction of ready separation of fluid from solid, and it is a point of popular knowledge that there are two distinct kinds of yeast common: one perfectly thick and heavy, the other very fluid, and, of necessity, heavy too.

I am aware that many qualified to form an opinion assert that such variation in physical appearance is simply accidental, that the fluid variety has not been subjected to the same perfect system of drainage as the solid; but my own opinion is, that it would be impossible, by any system of drainage, excepting that method which is adopted in the case of a filter press, to separate the intimately combined fluid portion of a liquid yeast, such as I refer to, so as to leave it in thick condition.

Filter press.

The fluidity of barm mentioned is often produced by what may be described artificial means, as distinct from the natural cause, which is undoubtedly a distinctive saline character of brewing water, viz., the use of sulphites combined with the employment of flour and salt dressing during fermentation.

If it resist ordinary drainage methods of separation so arranged as to remove a strata of liquid wherever it may happen to exist in bulk, or the slightly suctional filtration influence of a copper Ritchie vacuum press, then I think we may say that the yeast itself is so intimately combined with the fluid portion that serious harm to it would result if powerful mechanical pressure were brought to bear to effect the separation. I believe this view is confirmed practically, in so far as the best dry cake from a filter press and the brightest and best flavoured filtrate correspond with the thicker varieties of yeast pressed, and the fluid yeasts, *i.e.*, those that are naturally fluid, considerably bother the yeast presser, although much is to be done if the press is worked properly.

Ritchie vacuum press.

A good many people imagine that the filtering medium in a filter press is composed of a combination of fine canvas and "swansdown," but, as a matter of fact, it really consists of a thin film of yeast that is first

Filtering medium in a filter press.

Details of yeast-pressing.

deposited thereon. It is for this reason that so much care has to be taken in seeing that the yeast first pumped in is fresh and fairly thick as opposed to anything in the shape of bottoms, so that the film is attained as rapidly as possible, and the pores of the filter bags kept open, which would not be the case if any mere fluid was first passed through, or sedimentary yeast considered as being similar, as a bag coating material, to the fresh and thick variety that I have specified.

This is the entire secret of successful yeast pressing, and after the first film is deposited on inner bags, then an actual pressure may be applied with impunity, and the fluid separated from solid portions of yeast, no matter how strong the affinity between solid and fluid may be.

Economy of yeast pressings.

As regards the cost-price of beer, it makes a very considerable difference if the filtrate from the yeast of each individual brewing is not mixed off at time of racking, and if the filtrate be exceptionally sound and sweet there does not seem any *primâ facie* reason why they should not be so used; but I am bound to say that a certain dread respecting their influence on a stock beer is always felt, since no matter how sound and bright they may be they always exhibit a great tendency to rapid deterioration when unmixed.

Cause of deterioration.

This is ascribed to two distinct causes, the passage of the minute forms of diseased ferment life through pores of filtering material and a probable collapse of some of the alcoholic cells under the influence of the pressure applied, with a corresponding escape of soluble matter and minute inter-mixture of this with the fluid filtrate.

"Drawings" may be used, however, with impunity if sweet, in all the varieties of beer classed under the term

"*Running*," the more especially as it is now customary to employ a preservative in such beers, which, in its influence, would strongly militate against any possible putrid tendency that the small proportion of added "drawings" might possess.

I do not wish to stir up any fear or dread on this subject, while I equally desire not to give advice that might lead to unpleasant result, and summed up, as a whole, there is no doubt that the yeast press filtrate requires carefully dealing with.

Objections to pressing pitching yeast.

Lastly, in reference to pitching yeast, one does not quite like the idea of submitting it to pressure, since, as we know, alcoholic cells are delicate globular organisms that would undoubtedly suffer from any extreme compression, such as that of two or three atmospheres; but as many varieties of yeast would commence to deteriorate before exhibiting any tendency to ready separation from fluid, I think slight pressure might facilitate such separation, and have a strong notion that a copper Ritchie vacuum press for obtaining thick store barm at one uniform suctional pressure would be a most useful arrangement in the yeast room of any brewery where difficulties in connection with exact physical character of yeast are experienced.

Quantities of pitching yeast employed.

I do not know whether it is too late or out of place to mention the exact quantity of pitching yeast that is requisite to produce a certain result. I once heard the whole subject expressed in a very striking simile, the speaker comparing the wort of a brewer to a field that was being ploughed, and he remarked that when the land was of a heavy clay nature we naturally attached more horses to the plough than when the surface layer was of a light loam; and I may add a rider to this by saying that greater disaster results from the employment

Yeast work.

of a deficiency than of an excess of yeast, in the sense that as yeast accomplishes a certain amount of definite work, the larger the number of cells present the less we call upon them to do.

My readers will see why, in the case of slow fermentations as exampled in No. 4 table, the brewer is able to use a minimum of yeast without danger, since he is careful to supply, even from the very commencement of fermentation, one of the absolute necessities for keeping the mother-yeast in vigorous condition, and aiding the development of buds, this being a constant supply of minute quantities of air.

Result of using an excess of yeast.

All this does not mean that we are to use yeast in large excess, to prevent weakness, since in such case the attenuation would be too violent, and we should possibly be forced to check it by excessive and wasteful skimming, or by actually retarding heat, which, as I have explained before, is a very serious matter. Rather use too much than too little, and aid the healthy development of what we do use by attention to all the little details of working that I have dwelt upon so fully.

Is it possible to sum up the whole question of fermentation in such a way as will bring clearly before my readers all the salient features of a subject that is of such extreme importance as that now under consideration? Let me try. From the very moment that Pasteur, in his Studies,* proved conclusively that the chemico-physical theory of Liebig was untenable, brewers had to face the fact that in place of dealing in a strictly chemical sense with one of the constituents of wort, they had to turn their attention to the actual

* Studies on Fermentation, Faulkner and Robb. Published by Macmillan and Co., Bedford-street, London, W.C.

cultivation of a minute vegetable plant, orced to do so by knowledge not communicated to them by Pasteur, but brought under their notice by in many cases, painful experience, that, failing healthy cultivation, the crippled and poverty-stricken plant became the source of turbidity and acidity, ultimately leading to the putrefaction of their beer.

Influence of yeast on resulting beer.

I explained in the chapter on mashing how important it was to obtain in wort distinctive quantities of carbohydrate (*i.e.*, sugar, dextrin, and inert matter), nitrogenous, and saline bodies; that as yeast consisted largely of azotised matter * the nitrogenous constituent of wort became of extreme importance in this sense, that mere quantity was not sufficient, but that in all cases such albuminous matter must have a distinct nutritive character not attaching to all of it, but to such a portion of it as would suffice for the life necessities of the yeast to be cultivated; that saline matter was also of importance; that malt yielded a variety of salts that seemed to answer this special end; that substitution of sugars and some varieties of raw grain not only interfered with the normal percentage of saline matter yielded by malt, but also with the equally important nitrogenous percentage, and then I had to devote a great deal of time to a consideration of what resulted when inferior material came to be used.

Character of wort.

I showed that such material meant deficient nutrition for yeast; that ordinary soluble albuminous matter must be modified under some influence, probably diastatic, before it could act as nutritive

Influences of poor material.

* Azote is the term applied to nitrogen, derived from Alpha, privative, and Ζωή, life, and azotised is a term meaning merely nitrogenous, albuminous, or protein in nature and constitution.

albuminous matter; that the terms peptone or parapeptone were applied by writers and in ordinary text-books on chemistry to distinguish this especial condition or digested character of nitrogen compounds, and that, just as the diastatic power of malt varied, so would its nutritive character, and that in the case of poor material with low diastatic power it was not only absurd to lessen the nutritive nature of the wort yielded by the use of sugar and other substitutes for malt, but, on the other hand, to so coax the low diastase proportion as to practically induce it to accomplish not only the ordinary starch-hydration, but as large a modification of the otherwise crude soluble albuminous matter as possible.

Crude soluble albuminous matter.

If a practical example be required at this stage of what is meant by the presence of crude soluble as compared with peptonised albuminous matter, let my readers examine the head changes in those breweries where poverty-stricken material is used in conjunction with sugar. Not only is the yeast formation stage very late, but when it does appear its strange, fluffy, frothy appearance is a strikingly suggestive contrast to the yeasty head that is usual in breweries where good malt is employed.

I could not, in speaking of mashing, and even at this period, impress too strongly upon brewers the necessity of keeping in mind the true connection that exists between mashing and fermentation. Twist and turn the subject as you will, it is forcibly brought home to every one by the results achieved, and, if I am understood so far, it is but a single step to a consideration of what is meant by diseased as opposed to a healthy fermentation.

Brewers arrive at worts containing crude soluble, peptonised, and parapeptonised albuminous matter, and this may be either of healthy or diseased nature, in this sense: the original barley of the malt has been blighted during growth; it has been harvested in wretched condition, no step has been taken during the malting operations to retard a degradation of constituents that is in full progress, steep liquor has been left unchanged, couches and floors have been allowed to heat, rotten corns to mould in contact with their fellows, careless kiln drying has followed, and the malt, probably *touched up*, as one may express it, by the application of sulphur or salt on kiln fire, has been stored in a damp atmosphere.

Causes of diseased fermentation.

Defective malting.

One and all of these neglectful proceedings directly promote the condition of nitrogenous matter termed diseased, *i.e.*, a diseased state of the actual nutriment of yeast.

Degraded albuminous matter.

Some readers, perhaps a great many, may remark, but why specially should the nitrogenous constituents suffer? I refer them to my opening remarks on the subject of fermentation, where I stated that albuminous principles, when in moist condition, were known to putrefy with the greatest readiness; nay, that the very fact of this knowledge being possessed by chemists was the basis of the Liebig theory of fermentation, and if proof be required we have simply to expose a moist albuminoid substance to the air, and contrast it with the behaviour of a pure moist sugar, this latter being a mere carbo-hydrate body.

Deficiencies of moisture.

Unfortunately, in accepting Pasteur's theory, we have to study not only alcoholic ferments, but those termed lactic, putrid, and viscous, and although we may not be in the habit of seeing these in our commercial

Diseased ferments in yeast.

pitching yeast, it is absolutely certain that their germs exist there, as also in the worts produced from inferior material; for it is not at all certain, nay, it is highly improbable, that germs of ferment life are destroyed by the limited boiling of the slightly acid wort in which they exist.

It must be self-evident that if the nutritive condition of our wort tends to facilitate the development of ferments corresponding with its diseased condition, then the germs present will rapidly develop and exhibit themselves microscopically as vigorous ferments.

Experience in cleansing a series of mains.

I shall never forget a proof of this that I once had in commencing brewing operations in a plant that I regarded as being anything but clean. I had adopted the combined use of steam and strong caustic potash solution for cleaning an endless series of pumping and refrigerator wort mains, and I was struck by an inexplicable and immensely increasing impurity of yeast that appeared to correspond with the extra care taken in cleansing the plant.

The ordinary heads of yeast thrown up during fermentation, beautifully white and vinous, simply swarmed with filaments and putrid ferments, and I do not exaggerate when I say that the aspect of the yeast crop corresponded with the view depicted in plate II.

Dirt in mains.

Now, what does this mean? The mains of the brewery had been either left uncleaned or cleaned in a very inefficient manner for some years, a deposit had settled after each time of use, and had gradually hardened, especially in the case of the mains through which hot wort had passed, and this hard surface crust with moist subsidiary matter *locked in*, as I may express it, was at the seat of the whole impurity of the yeast that was afterwards experienced.

The combined use of steam and potash loosened the surface film, and the wort, passing through these same mains, picked up and held in solution portions of the sedimentary slime still unremoved, the influence of this in the direction of disease being immediately evident. This experience teaches one lesson at any rate: that removal of slime from piping is no easy matter, and that its removal becomes the more difficult the longer it has accumulated and the harder the film of scale that has formed.

Removal of slime from mains very difficult.

This question of condition, or, as Liebig would have expressed it, state of change of nitrogenous matter, is a basis not only for the use of the microscope during the preliminary stages of fermentation, yeast selection, and so forth, but also for those examinations of deposits from beer that tell the careful brewer so much, and those forcing tray experiments that enable him, by determining the tendency of beer extract, to predict with certainty what the future of each beer will be.

Normal acidity.

It is not necessary to enlarge further on the use that normal acidity has, of how excessive acidity not only examples imperfect malting, but directly tends to keep beer turbid through increase of affinity, such affinity holding amorphous matter and certain species of small cells in persistent suspension. I am quite ready for the accusation that I make too much of yeast development and too little of the objects for which beer is fermented, and my reply will be, it is simply because too much has always been made of fermentation in reference to alcohol, that I have taken as my text the subject of ferment-

Yeast development *versus* alcohol.

ation as influenced by yeast growth, the stability and clarification of beer as promoted by perfect vegetation and rendered impossible by the starvation of yeast.

Our plates.

It is time now to enter into a brief description of three of the plates which appear in this chapter, reproduced from my former work on brewing, and originally taken from 'Études sur la Bière.' I thought it wise in my chapter on laboratory matters to mention the connection that exists between biology and brewing, and I am hopeful that the present chapter will have convinced any reader that was before sceptical on this point of its absolute truthfulness. I have always insisted that one of the chief charms of Pasteur's original works on wine and beer centred in the beauty and artistic merit of the steel engravings, which in photograph form illustrated the statements and arguments of the writer, and practically enabled beginners not only to distinguish with ease the different forms of ferment life, but to go a step beyond this and work out by experiment based on the suggestions of Pasteur the actual life conditions of each ferment depicted.

Connection between biology and brewing.

Microscopical examination of yeast. Microscopic "powers."

In speaking of life conditions it is easy to see that the microscope should be an instrument capable, not only of exhibiting to us the varied forms of ferment life, but by demonstrating physical condition of interior tell us whether such ferment life be in vigorous condition or no. It is not only by internal appearance of cells or filaments that we attain this knowledge; relative size, rate of movement, and so forth are equally important indications; and thus, as I before mentioned, the microscope with great definition power is alone of service to the brewer.

PLATE I.

Principal Disease-Ferments met with in Wort & Beer.

INK-PHOTO, SPRAGUE & Co LONDON.

Plate I., as will be observed, is a microscopical field divided into seven sections duly numbered. No. 1 section indicates the ferments peculiar to *turned* beer—*i.e.*, a beer that has lost all its original characteristic sweetness and bitterness, and is practically on the high road to acidity. The section contains a few granulated alcoholic cells, while the others, or diseased ferments, are filaments, simple or articulated—*i.e.*, bent at an angle; and, if the microscope we are employing be a very good one, we shall see that each filament is composed of a number of shorter lengths, forming practical chains, having a diameter of only about 0·000393 of an inch. The shorter filaments spoken of are strictly immovable in their articulations, and the jointing, as a matter of fact, is scarcely visible. Plate No. 1 Section i.

No. 2 section exhibits the lactic ferments of wort and beer. These are small, slightly made, and narrow, or, as I may express it, *pinched* in the middle. They are generally detached, but sometimes occur in chains of two or three, while their diameter is greater than that of the filaments depicted in No. 1. Section ii.

No. 3 section shows putrid ferments, the kind that I was speaking of above in reference to dirty plant influence. It will be observed that they have no articulations, but are mostly vibrating filaments, the motion being more or less rapid, according to the temperature of the fluid in which they exist. For the most part their diameter is greater than that of the acid filaments and lactic ferments, and they only appear in cases of very defective working. Section iii.

No. 4 section corresponds to the ferments of viscous or ropy wort and beer, which the French term *filante*. They invariably form chaplets or chains of nearly spherical grains. Such ferments rarely appear in wort, and Section iv.

still less frequently in beer; and their growth undoubtedly hinges on a very abnormal and defective condition of nitrogenous matter.

Section v.

No. 5 section exhibits acetic acid ferments. These very rarely being seen, since, as I have explained, the acid normal to beer is lactic, and not acetic; and oxidation of alcohol to acetic acid, under the influence of an oxidising ferment, only takes place under very exceptional conditions, such as during prolonged storage in cask or vat. The ferments themselves appear in the shape of chaplets, and consist of the mycoderma aceti, which bears a close resemblance to lactic acid ferment, especially during the early stages of development; but in spite of this similarity their physiological functions are widely different.

Section vi.

No. 6 shows what is termed the amorphous deposit of a wort, which must in no sense be confounded with those of diseased ferments, since the latter are always visibly organised, whilst the amorphous deposit is of a more or less shapeless character, although it would not be easy at all times to decide between the two characters, unless several specimens of both descriptions existed side by side. This kind of deposit is found in wort during the cooling stage; but is not often present in beer, since it remains either in the hop back or on the coolers, or combines with the yeast, disappearing along with it. Among the shapeless granulations in No. 6 section, little balls of resinous or colouring matter may be discerned, these being usually only found in the deposit of an old beer.

Wort deposit.

Resinous matter.

No. VII.

Finally, No. 7 section depicts the ferments that are found in the case of very acid beers, that have an odour *sui generis*, the peculiar acidity reminding one of the pungent smell of unripe fruit. These ferments occur in the form of grains, resembling little spherical points placed two together, or forming triangles and squares. When appearing they are generally found in conjunction with the acid filaments shown in No. 1, but are far more to be feared than the latter, which, when alone, do not seem to cause any great deterioration.

When No. 7 appears alone, or in conjunction with No. 1, the beer invariably acquires a sour taste and smell that render it detestable, and the ferment in question is, without doubt, most fatal in its influence. There is, however, one point worthy of mention, and that is the close resemblance it presents to a minute and apparently organised form of ferment life that is frequently found in beers fermented with a yeast that has in some way or another been considerably weakened. I have specified them myself as "sugar ferments," since they almost invariably develope in beers in the production of which sugar is constantly employed, and generally indicate the necessity for a change of store; and my readers will see the immense importance of carefully distinguishing between a ferment that appears only as indicating the necessity of change of store, and one that corresponds invariably with disaster. I regard them as a defective sign, and they seem to constitute a class of cell life requiring further investigation.

No. VII. and No. I.

Sugar ferments.

Indications of weakened yeast.

It is clear, then, that Plate 1 enables us to determine with accuracy the meaning of each microscopical field we may prepare, and, as it includes examples of all the ordinary diseased beer ferments, it is pretty obvious that pitching yeast and finishing beer should be free from them, or, at any rate, practically free from them.

Plate 1.

Now, if we have an inferior wort, its nitrogenous constituent in degraded or diseased condition, it follows that, whether pitching yeast be apparently pure or no,

Influence of an inferior wort on the presence of diseased ferments.

diseased ferments will rapidly appear; while, on the other hand, if a wort be produced on acknowledged principles, likely to promote perfection, from the best materials, so that the condition of the peptonised albumen existing is entirely satisfactory, then, although the pitching yeast may contain actual evidences of disease, this will get less and less as reproduction of the original store takes place, on account of two distinct facts. To begin with—the wort is absolutely pure; its powers of nutrition facilitate the development of the large excess of alcoholic ferments introduced, and nothing is easier to understand than the gradual diminution in the percentage minority of diseased ferments struggling with abnormal conditions of growth side by side with the multitude of cell ferments in the presence of influences that determine rapid reproduction.

An impure yeast purified by growth in a sound wort.

This purification of a practically impure yeast is often carried out by brewers unknown to themselves, and is, perhaps, more noticeable in the case of breweries where a porter gyle is taken each week, for the simple reason that the caramelised material of the porter grist is strongly antiseptic, while good material generally favours the production of good yeast. It is amusing to hear brewers speak of their immunity from trouble, and to view their scepticism respecting the undoubted facts that I am enlarging upon. Their success has hinged upon the use of a brewing water that has played an active part in regulating character of wort obtained from undoubtedly good material, and I can quite believe their statement that no change of yeast is ever required. Once upset these conditions, introduce nitric acid into the well water, or allow but slight percolation of sewage; give them a supply of half-grown malt made from a weathered barley, and success will not longer be

Antiseptic nature of caramelised material.

Influence of good material and good water.

Causes of disaster.

PLATE II.

$\frac{400}{1}$

Appearance under the Microscope of the Deposit from "Turned" Beer.

INK-PHOTO, SPRAGUE & Co LONDON.

FERMENTATION SECTION

PLATE III.

$\frac{400}{1}$

Torulæ in Process of Developement

INK-PHOTO, SPRAGUE & C° LONDON.

apparent; and yet the conditions I name are common to a vast number of English breweries, and may yet become commoner still.

The third plate shows a field of yeast in process of development—not that we often see it so, unless we prepare a fluid specimen, and place it in what is termed an object box, since, if we examine wort itself at the commencement of fermentation, we are somewhat disappointed on account of the cells presenting a certain visionary appearance, and being mixed with a great deal of amorphous matter commonly in suspension at the stage named. Plate 3.

It will be observed that the right-hand section of plate exhibits yeast cells with nuclei fully developed in each case, the cells more or less conglomerated and enlarged to the extent of 400 diameters, but it does not present to us that peculiar primary formation of vacuole or aggregation of soluble plasma which is invariably seen as a first step in the development of the nuclei, and to my mind the best working yeast is one presenting great regularity of size of cell, a distinct vacuole in each with interior nuclei in all cases prominent; go but a step beyond this and we arrive at a disappearance of the vacuole, a conglomeration of nuclei, with no capacity of budding. Nuclei fully developed. Vacuole.

The plate shows an absolutely pure yeast, but this is rarely, if ever, seen in practical working, although this might happen if brewers filtered wort so as to remove the coagulated nitrogenous bodies, since, however opposed this statement may be to the advice given by a very old and worthy writer that cooler dregs should always be swept into fermenting vat, there is no question that such matter directly facilitates diseased ferment life, for what is more common knowledge than Pure yeast. Cooler dregs.

the ease and rapidity with which the first heads, cropped from a fast fermentation, putrefy?

Selection of yeast.

It is for this reason that I mentioned selection of yeast, and how such choice was next to impossible in the case of slow fermentations, when it is customary to collect the yeast crop in a single skimming.

First heads.

Middle crops.

The purity of different skimmings varies very considerably, the first heads containing much amorphous matter, as also, apparently in connection with this, diseased ferments. The middle crops are usually the purest, while towards the end of skimming the yeast darkens and again exhibits inferiority on account of smaller sedimentary yeast coming to the surface. As a general rule, I may say that if plant be kept clean, and good material be used, there is little to fear from false ferments unless the water be contaminated with putrescent matter or some saline body that directly determines disease.

The art of brewing.

Fine art in brewing, to my mind, is more exemplified when dealing with commonplace waters and inferior material, and still producing a saleable article, than when all conditions are favourable, and the beer of superior quality.

Deposits from racking samples.

The step that naturally follows all that I have said is summed up in the advice that, whether we adopt advanced forcing tray experiments or no, we should at any rate make ourselves perfectly familiar with the general character of the deposit that settles out of our racking samples and with the same deposit which is thrown down from a stock beer after it has passed through its first fret.

Forcing temperatures.

A step further is simply, as I have explained, the forcing on of a distinct fermentation under trying heat conditions, since the aspect of the deposit formed at the ordinary storage temperature of the brewer might be very different if thrown down at a temperature of 75° or 80°, and as it is impossible for the brewer to regulate storage temperature of his beer after it leaves the brewery, it is surely of some importance that he should ascertain what the result is likely to be when his beers brewed for stock are exposed to what I may term strictly common and yet actually forcing temperatures. Stock beers.

Finally, in reference to the subject of disease, what is more common in breweries, during the spring, summer, and autumn, than to find beers that have apparently been racked in perfect condition lapsing into what is termed by the brewer a persistent *sick fret*—a description of secondary fermentation that in many instances ends in something very much akin to ropiness. Sick fret.

If we are not able at the present time, with our limited range of knowledge, to describe offhand all the exact conditions of wort that render such changes possible, it is, at any rate, not going beyond the mark to describe them as being mainly due to the use of water without any particular determining character in conjunction with malt of evident inferior quality. This form of sickness is so common in many breweries, so frequently disastrous in results, that no amount of labour would seem badly spent if the exact cause of it all could be fully understood. Cause of sick fretting.

An investigation of the diseases to which Beer is subject, novel as the sentence may seem, is yet in its infancy, and I hope year by year that we shall find useful knowledge in this direction developing for the benefit of the brewing world. Diseases of beer.

Such, then, are some of the interesting theoretical and practical details of fermentation. I have tried to render the whole subject interesting in its theory and plain in its practice. It is, perhaps, difficult to accomplish all this when space is limited, and when the majority of readers care little for the theory of the subject matter; and, whatever the opinion of others may be, I have no shadow of doubt that the main success of all brewing operations depends upon the healthy cultivation of yeast. The conditions which facilitate this I have described in detail, and, indeed, I might be blamed by some of the more advanced readers for a certain amount of repetition, for continually harping upon the subject of peptonised albuminous matter; but as a supply of other forms of azotised principles would, so far as nutrition of yeast is in question, be entirely useless, it is, at any rate, wise for me, in the interest of beginners, to dwell on the subject that is of the most extreme importance.

Healthy cultivation of yeast.

Peptonised albuminous matter.

Mashing and fermentation.

If the chapters on mashing and fermentation are mastered together, I have no doubt of the result, although it must be borne in mind that great practical experience is necessary in order to carry out theoretical knowledge or suggestions successfully. There is one work that may be read with advantage by all those who wish for further knowledge on the subject of digested albuminous matter, and that is one by Dr. Roberts on "Digestive Ferments," published by Smith, Elder, and Co., a good deal of the experimental data being supplied by Mr. Horace Brown, who I have before referred to as a gentleman to whom brewers owe a debt of gratitude for his practical exemplification of the benefits that have accrued since Pasteur gave so much of his time and attention to the study of the subject of this chapter.

Dr. Roberts on digestive ferments.

CHAPTER XI.

RACKING, FINING, AND STORING OF BEER.

It is supposed by a great many brewers that after fermentation is finished and the beer run into racking-tank all anxiety is at an end, and that what happens afterwards is a mere question of chance; but if we go into the several subjects of this chapter we shall find that we are discussing questions of great moment, and that if we neglect the condition of the cask-plant in which our finished beer is placed, carelessly apply the artificial fining material that is now so common, or suppose that store-room arrangements and venting are matters of slight moment, final trouble will naturally follow, just as surely as if we had neglected some of the preliminary steps of our process.

Cask plant.

Storing and venting.

Racking itself is a very simple matter, and the chief points to observe seem to be the prevention of aëration and waste, although temperature at racking is of some special significance—for instance, if beer be racked at a high temperature it is not so free from suspended yeast as it would be when presenting the same appearance of brightness at the lower temperature, and as considerable aëration goes on, no matter how carefully we may carry out the racking process, it is not difficult to understand why in warm weather the high racking temperature facilitates a recommencement of fermenta-

Racking.

Influence of temperature on apparent degree of brightness.

tion, the air absorbed giving to each suspended cell a new lease of vigorous life.

On the other hand, while stated brightness means greater cleanliness at the low temperature, it is pretty evident that if this be fixed many degrees below that normal to the store there is a rapid rise immediately after racking, and this undoubtedly directly promotes fermentation unless the beer be very destitute of gas, since if the cask be shived off and gas be liberated by the rise of heat we have a state of turmoil inside corresponding to motion—another influence, as we have seen, inducing alcoholic change.

Rise of heat after racking.

On the face of it, therefore, it is wise to rack beer at the temperature of the main store, since it is no use racking higher, as in that case a drop in temperature results during preliminary storage, giving a cloud to the beer and a deposit in cask, which might just as well have taken place in tank ; and it is equally unwise to rack a beer at a very low temperature so that a rapid rise results ; rapidity of rise or fall in temperature in the case of finished beer invariably leading to fretfulness on the one hand, flatness and turbidity on the other.

Cloud in beer caused by a drop in temperature.

I may take a temperature of 55° to 59° as a range for winter and summer, most brewers, I presume, having storage sufficiently good to enable them to keep within such a range ; and, if so, the racking temperature for the warmer months should be about 58°, ranging downwards to 56° in the winter, although it is pretty evident that in the colder weather the brewer has little control over temperature of beer when exposed for any time in tanks on basement, unless the racking-room be much more closed in than is usual.

Range of temperature.

Exposure of beer.

It is perhaps the question of cask-plant that is worthy of the more notice than racking temperature in discussing this subject, since I have referred to wood as a veritable kind of sponge, the pores being full of matter more or less soluble, and either in a condition of inertness or capable of promoting all kinds of unsound action in beer that comes in contact with it, and I have explained why the common varieties of cask-plant timber are so faulty in this special respect, and why the rough-and-ready method of cask-washing generally carried out is so thoroughly out of unison with the necessities of the case.

Cask plant.

Pores of wood.

Cask-washing.

It is a point of popular knowledge that beer in bottle keeps much longer and better than beer in wood, this fact, of course, depending not only on account of a secondary fermentation having probably resulted in cask, with corresponding more perfect elimination of yeast-forming matter before "bottling," but especially because the glass bottle has a surface that can be cleaned, is not porous, and can be rendered air-tight.

Keeping property of bottled beers.

As glass is not porous, in the ordinary sense of the term, there is no seat or hiding-place, such as exists in wood, for decaying sedimentary matter, wort deposit, or sap; while if the beer in such bottle once gets into condition, and was sound when bottled, the absence of air and the pressure produced by the carbonic acid set free, combinedly oppose further change. Cannot we see, then, why the absolute cleanliness and fitness of cask-plant is so essential, and cannot we understand why those brewers who do the largest private trade business pay the greater attention to this special subject?

Glass non-porous.

Absence of air.

Necessity for cleanliness.

I should very much like to ask what is the condi-

Cask plant in a tied trade.

tion of cask-plant in the immense breweries doing a strictly public-house business, a trade that practically requires little stability on the part of the beer sold. I have no hesitation in saying that in the majority of instances the casks would be found thoroughly unfit for beer, and that if a few shavings of wood were taken from their inner surface, we should find the pores swarming with lactic and other ferments.

Cask shavings.

It is quite common to hear such brewers saying that they do not care for the untied private trade; they might say, with greater truth, that they are so accustomed to the rough-and-ready treatment of large quantities of beer that experiment on the same principle with small casks has never been successful. Naturally so: the beer that remains perfectly sound for a month at a fairly low temperature in one of these casks, exhibits great alteration when stored for two or three in the cellar of the private consumer; it contracts an unpleasant flavour, becomes flat and unsound.

Unpleasant flavours.

The pores of the cask contaminated.

The beer has penetrated thoroughly into the pores of the wood, and has become impregnated with soluble matters that it has found there. The carbonic acid escapes by the same porous gateway, and it is only natural that preliminary decomposition sets in. I myself have seen stacks of beer in breweries of this kind, no two casks of which would be in the same condition or present the same flavour, the strange variation in palate-character depending upon wide differences in surface flavour of timber of the individual casks, the condition most likely influenced by the unequal aëration communicated at the time of racking, some casks frothing very considerably, others not at all.

Variation in palate character.

Altogether, too much attention cannot be given to selection of timber for cask-plant, and the proper

Timber for cask plant.

cleansing of each vessel before it has passed into the racking-room; and I think that I described the *modus operandi* pretty fully when discussing the subject of brewery plant. Dry, cold, and sweet, no surface acidity apparent, free from all traces of surface mould; casks may be left in dry weather even two or three days, or longer, before being filled; but if weather be damp and temperature high, it is very common to find mould appearing in an apparently clean cask in twenty-four hours after it has passed from washing-shed. Mould.

The post of cask cooper—that is, the man deputed to select casks for racking—is, I should say, a most important one; but how often do we see a man without the slightest knowledge of his business passing casks forward to the racker after he has placed his finger in the bung-hole to ascertain their temperature, and his eye to the cork-hole to observe what he can of the inner surface! Cask cooper.

Brewers must judge for themselves whether such proceeding is all that is necessary; I hold myself that it is not, and that if a successful private trade is to be done the greatest care must be taken in selecting small casks for use. Selection of casks for racking.

It is usual to dry-hop the casks before filling, this preventing much frothing that would otherwise occur, although it necessitates a second topping over of beer, the dry hops absorbing a great deal of moisture. A certain amount of care is necessary in selecting hops for this purpose; they should be large, well matured, free from leaf, rich in *condition*, and of undoubted soundness, the twigs exhibiting the absence of mould, even when they are steeped in water, and the water examined microscopically. Dry-hopping. Selection of hops.

Some brewers object to the use of hops, saying that Objection to dry-hopping.

if beer becomes brisk, annoyance is experienced by the publican on account of minute fragments of flower or leaf floating about in the otherwise decently bright beer; but my own impression is, that if we investigate the exact composition of the so-called particles of hops, we shall find that instead of being so, the particles consist of conglomerated yeast cells. If brewers do experience such difficulty, it is quite easy to use a small quantity of lupulin for the purpose of hopping down, which they can procure for themselves by gently rubbing down the flower of hops upon a fine sieve.

Floating particles in beer.

Some little care is necessary in order to prevent cloudiness of beer through the over-use of new hops in cask, such variety yielding a very oleaginous extract for which no proper solvent exists in beer until ethereal products result from slow fermentation in cask.

New hops in cask.

I dare say most of my readers have noticed the peculiar grey shade that hangs upon heavily hopped pale beers during preliminary stages of storage, this seeming to be due to a larger quantity of oil existing than can be held in perfect solution by the small proportion of solid extract existing after fermentation; and this fact shows us that in spite of the strongly-marked antiseptic and protective agency of lupulin, or the *condition* of the hop-flower, in spite of the aid of hop-tannin, at the time of artificial fining it is undoubtedly a great mistake to over-hop running beers that are expected to be perfectly brilliant soon after being placed in the cellar of the publican; while it is just as necessary to heavily hop down stock and export beers that have to keep for prolonged periods of time.

Grey shade to beer.

Over-hopping running beers

The quantity of hops usually employed for dry-hopping amounts to some ¼lb. per barrel for beers of 20

Quantities employed.

to 22 grav., ½lb. from 22 to 26, ¾lb. to 1lb. for heavy beers ranking upwards from 27.

Fining.

In coming to the question of fining, we are face to face with a matter requiring thorough investigation, for the use of an artificial fining material has simply revolutionised brewing operations; for whereas some few years ago public taste was in favour of aged beer, and as very lengthy storage of the unfined beer in bulk was necessary to ensure brightness, a vast amount of capital was consequently locked up during such period, while, at the present time, I should say two-thirds of the beer produced in England is consumed within a month of its production, forced into a condition of brightness by artificial means.

Influence of finings on the trade generally.

Isinglass.

So far as I remember, the introduction of isinglass as a fining material was the primary cause of the complete change in *modus operandi* spoken of, for all previous artificial methods, such as the use of silver sand, alum, and so forth, were singularly ineffectual by comparison, and the beer so clarified was not calculated to impress people by its degree of brilliancy and early palate character; for I know of nothing that interferes so much with the delicate flavour of beer, especially of that of only moderate gravity, as the semi-cloudiness which means a very intimate kind of connection existing between the amorphous matter and yeast in suspension in the weak alcoholic fluid.

Other fining materials.

Semi-cloudiness.

Now, before describing the preparation of finings, or the several ways in which such material is employed, let us clearly understand what is meant by the term turbidity, and why the action of sand and alum was so faulty as compared with the influence of coagulated gelatine. Turbidity, or persistent cloudiness, means what is termed an equilibrium of

Turbidity.

Affinity.

affinity—that is, matter causing opaqueness is held in suspension under the influence of the affinity of a fluid which, in the case of beer, has a varying acidity ; in other words, the affinity existing is not strong enough to take such matter into solution, but is still potent enough in energy to keep it suspended.

Increase in affinity.

As before explained, affinity can be increased in various ways, such as by elevation of temperature, alteration in acidity percentage, and increase in such directions would promote clarification, while diminution of affinity by contrary steps would likewise facilitate brightening, although it is evident, while the drop in temperature lessened affinity and liberated a certain quantity of yeast, the practical chill would throw a fresh portion of matter out of complete into semi-solution, this being a point we shall have to discuss later on.

Drop in temperature.

Normal acidity of beer.

Such methods as these are, of course, not practical in the brewery ; the acidity of beer has to be normal, not exceeding 0·1 to 0·15 per cent., and beer has to be fined at the temperature of the publican's cellar, so alteration in affinity failed utterly as a method of promoting ready brilliancy, and it was only after the introduction of gelatine as a combined chemical and mechanical fining agent that brilliancy was attainable, and a mild beer produced fit for consumption almost directly after fermentation was complete.

Gelatine a combination of chemical and mechanical action.

Now in what sense is gelatine a combined example of chemical and mechanical action? I have mentioned tannin as one of the constituents of hops and beer, and it is the presence of tannic acid in beer when fined that enables us to describe the fining action now induced as partly chemical in nature, since the gelatine becomes partially converted into tannate in the form of a flocculent mass, while this rises mechanically through the beer as a result of its specific lightness, aided in no small measure by the buoyancy of air and escaping carbonic acid. The perfection of action when gelatine is used depends not only upon care and judgment in the special selection of isinglass, but also a great deal upon the preparation of the fining material in the preliminary softening or gelatinisation and the after disintegration and aëration accomplished by sieving.

The influence of tannin.

The preparation of finings.

The sources of gelatine are numerous, but I am afraid there is some little misunderstanding connected with the use of the term gelatine as applied to that special form of it which brewers obtain from isinglass, since gelatine, strictly speaking, is obtained principally from bones, skin, horny matter, and cartilages; or, more correctly, it results when these substances are boiled in water. Now, this form of gelatine is not capable of acting as a fining material, and the true gelatine upon which brewers depend constitutes the larger percentage of isinglass, which is chiefly prepared, as we know, from the swimming-bladder of the codfish.

The source of supply.

Other gelatines.

Bladder of the codfish.

We have, however, many varieties of fish-isinglass offered to us—ordinary cod-sound, Penang pipe, leaf, strips, Astrakan, Russian, and so forth, referring to the bladder isinglass of different species of fish common to those special localities. That variety which seems to be most suited to the requirements of the brewer is undoubtedly Penang leaf, but very great care is necessary in determining the presence of what is called *body* and the absence of what constitutes waste and costliness—viz., skin.

Varieties of fish isinglass.

Generally speaking, it suffices to hold the leaf to the

Testing its quality.

light, its transparency showing its purity, while each opened-out bladder should be thick, and white in colour; and while I am aware that the more particular brewers will give as much as 8s. or 9s. per lb. for good specimens of this kind, I think that 4s. 6d. to 5s. 6d. would be about what is usual, although I am bound to say that I do not agree with seeming economy in this direction, as I am sure that a great deal depends upon the absolute goodness of the glass itself.

Prices.

It will invariably be found that in dealing with the commoner varieties there is not only a great deal of waste, but when the finings are made and introduced into beer the cloud is not so much gelatinous as stringy in appearance—in other words, the gelatine of such varieties does not appear to become easily reduced to an absolute jelly, and unless this is so the stringy appearance invariably presents itself.

Common varieties.

Stringy in appearance.

It was very soon found that softening of gelatine had to be accomplished by other means than heat if the softened product was to be employed for fining purposes. In short, if gelatine be dissolved or softened in either *hot* water or beer the finings so made refuse to *cut*, so a variety of dilute acids have come into use which do not vary very much so far as the details of their employment are in question; the acids I refer to may be classed thus :—Lactic (old beer), sulphurous, tartaric, and commercial acetic—*i.e.*, as distinct from the acetic acid of absolutely *sour* beer.

Softening the glass necessary.

Acids employed.

The use of old beer for the purpose of softening isinglass has not only been of great service to brewers in the way of enabling them to work off returns, but has let us into a secret respecting the speed of softening that is most valuable. Of course, it is necessary for brewers to clearly understand that in using old beer

Old beer.

for such purpose they eventually introduce, when fining their mild beers, a perfect host of acid ferments, besides the gelatinous matter, which, of course, has more or less a tendency to decompose. If it were not for this I might say that old beer finings would be very far superior to those manufactured by the aid of stronger acids, for the simple reason that the old beer, with its 0·5 or 0·6 per cent. of lactic acid, is very slow indeed in effecting complete gelatinisation of the glass.

Objections to its employment.

The point connected with the use of old beer is indeed a very important one, since it is no exaggeration to say that the great majority of beers are now artificially fined, and that after being fined they are still in many cases expected to keep for two or three months, so that the introduction of a pint per barrel of what, practically speaking, must be regarded as semi-putrefying matter is simply tempting a result that may always be anticipated if the beer so treated comes to be stored, the brewer perpetuating, in fact, the very evils that have left him in the first instance with a quantity of returned beer that he is anxious to get rid of.

Introduction of diseased matter.

At the present time tartaric and sulphurous acids are chiefly employed, the former in the state of crystals, the latter in the form of a solution of a specific gravity of 1030 to 1040, the contention being that if higher gravities of acid be supplied, the excess, over and above that corresponding to the gravity stated, rapidly escapes.

Tartaric and sulphurous acids.

The general method of procedure is as follows: the glass is taken sometimes in whole leaves, sometimes more or less cut up. It is well to remark here that if the sample be in any sense inferior or dirty it should be carefully soaked, cut open, and cleaned before being

Details of procedure.

placed in steep-tubs, where it is covered with water and a definite quantity of the selected acid added, this quantity varying very considerably, some brewers wishing to prepare the finings very rapidly, others fancying that *slow* action is preferable. In order that I may give some idea of what is usual I may remark that something like 30 lbs. pure tartaric acid crystals dissolved in water would be necessary in softening 112 lbs. of glass, while from 16 to 18 gallons of the sulphurous acid at gravity stated would be required for the same purpose.

Quantities of acid used.

Sulphurous acid volatile.

In using the latter acid it is advisable to keep the tubs tightly covered down, the acid being very volatile. As the gelatine swells up more water is added, the softening mass being occasionally stirred, and this continues till each lump of glass is so gelatinised that it squeezes easily like jelly between the fingers. The next operation is practically one of disintegration and aëration combined, and is attained by rubbing the gelatinous material through a fine hair sieve by means of a soft dust brush or, what is more customary perhaps at the present day, through a series of finely-perforated copper sheets, on the principle of brush action, patented by several firms. It has always been my opinion that aëration has no small influence, and this opinion is more than confirmed in a letter of Dr. Moritz, in which he describes the action of flour-dressing as being largely due to the influence of air held in the interstices of the added flour, not only in its natural state, but much more so when whisked up (as it always is) prior to its addition to the fermenting wort. I am very glad that I have such an opinion to add to my own, since I have over and over again contended it is not merely the addition of gelatinised matter, coagulated as it is in

Rubbing through copper sheets and sieves.

Aëration by sieving.

Aëration by flour dressing.

semi-degree by tannin, that leads to rapid brightening of beer, but also to the air added with the fining material, and the carbonic acid that is naturally liberated from the beer by such addition.

If any proof is needed, what is more striking than the difference in result when fining a cask of beer with stick-stirring intermixture of finings, and when merely introducing the same quantity of finings, followed by a roll over of the cask? Now, why should there be this difference? Is it not perfectly evident that in vigorously stirring with a stick we not only obtain more perfect intermixture of the fining material, but introduce far more air and liberate far more carbonic acid than takes place in the other method? But all this, perhaps, is anticipating what should follow, and I only bring it forward to exhibit the necessity for the complete aëration of the disintegrated gelatine and the use of finings when such aëration is at its height, or, in other words, when they are fresh.

Fining by stick-stirring introduces air and liberates carbonic acid.

The essential points are absolute gelatinisation without solution, and complete aëration, since I care nothing for thickness, so long as these two conditions exist.

Gelatinisation and aëration.

The truth is that a great many brewers not only employ poor qualities of isinglass, so arriving at mere stringiness in place of gelatinous character, but often commence the rubbing-through process long before the glass employed is effectually *cut*. In truth, the manufacture of finings is no simple matter, and the only reason of bought finings being in many instances superior to those of home make, in spite of their being practically destitute of air, is simply due to superior softening of the original material. It is very amusing to hear people talk of solution as opposed to softening;

Bought finings.

Gelatine not taken into solution.

people, too, who ought to know how to deal with a saccharometer, and that its indications depend merely on matter dissolved. The demonstration of the fact that no solution of gelatine results is remarkably easy. What is simpler than to make a 50 per cent. mixture of finings and water, and then introduce a saccharometer? In all cases it will indicate no solution as represented by no gravity, while a complete difference will be noted if we test some fining material that has been prepared with boiling water.

The fining-room.

My readers will thus see that the fining-room of a brewery should be a definite department; that a good stock of glass in different stages of softening should always be kept on hand, and that finings for use should be rubbed through sieves daily; any quantity left being again returned to steep-tub. If sulphurous acid be employed, we gain a certain advantage from its antiseptic character, which is missing when tartaric acid is substituted, this organic acid seeming to facilitate the development of mould, so that it is usual to add sufficient calcic bisulphite to the steep-tubs when using the acid named, to prevent such growth.

Prepared daily.

Sulphurous acid antiseptic.

It is curious to think of this if we refer back to the influence of acid tartrate of potash in preventing development of fungoid growths in grape-must; but it will be readily understood that an acid may facilitate such growth, while a salt of the acid may determine the development of some different variety of ferment.

Prevention of mould growth.

Salicylic acid.

Salicylic acid has been suggested as a substitute for calcic bisulphite for the purpose specified, but my experience is that it has too astringent an influence on the fining material, and while it undoubtedly prevents moulding, it practically hardens the glass that we are attempting to soften.

If the definition of finings be understood, the method of using them naturally follows, and from what I have said respecting turbidity, it will be perfectly clear that certain conditions of effectual clarification must exist before flocculent gelatinous matter will promote it. Nothing is more common than to find beers that will not *cut* with finings, or, perhaps, the fining material undergoes its semi-coagulation, and seems to separate, but no distinct brightening takes place, and the reason of this is summed up in the expression that fermentation has failed in leading to that nice balance that must exist between the affinity of the fluid and the floating solids before a mere filter will remove them.

Semi-coagulation.

Affinity and floating solids.

A coagulated cloud of gelatinous matter is, to my mind, a most beautiful example of the addition of an absolute filter to beer, as opposed to the plan of filtering beer through a filter paper, much the same application, ingeniously carried out, being exemplified in the fining principle of M. Maignen, who practically introduces disintegrated cellulose into the fluid to be filtered, which is then passed through a canvas bag, the cellulose settling down as the filtering film on canvas.

Coagulated cloud of gelatinous matter.

Disintegrated cellulose.

The brewer, it will be observed, employs disintegrated gelatine, and he converts this into a filtering cloud practically by the tannin of his beer, the imperfection of the process being that the agent of filtration is left in the beer itself, while in the process of M. Maignen the filtering agent is removed while effecting clarification.

Influence of tannin.

The fact that our fining process is merely a system of filtration enables the brewer to carry out a very useful little experiment in deciding when beer will fine properly, since if it will comport itself well with finings it will do so equally when filtered through blotting-paper ;

Filtration through blotting paper.

and this invariably results unless the affinity of the beer is so nicely balanced that the addition of acid finings retards or prevents perfect mechanical filtration in the sense that the acid of the fining material added, which in the case of small experiments is always enormously in excess of the practical quantities used, so increases the affinity of the fluid for suspended matter that the mere mechanical action of the cloud of gelatinous matter rising to the surface is unable to separate it.

Small experiments.

I dare say many brewers have noticed that certain beers cut and fine very well in cask, while very inefficient clarification takes place when fining of a small bulk is attempted in open sample glass; and I am bound to state that this undoubtedly hinges upon the immense excess of finings used in the small experiment, although imperfect clarification under such circumstances seems to point to very defective working; in other words, the slightest alteration in acidity of fluid preventing clarification, shows that the beer contains a large quantity of suspended matter easily held in semi-solution by a very limited quantity of acid.

Bulk conditions.

Excess of finings.

Acidity of beer.

Now let us take as a starting point the case of beers that fine best, and then continue with those that exhibit the next degree of qualification for submitting readily to the fining action, and finally consider those that fine the least readily of all. They seem to stand in order of merit thus—soft-water slow fermented beers, sugar beers, and lastly, saline-water productions. Now, why should there be such difference?

Fining tendency of different varieties of beer.

In the case of the slow fermented beers time has been given for the yeast by slow reproduction to remove every particle of matter that is capable of

Slow fermented beers.

removal by such a means, including the amorphous matter that all wort contains, and the presence of which in the finished beer so impedes both spontaneous and artificial clarification; not only so, but the slow fermentation gives, as I have before explained, a finished beer more or less saturated with carbonic acid, which has such an immense influence in aiding the actual rise of the coagulated gelatine, and I do not hesitate to say that proof of all this is exhibited in the ease with which such beers fine absolutely brilliant.

Excess of carbonic acid.

Secondly, in the case of the sugar beers, we accomplish by the introduction of the sugar much that we set the yeast to do in the first instance, while we reduce in many cases the acidity of the finished article quite 0·03 or often 0·05 per cent. below what is normal to an entire malt fluid of average strength, and when we think that this amounts to one-third of the total acidity, and its influence in reference to affinity is extreme, it will be seen that I am not making too much of the special point. I asserted, as will be remembered, when discussing fermentation, that a great deal of the influence that the use of sugar exercises in promoting the easy spontaneous clarification of beer might justly be ascribed to its practically diminishing the normal acidity, which is often far too high when using inferior malt, and the second instance I give of its influence will consequently appear more striking.

Sugar beers; low acidity.

Besides this, the fermentations of beer produced on the lines of partial sugar use are generally moderately slow, in fact I often term them medium, as distinct from slow or fast, and the beer consequently contains more dissolved carbonic acid than in those quickly fermented at comparatively high temperatures.

Moderately slow fermentations.

Carbonic acid.

It may be remarked that as carbonic acid exhibits an acid reaction, its presence should add to the affinity of the fluid, but as a matter of fact there is but very slight difference in the acidity percentage of a beer partly saturated with this gas, and one that is almost destitute of it, so this argument has no substantial basis.

Hard-water beers; very poor fining capacity.

Now I come to the case of saline-water beers, which exhibit, at any rate comparatively speaking, a very poor artificial fining tendency, and it is undoubtedly necessary that we should all clearly understand why this is. When speaking of saline matter and its influence in reference to nitrogen compounds, I might with truth have said that hard waters did not sensibly decrease the quantity of azotised compounds extracted from malt, this knowledge having been recently put before us by several writers who have investigated the whole subject.

Nitrogenous matter.

I may take it, then, that a hard-water beer contains in its dry extract as much nitrogenous matter and suspended amorphous matter as one produced with a soft water, although the amorphous matter might probably be more in amount in this latter on account of the known disintegrating influence of a soft water on hop extract during boiling.

Elimination of amorphous matter.

Yeast outcrop.

However, I may ask what extent of elimination of such matter is accomplished during the very rapid attenuative change which is generally enforced in breweries where hard water is employed. To my view there is very little; the amount of yeast outcrop is small, and a very considerable proportion of what is left, partially, though not completely eliminated from solution, and, as a natural consequence, the beer, flat by comparison with the one first described, does not comport itself very well with finings.

As is usual, let me bring forward a proof of this statement. The saline water beer which refuses to cut at time of racking does so with perfect ease after it has been casked for a short period and passed through a secondary fermentation, either incipient or complete. Why? This second fermentation has, in reality, completed the elimination which should have been achieved in the first, such elimination being accomplished in the slow changes first described, and besides this the beer becomes gradually more and more saturated with the carbonic acid resulting from the slow fermentation under pressure. I believe that this explains the exact difference between the three kinds of beer, while in the case of beers that refuse to take finings at all it is evident that the brewer has utterly failed in his fermentation to accomplish that reorganisation of constituents that it is one of the main offices of yeast to achieve.

Secondary fermentation.

I can now the more readily describe the combined chemical and mechanical connection of finings. Introduced into beer and vigorously intermixed, the fining material is immediately acted upon by the tannin of the hop extract, which, fortunately for brewers, exists in exactly proper proportion—a proportion, however, that varies with the quantity of hops in use, light beers pretty heavily hopped clarifying better than those of a similar gravity lightly hopped.

The chemical and mechanical connection of finings.

The extent of coagulation produced is practically very slight, for while an excess of tannin would convert the gelatinous material into lumpy matter, the small quantity present simply leads to the formation of a flocculent cloud, the interstices of which are filled with

Extent of coagulation.

Specific gravity of fining cloud.

air and carbonic acid, so that the gravity of the cloud is considerably less than that of the fluid in which it floats ; it consequently tends to rise, although in the case of small experiments, with an excess of gelatine, the rise is somewhat impeded by the attraction of the surface of the vessel and the practical blocking of the rising coagulum in cylinder.

Cause of finings rising or sinking.

It has often been a question whether finings rise or sink, some asserting one thing, some another ; but as a matter of fact, the whole case is one of mere gravity, and if our original isinglass has been sufficiently disintegrated, if it has not been over-coagulated by the tannin, and if during its separation as a cloud it does not collect too great a quantity of comparatively heavy floating impurities, then it will undoubtedly rise, while if insufficiently gelatinised and over tanned on account of minuteness of quantity added to beer, then in collecting floating yeast or amorphous matter it soon becomes sufficiently heavy to sink, and it is clear that surface attraction, far more than absolute filtration, is the actual fining agency in such a case.

Surface attraction.

Action of finings.

When finings are added to beer in glass, it is, indeed, instructive to notice the variety of change which results —*i.e.*, if the formation of flocculent appearance is immediate, and rapid separation takes place, then we may know, of a certainty, that one of the main results of fermentation has been obtained ; while if, on the other hand, the fining material breaks up into numberless little particles that gradually subside, showing their comparative weightiness without producing clarification, we may know that matters generally are out of gear— the finings are either imperfect, or the beer itself is not healthy, which means, on the one hand, that

An index of condition of beer.

fermentation is in progress, or altogether incomplete and unsatisfactory.

Necessity for spontaneous clarification.

The mere fact that such beer clarifies decently afterwards should be no sufficient satisfaction to the brewer, for, as fermentation is carried out with a distinct idea, we should alone rest content with the full and complete attainment of it, the more especially as the enforced carrying down of yeasty matter to the bottom of a cask by artificial means leaves the beer in such a state that it is sure to undergo deterioration, sooner or later, if warmth or motion, or both combined, bring the deposit again into active fermentative condition. I make these remarks since a custom of fining beer in racking tanks has become more or less prevalent, the brewers adopting it being apparently unable to attain by fermentation alone the exact degree of brightness necessary for a racking beer, and while I admit the advisability of forcing beer artificially when we cannot attain brightness naturally, I still hold to the opinion that the racking tank is not the place for finings, and that endless steps should be taken in the direction of obtaining what I take to be the invariable sign of success in fermentation, namely, the spontaneous and decided clearing of the finished beer.

Forcing brightness.

London public-house beer.

It may be asked, If the tank is unsuitable for fining operations, where should it be accomplished? Now, I have spoken, among other matters, of London beers that are fined by the publican, and, in many large towns, more especially in the North of England, it is quite customary for the brewer to supply finings to the publican, which he applies as he thinks proper.

The London manipulation is, however, unique in its way, the finings practically being thrown out of the bung-hole on account of the beer itself being supplied to the houses in very fresh, and what I may term yeasty, condition ; while, in the other towns mentioned, the beer is supplied very clean, and the finings go directly to the bottom, the cask being bunged tightly up. This brings me naturally to a process that has been much discussed—viz., the *working-out* plan, which is common enough in the colonies, but only occasionally resorted to by English brewers, since very few are adepts at all the little intricacies of the process that are so necessary to ensure success.

Ejection of finings.

The working-out process.

The plan I refer to may be applied, not only to beers that exhibit, for one reason or another, a disinclination to clarify spontaneously, but also to those that are required for shipment before brightness can be expected, but whatever the circumstances may be, it is absolutely essential that they should be healthy, which means that no fermentation should be going on, that the attenuation accomplished should have eliminated, or, what is more correct wording, should have ended in the elimination of the matters previously mentioned, and that in every case the sample should exhibit a ready tendency to *upward* separation of gelatinous cloud.

Conditions of working out.

Importance of temperature.

The question of temperature is of extreme importance, for I have never known a beer to throw out finings well under a temperature of 60°, while the slightest drop is fatal, for this not only tends to contract floating particles and finings, so rendering them heavier, but throws out of solution matter that was previously dissolved.

Chilling.

This influence of chilling is not only of importance in reference to this special subject, but is of similar influence in many annoying instances that brewers experience during the winter months, for although beer will fine at pretty nearly any temperature between 35° and 65°, it is necessary that no drop of temperature should take place either during or after the fining action.

Thus, when the brewer introduces finings into a cask of beer that happens to exist at a temperature of 55°, and the cask is forthwith transported into the cellar of some customer naturally standing at 50° or below, it is not to be expected that the fining will result in brightness, but I will defer till I come to the question of storage some few further remarks that may be made on this point.

Example of its influence.

The care requisite, then, in adopting the *working out* of beer centres in steadiness of temperature, healthiness of beer, good quality of finings, and perfect intermixture, and to attain all this in the colder months of the year it is obvious that the beer in cask must be kept off the ground in a racking-room or cellar where it will not be exposed to variations of heat.

Specified conditions.

Practically speaking, the beer should be racked direct from fermenting vessels at a stage that should correspond to that of settling, and should be placed on shallow stillions in rows, being immediately fined with very vigorous stick-stirring at the temperature of 60° or 61°. The bungs are left out, and in the course of an hour, if the rows of casks be carefully topped over, the finings, with the collected yeasty impurities, will be seen coming in bunches to the surface, and if the action be perfect they will be thrown through the bung-hole like so much yeast.

Working-out temperature.

At this stage careful topping over with bright beer and removal of lumpy matter by the finger inserted through the bung-hole, directly aids rapid elimination, which continues pretty steadily for some six hours, while the clean beer is allowed to remain for another four or five hours to give time for all precipitated

Ejection of finings.

matter to conglomerate together, so that it may be the more readily removed during the next stage of the process.

Valinching of bottoms.

This may be described as "valinching"; that is, the removal of sedimentary matter by means of a suction tube, just as a chemist picks up a deposited precipitate by means of a pipette. It is remarkable how well a skilful workman can remove bottom deposit by such means, and in all cases it is advisable that the last two or three draws should be obtained by a glass valinch in order that he may know that he has accomplished his purpose.

Glass valinch.

Variable success.

I may say at once that I have known this process put in operation and lead to a large increase in output as a proof of its efficiency as a means of attaining a certain end, and, on the other hand, I have known people adopt it and give it up again, for the simple reason that it did not appear the success they anticipated, and this is by no means difficult to understand.

I do not for a moment suppose that "working-out" can convert a bad beer into a good one, or prevent the frets in cask that are certain to result if the condition of the yeast-forming matter of the beer is in any of those peculiar, changeable states to which I have referred; but I am convinced that as a process it stands out as being eminently serviceable when from some untoward cause the spontaneous clarification of beer seems to hang fire just before brightness should result, and it is perfectly easy for any one to come to their own conclusions on the matter if they will put it in operation with the due attention to detail that I have insisted upon as being necessary.

Its serviceable nature.

Period of fining.

The use of finings in beer supplied to private customers opens up naturally a consideration of the time at which such fining material should be introduced, and up to very recent periods it was quite customary for brewers to fine down beer in casks at time of racking, shiving up, and stowing away in the ordinary manner.

If we think for a moment we shall see at once that such manipulation is very faulty, for we lock up in our beer gelatinous material of a putrescent character, and as the fining action depends upon the formation of a flocculent cloud of semi-coagulated gelatine, such action failing to result a second time, we should of necessity be depending upon conglomeration of particles and surface attraction influences for any secondary brightening of the beer after the cask so fined and stowed away was removed to some fresh position. **Fining prior to storage, faulty.**

This can be proved by experimenting with an open cylinder, and we shall then see, if we allow the fined sample to stand a few days, how the first formed light flocculent coagulum which has risen to the surface with its collected impurities gradually aggregates on account of the gaseous constituent escaping, while if we detach it from the sides of the cylinder we shall see it gradually sinking through the fluid to the bottom. **Cylinder experiment.**

If we shake up the cylinder with its contents this lump of fining material and collected impurities will be disintegrated and mixed with the limpid fluid, only acting when the cylinder is left stationary again in much the same way that silver sand would act, each minute particle now heavier than the fluid unsupported by any air or gas, sinking to the bottom again, leaving the beer fairly fine, perhaps, but short of the old brilliancy which only results again after several days' standing. Now this is exactly the case of the cask which is fined down at racking and stowed away perhaps for weeks before being shipped to the consumer.

Fining at time of shipment.

By far the best plan, therefore, is to add the fining material at the time of shipment, and this may be readily done if beer be carefully looked after during storage, while there is no difficulty in introducing finings under pressure, if we are dealing with hard water beers that have to get into condition before readily taking finings.

Quantity of Finings.

The quantity of fining matter actually used amounts, if the material be thick, to one pint per 36 gallons, while if fluid the quantity would have to be at least double.

Stick stirring.

There is a great deal of knack even in fining with stick stirring, but I believe this mainly depends upon the different degree of intermixture accomplished by varying twists with the mixing-stick, and a plan often followed by publicans who desire to fine very rapidly is that of drawing out of the cask to be fined some three gallons of beer into an open tub, the finings being then thoroughly whisked up with this quantity and the whole put back again into the cask, which is then either rolled over or well stirred up. From this it is clear that the case is one, as I said above, of complete distribution of the gelatine throughout the entire bulk of the beer to be fined.

Distribution of gelatine.

Action of finings during fermentation or a fret.

It is, of course, useless attempting to fine a beer artificially if fermentation is going on, since under such circumstances practical convection is in progress, altogether interfering with the rise or fall of coagulated fining matter, while as each particle of sugar splits up a definite and corresponding quantity of developing yeast appears, again producing cloudiness or turbidity, and it is merely folly to add finings to beer that is either likely to undergo an immediate fret or is actually in fretting condition at the time, and yet this is constantly done.

Care of stock.

What is easier than for the cellarman to keep a watch upon brewings of different qualities in order of rotation, occasionally fining a sample of each stack or gyle, to determine its capacity in this direction? If this were done we should steer clear of a great many complaints that are rife at seasons of the year when frets are more or less common.

Storage conditions.

I now come to storage conditions, and may lay down at once a very simple axiom. Beer, being a vegetable fluid of no very great stability, improves by undergoing slow incipient fermentation changes under pressure in cask, so long as the temperature of change is perfectly steady and of an intensity that will not force on violent action. For instance, we know from Continental experience, as well as from Pasteur's assertion, that under 50° unhealthy change is impossible, but such a temperature of storage is, of course, unsuited to English beers. On the other hand, the character of the dry extract of most English beers is so wanting in stability that we do not care to practically test them at any heat over 60°, so that as far as such beer is concerned we may say that if well brewed the secondary fermentation under pressure at a temperature of about 57° or 58° will lead to definite improvement in flavour, a higher alcoholic percentage, and an increased deposit.

The temperature of 50° preservative.

Influence of higher temperatures.

Variation in temperature.

Now, variation in temperature upsets these good results, since rises lead in the one direction to continued frets, while chills occasioned by lowering of temperature frequently lead to unpleasant dimness, and what invariably follows from the suspension of traces of yeast —a most determined mawkishness.

It is pretty evident from this that it is useless calling any room on the ground-floor with windows all round, frequently with half the panes out, subject as such a room is to all the fluctuations in atmospheric temperature, a suitable beer store.

Faulty store-room.

Underground cellars.

To be of any real good, a cellar for the storage of stock beer should undoubtedly be underground, and so cut off from the atmosphere that a steady temperature of about 57° is attainable. The only defect of such arrangement is that it necessitates the use of gas, while it is next to impossible to connect it to the ordinary drainage system, and in many cases a basement cellar of this kind is apt to be unpleasantly flooded.

Flooring.

It is a most difficult matter to arrange the flooring for a store in which beer is stacked, for either the floor or the casks suffer when stacks are pulled down or on being driven by coopers while up-ended.

There are only two floors that I have the least faith in. If the ordinary basement strata is pretty firm in character, I imagine there is no better plan than to cover it to the depth of an inch or two with the wood shavings that are made when turning up shives and pegs, such material having great disinfecting character, and being, of course, very cheap, it can be replaced as often as is thought necessary. Again, if we prefer a hard floor at a certain pitch, then a mixture of granite and cement laid upon concrete is certainly the best, and entirely superior to brick, flag, cement, or asphalte, which one and all suffer from the constant friction of rolling casks and the chipping action resulting when casks are roughly up-ended.

Wood shavings.

Hard bottom.

Treatment of beer in store.

In coming to the actual treatment of beer in store we have to consider for what purposes it is intended: if for stock it is naturally lowered into the basement, while if mild and for public-house use it remains either in racking-room or in store on ground level, since as the cellars of the publican are not, as a rule, of the best, with temperature restricted by their natural position, it is useless paying particular attention to such beers if at the end of a few hours they are to be moved away to the consumer. It has always seemed to me a point of extreme importance that such beers as are brewed expressly for public-house use should, during the colder months of the year, be kept at a moderately low temperature on the premises of the brewer, so as to escape those constant chills which frequently result in the cellars of the smaller publicans, which are mostly exposed to atmospheric influences. During the warmer months of the year we have to keep such beers as cool as possible so as to ward off a secondary fermentation, which is common to all beers alike, and which comes on sooner or later according to their exact quality, degree of fermentative capacity at the time of racking, and the variation of heat that may take place directly after racking.

Public-house beer.

Treatment in store.

All beer, as I have said, contains carbonic acid, and in the case of such qualities as necessarily have to undergo fining it is important to prevent the collection of free carbonic acid in cask prior to the fining being carried out. For instance, if we happen to rack beer on a warm day, and the temperature of the racking-room facilitates rise of heat, a certain amount of carbonic acid is set free from the beer in cask, and if the bung or shive be out it readily passes off, while if the cask be tightly bunged or shived, the gas set free by the rise of heat accumulates, creates pressure and a variety of motion that acts very energetically in bringing on secondary change ; and it is for this reason

Influence of carbonic acid.

Preliminary and faulty kick-up.

that beers of fermentative capacity require carefully venting immediately the casks are filled, when the temperature of the store naturally causes an increase in heat. If this is neglected it will be found that in many cases a determined secondary fermentation will set in at the end of a very few hours.

Dublin porter for town trade.

This is exampled in the case of Dublin porter, brewed for *town* trade. With such a beer, of no great stability, and which would not be consumed if flat, it is necessary to force on a cask fermentation to lead to immediate condition; and this is done by merely racking the beer in rooms kept moderately warm by steam pipes, the induced rise of temperature being quite sufficient to set in motion further fermentation, so long as the cask is tightly shived up. At one time there was a dispute as to whether it was advisable to regulate condition in cask or to allow cask fermentation full swing, the upholders of the latter idea asserting that under the great internal cask pressure the secondary fermentation was much more healthy, and was put an end to by pressure itself. I believe that there is a great deal of merit in such a notion, and if the stock beer existed in the cellar from which it was to be drawn, there is no doubt but that the beer fermented under such high-pressure conditions would be remarkably good if it could be tapped and consumed without any disturbance of the bottom deposit.

Fermentation under pressure.

As a practical question, the process is a faulty or impossible one; however bright the beer might be the extreme pressure would lead to immediate turbidity directly it was reduced, by diminishing quantity of fluid contents; while if the beer be stored for lengthy periods, the high pressure gradually disappears, much of the gas causing it passing through the pores of the wood,

Varying influence of pressure.

while the remainder is taken into solution, and when the cask is shipped away it is by no means full, and the contents exhibit but slight capacity of again becoming brisk, the violent fermentation that originally led to the pressure ending in excessive reduction of fermentable character, the high pressure very seriously influencing the vital power of the alcoholic cells present.

For these reasons it is customary to carefully control cask changes by the simple process of pegging, which, almost in a mysterious manner, prevents all excessive action, since my readers must remember that conditions of fermentation in cask are entirely different to those existing during primary splitting up of fermentable matter.

Control of condition.

There is no, or at any rate, very little air present, no motion, and the suspended yeast, limited in amount, exhibits in a well-brewed beer a peculiar condition of inertness. I have mentioned that the type of yeast developing in cask under these abnormal influences is, or should be, altogether different from ordinary alcoholic yeast; indeed, I held that the appearance of a cask deposit was a pretty sure proof of the fitness of beer for storage, since, if merely consisting of the round or ovoid vinous cells, we might take it for granted that we were finishing, in cask, a range of attenuation that should have been accomplished in the fermenting vessel. This is perfectly true, and the species of alcoholic cell life that gives us cask condition, in the case of a well-brewed stock beer, closely corresponds to the *saccharomyces Pastorianus*, presenting the elongated appearance far more prominently than ordinary brewery yeast is able to do, even when nutritive conditions are so abnormal as I have just explained them to be in store casks.

Cask deposit.

Its microscopical character.

For this reason, if beer be left quiescent and unaërated by "*rolling*," at a proper storage temperature—which in England, as I have said, is somewhere about 58°—the second fermentation is easily controlled or regulated by venting; and this is much more readily accomplished by the tight peg, eased as required, than by porous pegs, which are supposed to act automatically.

Venting by tight peg.

Briefly described, the venting process allows of carbonic acid escaping, when in excess, without any chance of aëration by exposure, and on this principle we have a ready means of preventing flatness of beer during the colder months of the year, since if nonaëration tend to retard cask fermentation, it is evident that motion facilitating mixture of air with beer must encourage it.

Its advantages.

Brewers frequently experience the following kind of annoyance when the normal temperature of the atmosphere tends to prevent early cask condition; their beer racked of necessity fairly clean is immediately stacked, and, the temperature being low, no fermentation results, since the suspended yeast rapidly settles to the bottom of the cask, and remains dormant there on account of the lowness of store temperature.

Cause of winter flatness.

Now, if we oppose this restrictive influence by the combined agency of motion and resulting aëration, we shall not only prevent the subsidence of yeast, but also bring it into vigorous vital condition, all this being easily done by a daily *rolling* of the beer for some little time after racking.

Rolling of beer.

The great advantage that Continental beer possesses turns very much upon storage influences—*i.e.*, the lowness of temperature prevents violent fermentative

Continental beer.

action, and keeps the beer fully saturated with gas, while the automatic method of preventing rise of bottom yeast by keeping pressure in cask uniform is a system that might well be adopted in large restaurants. Unfortunately, English conditions of brewing hinge upon some very complex methods for attaining stability by a process entirely different to that common abroad, and the successful brewer is the one who succeeds in producing a fluid with its fermentative capacity so regulated that fairly constant condition in cask is secured without tendency to any violent changes that would mean an excess of flocculent sedimentary matter in cask and constant cloudiness or turbidity of beer.

Home conditions.

Changeable nature of English beer.

It is for this reason that English beer requires such careful attention during storage, since we are dealing practically with a fluid containing suspended yeast, the storage temperature exerting an immense influence in one direction or the other; if too high, it leads to violent action; too low, flatness and corresponding cloudiness result. I have explained how the mere influence of heat can be modified in one direction by motion and aëration, or by leaving the racked beer in more fermentable condition; and how, on the other hand, comparatively high temperatures may be neutralised by greater dextrinous nature of beer, more perfect elimination of yeast-forming matter and yeast, and perfect quiescence of beer during storage.

Attention to heat influences.

In concluding this subject, brief reference must be made to the question of export beer and bottling.

It is not too much to say that good quality of export beer turns very much upon the nature of material used in producing it in special reference to

Export beer.

the possible dextrine proportion normal to different beers.

Inferior malt beers.

I explained, when speaking of material and mashing, that poor malts not only gave worts deficient in dextrin, but that, as we had to stew worts from inferior malt, we seriously diminished even the low dextrin proportion characteristic in such cases, and it is easy to see how the use of saccharine, as a substitute for malt, practically leads to the same result.

Use of good malt with sugar.

For this reason, if by custom or necessity we happen to be users of invert sugars or saccharines, and at the same time wish to produce export and bottling beers, it is of extreme importance that the malt employed should be so good as to render stewing quite unnecessary in order that the beer with its proportion of added saccharine may still be sufficiently dextrinous.

Importance of dextrinous character.

Now, why is dextrinous character so important? Because in the case of a beer that is required to mature very gradually the non-fermentable dextrin, becoming slowly hydrated, affords a basis for prolonged and yet perfectly regular action, and on this account such a beer, if racked properly clean, never undergoes those violent cask changes, and, indeed, may be bottled at a much earlier stage than beers which are extremely rich in fermentable sugars deficient in indirectly fermentable dextrin, and containing sufficient ferment matter to act upon the sugar constituent.

General rule.

This general rule may accordingly be laid down: if our beer be of dextrinous character it may not only be racked earlier, which means at higher gravity, and with less settling, but may be bottled or exported after a brief stay in stores; while, on the other hand, with beers deficient in dextrinous nature, we naturally ward off rapid secondary changes by more perfect elimination of yeast, greater racking brightness, and careful management of the second fermentation in cask before allowing it to pass from our control, and even then I doubt whether such a beer would export well in wood, although it does so admirably enough in bottle, since here any condition, resulting after bottling, is retained as a permanency, while in wood it would be evanescent, and unless fermentation continued—an unlikely occurrence—flatness would result.

Export beer.

I think this is confirmed by practical experience, for the bottler of a Burton beer brewed entirely from malt and with water of a saline character so depends upon its permanent, yet gradual, fermentative capacity that he bottles comparatively early with beer moderately bright and in no condition; he depends, in short, upon all the good qualities resulting in bottle from the slow fermentation that will progress therein; while the bottler of a sugar beer is not only careful to bottle perfectly bright and in good condition, but at a time when these naturally result from the secondary fermentation that has taken place in cask. In short, he makes certain that all violent action is over before placing beer in bottle, and as this would probably mean flatness, he bottles in good order, corking immediately.

Treatment of hard and soft water beers for bottling.

There is, indeed, considerable art in this process, as evidenced by the great variation in quality of bottled beer of different brands sold by various firms, and in order to prove how much the whole character of beer has altered within the last few years I may

Sulphurous acid spray.

say that the use of sulphurous acid spray in the bottling of beer is now almost universal, this meaning that modern beer, even when existing in bottle, still requires the presence of an antiseptic to prevent deterioration.

CHAPTER XII.

THE PRODUCTION OF BLACK BEERS.

I THINK that the present work would be incomplete if I did not devote a separate chapter to a consideration of the production of black beers, which year by year are growing in popular favour, and are to be commended on account of their superior nutritive character, and in many cases their freedom from chemical substances that are not always looked upon with favour by the consumers.

Black beers.

The varying classes of black beer are produced in several distinct centres of brewing by as many different methods, but, as a rule, we have two main principles in operation—the use of a soft water in conjunction with malt of distinctly heavy character, not inefficiently grown, but at the same time not by necessity so fully vegetated as that employed in the production of pale or stock beers.

Different classes of black beers.

The possibility of using such material turns upon the fact that a large proportion of the malt used consists of highly caramelised varieties, and, as before explained, caramelised bodies possess a marked preservative or antiseptic character, while the black beers produced are not always required to keep for any very lengthy period. To begin with, then, it is not

Preservative nature of caramelised material.

customary to employ saline waters, or, in other words, if such water be employed the black beer produced is deficient in that roundness and fulness of palate taste that is considered so necessary a feature, while I can example this by referring to the black beer produced at Burton, which has been universally described as a mere black pale ale—*i.e.*, though black in colour, its palate taste reminds one very strongly of the pale beers produced by Burton firms. It will be quite understood that I am not decrying this article; it may and does suit many palate tastes, and is thought a great deal of on the Continent, but at the same time it differs very widely from the accepted standard quality of a black beer as specified.

Burton black beer.

Continental palate.

It will be best, perhaps, to divide the subject under three headings—the production of Irish porter, London porter, and porter produced, as I may say, by a process of manipulation, my meaning being a process based upon the use of large quantities of sugar, not only in the production of the wort, but in the heading of the finished beer.

Dublin porter.

I suppose that Dublin porter, especially that produced by one firm, stands out pre-eminently as a special and distinct type of beer, and just as Mr. Steele, in his work on brewing, asserted that the whole success of the original London porter brewer turned upon the adoption of deep and closed-in coppers, so much of the distinctive character of the Dublin porter spoken of depends undoubtedly upon the immense capacity of the store vats.

Influence of store vats.

Mr. Steele's theory.

According to Mr. Steele's idea, restricted convection and increased temperature of ebullition decide more perfect caramelisation of wort extract; and, on the other hand, depth during storage determines definite fermentative changes and the development of special varieties of alcoholic ferments. Now let me, in full view of these two distinct influences, which depend altogether upon plant arrangement, and which have been undoubtedly accidentally adopted, describe the main features of the Irish process.

Plant arrangement.

First of all, there is the undoubted softness of water, that used in Dublin being a mixture of mere canal and river water, the organic impurity of which is counterbalanced, comparatively, by the antiseptic nature of wort constituents; then follows the selection of material, there being but little diversity of opinion as to what proportion of the different descriptions are most suited to the special flavour requisite, while as a general rule the Dublin brewers strictly adhere to exceptionally good pale and black malts, the proportion varying from 90 to 94 of so-called pale, according to its exact colour yield, and the balance of black. This is a very simple matter—a mere question of colour; and all I want to point out is that brown, amber, or crystalline malts are not used in this centre.

Dublin water.

Grist proportions.

There is little to say about the actual mashing process, boiling, or collection of wort.

Invariably using good material there is no necessity for stewing or any of the careful manipulation that is usual when dealing with inferior malt, when employed for the production of pale beers. The wort is frequently, indeed, procured by making up lengths, the liquor of which has been sparged over goods at the boiling temperature, while enormous boiling quantities leading to extreme caramelisation are submitted to ebullition in closed coppers.

Stewing unnecessary.

High sparge temperature.

It is pretty clear, then, that by employing material of the nature referred to, mashing it at comparatively low temperature, and rapidly boiling off the collected worts, a dry extract is obtained, abnormally rich in dextrin, albuminous, and inert bodies, a combination which invariably ensures palate fulness; but it is not exactly the character of wort that has gained for Dublin the renown undoubtedly attaching to its black beers, this being due more to a peculiarity of flavour, partly acquired through the fermentation of immense bulks, the storage of similar bulks for prolonged periods in vats, and the very careful system of "blending" carried out.

Character of wort produced.

Influence of immense bulks.

For instance, a Dublin brewer, we will say, brews in the season large quantities of a high-gravity stout at 32 to 35 lbs. saccharometer weight, this being stored in the immense vats mentioned for some twelve months, although it is possible that this period of storage varies according to the time when the matured flavour commences to develop, this matured heavy stout constituting, as I may describe it, *the flavouring portion* of the mixed or blended beer that is afterwards disposed of locally or exported.

Vatted stout.

Next we have the mild porter, brewed daily according to requirements upon the usual lines, but not finally vatted; and, thirdly, we have the "*heading*," which, in several of the breweries, consists of a portion of very strong first wort partially fermented, say to half original gravity, and clarified to a definite extent by skimming; this prepared day by day, and employed, as I may express it, perfectly fresh, and in that exact condition of quietude that each brewer finds necessary.

Mild porter.

"Heading."

There is nothing difficult in seeing that if these three distinct beers—the one matured, the other mild and clean, and the third half-fermented, be mixed together in different proportions, we can secure a great many varying flavours, degrees of fulness, and tendency to early cask condition.

How to attain varying flavours.

In other words, the required flavour and condition for the several trade outlets are arrived at, not by uniformity of intermixture, but by a perfectly distinct variation in the several percentages of *vatted*, *mild*, and *heading* descriptions. I have no hesitation in saying that the success of Messrs. Guinness depends on good material, great bulk during fermentation and vatting, and ingenious intermixture of different qualities of produce, whereby a perfectly uniform palate flavour is secured.

Percentage intermixtures.

Messrs. Guinness.

For instance, what would be the proceeding for a mere local demand? It might be summed up thus: A large and definite proportion of mild, a dash of matured, a heavy quantity of what is termed *gyle* or *heading*, and a warm racking room, to give the immediate cask condition; while, on the other hand, and to simply give the extreme case for export, the proportionate intermixture would be entirely different and the heading would sink to a minimum.

Local demand.

Export stout.

This general principle underlies the whole of the several processes common to Irish breweries, but I think it would be manifestly unfair to enter into further detail. Many people have attempted to imitate the treble intermixture process by substituting returned porter or old beer, which has been bought, for what I have described as the matured or vatted stout, and by using, for heading purposes, actual fermenting wort or simple malt flour, but in every case complete failure has resulted. The old, or returned beer is different in every way to stout

Use of returns to give matured flavour.

matured under pressure, while the fermenting wort or the malt flour, however vigorous they may be in the direction of inducing condition, are in no sense comparable with a strong wort partially fermented; since, in one case, we are introducing developing yeast wholesale, in the other merely wort with high fermentative capacity, freed from excess of yeast-forming matter by the semi-fermentation that it has passed through.

Use of sugar.

I do not think that the Irish brewers touch sugar at all; it certainly would not answer for the special kind of beer produced by the one firm that exports alone 350,000 barrels a year, and I hold that, as this export does not represent tied trade in any sense, it practically means perfect system of production. In main, I have pointed out the principle on which such production depends, while there is no doubt that, theoretically speaking, it is both interesting and instructive.

Perfect system of production.

I have often heard brewers extol the peculiar softness of their own stouts, but they have generally ended with the remark that, do what they will, they cannot procure the exact Dublin flavour. They will not, perhaps, wonder at this after reading the above description of the Irish process; and I again lay special stress upon pressure, grist proportion, and uniform blending of distinct quantities of three definite beers.

Irish process.

English black beers.

In coming to England we have very different processes in operation, the only common property, perhaps, being the use of waters deficient in or destitute of saline character. I may as well say, at this point, that so strong a view exists respecting necessity of softness, that in cases where the available brewing water happens to be at all saline, it is customary to soften the brewing water by employing saline bodies that have not only an extractive capacity, but also the power of throwing out of solution salts constituting permanent hardness, thus leading to practical softening of the water, and a double increase of its special extractive power.

Softening of water.

I do not know if this process is to be exactly commended; it is better, perhaps, for a water to be naturally extractive instead of being made so artificially, while the carbonates of soda and potash may extract from malt a good deal of material that would be quite as well left behind. At the same time both these bodies are used very extensively, the latter, perhaps, by preference, to the extent of 30 to 35 grs. per gall., and if any calcic sulphate happens to exist in the water, it is thrown out of solution as carbonate, while the sodic or potassic sulphate is neutral, or apparently so, in influence. The London system, a few years ago, depended simply on the employment of deep-well water, naturally containing, as taken from the tertiary beds below the clay, a quantity of alkaline carbonates; three and sometimes four malts were used, the resulting beer generally going straight into the cellars of the publican, while the better qualities were vatted for a certain length of time.

Carbonates of soda and potash.

Reactions.

London porter conditions.

This proves at once the entirely different character of the porter common to London; it is mild, full tasted, and absolutely free from acidity. Recently, the system has been modified, raw sugar coming into pretty general use, this, probably determining the more speedy consumption of the beer, giving it at the same time greater sweetness; but much of the distinct flavour depends on the fact that many varieties of malt were

Raw sugar.

and are still used, while boiling pressure and bulk during fermentation contribute no doubt in no small degree to the definite flavour that attaches to the black beer of this centre.

Speedy consumption necessary.

It is difficult to speak with respect on a process that turns on the free use of inferior material, and the speedy consumption of the resulting beer; and it is not wide of the mark to say that two-thirds of the London porter is utterly devoid of the least stability. It is consumed, indeed, almost prior to the completion of fermentation, the last traces of yeast being removed by artificial fining, carried out at a stage that leaves the beer moderately fresh to the palate—*i.e.*, the flattening is not so great by fining as if carried out later.

Working out of London porter.

The common course is merely to work out with finings, as described previously, and I presume that the practically rapid turn over of capital that is possible with a strictly tied trade, and by such *modus operandi*, sufficiently justifies the adoption of it; but, as compared with the Dublin system, it sinks into insignificance.

Cause of disaster.

The dangers resulting from the use of raw sugar have been already referred to; they combine to produce those disasters which the large London brewers are known to experience. It is all very well to secure stability for short periods by the use of strong antiseptics; but that surely is not good brewing, and with this remark I may leave the users of raw unrefined sugars to proceed as they think proper. One benefit, perhaps, that attaches to such a process is the ready fermentability of the finished beer, for the heading principle is by no means general when the black beer is so produced, while, if found necessary, it com-

Antiseptics.

Heading.

monly consists of the same raw sugar in concentrated form.

It is curious to observe the different flavours that can be produced by slight variation in percentage intermixture of grist. The four or five varieties of malt common to London may be described as pale amber, crystalline, brown, and black; and it is by mixing three of these, or all of them, in different proportions that enables each brewer to suit his own palate judgment or the requirements of his customers.

Different malts employed.

A very common percentage is 82 pale, 12 brown, 6 black, while others producing the black beer of more liquorice flavour double the quantity of brown malt. A great deal is supposed to depend upon temperature of fermentation, the majority of London brewers working as high as 80°, a temperature which is held to determine a distinctiveness of flavour much liked. There is, of course, nothing difficult to understand about this, each range of temperature corresponding to a different species of ferment development, an extreme instance of this being seen on the one hand in the case of bottom fermentation, on the other in the fact that "caseous ferment" is the only example of alcoholic cell life that will develop at a temperature of 120°.

Percentage quantities.

Fermentation temperature.

Caseous ferment.

This covers, I think, the proceedings common to London breweries: the water is soft, the material good, if for the production of heavy-vatted stouts; a perfect medley when the ordinary London public-house porter is required. Fermented very carelessly, it is either fined in large vats or sent to the publican in such a condition that when fined it will eject the fining material from the bung-hole, the porter being immediately afterwards drawn for consumption, and, if we are to

Careless fermentation.

believe some people, capped with an artificial head of fining froth.

Fining froth.

Country black beers.

Preservatives.

I now come to the country as a whole, for outside London and Dublin the production of black beer is carried on in no very distinct manner; some brewers softening water, some using sugar, others employing malt-flour, and sugar solutions for heading purposes, and most falling back upon some definite preservative agent to prevent early deterioration. As a rule, country brewers have no very heavy demand for their black beers, and they have to brew them accordingly—*i.e.*, if for immediate sale, and if prompt draught can be relied upon, country brewers imitate, to a certain extent, the example set them by Londoners, using sugar as a portion of the extract, raw sugar solution as the heading.

Entire malt stout brewings.

Low initial.

Brief stand of mash.

High racking gravity.

On the other hand, the majority, bound to produce an article of some stability, and one that will only come into condition after considerable storage, strictly adhere to entire malt brewings with low initial temperatures of mash, comparatively brief standing periods, fermentations progressing with free range of heat, racking their beer sometimes as high as ⅓rd of original gravity. Finally, they employ some definite kind of heading, either introducing it at the racking stage, or at period of shipment. Many different varieties of heading have found favour, some of them being substances easily fermentable, others practically wort in a state of fermentation, or when in the state of dry flour forming, as we may suppose, the food of ferments.

Action of flour.

Quite recently it has been suggested that flour only acts in the sense of being the store-house of so much air; but this view seems hardly correct in face of the fact that the addition of flour to black beer undoubtedly leads to secondary fermentation, more or less prolonged in character, and I think there is no doubt that the crude albuminous matters of raw or malted grain become slowly modified into yeast-forming material when placed in a fluid undergoing fermentation.

Secondary fermentation.

The use of flour does not, however, commend itself to many, since it is apt to lead to the slow generation of gas in place of that high condition that is considered so essential, so the popular plan at the present time is to introduce a prepared solution of sugar, either perfectly quiescent or brought into a state of incipient fermentation a few hours previous to the shipment of the beer. This operation would be costly if the sugar so used was not taken into account when calculating original gravity; it is customary therefore to fix upon a certain quantity of sugar solution to be added per barrel, and then reducing the brewing gravity of the beer so that the final addition of sugar brings it up to standard.

Flour *versus* sugar as heading.

The best variety of sugar to use seems to be either dextrin-maltose or some pure saccharine. A boiling-hot solution is made, cooled, and added to each cask, the ordinary quantity being some three gallons per barrel of a gravity corresponding to 1,150, those desiring very rapid condition inducing a quiet fermentation in the strong sugar solution by adding a small weight of yeast. It will be evident that such a solution requires constantly making afresh, and it is well even then to treat it with salicylic acid to prevent any deterioration. To admit of its use it is necessary to keep the black beer in stock more or less quiet, since it is not customary to add this form of dressing before

Dextrin-maltose.

Gravity 1,150.

Salicylic acid.

the beer is required for use, very rapid fermentation immediately following its addition.

I need hardly say that if this heading has been treated with a little yeast, or if a little malt flour be added with it, it puts an end at once to all possibility of flatness, while the degree of condition that results may be increased or diminished at will by varying the quantity of sugar heading employed, or the proportion of flour or yeast that is added with it.

Degree of "condition."

Diversity in detail of systems.

These several systems of porter brewing are, it will be observed, sufficiently diverse in detail, but of late years it has been found that a preservative is almost as essential in the case of these as when brewing beers from pale malt alone. I mention this to exhibit the peculiarity that attaches to the use of pure sulphites.

Acid sulphites.

It has long been known that acid sulphites could not be used with impunity in certain soft-water beers, a decided stink invariably resulting, this apparently being due either directly to some low form of nitrogenous matter, or indirectly to the presence of some form of ferment life determined by the presence of such albuminous compound. Now, black beers are all produced with soft water, and the same rule holds good in reference to them. No acid sulphite can be employed, and the brewer has of necessity to fall back upon either salicylic acid or a neutral sulphite, while taking into consideration the price of the former, there is no wonder that he has selected the cheaper article. The neutral sulphite employed is that of lime, and it i somewhat important to see that the selected variety is of stated purity, and considerable reliance may in this respect be placed in analytical reports.

Neutral sulphite.

Analytical purity.

This subject of preserving porter is undoubtedly worthy of attention, since porter returns are practically

Porter returns.

valueless, and yet up to very recent times few brewers commenced the use of antiseptic agents on account of the dread existing respecting unpleasant smell. I think it will be found that in the great majority of instances pure calcic sulphite will resist reduction and put an end to losses in porter production that have hitherto been very common. I would wish every one to pay special attention to the exact differences in system that I have so enlarged upon, while there are some influences in brewing that have up to the present time been strangely neglected, for no doubt pressure as induced by bulk has a very great deal to do with the characteristic flavours of certain well-known brands of beer.

Influence of pressure as induced by bulk.

I have designedly left the above subject to form a concluding portion of my work, as it was difficult to find any more appropriate position for it. In a book of this description it is hardly advisable to touch upon the production of certain classes of beer, but to lay down as clearly as possible the general principles that guide us, or should do so, in producing all. The only novelty I can claim for the contents of the volume s that I have tried to explain, in a strictly practical manner, the intimate connection that exists between character of wort, system of fermentation, and final quality and stability of beer.

Principle of the book.

Connection between wort and beer.

From first to last I have urged the immense importance of the fact that all success in brewing depends on the careful cultivation of much-despised yeast. I am well aware of the bearing that material has upon flavour, but at the same time we may use the very best malt, sugar, and hops, the very purest water, and yet be completely unsuccessful if we ignore the necessities of yeast growth.

Yeast cultivation

Advanced topics avoided.

I have not attempted to branch out into a discussion of any advanced points, or to touch upon subjects that are matters of dispute; and if I may attach special significance to any of the chapters, it is most undoubtedly to those on Mashing and Fermentation, since in the former I had to deal with the preparation of the field of growth, in the latter with the cultivation of the seed sown.

Laboratory manipulation.

My strong impression is, that in view of constantly increasing difficulties in brewing, brewers should make themselves masters of simple laboratory manipulation that will enable them to determine quality of material employed, for so long as they use inferior malt, sugar, and hops, so surely will they have to adopt complex methods of proceeding in order to overcome their influences, or court disaster when not doing so.

Peptones.

Deterioration of English barleys.

The question for my readers to determine is a very simple one. Is it easier and more economical to employ the cheaper material necessitating the complex process, or buy, at a high price, malt, hops, and sugar that will readily submit themselves to the old-fashioned simple processes of production? Over and over again I have referred to the subject of peptones, and I hope that I have clearly explained what such term means in a brewing sense; while if we remember for a moment the kind of deterioration that has been seen in the case of the vast bulk of English barleys cultivated during the last ten years, we shall have no difficulty in satisfying ourselves of the connection between limited diastatic capacity of malt, deficient *peptonic* nature of wort, and corresponding want of stability of beer.

Inferior worts.

It is not that diseased ferments are novelties, but these wretched worts that favour rather the development of acid ferments than those which the brewer is specially interested in cultivating.

We English brewers want to take some distinct course. If we persist in using the semi-raw grain, let us by all means have the plant that will enable us to treat it effectually, let us adopt the bottom fermentation system and preservation of beer by cold, or take the other sensible course: malt barley that will grow, malt it efficiently, and procure worts of a nature that was common a few years back—now very scarce. Go where you will, the successful brewer, who does not know what worry or trouble means, is the brewer in some favoured spot who finds the very best of barley always ready to hand at a reasonable price. Is there not a simple lesson in this that amply confirms all that I have been saying and repeating over and over again?

It is not, I think, the fact that brewers are becoming more ignorant that accounts for the terrible misfortunes that befall so many, but that one and all carelessly ignore the change that has gradually crept over the general character of English-grown grain, rendering the brewing process a much more complex manipulation than was previously necessary.

No book on brewing that was ever written can make up for defective practical knowledge; but I shall be very glad indeed if this volume is sufficiently plain in its wording of theoretical matter to enable the experienced manager to grapple successfully with the new order of things, and prove to the student that there is really something to learn as regards "the theory and practice of modern brewing."

APPENDIX.

CHAPTER I.

MALT AND ITS MANUFACTURE.

It is not my intention in this brief chapter to go into any very great detail on the subject of malt and the differences in character of extract that it yields, since points of this kind will come up, of course, for discussion in the following chapter on mashing, which embraces an account of the Continental process, with variations in character of extract that result from the adoption of limited or complete decoction. In experimental work that I have recently carried on, however, I have seen so much to impress me with the idea that malt, during recent years, has undergone changes in character of no small moment to brewers, that I think it advisable to touch upon two or three points in reference to this particular subject that will, I am sure, interest readers generally.

What better statement could be taken as a text than that the question of yeast reproduction is now occupying the serious attention of brewers, who, year by year, perhaps experience increasing difficulty in successfully reproducing the particular type of ferment peculiar to their own system of working, determining the more recommendable flavour of beer, while at the same time purging the collected wort to an extent ensuring stability of beer either during prolonged storage at home or shipment abroad.

Cold water mashing.

The practical work referred to above has been in connection with the subject of cold water mashing, while I have found that when inferior malts are intermixed with cold water as a preliminary step, and digested at a temperature of 95° for a considerable period before mash is finally raised to 150°, or above, a wonderful increase in proportion of soluble albuminous matter, as finally existing in cooler wort, is attained, while, on the other hand, when dealing with malt of high-class character in a similar way, little or no increase is noted in the soluble albuminous percentage, even when carrying out the cold infusion process as an initial step in the mashing operation. This particular statement is so important, that it could not possibly be passed over without thorough explanation, although this shall be kept in as limited a space as possible.

Objects of malting.

For what purpose do we malt grain? Surely to accomplish by artificial vegetation exactly the same modifications of original crude barley extract as that naturally taking place in the soil, stopping such modification, however, before any considerable loss of soluble constituents results from overgrowth or undue development of root or spire.

It would be sufficiently easy to show that if such artificial vegetation is forced by an excessive supply of either moisture or warmth, we fail to accomplish the modification that is naturally attained in the soil. In other words, we may either malt grain so as to attain perfect modification of crude matters, corresponding to results of natural growth, or we may force the indices of vegetation without arriving at the requisite changes—at any rate, to the desired extent; and this is exactly what we mean, or what we should mean, when speaking of defective material, *i.e.*, malt apparently well grown, but vegetated under such faulty, abnormal, and strictly artificial conditions, that natural modifications that should have taken place during floor process, have in no way proved satisfactory in result. This, indeed, is why inferior malt benefits so much from being first of all infused in cold water, and then kept for a prolonged period at a digestive temperature, since we thus complete in the mash tun the modification process that ought to have been determined on the malting floor; while good malt, on the other hand, may be referred to as material that has passed through a prolonged process of artificial vegetation, based strictly upon natural lines of working, the interior constituents of the grain being much more completely modified than under other circumstances, while the resulting extract contains, in consequence, the requisite amount of fully digested forms of soluble nitrogenous matter.

Natural and forced growth.

Now, in order that this statement may be clearly understood, I think it best to append figures showing the variation in results obtained when submitting common-class material first of all to cold infusion, and then to the ordinary system of mashing; while, in the second case, the figures show the variation in results when dealing in exactly similar manner with malt of high-class quality.

Albumen percentages in wort from good and bad malt.

COMPARATIVE ANALYSES, SHOWING THE COMPOSITION OF WORT EXTRACT OBTAINED BY MASHING (*a*) BY THE ORDINARY INFUSION PROCESS, (*b*) BY THE COLD MASH METHOD.

I. *Common English Barley Malt.*

	100 parts Wort Extract contain	
	Ordinary Infusion Method.	Cold Mash Method.
Maltose	70·00	67·10
Dextrine	13·07	16·01
Albumen	4·72	7·40
Ash	2·15	2·36
Inert matter	9·06	7·13

II. *Fine English Barley Malt.*

	100 parts Wort Extract contain	
	Ordinary Infusion Method.	Cold Mash Method.
Maltose	71·13	65·65
Dextrine	12·01	17·25
Albumen	5·78	6·32
Ash	2·29	2·30
Inert matter	8·79	6·48

These results are, no doubt, conclusive, since they show at once, in the clearest possible manner, that good material submits itself readily to almost any method of mashing, practically yielding the same proportion of soluble nitrogenous matter when intermixed with liquor at 168° or 170°, as it does when infused in a preliminary way with liquor at a temperature of 100°, or even lower.

Does not this explain why brewers suffer so much when dealing with defective material? Obviously it contains an insufficient amount of albuminous matter soluble at high temperatures, while the unfortunate operator, driven to infuse it at heats unfavourable to the formation of soluble albuminoids, the resulting wort is, in consequence, more or less sterile in character. The English mash tun, in short, is not adapted for such material; it is a vessel constructed for dealing only with grain which, through the influence of judicious growth, has become so modified, that simple infusion with hot water suffices; while, if readers have been following what I have said, it will be clear that this result only occurs when the malting process is thoroughly organised, and when artificial growth of grain proceeds exactly as it does when taking place naturally in the soil. If forced by abnormal conditions—that is, by either undue application of warmth or moisture—we merely have the indices of growth in spire and root, without the modification results of natural vegetation.

English mash-tun adapted for good malt only.

Now, it would be rash for English brewers to alter their mashing plant to enable them to deal with defective material in a more satisfactory manner than at present, since their best interests would be served by either making their own malt, or insisting upon the maltster steadily adhering to principles which, no doubt, governed the process many years ago, but which have been more or less abandoned at the present day, partly under the influence of substitution of beer duty

Solution of malt difficulty.

for malt tax, partly under that of altered character of grain, but principally, no doubt, on account of the constant cry raised by brewers that malt should be efficiently grown.

The maltster, willing enough to conform to these requirements, has in many cases secured growth at the expense of good quality of malt made, in special reference to its capacity of yielding those very essential forms of yeast nutriment that are at all times required, especially when substitutes for malt, in the shape of sugar, are employed to any considerable extent in practical brewing. I am aware of no subject, indeed, of greater importance than this; and although, very likely, the great majority of maltsters would assert that they have been effecting constant improvement in process during the last twenty years, I am strongly of opinion that many have failed to recognise the true influence of perfect vegetation as favouring the ends of the brewer, and have been too ready to sacrifice nitrogenous bodies in determining mere appearance of perfect growth, without attaining the actual results of it.

Miniature brewing plant for testing malt.

It would be useless for me to reiterate arguments in reference to this matter, since readers capable of working a miniature plant could easily prove to their own satisfaction the truthfulness of all the points referred to. This miniature plant will be described and illustrated in the final chapter, while the figures that I have given, showing the varying analytical composition of wort, may be taken as absolutely correct, and as evidencing the immense variations in nitrogenous proportions, existing in cooler wort, that malts of different quality are capable of yielding when infused at distinctive temperatures. The sum total of my contention is that if malting were properly carried out, the resulting material would be perfectly suited for use in the brewer's ordinary infusion mash tun, and when infused with liquor at the high striking heat necessary to determine a primary initial of 150°, would still yield a sufficiency of yeast-forming nutriment, and so put an end to one of the greatest practical difficulties of modern brewing.

Intermediate carbo-hydrates.

I may refer, perhaps, in this preliminary chapter to another matter in reference to malt that is of equal importance, since, if the material operated upon is at all defective in character, it invariably yields a very large proportion of what has been termed intermediate or inert carbo-hydrate matter. In a succeeding chapter I shall have to deal with the subject of hot circulation of wort, and shall then show that by circulating wort at any very high temperature, we undoubtedly commence to attack the vitrified portions of malt starch, and consequently obtain in mash wort a larger percentage of total sugars than is known to exist under ordinary circumstances, this normal percentage ranging, as readers probably know, to about 82½ per cent. of extract, while the proportion of so-called intermediate bodies generally runs to close upon 10 per cent. If hot circulation of wort is carried on, however, it will be found that the total sugar proportion will increase, while there will be a decrease to a slight extent in nitrogenous matter and corresponding diminution in the proportion of intermediate carbo-hydrate bodies.

Total sugar percentages of wort.

At this point I may ask at what expense? The reply is obvious, since, if circulating wort at any very high temperature,—a temperature sufficient to attack the vitrified starchy matter of malt,—we must of necessity destroy at the same time those active principles of malt extract that the brewer relies upon for effecting hydra-

Vitrified starch.

tion and peptonisation changes during the mash tun process. Is there then any process known for effectually minimising the proportion of intermediate bodies existing, without interfering with the active constituents of malt extract as a whole? This question is sufficiently easy to answer, since, if malt is perfectly made, if artificial vegetation has coincided closely in result with that attained by natural growth, it is obvious that the greater portion of malt constituents will be in a condition to admit of their ready solution and hydration; but, unfortunately, even with the best of material, artificial growth has to be checked long before complete modification of interior constituents in the direction of solubility has been attained, so, although the proportion of inert matter existing in a wort obtained from high class material is by comparison small, it nevertheless runs to a percentage of seven, or even a little higher, while in worts from defective material, *i.e.*, from grain that has not been perfectly grown, the proportion sometimes exceeds even 10 or 12 per cent. Readers will thus see that we cannot materially reduce the proportion of these somewhat worthless constituents of mash wort, even by selecting for use grain of the most recommendable quality.

Hot grist mashing.

I come, therefore, to a novel process that has not, I think, been previously referred to in any published work —a process that, if practised, enables the brewer to minimise the proportion of these intermediate matters by at least 50 or 60 per cent.

The principle of working turns either upon re-kilning malt and grinding it while hot, or heating the grist itself to a high temperature by means of hot dry air some short time before making the actual infusion, one in-

Reduction of inert matters.

fluence of the process being seen in the diminished proportions of inert matters existing in resulting worts. It is pretty clear, therefore, that the influence of re-kilning malt or heating grist is to modify, in the direction of greater solubility, certain matters of vitrified nature that would otherwise resist hydration during the after mashing process, although it is difficult to understand why such modification did not result when the grain intact was exposed to the same degree of heat during original kiln-drying.

Change in malt during storage.

It is possible, of course, that the paradoxical result referred to may hinge upon the fact that stored grain is, practically speaking, never stationary in composition; its constituents, in short, are continually undergoing slow change, and up to a certain limit of time desirable modification, and, as a consequence of this statement, it is probable that the same results might not be obtained when heating grist prepared from perfectly new material. So far, my own experiments have been made with material several months old, in which a certain degree of modification had possibly taken place, so that, in re-drying the malt to secure the hot grist, some change in character of vitrified matter was obviously determined, leading to a solubility of starchy bodies that would not otherwise have resulted, with consequent decrease in percentage of intermediate carbo-hydrate matter as constituents of resulting worts.

Aroma and brilliancy of wort.

This particular re-kilning or hot grist process has indeed other influences besides that of minimising intermediate carbo-hydrate proportions—influences that lead to powerful aroma of wort, exceeding brilliancy of same as running from mash tun, far more satisfactory fermentation results, and increased yeast reproduction. It is only necessary for me to observe that when mashing with grist that has been raised to a very high temperature, it naturally follows that we have to reduce the heat of striking liquor, this alone having immense bearing upon the question of yeast growth, while, in order that readers may have some knowledge of the practical operation, I may remark that it is usual, when carrying out this system, to reduce the striking heat of liquor by about 10° Fahr., that is, when desiring to obtain the ordinary primary initial of 152°, further details having appeared in the *Brewers' Journal* "Occasional Notes" and my recently published pamphlet.

In this preliminary chapter, therefore, I have attempted in very brief manner to explain how malt has deteriorated in one particular direction during the last few years, and the steps that brewers should either take themselves or insist upon maltsters taking, in order to render the material supplied capable of facilitating more satisfactory yeast reproduction, since this is not only of importance in so far that perfect yeast growth enables the brewer to purge wort satisfactorily, but since every desirable flavour of beer turns more or less upon type of alcoholic yeast cultivated, it is surely essential that brewers should attempt to reproduce the more recommendable forms of alcoholic yeast, while this can only be accomplished when the malt employed is at all times of thoroughly good quality.

Yeast reproduction.

I hardly know of any subject that claims more careful attention at the present day than the particular one in reference to malt and its general character, while I have attempted to show how this desirable character may be practically ascertained by mashing material on a small scale, and carefully analysing the worts arrived at by different methods of procedure.

I have tried also, in a preliminary manner, to explain how composition of wort extract may be modified in a totally different direction, by re-kilning malt and securing grist at a very considerable temperature before exposing it to infusion influences, while in succeeding chapters I shall have much more to say upon the general subject of variations in mashing process.

CHAPTER II.

MASHING: THE INFLUENCES OF THE CONTINENTAL PROCESS—LIMITED DECOCTION—HOT CIRCULATION OF WORT—HOT AËRATION OF WORT.

Decoction mashing.

Low infusion heats.

Corrective influences.

Regulation of hydration.

If I may describe the Continental system of obtaining malt extract, in a brief sentence, I may refer to it as a method hinging upon the point of first determining, under the influence of a low infusion temperature, the full extraction of all of those soluble albuminous matters that are so desirable as wort constituents, and secondly, the adoption of corrective means for eliminating such albuminous matter as may be objectionable, or alterable in type, while strictly regulating at the same time the transformation products of hydration, namely, maltose and dextrine.

The general Continental process, indeed, involves the intermixture of grist with liquor either cold or at a very moderate temperature, this deciding the solution of the more readily soluble forms of albuminous matter without promoting to any great extent hydration results. As soon as intermixture of material is complete, the German brewer slowly raises the temperature of mixture, so setting in motion incipient hydration, while preventing complete transformation results by gradually destroying the larger proportion of diastatic agency, this being accomplished by his series of Dick and Lauter maisches.

Now, if this practical digestion process were not carried out, what chance would the Continental brewer have of successfully fermenting wort at the low temperature of 45° to 48°? Is it not clear that he determines, in the first instance, fermentable nature of wort, not through sugar agency, but by facilitating the solution from malt of those forms of nitrogenous matter which, becoming peptonised later on, directly determine the fermentability of wort by supplying a sufficiency of yeast food, even when such wort is fermented at an exceedingly low temperature? Does the English brewer ever think of this, or, if giving it some slight attention, does he ever carry out such a process in practice, even in the most elementary manner? No; his general process centres upon a totally different idea, and he is consequently forced to determine character of extract by temperature of mashing liquor, this practically saving him the trouble of carrying out any corrective manipulation at all during mashing, although it does not enable him to control to any extent the character of the ordinary transformation products of malt extract, which are frequently decided by the imperfect nature of the malt employed, and generally, I fear, in a very detrimental direction, the resulting worts being poverty stricken in reference to dextrine and desirable types of albuminous matter.

Fermentable nature of decoction wort

I am afraid that I shall not be able in this chapter to advise English brewers to adopt the cold system of mashing in its entirety, or to explain how a fermentable character of wort through the presence of nitrogenous matter can be brought about excepting by means of those agencies that could be practised, no doubt, in the malt-house, since cold water mashing, for instance, in the case of English breweries would necessitate the erection of entirely new plant, and as this would completely revolutionise existing operations, and prove, moreover, exceedingly costly, few readers would give such suggestion a moment's consideration.

Modified German process.

My object, however, will be to show that by carrying out a modified German process we can, at any rate, control starch transformation results, and remove many objectionable and otherwise alterable forms of albuminous matters existing in wort at the present day, assignable in main, I think, to changes in character of grain, brought about by the adoption of methods of agriculture which, while facilitating possible increase in weight of reproduced grain, have not determined improvement in the general character of extract yielded, but rather the reverse.

Limited decoction.

Most readers presumably have heard of limited decoction, and have wondered, perhaps, why the term "limited" was employed as a prefix. This is very easily understood if we remember for a moment that Continental brewers submit, practically speaking, the whole of their mash to decoction influences, without, however, destroying every portion of diastatic matter, while as the English brewer does not either possess the Continental mashing plant, or think of carrying out preliminary cold infusion, he is driven, as I may say, to restrict, or, in other words, to "limit" decoction influences, and thus we have an explanation of the qualifying expression "limited" attached to the simple decoction process that is carried out by certain English brewers, preferably, as I think, in plant as illustrated.

Explanation of term "limited."

I may as well remark at this point that by adopting any mere modification of the infusion system, we fall far short of the results attained in German decoction breweries, since the particular steps we take in revolutionising transformation products, in so far as maltose and dextrine percentages are concerned, minimise at the same time the proportion of peptonised matter existing, since we limit in the first instance its formation very seriously through the agency of high striking heats and prolonged hot infusion, while we still further impede the formation of peptones by either submitting wort to hot circulation, or a portion of the entire grist to decoction. On the other hand, if we are not altogether conservative in our views respecting the absolute necessity of yeast reproduction, if it is possible for us to obtain a suitable yeast supply from outside sources, it may be, and frequently is, indeed, very recommendable to adopt alternative methods of mashing that enable us to produce beers of greater palate fulness or more recommendable clarifying capacity and general cask stability at the expense of yeast outcrops.

Dextrinous not always stable.

It would not be difficult to prove that beers containing sugars of good type evidence a stability not attaching to those having too large a proportion of actual fermentable matter present; but, on the other hand, I must warn readers against the error of supposing that stability will result merely through deciding the presence of a non-fermentable sugar in beer on completion of attenuation, since capacity of gradual cask fermentation is an actual aid to stability, a thin, clean, flat beer invariably acidifying with great ease during the spring and summer months. This statement then clears the ground, while no one must conclude for a moment that by merely carrying out the modified systems of mashing which I am about to describe, he can in any case produce worts so rich in peptonised forms of albuminous matter as those resulting from the very scientific and complex process of the Continental lager beer brewer.

Yeast reproduction in infusion worts.

English brewers, therefore, must solve the yeast reproduction question, indeed, by evidencing greater care in the selection of barley, and the more perfect manipulation of same during its artificial vegetation, since in adopting either limited decoction or definite hot circulation of wort as a means of revolutionising general character of extract obtained, they decide, no doubt, at the same moment the comparative non-ferment-forming capacity of the albumens existing in resulting wort.

It was in view of this statement that I incidentally mentioned that such novel processes appeal with greater force, perhaps, to those brewers who are interested more in the character of beer produced than in what may, in some cases, be a necessary reproduction of yeast. I am perfectly certain, indeed, that no such reproduction is possible if malt of inferior quality is used, and resulting material or wort itself be submitted to decoction influences, while, on the other hand, if yeast reproduction is a necessity, readers must either abandon the combined processes spoken of, make no attempt to put them in operation, or otherwise take care that the malt itself decides the question of yeast reproduction in all cases when a limited proportion of either material or the resulting wort is to be submitted to the extreme influences covered by the expression decoction.

Of course, the influence of such manipulation will vary according to the length of time elapsing between the intermixture of grain and the application of those high temperatures to material or wort that minimise diastatic capacity, and lead at the same moment to a greater solubility of starch. Benefit in special reference to yeast-reproducing tendency may, perhaps, frequently result from making a preliminary cold infusion of the decocted portion of grist, imitating in this sense the proceedings of the Continental brewer in the case of his entire mash.

I have stated in the chapter dealing with the question of malt, that the ordinary transformation products of malt extract met with in English infusion breweries at the present time, contain about 70 per cent. of reducing sugars and 12 or 13 per cent. of dextrine, while in the case of the limited decoction worts they vary very considerably according to the exact method of decoction carried on, or the class of material that is dealt with. For instance, if we carry out decoction in the mashing vessel itself, we destroy far more diastase under the influence of raw steam heat than when practising the process on limited lines in plant specially designed for this purpose, and duly illustrated in detail. Under such circumstances—that is, when practised in the mash tun—the decoction process may lead to vast increase in dextrine percentage, while, as carried out to a limited extent in the special plant spoken of, it does not of necessity lead to any very definite increase in dextrine percentage, but to the presence in the wort of a larger portion of intermediate carbo-hydrate bodies, and astringent matters as dissolved from grain, matters that are resinous in their nature—a point that has a great deal to do with the more speedy clarification of resulting worts and beers.

Dextrine percentage of infusion worts.

Dextrine percentage of decoction worts.

Clarification.

Now the question as to whether such limited process of decoction determines increase in dextrine percentage or no, turns very much upon the class of material employed, since if the whole bulk of malt mashed is poor in quality, consequently possessing but low diastatic activity, diminution in diastatic matter, to a serious extent, will result from the adoption of the limited decoction process, so that hydration results would not as a consequence be very advanced. On the other hand, if material is good and highly diastatic, the mere destruction of 25 per cent. of the total diastatic matter would not seriously interfere with the hydrating capacity of the 75 per cent. of material merely submitted to infusion, while, as the starch of the decocted portion would be much more soluble and readily modified, the hydration products might in this case be more extreme, and final extract become more definitely saccharine.

Destruction of diastase.

Brewers, therefore, carrying out the decoction process in the mash tun itself, and practically submitting 75 per cent. of the material to decoction influences, secure large increase in dextrine proportion, although, generally speaking, a coarser kind of extract, while those practising the process in special plant do not, as a rule, find large increase in dextrine percentage as a result of the proceedings, but, nevertheless, produce beers of more excellent quality, rapid clarifying tendency, and greater stability during storage.

Summarised advantages of decoction.

Such, then, are the differences between the various systems of decoction practised in England and abroad. The German method involves, as I have said, cold infusion, complete decoction of material, and corresponding decoction of wort, fermentability of wort being determined through the presence of a large excess of peptonised forms of nitrogenous matter, resulting from prolonged cold infusion, highly dextrinous character of wort as due to complete decoction, distinct clarifying tendency of beer running in connection with the Lauter maische process, while, as a combined result of the entire method, the Continental operator secures weak beers, capable of carrying persistent creamy heads, not necessarily due to the presence of any excessive proportion of dextrine, but to the existence in the fluid of very definite quantities and types of soluble peptonised susbtances, that possess a marvellous influence in determining a distinctive viscidity of fluids in which they exist. Following this extreme system of decoction, we have the modified processes common in some English breweries, decoction being either carried on in the mash tun itself, or, to a limited extent, in distinct plant, with results varying accordingly.

I come now to the process of hot circulation of wort, which is entirely distinct, and corresponds more or less to the Lauter maische process of the Continental brewer. The principle involved in the hot circulation method turns upon the fact, that by commencing the circulation of mash wort at the end of a limited period, before hydration has proceeded to full extent, we can decide the absolute destruction of all diastatic matter in the portion of wort circulated, while if the wort is re-sparged on to goods at any very high temperature, portions of vitrified starch become dissolved, total sugars and dry extract are increased, and the transformation products become much more dextrinous in nature, the diastatic bodies existing in mash-tun wort being rendered inactive under the influence of the extreme heat applied during circulation.

Hot circulation of wort. **Diastase destroyed.** **Vitrified starch dissolved.** **Extract increased, also dextrine.**

The German brewer practically carries out the same process, although for a somewhat different purpose, when circulating wort (Lauter maische) on completion of decoction, since this circulation does not lead so much to increase in dextrine proportion as to the greater purification of malt wort so treated. So much, however, will have to be said upon this particular matter later on, that it will, perhaps, be well for me to proceed at once to a practical description not only

Mashing plant.

of the several forms of mashing plant illustrated, but to the means of working same to the best advantage.

I think that I have been sufficiently explicit in showing the exact difference between decoction carried out in the ordinary infusion mash tun, and the process practised in distinct plant, which I am most

Special decoction vessel.

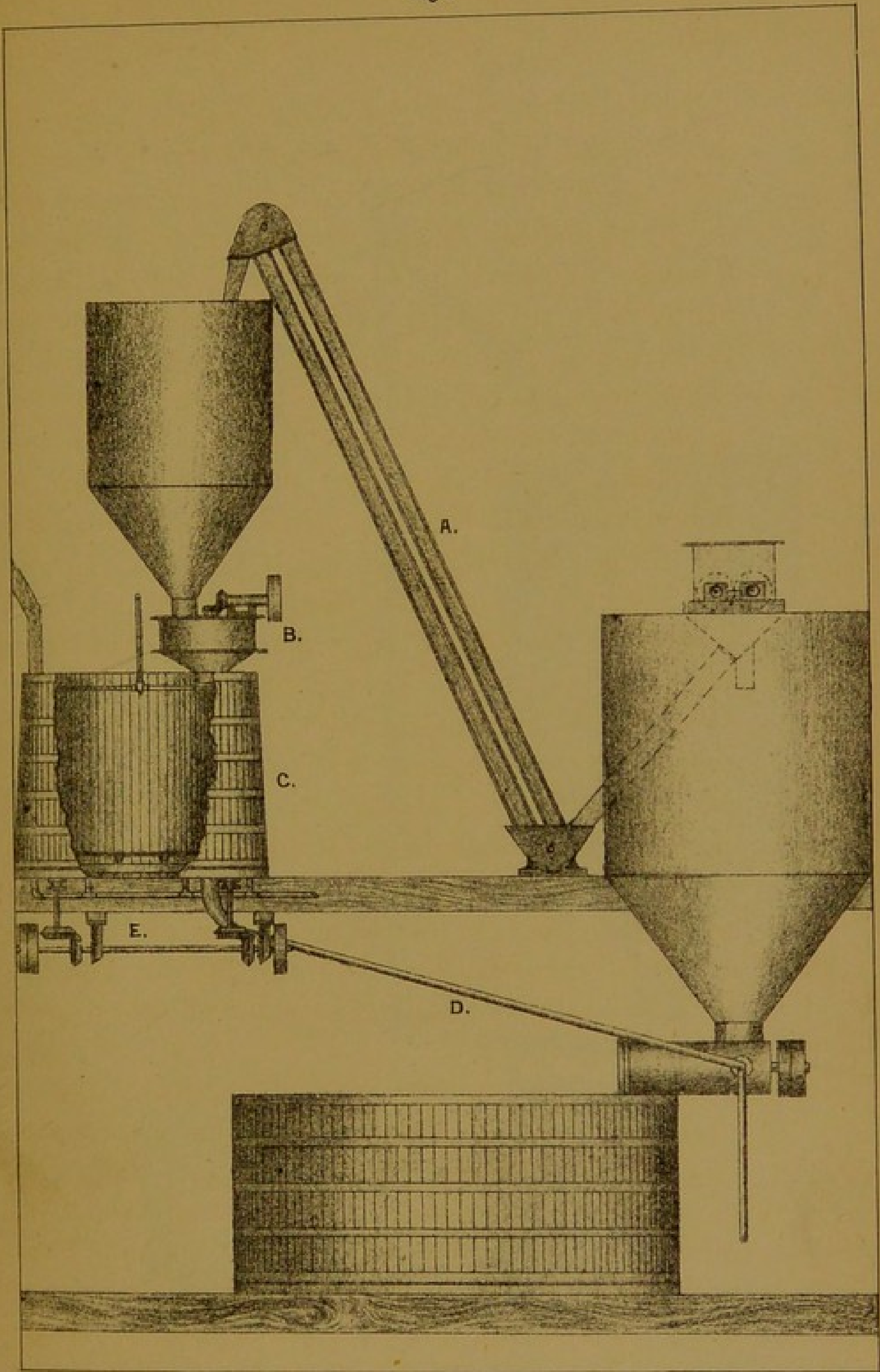
anxious to describe as plant that can be used for a variety of purposes. For instance, there are many brewers who occasionally wish to produce a small quantity of some special beer, while they recognise the inadvisability of mashing a small proportion of malt in a large mash tun. If, therefore, the 25 to 30 per cent. limited decoction plant be fitted with an ordinary copper false bottom and sparge arrangement, it will be apparent surely how this limited plant can be recommendably used when producing special beers in small quantity.

Again, as many brewers at the present time carry out sugar inversion and blending operations with liquor, this limited decoction plant, placed at high level, answers admirably for both purposes, so long as all the interior fittings are of gun metal or copper. Take,

Sugar inversion.

for instance, the case of sugar inversion: The motive power, consisting of screw propellers, answers well for determining that constant intermixture of dilute syrup which is always advisable, not only when the sugar is first dissolving, but on the neutralisation of the acid

Fig. I.

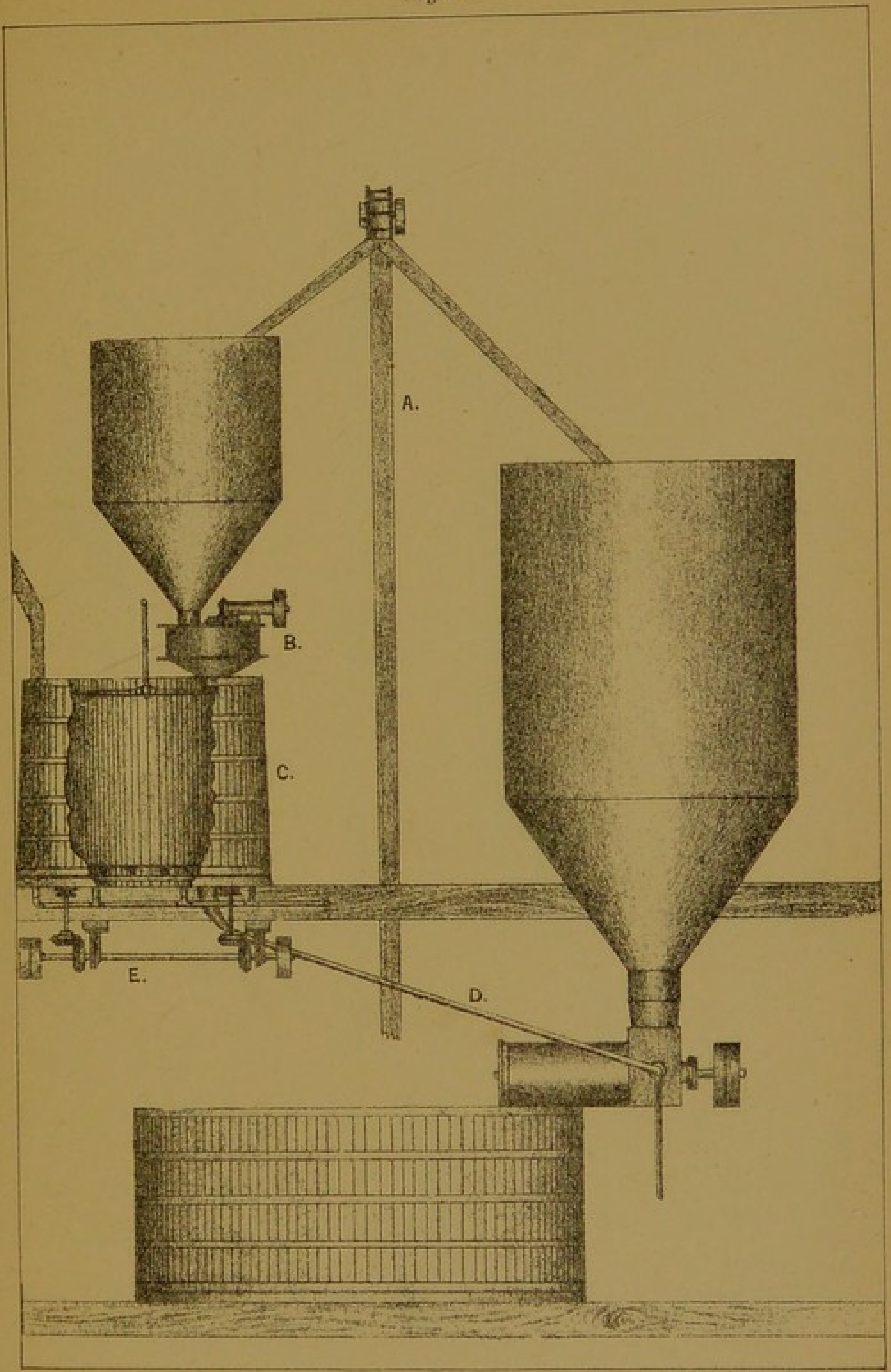


INK-PHOTO, SPRAGUE & Co. LONDON.

LIMITED DECOCTION PLANT.

A. Elevator. B. External Mixing Machine. C. Decoction Vessel. D. Connecting Pipes to Mash Tun.
E. Machinery Driving Interior Screw Propellers.

Fig. I[a]

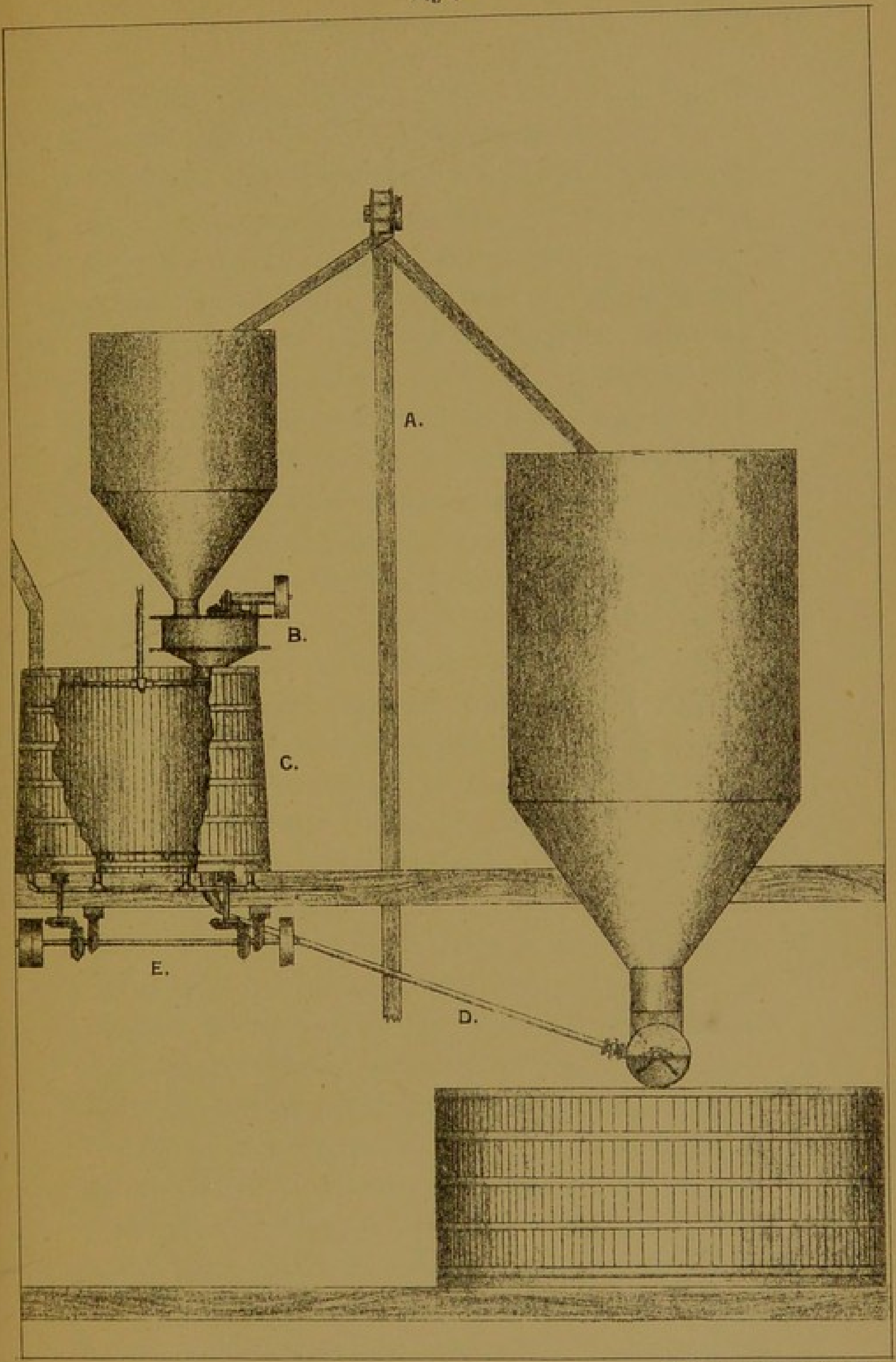


INK-PHOTO, SPRAGUE & C° LONDON.

LIMITED DECOCTION PLANT.

. Elevator. B. External Mixing Machine. C. Decoction Vessel. D. Connecting Pipes to Mash Tun.
E. Machinery Driving Interior Screw Propellers.

Fig. I[b]



INK-PHOTO, SPRAGUE & Cº LONDON.

LIMITED DECOCTION PLANT.

Elevator. B. External Mixing Machine. C. Decoction Vessel. D. Connecting Pipes to Mash Tun.
E. Machinery Driving Interior Screw Propellers.

employed for determining hydration of cane sugar to invert. Or take the case of blending liquor, which requires some little treatment with acid to convert all calcic or magnesic carbonates into corresponding sulphites or sulphates. The same vessel answers for the preparation of such liquor, since by constant use all flavouring matter has been withdrawn from the pores of the timber, while the motive power spoken of enables us to readily intermix the small proportion of acid required with the liquor undergoing treatment. I am able to say, therefore, that such exterior plant is very serviceable in a number of ways, and cannot in any sense be regarded as merely available for decoction purposes.

Blending liquor.

In the next place, it becomes necessary for me to carefully explain the limited decoction process, as carried out in the plant illustrated so fully, and while doing so I shall endeavour to keep this part of my subject perfectly distinct from that of multitubular hot circulation of wort, which determines, as I have said, very different results.

Malt for decoction mashing.

From one point of view, all inferior grain should be submitted to decoction influences, but my own special idea is that if carrying on this process with the desire of determining the best possible results, it is always advisable to employ material of fine character, since decoction heats are very apt to extract from malt of defective type objectionable flavouring matters, which may communicate a distinctive foreign flavour to our high fermented beers. This particular point concerning temperature of fermentation must not be overlooked when comparing English decoction results with those attained in Continental plants, and in one or two English lager beer breweries.

Temperatures of decoction mashing

We have next to consider the question of temperature at which we should commence decoction, the influence of mashing periods, bearing of prolonged high temperatures, and lastly decide upon the after-method of intermixture and general management of the entire mash made. I confess that I have been somewhat disappointed with the results of attempting preliminary cold infusion, since English malt, or the English system of fermentation, does not altogether seem to be in unison with the process that is so undeniably successful abroad; while I have experienced personally, over and over again, preferable results by intermixing the decoction portion of grist with liquor at a temperature of about 165°, and my readers may, indeed, take this as an entirely suitable initial heat for liquor in decoction mashing.

Duration of decoction.

In reference to period of time during which preliminary mixture stands, I have to make a statement of considerable moment. Looking at the question in a merely theoretical sense, we might presume that it would be advisable to rapidly raise the heat of mixture in decoction vessel to a degree that would destroy all diastase, gelatinise and dissolve the greater portion of starchy matter. I can only say that I have not personally found this to be the case in practice ; in short, it seems to me absolutely necessary to leave the intermixture for quite thirty minutes before attempting to raise the heat rapidly to the limit of gelatinisation, which is distinctly short of the actual boiling point.

Period of quiescence.

It will be clear, of course, that this necessary period of quiescence is sometimes accidentally determined by the slow intermixture of material as due to the large quantity of malt being dealt with, so that in this case it might be possible to raise the temperature of intermixture very much sooner or more rapidly, since the greater portion of it would have existed in a state of quiescence for some considerable time. The sum total of this argument is that period of quiescence on first intermixture of a decoction mash is a point worthy of notice, in fact we should in all cases allow an interval of twenty or thirty minutes to elapse before blowing in naked steam in order to run up the heat.

There is, of necessity, a vast difference again between the influence of naked steam and that of steam indirectly applied, the steam that is actually condensed in decocted mash being much more destructive to diastase, and, generally speaking, more extractive in its influence in reference to flavouring matters, as well as total extract, than similar steam applied at same pressure through the agency of jacket or coil, and it is for this reason that I prefer a vessel as illustrated, in place of one of metal fitted with a steam jacket, while brewers adopting the metal vessel and jacket arrangement would always do well to supplement the heating agency by the introduction of raw or naked steam, taking care, of course, that all steam so used is obtained from boilers fed with water of fair purity, and not artificially treated in any way. I need not at the moment refer to this subject in greater detail, since it will naturally come up for discussion in the chapter that I am devoting to boiling operations ; I must, however, impress upon readers the absolute necessity of employing naked steam, either partially or entirely, when carrying out the decoction mash, since it will be remembered that we only submit some 25 or 30 per cent. of raw material to decoction influences, and not the whole of the mash that we are eventually dealing with.

Naked steam.

On the expiration of the fixed period of quiescence mentioned, it matters little how rapidly the heat of mixture is raised; although theoretically, of course, general perfection in results would correspond with rapid rise of temperature as minimising possible hydration.

Final heats of decoction mashes.

We have next to decide as to the final heat of the decocted portion of mash, some writers advocating actual ebullition, others a lower temperature for a longer period of time. Now, if distinct ebullition is practised, it must, of necessity, lead to extreme disintegration of material, rendering the decoction mash exceedingly sloppy, while we obtain from the husk of malt a far more prominent flavour, so that eventual beer possesses a decided foreign, if not a distinctly objectionable taste.

The comparative palate delicacy of a Continental lager beer depends mainly upon the point that German brewers do not use naked steam in carrying out their complete as distinct from our "limited" decoction process, nor do they ferment the eventual worts, either rapidly or at any high temperature. No practical brewer, I suppose, will fail to recognise the influence of high temperature of fermentation as determining increase in normal flavour of the original wort fermented, since if the beer or wort flavour is in any sense crude and objectionable to begin with, it becomes magnified exceedingly during after-fermentation.

I prefer, therefore, that the decocted portion of grain should be raised only to about 200° or 205°, and kept at that heat for about fifteen minutes before being lowered to the mashing or final intermixture temperature of about 162°, while I believe this view of the subject is entirely confirmed by the proceedings of those English brewers who are at the present time practising the decoction process, even to the limited extent specified.

These preliminary proceedings occupy about one hour or one hour and a half, and lengthen the brewing-day consequently by that period, so that it may not be difficult to understand why so many working brewers strongly object to the adoption of a process which necessitates longer hours of working, or greater personal supervision. Length of brewing-day with decoction.

By glancing at the illustrations, readers will note that the proportion of grain reserved for decoction is carried by elevators from the ordinary mill or grist case to the decoction bin or grist case commanding the vessel below, intermixture being made through a very simple form of horizontal mixing machine, taking up but little room, and connected to a distinct liquor supply with all the usual fittings, gauges, check-thermometers, and appliances for controlling temperature of mashing liquor.

The final or complete mash is a very practical process, the decocted material being much more easily dealt with than raw grain, although in the case of a simple decoction mash it is advisable to prevent the decocted portion impinging too heavily upon goods when entering the mash tun, a splashing board being suspended below lip of mashing machine, to break as perfectly as possible the fall of decoction mash when entering the infusion vessel itself. Method of using decocted material in mash tun.

The decocted portion—very liquid, of course, on account of gelatinisation, solution, partial hydration of starch, and final dilution—when cooled down to mashing temperature, is used practically as mashing liquor, not entirely taking the place of liquor, however, but only to a certain extent. When starting the complete mash, the working brewer commences intermixture of malt with liquor, while, on having a depth of twelve or fourteen inches of entire malt mash on the plates of mash tun, he merely turns on the dilute decoction mash, minimising at the same moment the proportion of liquor previously used for intermixture, finally taking care to complete the intermixture of decoction mash prior to that of malt itself. The process, indeed, is very similar to that carried out when raw grain first came into use, but is far more simple in detail. While free from many of the difficulties attending raw grain brewing, on account of the relative buoyancy of decocted malt as compared with extreme gravity of similar decocted raw grain, success nevertheless in making the complete mash depends very much upon the skill of the individual brewer, as well as upon the necessary degree of dilution in the case of the decocted portion itself. If properly carried out from first to last, taps may be set at the usual period, and the wort will run off perfectly brilliant, while no difficulty will be experienced in obtaining the full available extract, which, generally speaking, is indeed a little higher, perhaps, than when dealing with similar malt upon ordinary infusion lines.

Decoction extract.

Some readers might wonder, perhaps, why a largely increased extract percentage should not result from the process described. This is sufficiently easy to explain, since, while we gain in character of extract by obtaining probably more starch and the hydrated products thereof in solution, every step taken in the direction of decoction must of necessity render material more sloppy and retentive, so that many of the lower forms of viscid malt extract are not so readily extracted by sparging as under other circumstances. It may be said, indeed, that by means of decoction we gain in quality of extract without appreciable increase in quantity, while in some instances slight loss is experienced on account of deficient drainage area or an imperfect intermixture of decocted portion of grain.

Results of decoction mashing summarised.

How can I sum up the results of the process? To begin with, I have explained that it does not always result in definite increase in dextrine percentage; it may or may not do so, according to character of malt dealt with, and variation in the conditions of decoction lines specified, but in any case we have increased brilliancy of wort, while beer exhibits a definite alteration in palate character, undeniable increase in body, and a well understood improvement in general stability. In other words, the process is thoroughly successful in practice, and sooner or later will prove, as I believe, a stepping-stone to the adoption of the German method of working—sooner, if Parliamentary steps are taken interfering in any way with so-called "vested interests;" later, if the brewing industry is allowed to remain, as in many cases it undeniably is, an unjustifiable, and in no sense recommendable monopoly.

Space will not admit of my referring in any greater detail to this very interesting process, and I trust that I have been fair in specifying that the decoction operation, as carried out in the mash tun itself, may in certain cases prove preferable in result to the process described, since no great expenditure is required for plant alterations, while, as a result of the method of working adopted, a more dextrinous beer is obtained, although, as I must contend, a fluid of coarser quality. Besides this, it will be clear that brewers carrying out this mash tun process fail to have the advantages of a smaller mashing plant, which may prove exceedingly useful in the several ways mentioned; and although I may suppose that a certain rivalry exists between the two working methods and their respective advocates, it certainly ought not to be an unfriendly rivalry in view of the varying results aimed at.

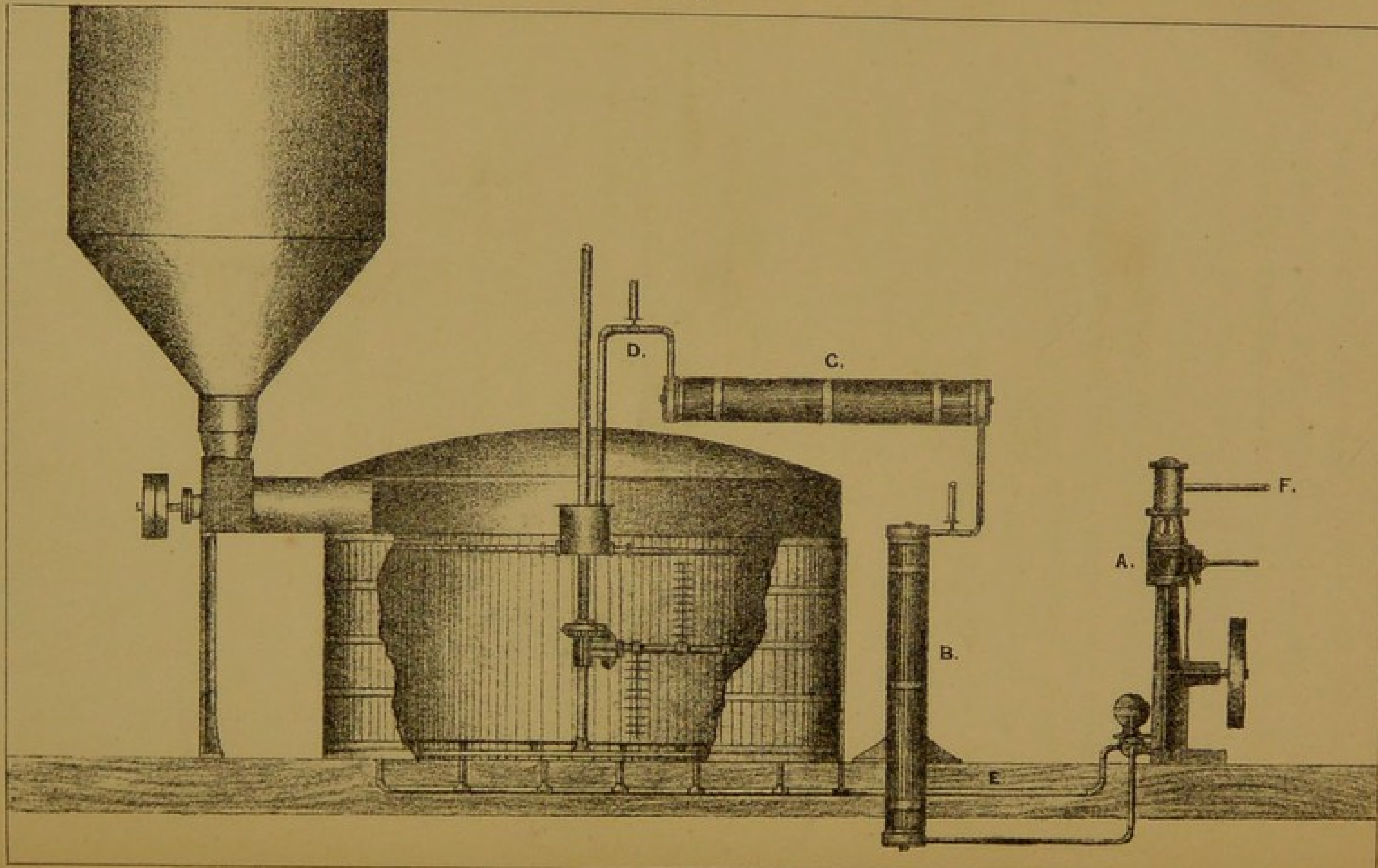
Hot circulation of wort.

The second process, carried out, as I have said, with the idea of completely revolutionising the ordinary transformation results of starch hydration, is in no sense entirely novel, since English brewers, within my own knowledge, have frequently used raw steam as a means of bringing up the temperature of a mash, while others have rapidly boiled the mash tun wort as passing to copper, or have set tap after a very limited period of standing, again returning a certain portion of this drawn-off wort, after boiling, to the mash. German brewers also, for a number of years, have carried out their Lauter maische proceedings, this being indeed the step generally taken on completion of decoction. On the other hand, I contend that in working hot circulation of wort, as I shall directly describe the process, hydration results are uniform and distinctive, whereas, in carrying out destruction of diastase and peptonising agencies by other means, nearly everything depends upon the length of time elapsing between the moment when the wort leaves the goods and the moment when its temperature is raised to a point destructive to the active nitrogenous matters existing in solution. Let me make myself, however, a little more clear. If we blow steam into a mash to destroy diastatic matter, the period of destruction will depend, not only upon the pressure under which the steam employed exists, but also upon the ease with which the steam vesicles make their way through bed of goods, and, as a result of possible irregularity, we have variation in transformation results. The same assertion applies when steam is used for effecting circulation of wort, much—and I use the word in wide sense—depending upon the steam

The German Lauter maische

Circulation with steam.

Fig. 2.



INK-PHOTO, SPRAGUE & Cº LONDON.

MASH TUN MULTITUBULAR CIRCULATING PLANT.

A. Combination Pump. B. Multitubular Heating Cylinder. C. Multitubular Cooling Cylinder. D. Supply to Sparge Dish. E. Supply to Pump. F. Air Pipe.

pressure, while if the flow of wort is rapid, the temperature of wort never rises to any very high point, the amount of steam employed being proportionately small, whereas if excess of steam be used, the circulating wort might soon boil.

Crockford's process.

Again, when carrying out Crockford's original process of wort circulation, or any modification of same, much delay occurs between the time when the wort leaves the mash and when finally arriving at a temperature destructive to diastatic energy, rapid hydration seeming to result during periods of delay through contact of wort with air, the action of a definite hydrating temperature, and as aided by distinct agitation while passing to the heating tank, which is generally placed over the mash tun itself.

Multitubular heater.

I claim, therefore, that in circulating wort by means of some simple form of pump drawing its supply from the bottom of the mash tun direct, and steadily throwing such wort through multitubular heater, hydration results are not only absolutely regular, but the brewer can determine with the greatest accuracy any particular dextrine percentage that he thinks most desirable.

Dextrine proportions in circulated worts.

ANALYSES OF SAMPLES OF WORT, SHOWING THE EFFECT OF CIRCULATION AT HIGH TEMPERATURES DURING MASHING ON THE DEXTRINE PERCENTAGES OF WORT.

	Spec. Grav. of Wort.	100 parts of Wort contain			100 parts of Extract contain			Ratio of Maltose to Dextrine.
		Extract.	Maltose.	Dextrine.	Maltose.	Dextrine.	Albumen, Ash, Inert Matter.	
I.	1090·28	23·47	15·89	3·74	67·70	15·91	16·39	100 : 22
II.	1100·0	26·00	16·44	5·12	63·23	19·70	17·07	100 : 31·1
III.	1095·0	24·70	15·10	5·35	61·13	21·65	17·22	100 : 35·4
IV.	1095·0	24·70	14·95	5·87	60·60	23·78	15·62	100 : 39
V.	1103·6	26·89	15·74	6·48	58·53	24·11	17·36	100 : 41

I cannot do better than ask my readers to study carefully the foregoing tabular statement, showing dextrine proportions in worts arrived at by the use of this very simple multitubular plant, making only the comment that any number of similar results obtained at different breweries might be given, although it is necessary to explain, perhaps, the variation apparent in them, much depending, as I have said, upon the exact temperature and duration of wort circulation itself, while character of grain dealt with constitutes also an important factor.

For instance, if we circulate wort at 185°—a temperature absolutely destructive to diastase and peptase—we do not effect any pronounced gelatinisation or solution of the vitrified starch of malt, and our extract will contain the normal 82½ per cent. of total sugars, while, on the other hand, if we carry on circulation for a prolonged period at 195° to 200°, we can see the influence of this, not only in a definitely increased dextrine proportion, but also in a larger yield of total sugars. This fact will be noticed if my readers will glance at the tabular statement referred to, and make a mental addition of the maltose and dextrine percentages indicated; they will find that in some cases they amount to more than 82½ per cent., this being, as they will remember, the normal proportion of combined sugars in all simple infusion wort extracts.

It will, I think, be now quite apparent that the results of hot circulation depend in main upon the following crucial points:—

Influencing agents during circulation.

First, the stage in the mashing operations at which we commence the circulation process; second, the temperature of circulating wort; and, third, the length of time during which we carry on such circulation. The class of malt dealt with and striking liquor heats will also have an influence as deciding the primary transformation results, so that, on setting tap at the end of forty-five minutes or one hour, the wort we intend circulating may have a totally different composition in one case as compared with that in another, and I must therefore supplement this statement by saying that it does not always follow that hot circulation will determine a distinct increase of from 10 to 15 per cent. in dextrine proportion, the percentage previously obtained by mere infusion influencing to a greater or less extent the final result.

As a general rule, however, the influences of hot circulation are seen to prove the correctness of my statements, the process equalising hydration results, leading to greater dextrine formation in the case of worts prepared from defective malt than would otherwise be the case, while in all instances we can greatly increase even the highest dextrine proportion attained when dealing with malt of fine quality, and striking it with liquor at a temperature that would not be possible—nay, would be absolutely dangerous—when dealing with material of inferior or even passable quality.

Effect of circulation on peptase.

If readers have understood my general comments so far, they will easily understand the criticism that can be passed on the process itself, since an ordinary scientist would say, What becomes of the peptase while practising this very ingenious method of determining reliable or requisite dextrine proportion? I must confess, of course, that in destroying diastase we should also put an end to the existence of the peptonising type of nitrogenous matter in circulating wort, but, as I before stated, there are many brewers employing defective material who find it preferable to regulate dextrine proportions in wort extract—even if the process carried out for determining this necessitates frequent yeast changes—than to study yeast reproduction at the expense of the palate character that dextrine is capable of determining, while I have carefully shown that if we recognise the true influence of the German decoction process, we can devise a means, perhaps, of determining recommendable reproduction of yeast, while still carrying out our hot circulation of wort as a means of regulating starch transformation results. I can state, indeed, as an absolute fact, that it is perfectly possible for a brewer working the hot circulation process to raise the initial heat of goods by at least sixteen or eighteen degrees, this being accomplished, be it observed, without any dilution of malt extract.

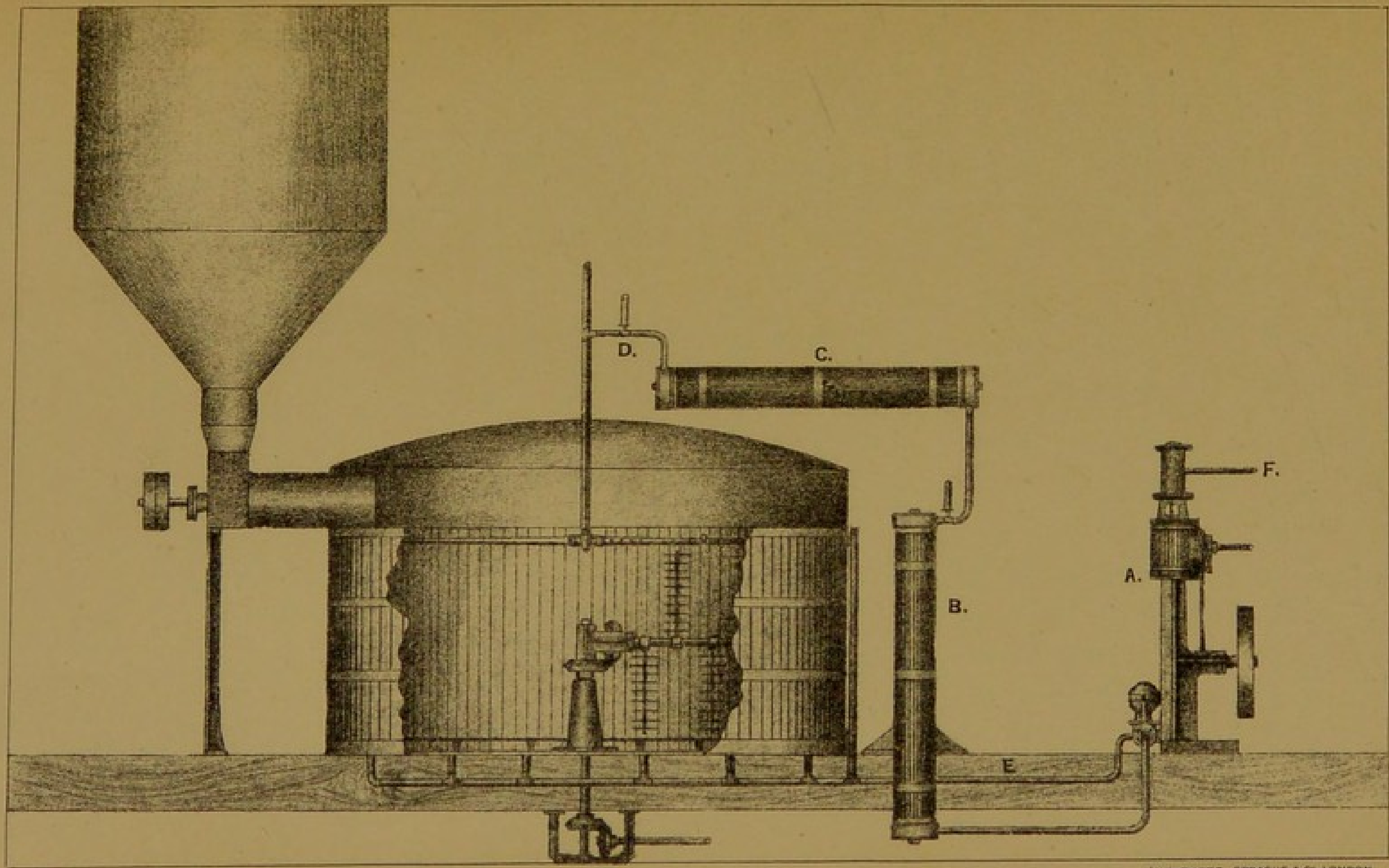
Peptonisation facilitated by low initial.

As a necessary consequence of this statement, it is perfectly reasonable for a brewer practising the process to obtain first of all a preliminary infusion heat of 140°, or even lower still, this deciding extreme solubility and extended activity of nitrogenous matter in the direction of very definite peptonised condition of same, if we can only leave such mash standing for a period of forty-five minutes or one hour before eventually bringing up the heat to 158°, or even higher, by the aid of circulating wort.

Construction of multitubular heater.

There is, I may say, nothing very peculiar in the construction and action of a multitubular circulating heater, since it is similar in every way to the steam boilers with similar prefix, *i.e.*, it constitutes a cylindrical arrangement in which we secure the greatest possible heating area, so that, within the compass of a small multitubular cylinder, we can bring up the

Fig. 2a



INK-PHOTO, SPRAGUE & Co LONDON.

MASH TUN MULTITUBULAR CIRCULATING PLANT.

A. Combination Pump. B. Multitubular Heating Cylinder. C. Multitubular Cooling Cylinder.

D. Supply to Sparge. E. Supply to Pump. F. Air Pipe.

temperature of a considerable body of wort very rapidly, so long as our steam heat, as determined both by boiler pressure and the volume of steam passing through the heater itself, is sufficiently intense.

Again, direct pump connection to mash tun is a matter of considerable moment, although any definite suction must be prevented by the erection of a simple stand-pipe. Wort so pumped flows steadily (without any intermixture of air acting as a cushion), the pump driving the wort effectually—that is, causing it to perfectly fill the tubes of heater. If brewers, on the other hand, employ ordinary pumps and suck wort from the underback, and throw such wort through a multitubular heater, they are invariably disappointed in results, since the heating agency at once becomes very variable through irregularity of wort supply; a similar variation being caused also by the retention of mash wort in some intermediate vessel prior to passing it through the multitubular heater.

Pumps for circulating.

By glancing at the sketch, my readers will see that this multitubular cylindrical heater is attached to the side of mash tun and connected to pump, which is itself in connection with the bottom of mash tun, the delivery tube commanding sparge dish.

Every arrangement is devised for effecting the rapid cleansing of the entire arrangement, which is perfectly under control, although, to ensure regularity of heating agency, it is advisable in all cases to connect the steam exhaust to boilers direct, this being far preferable to the employment of steam traps, which are not, as a rule, I think, to be depended upon for determining absolute regularity of pressure. It must be remembered also that as boilers frequently prime very considerably, necessity arises for cleansing the exterior, as well as the

Cleansing of circulation plant.

interior, of multitubular steam-pipes, which become coated with a deposit of wort extract on inner, and saline matter on outer surface, while it is recommendable also to connect the suction-pipe of pump to hot liquor tanks, so that on completing the circulation of wort the arrangement can still be utilised for sparge liquor until multitubular plant is perfectly free from wort itself.

Heating capacity of cylinder.

It will be advisable for me at this point to give some idea, not only of the heating capacity of the cylinders, but also of the increase in initial heat of mash which may be effected when some definite bulk per quarter of mash wort is circulated at a temperature ranging say from 185° to 195°. I can best explain this by saying that the size of multitubular heater is so regulated for each plant that one barrel per quarter of mash wort can be usually circulated in a period of thirty to forty-five minutes at a steady temperature of 190°. If, on the other hand, the individual brewer prefers to decoct the wort (that is, to actually boil it) and again cool to the stated temperature of 185° or 190° before re-sparging on to goods, the multitubular heater would, of necessity, be constructed with a greater heating area, while the delivery pipe would convey contents to a corresponding multitubular cooler to reduce the temperature of decocted wort to the stated heat before re-sparging on to goods, so preventing any excessive gelatinisation of vitrified starchy matter or the extraction of too intense a form of husky flavour, a defect that might result if the decocted wort was actually resparged at boiling heat.

Rise of heat in mash.

The next question is in reference to the corresponding rise in initial heat of mash, and from repeated experiments on a large scale, I have found that an available range of about ten to fifteen degrees is possible in the period of time named if the first initial is about 145°, although this range would vary a little in one direction or another, according to exact primary initial heat of mash arrived at.

Résumé of results obtained by circulation.

As for the results of this very interesting process, they are indeed beyond question, while brewers carrying it out can at will adopt the very important principle of low infusion heats, with corresponding extraction of favourable types of albuminous matter and peptonisation of same, for a period say of an hour and a half before utilising hot circulation of wort as a means of rapidly increasing dextrine proportions, and getting rid of many of the more objectionable forms of albuminous matter that a low infusion heat wort would undoubtedly contain. This particular process, in short, is a distinct step in the direction of Continental working, depending, as the German decoction method does, upon low infusion heats as determined by comparatively cold water mashing, and after-decoction of material and wort combined.

Circulation preferable to decoction for delicate beers.

The process specified appeals also, with greater force, to the producers of superior beer who might object to absolute decoction flavours, while yet desirous of arriving at definite dextrine percentages. In all cases it is well to remember that the preliminary low infusion heats should be allowed to exist for some little time, while good material would of necessity have to be used in order to render the process thoroughly successful, since if faulty malt be employed, yielding, as it would, a low proportion of amides, hot circulation of wort, especially if practised early, would still further minimise the possibility of successful yeast reproduction in the wort obtained.

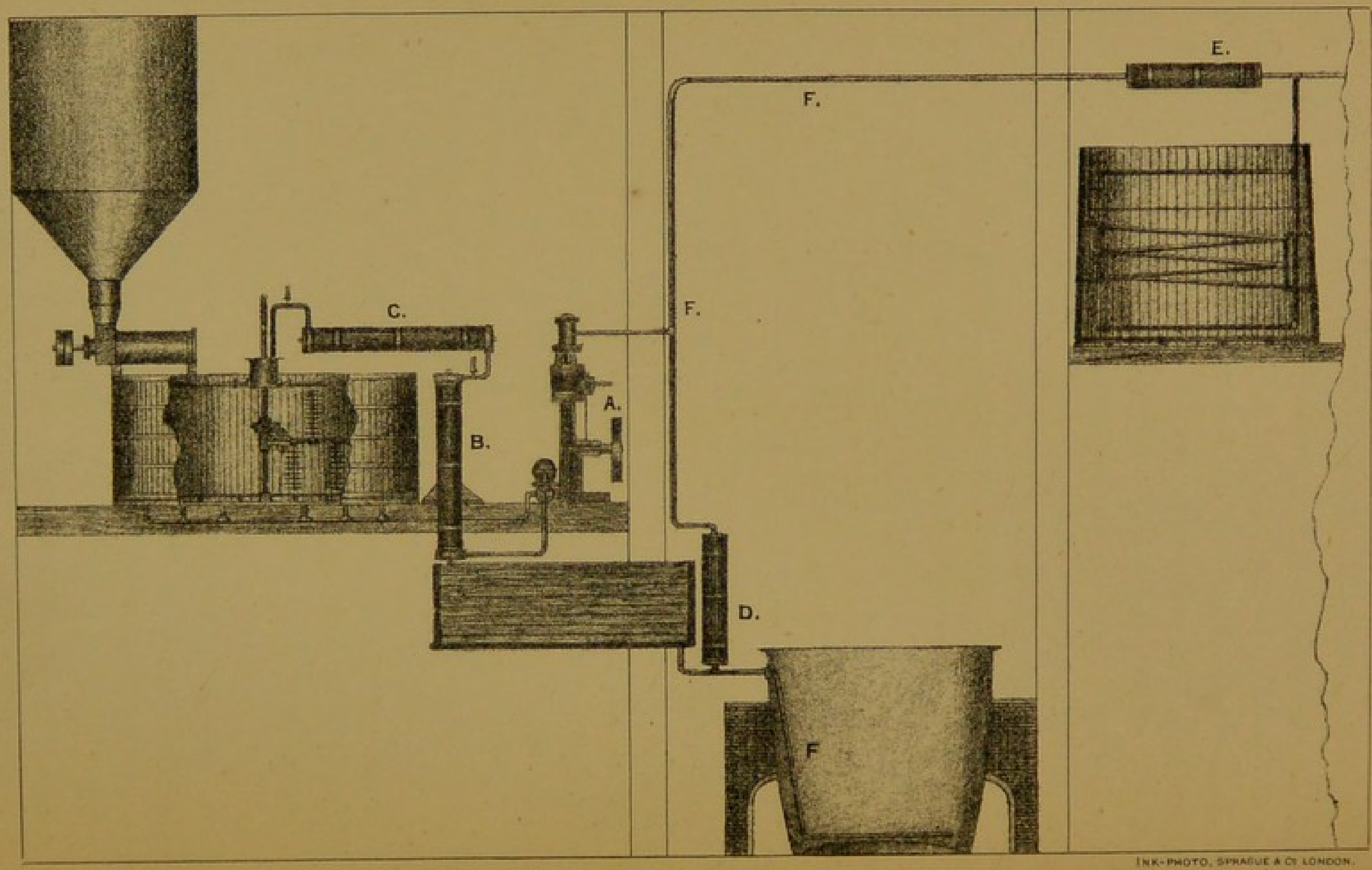
I believe that the illustrations, which are fairly detailed, will enable readers to understand the general arrangements of plant specified, while as decoction of wort is notably different from decoction of malt, I have thought it well to enter into considerable detail in describing the former process and the means of carrying it out, and can assert, with the greatest confidence, that if properly worked, no difficulty whatever will be found in the after ready fermentability of the wort so treated, which, on the other hand, will undergo vast improvement in two very distinct directions, the normal dextrine proportion being considerably increased, while the semi-decoction of wort eliminates many forms of nitrogenous matter that are in no sense of any value.

Hot aëration during circulation.

Before concluding this chapter, I must refer in a brief manner to the subject of hot aëration, since many brewers prefer to bring such influence into operation during the early stages of their infusion process, introducing the heated air, in fact, during the circulation of mash wort itself. Some years ago I fancied in my ignorance that hot air could be utilised as a forcing power, but of course soon found that it was entirely unsuited for this purpose, so that I was compelled to abandon my original idea of circulating wort through a multitubular heater, driving the wort by the agency of hot air under pressure, and adopt instead the most simple form of pump that could be devised, introducing the hot air during wort circulation or at any convenient later stage.

It will surprise many of my readers to know that hot air existing under pressure has no particular heating capacity; in other words, much of the heat attaching to such air corresponds only to its degree of compression, so that when released from pressure, on escaping into wort, it naturally expands, rendering heat

Fig. 4.



HOT AND COLD AERATION PLANT.

A. Combination Pump. B. Multitubular Heater. C. Multitubular Cooler. D. Air Heater.

latent in consequence, and in many cases actually cooling the wort in place of causing a definite rise in temperature. In order to determine any direct heating agency the hot air itself would have to exist at an extremely high temperature, *i.e.*, for hot air to possess heating agency there must be a vast relative difference between the temperature of the fluid to be heated and that of the air used for the purpose of causing increase in temperature. This explains why it is perfectly safe to introduce compressed air at a temperature of 270° into wort existing at 165°, since for the reasons stated no actual heating would take place, the relative difference between the two temperatures in question not being sufficiently extreme.

Air-heating apparatus.

There are various means of arriving at what I term hot air, the most simple arrangement being that of a definite heating cylinder with an air pipe passing through it in spiral form so as to determine great heating surface, while steam under pressure is utilised in the cylinder for the purpose of imparting the necessary temperature to the air to be utilised for the specific purpose named. This arrangement, of course, necessitates suction of air to begin with, this facilitating filtration through cotton wool, while the force of pump in driving such air through spiral coil of cylinder determines a pressure, which, as I have before said, has a great deal to do with the temperature eventually arrived at. That is, the temperature of compressed air is fictitious in a certain sense, and corresponds in no small degree to variations in pressure. Brewers working such plant have, indeed, often been surprised to find that the quicker the speed of pump-engine, the higher the temperature of air passing through spiral heater, and *vice versâ*. So much then for hot air and

Fictitious heat of compressed air.

the means of obtaining it; let me try and explain now its supposed influence when used.

Influence of hot air on strong wort and weak runnings.

May I suggest that readers interested in this special subject should pass some hot air through a strong mash tun wort; they will find in result that the fluid will become perfectly turbid, while if they carry on the same treatment with a series of samples of varying gravities, they will soon see that weak worts apparently contain less nitrogenous matter capable of undergoing oxidation and elimination by such influence than strong worts, this giving a direct clue to the practical fact that when definite hot aëration of wort is carried on, it is far more recommendable in the case of strong worts than in the treatment of those of lower gravity.

Does not this explain also why practical brewers have always stated that it is far easier to produce a table beer of stable character than one having double the gravity of such variety? Is it not a fact also that when brewers are in difficulties, they experience greater trouble with an intermediate description of fluid, *i.e.*, one containing a considerable proportion of strong wort, while not protected by any great alcoholic strength or percentage of hop extract?

If my readers will carefully consider these important assertions, they will admit, I think, that they throw considerable light upon many of the troubles attending the operations of brewers at different seasons of the year. It is indeed quite erroneous to regard all weak runnings with disfavour, in view of the fact that a very weak wort resists oxidation change, while those of considerable strength are apparently suggestively open to it.

Clean worts.

I am perfectly aware that scientists might be inclined to dispute this statement; but in view of all that takes place when working such aëration plant, the comparative cleanliness of the coolers after the passage of worts over them, the freedom of the refrigerators from the unpleasant white deposit which, during the passage of strong wort, or those not aërated at all, frequently makes its appearance, I may conclude, I think without much doubt, that brewing readers, at any rate, will admit that if such decided cleanliness of wort results from hot aëration, it is at all events a process practically recommendable, no matter what the particular view of the scientist may be who deals only with fractional portions of wort, and determines percentage amides and other forms of nitrogenous matter by processes, which, to say the least, are not always very reliable in result.

Theoretical view.

Continental aëration.

Many of my readers no doubt know that a Continental brewer is in the habit of either boiling wort for a very prolonged period under slight pressure, or even in certain cases double-boiling it, the after cooler process being also very lengthy. May I not ask why they should take all this trouble unless they are thoroughly aware that air, either naturally absorbed or introduced into wort, has an enormous influence upon the after non-changeable character of extract present in the beer produced? No scepticism can exist as to this, while a simple experiment will, I think, sufficiently prove the truth of the statement, since if any one will take the trouble to submit cooler-wort to ebullition in a beaker, he will observe that it is capable of throwing down a second copious precipitate, although presumably such wort should have precipitated all its possible coagulable matter during the copper process, and we must conclude, therefore, that it gained the capacity of throwing down a second portion of coagulable matter after

Aëration of cooler-wort.

leaving the copper and passing to the cooler. This means, in point of fact, that such capacity has been attained on account of the wort taking up air after leaving the copper and while remaining on coolers.

It was indeed to save this tedious process of double boiling that I suggested the application of air directly introduced into copper wort, having previously applied the principle some years ago to the manufacture of vinegar, with the idea of minimising the proportion of albuminous matters existing in wash that would otherwise precipitate during the ullage of vinegar itself.

It would be tedious to enter into any great amount of theoretical detail in reference to such statements, since the truthfulness of my general argument is most easily proved, as I think, by the simple experiment suggested, and I cannot therefore agree with the views of mere chemical scientists who attempt to show that there is no difference in the percentage of nitrogenous matters present in wort after pronounced hot aëration has been determined.

Cold air during fermentation.

The plant illustrated has, of course, a second office to perform, viz., that of supplying cold pure air, if the type of yeast undergoing cultivation requires any such supply in order to render it capable of extended alcoholic action or increased assimilative capacity. I shall have to deal later on, however, with this part of the subject, so that a brief reference to it will now suffice.

Cooling influence of aëration.

Compression, of course, has the same influence in deciding temperature of cold air as that of hot, and in this way we can secure a direct advantage, since if we deal with cooled compressed air we secure increased cooling capacity through this agency, since it again expands when liberated from air pipe, and in expanding becomes still colder. This is exactly what takes place when passing nominally cold air through a spiral tube placed in a cylinder, through which cold water is constantly flowing, while to prevent any undue heating by primary compression, the air cylinder of combination pump itself is also surrounded by a water jacket.

While in no way pretending that such supply of cold air can be used definitely for cooling any large extent of atmosphere, it is still of the utmost usefulness in facilitating a supply of cold pure air that can be blown over surface of fermenting wort, as also for introducing similar air, when requisite, into the wort itself at certain intervals during prolonged fermentation, although it must be remembered that the quantity of air so introduced should be strictly limited, while, having an extreme influence, it must of course be used with due discretion, the energy of its action, indeed, proving the usefulness of it for the specified purpose.

Arrangement of air pump.

In order that the construction and working of the air pump may be clearly understood, it is well to point out that it constitutes what may be described as a combination arrangement, a single piston rod running through three cylinders—the upper one being the air chamber, the second cylinder the steam chest, while the lower one constitutes the pump for wort circulating purposes, which may be disconnected, of course, if not required.

Filtration of air.

In concluding these remarks I have only to observe that all air dealt with is purified by filtration through cotton wool, kept more or less constantly changed, while, as lubricants are of necessity employed to a limited extent in cylinders, it is advisable to filter the air a second time through cotton wool in order to remove all traces of oily matter.

Résumé.

I have thus attempted to describe in my appendix chapter on mashing how infusion worts can be modified in a variety of ways; and if proper care is taken in reference to class of material employed and preliminary infusion heats, it will be evident to readers that we can not only secure the requisite proportion of albuminous matters for yeast aliment, but at the same time an equally recommendable dextrine percentage, while finally eliminating from the mash wort, by direct oxidation, and after ebullition, many of those forms of alterable albuminous matter which are so very objectionable as constituents of finished beer.

CHAPTER III.

BOILING OPERATIONS: THE DIFFERENCE BETWEEN STEAM AND FIRE HEAT—THE MEANS OF OBTAINING PURE STEAM—THE RELATIVE DIFFERENCE BETWEEN RAW STEAM INJECTED AND STEAM EMPLOYED INDIRECTLY THROUGH COILS—WATER-SOFTENING PLANT.

Corrective influence of boiling.

HITHERTO it has been supposed that the boiling operation constituted the first definite corrective process carried out by the English brewer in reference to the character of mash wort, *i.e.*, in submitting the wort to ebullition with hops we not only take into solution desirable forms of hop extract, but eliminate, under the influence of extreme heat combined with that of hop extract, or the more astringent bodies that it contains, many other forms of nitrogenous matter that would otherwise resist mere heat coagulating influences alone.

In view of the statements that I have made in the chapter on mashing operations, we must, I think, give up the idea that boiling constitutes the first corrective method of the brewer, since I have specified several other important agencies in that chapter, but we may nevertheless still hold fast to the belief that true ebullition, if thoroughly carried out, must of necessity have an enormous influence upon the character of wort boiled, as also upon that of resulting beer. It is not too much to say, indeed, that many brewing troubles that crop up during the summer months can, in many instances, be directly traced to inefficiency of ebullition having been allowed to pass without notice, while so many arrangements, of doubtful utility, in this particular direction, have been fitted up in breweries of late years, that it will perhaps be advisable that I should clearly explain the differences that exist between the influence of steam and fire heat, and the relative value of steam heat itself as directly or indirectly applied.

Inefficient ebullition and its results.

First of all let me touch upon the subject of heat. What do we mean when speaking of this? Simply the liberation of heat units from carbonaceous matter undergoing combustion, which we either directly apply, *i.e.*, pass straight into the wort contained in our copper, or which, on the other hand, we employ indirectly as a means of converting water into vapour, storing up these heat units in the steam under pressure, and finally using such vapour as a means of raising the temperature of our wort, either by passing it directly into the fluid itself, or indirectly applying it as it passes through coil or jacket of boiling pan.

Heat, and its production.

The majority of my readers will remember, no doubt, that the temperature of steam is, in a sense, somewhat fictitious, or in other words that a great number of heat units are locked up in steam in latent form, and remain locked up so long as the water exists in the physical form of vapour, so that when we employ steam indirectly we do not utilise any of these latent heat units for cooking or caramelising purposes, but depend merely upon the apparent heat of steam as existing under pressure.

Latent heat of steam.

Now this apparent heat of steam varies enormously according to pressure, standing at about 212° under ordinary atmospheric conditions, and rising to as high a limit as 260° or 270° under a pressure of three atmospheres, or 45 lbs. per square inch. I wonder how many brewers recognise this particular point, or take steps in the direction of determining constancy of pressure while using steam for boiling purposes? Surely they can see that unless such pressure is uniform, the apparent heat of the steam will fluctuate more or less when passing from the boiler, and finally making its free exit through coil or jacket. It is very difficult, of course, to determine an equilibrium of pressure in such arrangements unless the exhaust pipe carries the steam back again to the boiler whence it came, while it is not all copper jackets or coils that are capable of withstanding the boiler pressure that alone decides a thorough efficiency of steam heat indirectly applied.

Apparent heat of steam.

If I am understood so far, readers will readily see how preferable raw or naked steam must be to the same vapour indirectly applied, if only it can be safely used in copper wort, since in this case we not only have the full influence of apparent heat as determined by boiler pressure, but, on account of the actual condensation of steam in the wort itself, we bring into operation that latent or hidden heat that has previously been keeping it in the physical form of vapour. It is for this reason that the temperature of naked or raw steam is vastly superior in every way to that of steam indirectly applied, and no words of mine could possibly emphasise too much the importance of this statement.

Superior heating power of naked steam.

Let me give an example or two in order to prove my point. If some brewing reader, who has suffered from persistent sluggishness of clarification in the case of

Naked steam and clarification of beer.

mild beers not possessing the influence of hop extract to any large extent, will only submit his worts to ebullition under the influence of raw or naked steam, he will soon discover for himself the enormous power that such heat so applied has of determining the possible clarification of beer not otherwise very readily secured.

Or let me take again the example of sugar inversion.

Naked steam for sugar inversion.

It is no easy matter to accomplish complete hydration of sugar in any reasonable time through the agency of limited acidity at a mere boiling temperature, but if we effect ebullition under the influence of raw or naked steam directly introduced into the dilute syrup, hydration invariably results not only much more quickly, but is actually completed thoroughly, the difference in results as determined by the two methods of ebullition being very striking.

I do not for a moment suppose that either form of steam heat can readily be considered so efficient as that of fire, for in this case the heat units are not limited to anything like the same extent; but, personally, I should always prefer to determine ebullition of wort through the agency of pure naked steam, than rely upon the same heating agency that may possibly be faultily applied in some indirect manner.

Boiler feed-water.

Now the question at once crops up as to whether it is recommendable to utilise steam in a direct manner in face of the fact that the feed water of many boilers is more or less foul, while as priming possibly goes on the resulting steam can hardly be regarded as absolutely pure. This kind of comment is worthy of due attention, because, if desiring to employ raw steam for any purpose in the brewery, it is always advisable to take steps to ensure its absolute purity, and nothing perhaps is easier if we only take care to feed our steam boilers with water of reasonable quality.

There are few readers, I imagine, who fail to recognise that the steam-producing capacity of a boiler soon becomes seriously minimised by scale formed by the continually subsiding sedimentary matters, and I think it advisable, therefore, to describe a process by which we can not only vastly increase the steam-producing power of boilers, but at the same time secure a supply of steam, that is recommendable in point of purity.

Methods of softening boiler feed-water.

Many large manufacturers have, within my own knowledge, during the last year or two adopted a most simple device for effectually softening boiler feed-water, not, I admit, on any very novel principle so far as artificial treatment for effecting actual softening is concerned, but through the agency of very ingenious plant, which has been much improved in detail during recent years, and rendered far less costly than when first introduced to the notice of sugar refiners and other large users of steam, who, in using the plant, score immense advantage through economy in the consumption of coal, and in obtaining pure supplies of steam for their several purposes.

Chemical processes.

Mere chemical softening of boiler feed-water is, of course, a very simple matter, since by neutralising free and loosely combined carbonic acid we immediately precipitate lime and a portion of the magnesic carbonates, while we can decompose and convert gypsum into sulphate of soda by the addition of sodic carbonate, precipitating the bye-product of the reaction as an insoluble carbonate of lime.

The practical point, however, is to get rid of these subsiding saline matters in the treated water, as their natural gravitation from a large bulk of fluid would be, of course, a lengthy process. The problem, then, is to facilitate separation of saline matters by some agency that can practically be brought into play without any great amount of trouble or expense. This has been accomplished by Messrs. Howatson, whose water-softening plant I illustrate, the principle of this arrangement depending upon the influence of surface attraction, the feed water duly softened, and possibly heavily charged with subsiding saline matters, passing slowly through narrow channels composed of some material exercising powerful attractive influence for the suspended bodies in question, the channels spoken of being composed of plates placed so close together that the film of water flowing through intervening space is relatively very slight in point of bulk.

Howatson's plant.

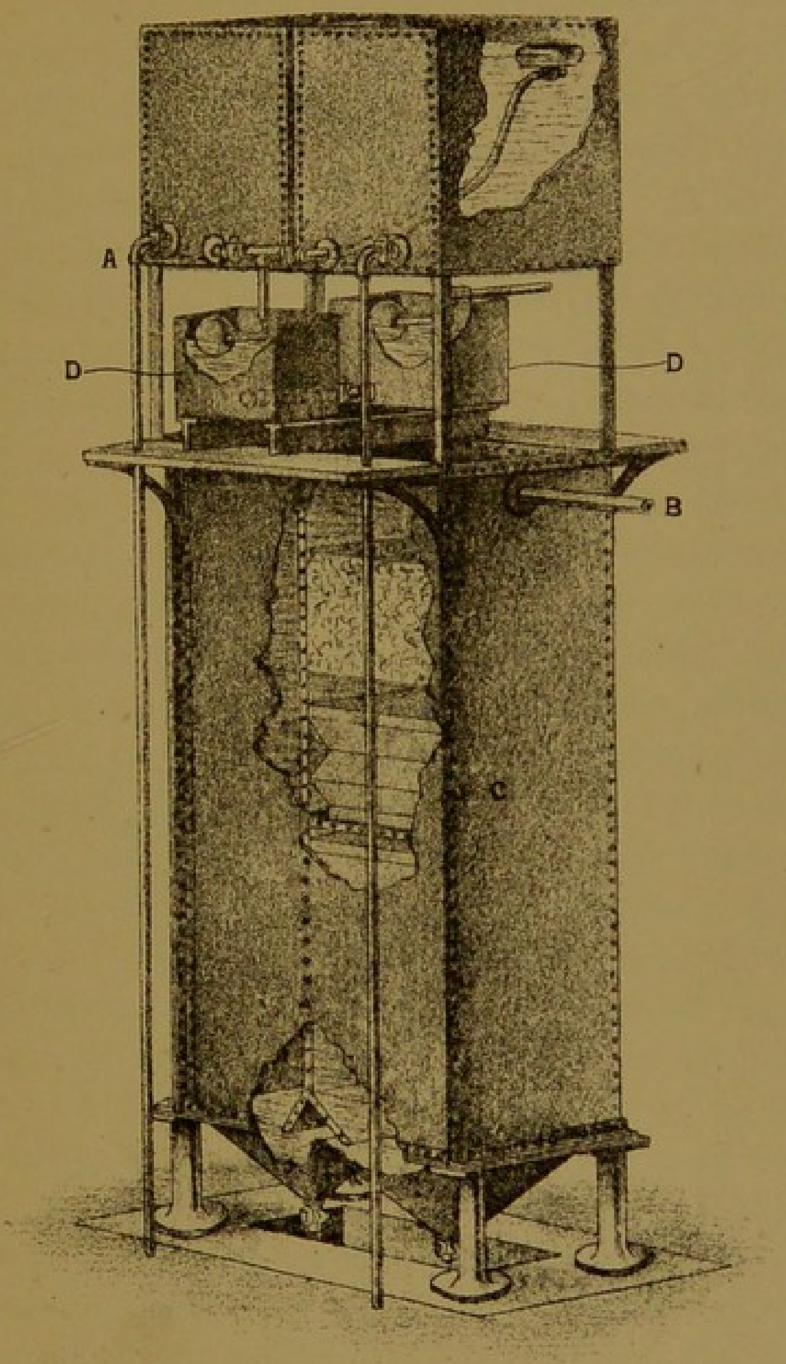
Through the action of this machine (which, I may say, is strictly automatic, and the details of which will be readily understood by glancing at the illustration), the water passing to boilers is not only artificially softened, buc cleared of all suspended bodies, saline or organic, so that, by the time it reaches the outlet of purifier, it is perfectly soft and clear, and, as a feed supply, is incapable of throwing down a sedimentary deposit or scale, while, of necessity, eventually yielding steam of great purity. I can confidently recommend this plant to the notice of those brewers who read between the lines, and estimate aright the true influence of raw steam, while recognising that when used it should, in all cases, be sufficiently pure.

To return, however, to the question of wort-ebullition. Are there any other points worthy of notice in discussing this important subject?

Pressure during ebullition.

To begin with, there is that of pressure, which, if

Fig. 3.



INK-PHOTO, SPRAGUE & C° LONDON.

HOWATSON'S WATER SOFTENING PLANT.

A. Inlet. B. Outlet. C. Subsidence Filter in Section

D. Tanks for Precipitants.

definitely applied, determines increase in temperature of ebullition by preventing free escape of vapour, which practically means fixing in the wort undergoing ebullition a greater amount of heat units than would be present if free evaporation took place.

Both German and American brewers have recognised the importance of this statement, but, seeing that it would be perfectly impossible to boil a pale beer wort under any very permanent or constant pressure, as evidenced in the working of a closed copper, our Continental and American friends have skilfully adopted the principle of limited pressure, this being occasionally applied during the boiling process with the best possible results. For instance, I heard quite recently of a weak (13 lb. or 14 lb.) beer being actually boiled for a period of eight hours under a slight pressure, intermittently applied, so that, after a considerable stay on cooler, the collected wort was absolutely brilliant when cold, so constituting a non-fermentable kind of weak beer, incapable of either fretting down in gravity during attenuation, or exhibiting any tendency to fretful change when finally placed in shipment casks.

Intermittent pressure.

Great changes, too, have taken place even in the English brewers' process during the last few years. Copper worts are, indeed, far less viscid than they were, partly on account of sugar use and the extended employment of thin varieties of grain, but partly also in consequence of the production of weaker beers, or fluids less heavily hopped in proportion than those of higher gravity.

Influence of viscidity.

Now, as we diminish the viscidity of a fluid under such influences as those specified, we directly favour, of course, the escape of heat units locked up in latent form in the vapour passing off, so that mere evapora-

Evaporation distinct from "cooking."

tion is no certain sign of true caramelising or cooking influence, but only shows that the wort is sufficiently limpid, and the mechanical agitation of boiling or rapid evaporation sufficiently energetic, to decide an extreme escape of vapour and corresponding loss of heat units which, if concentrated in the wort, would have determined the greater cooking or semi-caramelising influence required. In this statement, then, we have both a simple and conclusive explanation of the thorough inefficiency of many boiling operations, since, in these cases, we may, of course, pass into our worts a large amount of heat, but, unfortunately, allow it to escape again before it has determined its true influence; our coppers, under such circumstances, descend to the level of mere evaporating pans, the boiling operation, indeed, being very different in every way to that which would have resulted with diminished evaporation, as, in the case of a deep vessel, covered with a dome to prevent free escape of vapour and facilitate rapid increase in pressure.

Limpidity of wort necessitates prolonged boiling.

It may now be clear to my readers why, during recent years, it has been necessary for them to extend boiling operations in point of time, although some of them have not, I fear, looked into the question of efficiency as a corresponding factor. Our copper worts, indeed, have, for reasons already specified, become more and more limpid, so retarding in minimised degree convection of heat vesicles (*i.e.*, minute globules of vapour, passing in myriads through the fluid undergoing ebullition). We have been, I think, too apt to accept mere mechanical violence of ebullition as proof of efficiency, and have frequently aided such mechanical motion of fluid by placing fountains, domes, and other appliances in our coppers to prevent wort boiling over,

Fountains, domes, &c.

entirely forgetting, while doing so, that we are deliberately facilitating the very escape of heat that is so necessary to determine true efficiency of ebullition.

In the next place, brewers have, often unwittingly, adopted steam boiling pans in which steam heat indirectly applied has been most faultily used, no attention whatever having been paid to the pressure under which it existed, or as to whether condensation resulted in its passage from boiler to coil or jacket. Others have allowed boilers to prime in such a way that, in place of steam passing forward to accomplish its work, even indirectly in pure vapour form, it has existed overladen with priming water, which has still further tended to determine increased condensation and reduced pressure, while in result we have found such brewers extending their boiling periods in the vain hope of determining greater efficiency of ebullition, oftentimes discovering to their cost that mere extension in period of ebullition can in no sense make up for deficiency of caramelising influence, not existing, be it understood, as an actual colouring agency, but determining a curing of wort in a similar sense to that when employing the same expression in reference to malt. A better word, perhaps, is that of "cooking," which means that, in submitting wort extract to a suitable temperature, we so modify it under the influence of heat that it is far less changeable in its general nature than before.

Condensed water in jackets and coils.

Curing wort.

"Cooking."

What is the conclusion that we may come to when mastering all these points that underlie the whole question as to efficiency of boiling operations? Simply this, that it is far easier to ensure efficiency of ebullition by means of direct fire heat than to accomplish it by the aid of steam, while the influence of steam indirectly used is frequently disastrous, since, in applying it, we

Fire heat.

oftentimes forget the points that control its efficiency when so employed, such, for instance, as the quantity passing to coil or jacket, or the pressure under which it exists.

We cannot be surprised, therefore, if the organic fluid we are attempting to correct by means of ebullition, should sometimes exhibit a very changeable character, proving most completely that we have failed in our object. If this is the case with brewings produced by any of my readers, let me strongly advise them to rectify their steam boiling operations, to apply a pressure gauge to their coil or jacket in order to ascertain the temperature of steam used as indicated by pressure, and to take due notice also of the quantity passing through the coil or jacket in a given limit of time. If the steam supply is insufficient in quantity, either through defects of boiler or natural condensation, let them see if they cannot obtain a pure supply, and employ this direct as injected into wort, condensing such vapour, and so deriving benefit, not only from its heat under pressure, but also from the latent heat which comes into play as an influence when liberated from its hidden form, such liberation, of course, taking place immediately on condensation resulting.

Pressure gauge for steam supply.

Then again, when erecting any new form of boiling plant, let them remember that shape and depth of vessel have an enormous influence, a narrow copper definitely restricting convection, a deep one determining also increased pressure and consequently increased heat. It is impossible, of course, to advise the general employment of dome coppers, since these can be used with advantage only in the case of black worts; but surely if it is necessary in the case of a black beer brewing to employ a closed copper for a definite purpose,

Form of boiling vessel.

Dome coppers.

it is equally necessary to bear in mind the influence that pressure possesses when dealing with the case of pale ales! If I am understood rightly, I have mainly tried to show that the influence of pressure is chiefly evidenced in the direction of increasing heat during ebullition, although pressure at the same time may possibly exercise an influence of its own, while deciding more perfect action on the part of a certain degree of heat when this is determined through its agency.

It is easy to see, therefore, that when we are not dealing with viscid worts which sufficiently restrict convection of heat vesicles on account of their own viscid character, and we cannot commendably employ direct pressure, it is always advisable to make up for deficiencies in this direction, and for what I may term the necessary or accidental absence of mechanical methods of determining pressure as an influence, by utilising for our purpose degrees of heat that can accomplish that exact cooking of extract which is so essential a point in practical brewing, while I presume that I have already sufficiently specified the meaning of this statement.

Solution of boiling difficulties.

The simplest way out of all difficulty, if this should arise through inefficiency of heat, is to obtain first of all a pure steam supply in the way that I have described, *i.e.*, by effectually softening the feed-water of our boilers, and to use such pure steam in the copper wort direct, gaining not only, as I have said, the violent mechanical motion which its introduction would determine, but at the very same time the definite heating influence which is so invariably necessary.

It is not too much to say that the brewer, in many cases, should actually look with suspicion on the violent mechanical motion that copper wort sometimes undergoes, indicating, as this does, the very rapid escape of heat vesicles, and it would be well for us all, before regarding such form of ebullition as perfect, to satisfy ourselves that the amount of heat introduced into wort is more than sufficient for the required purpose, so that excess may be allowed to escape, and cause the violent mechanical agitation commonly indicating a so-called vigorous boil, but not always, as I contend, proving the actual cooking of wort extract that is necessary.

Vigorous boiling.

Résumé.

In this third chapter, therefore, I have tried to make plain why brewers would do well to give increased attention to their boiling operations, since in the vast number of cases fretfulness, sickness, persistent turbidity and general changeability of beer may be directly ascribed to inefficiency of ebullition, a practical brewing process not correctly understood, I fear, by all brewers, and the real object of which is sometimes rendered absolutely impossible of attainment by mistakes made by the brewery engineer, who frequently imagines that if he can erect a vessel in which wort can be evaporated, and ebullition be denoted by mechanical movement of fluid as resulting from the escape of steam vesicles, he must have provided what the brewer actually requires for his purpose. I have tried to make clear that it is not so, while as a last suggestion I should recommend those who see no other way out of the difficulty, to test for themselves what can be accomplished through the agency of the double boiling process, incidentally referred to in the chapter dealing with the subject of hot aëration of wort.

In a few words, ebullition, indeed, is capable of leading to the coagulation of certain forms of wort extract, partly *per se* and partly when such matters have been modified under the astringent agency of hop extract, or partially oxidised under the influence of air either absorbed from the atmosphere, or directly pumped into wort. The hot air plant, illustrated and previously described, is used for introducing this necessary quantity of air, not when the hops are in the wort, since in this case such introduced air might oxidise and unnecessarily disintegrate hop extract, but during the collection of those portions of entire wort which contain the excess of precipitable matters.

Now this applies directly to the principle of double boiling, since readers will see that if wort is pumped to the cooler it naturally absorbs air during its passage from hop back and during the time that it remains exposed on cooler floor, while the mere fact of its throwing down a second copious deposit on being reboiled, proves that such air must have modified the character of wort extract, so that on again being boiled the wort is no longer able to hold it in solution.

If I have succeeded, even by constant repetition, in making clear the very important point that great results are secured through the influence of ebullition, when correctly understood and wisely determined, I shall be content.

I have specified in detail the means of ascertaining whether the heating influence is inefficient in its agency, as also the various means of determining thorough efficiency when this is found to be faulty, and I can, therefore, pass on at once to the consideration of an equally important subject, constituting the text of succeeding chapter.

CHAPTER IV.

FERMENTATION: THE CONNECTION BETWEEN OXYGEN AND YEAST—COLD AIR AS AN AGENCY OF PURITY—COLD AËRATION—YEAST REPRODUCTION AND YEAST FEEDING—THE MICROSCOPE AND HOW TO USE IT.

In the body of this work I dealt very fully with the whole subject of fermentation, explaining at great length the connection that existed between the original idea of Liebig, and the modern view as foreshadowed by Pasteur. In the present appendix, therefore, I am only anxious to refer to several very important matters in connection with fermentation not previously dilated upon, while specifying methods of facilitating more satisfactory yeast reproduction, and greater purity of barm than is sometimes apparent when working upon ordinary infusion lines, without any particular attention to the character of malt employed, or the method of dealing with it in the preparation of the wort.

Cultivation of pure yeast.

Many readers are possibly aware that great strides have recently been made abroad in the cultivation of pure yeast, a central agency existing at the present time for the supply of such pure yeast to brewers. Little doubt, therefore, can be felt that a direct advance has been made in this direction by Continental brewers, an advance that is likely to exercise a momentous influence in the immediate future in England, since I have no hesitation in saying that quite one half of the difficulties of English workers turns upon the employment of yeast that is either diseased, weakly, or different in type to that which should be used for the special worts that they may be producing.

Pasteur's method of yeast purification.

Now Pasteur in his work on Fermentation explained methods of purifying yeast, but found, as indeed he was forced to admit, that the very steps taken for determining the purity of commercial yeast led unfortunately to the extermination of certain species of alcoholic ferments, which apparently had a great deal to do with the flavour and general character of resulting beers when the yeast of the brewery was employed in ordinary normal condition without having been submitted to purification of any kind. In other words, Pasteur was forced to see that the purification of an ordinary commercial yeast by the brewer himself was not a successful process.

The existing method, however, devised and perfected by Hansen, although based, no doubt, upon the original view of Pasteur, is perfectly reliable and practically successful, the details of the process also being totally different to those suggested by Pasteur himself.

Single-cell yeast.

By this method the special type of alcoholic ferment required is first secured in the shape of one single cell, while this is subsequently cultivated until it reproduces itself to a sufficient extent for use in practical operations. Once having secured a sufficient quantity of seed of specified type, it can, of course, be reproduced at will, while it is easy, even for the practical brewer, to understand that at some central depôt many varieties of yeast can thus be cultivated in a state of absolute purity, these being eventually handed over to the brewer as pitching yeast of pure quality, giving him full confidence not only that the resulting fermentation will of necessity prove satisfactory (which is more than can be said indeed for many of the fermentations taking place in English breweries at the present time), but that the finished beer also will have the desired flavour.

Yeast changes often unsatisfactory.

How often is it, may I ask, that the English brewer is disappointed with the results of a yeast change? The fermentation appearances are frequently thoroughly unsatisfactory, while the clarification of beer so pitched is equally dubious. Cannot my readers see that this depends upon not having obtained in the first instance either a yeast of sufficient purity, or of a type suited to the character of wort in which it is pitched? How can they possibly know whence such yeast comes if obtaining it through a factor who simply secures from the brewer what may be described as surplus yeast, a type of barm that would not be used very likely by the brewer for his own purpose, and which he is only too glad to get rid of at a remunerative price?

The process, therefore, that is now developing abroad of cultivating different species of yeast in a state of absolute purity would, if practised in England, put an end to many of those unsatisfactory results that are only too common at the present day. The same general idea is likely to develope even in reference to wine manufacture, the spontaneous fermentation yeast now relied upon sometimes being more or less defective, this being occasioned by the different condition of "grape must" as due to changes in character of soil and climatic conditions, which must of necessity influence such fruit as grapes exactly as it does the reproduced seed of barley. It is in this particular direction, therefore, that we are likely to see, within the next few years, great alterations, arising from a more careful discrimination on the part of brewers in selecting yeast changes for use, in view of the knowledge that there are many types of alcoholic yeast, and that their purging or assimilative capacity depends very much upon type and the conditions under which they have been previously cultivated.

Great changes impending.

I believe that in the original chapter on Fermentation, I sufficiently detailed the connection that existed between oxygen and yeast, showing that any small quantity of air, introduced directly, facilitated fermentation, while excess tended to modify the alcoholic activity of a yeast, increasing at the same time its assimilative tendency, and that if this view were carried out to its literal termination, we could secure a yeast perfectly incapable of causing alcoholic change, while growing vigorously itself as an assimilative type of aërobian vegetable.

Oxygen and yeast.

I presume that all will be ready to admit that if air is used at all during fermentation with the idea of accelerating alcoholic energy of yeast, it is advisable to employ it in a state of purity, the ordinary atmosphere varying widely in this respect, being very pure in certain districts or at certain altitudes, very impure in places contiguous to large towns, or during extremely dry weather, when climatic temperature is also high.

Pure air a desideratum.

Pasteur has stated that all wort contained an excess of air in free condition; but I am afraid that this eminent scientist always presumed that a brewer passed his wort over extensive coolers, and employed yeast in fully matured condition, requiring no great supply of free air to revive or encourage it in causing definite alcoholic change. Now in direct reference to this view, let any brewer pitch yeast in the ordinary way with some warm wort, and, before adding it to the collecting wort in fermenting vessel, let him energetically aërate such mixture, allowing the yeast to expand and possibly commence budding at the favourable temperature of wort, aided in such development by the presence of the large excess of air introduced by the whisking process.

Yeast pitched with and without aëration.

Let another case be taken in which the same yeast in similar proportion is merely mixed with some cold wort and pitched in main bulk, collected, in fact, without intermixture with warm wort, or any very definite aëration. Readers will easily understand what follows: the fermentation of the first portion of wort, pitched as described, will be very much more satisfactory from commencement to finish, while the second method of effecting pitching, although it may possibly enable the brewer to escape some slight duty charge, will prove thoroughly unsatisfactory in every way.

The reason for this surely is apparent, since the first portion of pitching yeast referred to was encouraged in its preliminary development by conditions involving warmth and the presence of an excess of air in contact with it, so that, as a result of the pitching operation, it finally passed, no doubt, into gathered wort in a more or less matured and budding condition. It is for this reason that all wort as collected for fermentation should contain a sufficiency of free air, in order to determine this necessary alcoholic energy of yeast during the early stages of attenuation, since the quantity of air contained naturally by wort must depend very much upon the time of year, the depth at which such wort existed on coolers, the speed with which it was re-

Aëration during wort collection.

frigerated, and the description of cooling machine through which it passed on its way to collection vessel, while much also hinges upon the manner in which wort is collected as running to such vessel.

Danger of excessive aëration.

I am perfectly aware that cold air introduced in large excess may do a great deal of harm, encouraging yeast merely in alcoholic sense, while giving it a vigour that must practically prove detrimental, lessening at the same time, indeed, its otherwise distinctive assimilative character. On the other hand, there is every reason to believe that a very distinct supply of pure cold air is desirable; while, in carrying out the principle of application, it is advisable to introduce such air at the time when its addition must of necessity accomplish some good, adding it also in a state of absolute purity, such recommendable condition being easily arrived at either by the system of water washing carried out practically in pneumatic maltings, or otherwise by the filtration of air through cotton wool.

Temperature of introduced air.

The temperature of such air also requires some notice, since it should not be introduced so as to cause either definite heating or cooling; while if employed in keeping down the temperature of atmosphere immediately above the level of fermenting wort, it is advisable that the temperature of the air so used should be sufficiently low to enable it to control the heat of the atmosphere in question.

Aëration plant.

The plant, therefore, that has previously been referred to as being of service for determining hot aëration of mash or copper wort, may serve also the recommendable purpose of giving us the requisite supply of cold air, this being cooled practically when in compressed condition, so that, on release from pressure, it immediately expands and becomes cooler still. When introduced in limited quantity to fermenting wort, at early stages of fermentation when temperature of fluid is not high, it could not to any extent interfere with steadiness of rise; while, on the other hand, continually blown as a blast over the surface of fermenting wort, it would still possess the capacity of determining purity of atmosphere immediately above wort, and its gradual cooling at the same time.

I have previously called attention to the fact that brewers have been well advised in erecting their breweries in parts of the country where the surrounding atmosphere is more or less free from any excess of aërial dust, while I have repeatedly pointed out, in the case of pneumatic malting, that the absence of mould from either cut or damaged corn and the slowness of putrefactive changes, so characteristic of the malting process, may be directly ascribed to the fact that, in order to secure a cold atmosphere, the maltster has succeeded in washing out the whole of the suspended impurities, and thus passes into his germinating room an atmosphere free from all possible cause of either mould or putrefaction; he washes out, indeed, all aërial dust—mineral, organic, and organised. It would be well indeed if brewers, erecting new buildings or special fermenting rooms, would keep this simple fact in mind, since to me it seems perfectly possible to practically arrive at an atmosphere of sufficient purity, and one that would vastly improve the general results of fermentation as at present carried out. In many parts of the country the ordinary atmosphere is so vitiated, that not only are the materials and vessels we use in the production of beer coated with an excess of aërial matter of very detrimental nature, but our worts, also exposed for lengthy periods on coolers, must of necessity take up in

Aërial dust.

Pure air for fermenting rooms.

like manner similar aërial impurities, which sooner or later exercise an influence of their own when the organised portion of dust has once a free chance of developing in the nutritive wort or fully attenuated beer.

Continental, and even American brewers, are paying attention to this particular point by purifying the air passing to their fermenting rooms, and by securing pitching yeast of absolute purity from some central agency, this having been cultivated specially for the brewer's purpose. Some few English firms also, recognising the importance of the matter I am dealing with, have, indeed, acted upon the well-demonstrated truth that beers, produced in country districts amid pure air, are preferable in flavour and stability to those commoner varieties brewed in large centres of population; while these latter would not, perhaps, be so good even as they are, if the beer brewed in large manufacturing towns was not invariably speedily consumed. Any step, therefore, that we can take in the direction of securing a supply of pure filtered air in the case of fermenting rooms must of necessity prove advantageous, while, as the circumstances of its introduction determine minimised temperature of entire bulk of air present, this also warrants its employment very freely, especially during the warmer months of the year. The plant that I have already specified, and which is duly illustrated, gives the brewer at all times the limited supply of cold pure air that he may desire to utilise in favouring alcoholic capacity of yeast, while carefully preventing any excessive aëration that could induce fretfulness or prolonged alcoholic action.

Flavour and stability of beer influenced by atmospherical conditions.

The tendency of the above remarks is justifiable, I think, if we consider for a moment that English brewers have been taking measures during the last few years to

Deterioration of yeast.

prevent more or less the usual rapid deterioration of yeast. English brewers, in fact, have been paying far more attention lately to the temperature of such yeast existing in union stillions or floating upon the surface of fermenting wort, and have, in many cases, fitted up yeast storage rooms in which the young yeast can be placed under conditions favouring its development, without possibility of putrefaction or weakness resulting.

Deteriorating agencies.

It is a well-known fact, I believe, that yeasts of the present day, for reasons in connection with the altered character of mash wort, are not quite so capable of withstanding the combined action of heat, agitation, and intermixture of air, as the store barm of many years ago, which was always reproduced from an entire malt wort, and naturally collected from a cleansing beer. It is mainly for this reason, indeed, that brewers have been driven to partially modify skimming methods, and take greater care of the skimmed yeast after its removal, all steps in this direction turning upon the principle of minimising agitation, and facilitating separation of yeast from fluid before finally storing such young yeast under conditions of temperature tending to prevent fretfulness or ready change.

Storing of pitching yeast.

A very simple experiment will serve to prove the injury that results from any intermixture of either warm or impure air with young yeast, and the necessity that exists at all times for determining a rapid separation of yeast from fluid, since the principle of successfully storing pitching yeast should turn upon the idea of favouring interior physical development, while preventing at the same time all possible budding, the storage conditions therefore being exactly the reverse of those governing the preparation of yeast for alcoholic fermentation.

If readers will refer back, they will note that these fermentation conditions turn upon warmth, air supply, and the existence of the necessary nutritive matter, while the reverse conditions are, therefore, cold, quiescence, and the separation of all nutritive matter when yeast is sufficiently expanded, and when we are merely waiting for the physical development of plasma in the direction of maturity. This is accomplished easily enough in the case of either union or puncheon working, since the yeast floating upon the surface of fluid is kept cool by attemperating methods, the beer being finally drawn off to feed backs, or passed through filter bags when first commencing to clarify.

Union and puncheon yeast

In the case of the skimming process, however, we miss the special advantages of cleansing, since the yeast skimmed off generally passes to yeast back or other receptacle with considerable intermixture of beer, while the drop of the fluid yeast through parachutes invariably intermixes a large quantity of air that is neither pure nor cool, each intermittent skimming leading also to extreme agitation, this introducing further quantities of air, the action of which must be exceedingly detrimental.

Skimmed yeast.

Now the experiment that I suggest above is, that yeast should be skimmed into a canvas filter bag with very considerable drainage area, and as this will facilitate rapid separation of fluid, and prevent all intermixture of air, it will be found that skimmed yeast collected under such circumstances will mature much more perfectly than if removed from beer under ordinary conditions, and collected in some yeast back without any means of controlling temperature, or minimising that agitation and induced aëration that I have referred to as being so very detrimental at this particular time.

Experiment on yeast storage.

Temperature of yeasty heads.

It has always appeared to me as strange that the great mass of English brewers have taken no steps whatever in the direction of controlling temperature of yeasty heads; these were controlled naturally, and perhaps more or less satisfactorily, when the cleansing system was universally practised, since the beer was cleansed at earlier stages of gravity, and when temperature of wort was not very high, while collecting in stillions of considerable area, the rapidly resulting evaporation apparently prevented any great rise in heat of yeast as collected.

On the other hand, when adopting the skimming process, brewers forget that temperature of fermenting wort increases to such an extent prior to the removal of yeast outcrops that all barm existing on the surface of wort rises in heat, frequently reaching a limit of 10° or 15° in advance of the temperature of the fermenting fluid, such rise of heat being in no way controlled, although the union brewer, recognising the influences at work in his very rapid system of attenuation (the employment of union casks having a great deal to do with this), has been wise enough to regulate temperature of yeast outcrops in stillion by ingenious methods of attemperation. Well indeed would it be for the skimming brewer if he would only take the same course. I can, therefore, commend the principle of moving young yeast as freshly skimmed into water-jacketed slate squares, these being placed in a special room in which a quiescent and cool atmosphere can be kept without any possibility of the surrounding air becoming contaminated by effluvia from drains, or the decomposing bye-products of the brewery.

Slate backs for yeast.

The advantages of such a step will be apparent to those who know anything at all of the subject of yeast and its contamination, and who recognise that a Continental worker is fully justified in giving the deep attention that he does to the absolute purity of the pitching yeast that he employs, while I am confident that the methods I have specified as a means of improving the general quality of yeast are far preferable in every way to the alternative and not very recommendable agencies of yeast washing, since the physical structure of yeast, consisting as it does of a porous envelope containing interior soluble matter of nitrogenous type, should prove, even to the most sceptical worker, that such method of determining the purity of yeast must of necessity be detrimental to its quality. It is far better, indeed, to battle with the primary cause of defect, and decide purity of yeast by class of material and cleanliness of plant employed, while determining prolonged strength by cultivating such yeast under conditions of growth that will prevent the slightest weakness, finally collecting and storing it under circumstances that will minimise the chances of deterioration.

Yeast washing.

There is, perhaps, one little matter in reference to yeast storage, that should not escape notice, since many workers actually spoil pitching yeast by draining from it not a clear fluid, but a fluid that has intermingled with it a large excess of very recommendable yeast too dense and heavy to float perfectly. I am quite aware that bottom yeast in an English fermentation may be regarded generally as a sign of weakness or unfitness for use; but such yeast as that I am now specifying cannot be classed as inferior bottom yeast in any sense of the word, since it merely exists in a condition of gravity that carries it to the

Bottom yeast.

bottom of the fluid in which it is suspended. If yeast stillions are drained carelessly, we actually draw off some of the most perfect physical yeast that could possibly be selected, far preferable, indeed, to the more buoyant forms of yeast existing on the surface of the attenuated beer, frequently blown out as it is into fluffy condition by want of viscidity, and under the influence of the escaping carbonic acid gas.

Careless drainage.

I naturally come now to the question of possible yeast reproduction, this leading on to the subject of yeast feeding.

Yeast reproduction.

It is sufficiently easy to understand why yeast reproduction at the present day is at times a matter of such extreme difficulty. Take, for instance, half-grown malt, mash this at a low heat, and boil off the resulting wort in a single length at a gravity of 25 or 26 lbs., and there will be no great difficulty in securing a very satisfactory yeast crop; while, on the other hand, if we only recognise the fact that much of the over-vegetated malt of the present day is frequently mashed with liquor at very high temperature, that worts are boiled off in several lengths, the boiling operation being very prolonged and quantity of hop extract present very marked, we shall see that no great wonder can be felt that satisfactory reproduction of yeast under such circumstances may prove to be more or less difficult.

Influence of mashing heats, &c.

In the case of overgrown malt, in which the indices of extended vegetation are to be seen in excessive root percentage, and a full extension of spire, even to the extremity of the grain, is it not evident that such root and spire must of necessity be composed of the very same forms of soluble albuminous matter as favour the after-reproduction of yeast? It is interesting, indeed, to note that certain yeast factors

Influence of overgrown malt.

employ an infusion of malt dust as feeding material, steeping such bye-product in water in order to obtain from it some particular form of nutriment. Such a proceeding as this is, of course, impossible in connection with practical brewing. It would, indeed, be thoroughly erroneous in principle, since the factor may be justified in using albuminous matter that has already been worked upon in favouring growth of grain (or extension of the spire and root, which are taken as evidences of growth), while it is utterly impossible that such form of nitrogenous matter could be in a favourable condition (even if soluble) to warrant its employment in the feeding of pitching yeast in the special direction that I am about to refer to.

It is quite true that the recent abandonment of the old method of malting, which may be summed up in the phrase "modification without forced growth," has decidedly led to exhaustion of grain in a direction little understood. The malt, indeed, may possibly be more buoyant and friable, it may yield with greater ease the bright wort, the more stable beer, but what it does not give is that particular form or type of nitrogenous matter that determines at once through its agency, when existing in combination with certain phosphates, the prominent yeast reproduction which places the brewer securing it in a very commanding position, and quite free from obligations to neighbours, who are invariably more or less jealous in reference to yeast supply, and who seldom take the trouble to select the particular kind of yeast that would answer the purpose of competitors in the trade that they are called upon to supply.

Forced growth of malt.

This is not all, since each description of wort produced requires a certain type of yeast for its perfect attenuation and purging; and although it is possible to

Yeast types.

secure almost from anywhere some form or description of yeast, the imported barm is seldom capable of determining attenuation and purging at the same time, but is seen to gain in purging capacity after each succeeding reproduction, if only the reproduced seed is satisfactory in point of physical strength.

Here, then, we confront at once the somewhat tantalising difficulty of many brewers, since if the material they employ is faulty, if the soluble albuminous percentage is low, it is not likely that the infusion method of mashing they carry out, with the influence of a definitely high striking heat, can possibly improve the yeast-reproducing capacity of the wort that such malt is likely to yield, while the main results of this defect in material will soon show itself in the shape of definite

Yeast weakness.

yeast weakness; and if, with a kind of conservative feeling, the brewer insists upon employing his own reproduced yeast-seed time after time for pitching purposes, the second step in the direction of disaster is definitely courted, since when the weakness of yeast advances to a certain point, it is not long before the wort holds in suspension plasmatic matter that should have remained in the yeast cell, and would have done so if such yeast had only been allowed to retain its strength and retentive capacity.

Solution of yeast question.

I can only urge my readers, therefore, to look at brewing matters from this special point of view, and solve the yeast question, so far as mere nutritive capacity of wort is concerned, by relying only upon the very best of malt—malt, indeed, of a certain standard, not only well grown and cured, but so cultivated that it contains the requisite percentage of soluble albuminous matter, which should invariably stand at something over fifty-five per cent. on total quantity present in the vegetated material, ranging upwards, however, according to quality of barley dealt with. The advice is, perhaps, the more necessary, since with English mashing plant we are practically restricted to our present method of working, and are therefore dependent more or less upon the operations of the maltster for after-success in brewing. I am the more anxious, indeed, that readers should look at the subject from this particular point of view, because a lengthy and varied experience has taught me that during the summer months especially, disaster turns, as I endeavoured to show in Chapter III., partly on inefficiency of wort ebullition, and very much, as I am now trying to prove, upon the use of definitely weak and unsatisfactory yeast, which soon becomes impure as a result of weakness, while a totally different class of diseased ferments eventually make their appearance in the fluid owing to the final escape of the plasmatic nutriment from the weakened cells. So much for possible yeast reproduction in malt wort.

Yeast feeding.

I come now very naturally to the subject of yeast feeding, which developes into a necessity, perhaps, if the natural character of the yeast, taken as an outcrop from a certain wort, persistently indicates preliminary evidences of weakness that may justifiably be overcome by the adoption of some definite plan of practical yeast coaxing. There is nothing to astonish brewers in such a suggestion, since they are aware of the fact that, abroad at any rate, the cultivation of a yeast from a single cell is carried on. Yeast is also held over from season to season in many hot climates without becoming worn out or inert, while, before being again employed for pitching purposes, it is thoroughly revived by cultivation in a nutritive fluid.

If brewers will persist in continually carrying on cultivation of yeast in worts that are destitute of the necessary forms of phosphates and nitrogenous compounds, they can but expect the results mentioned above, whereas if they will only take a hint from the contents of this chapter, they may possibly be able to stave off disasters that would otherwise most certainly handicap their success.

Phosphates.

The question as to what form of yeast feeding is desirable at once presents itself, while from a recent controversy that occurred, we may probably conclude that the direct employment of phosphate matter is not actually requisite, since very distinct statements were made in the dispute referred to, that worts, even from defective types of malt, still contain a large excess of phosphoric acid compounds. In this matter, however, we may as well proceed on the idea of supplying yeast with the exact kind of nutriment it would meet with in wort of good quality; and what plan could be more simple than to prepare, day by day, a small quantity of very concentrated wort from malt of excellent type, infusing this at a very low heat, and finally concentrating the resulting wort by ebullition, since this will not interfere with fully digested forms of nitrogenous matter, the more especially as such wort is not impregnated, of course, with hop extract. The concentrated fluid is, after ebullition, cooled and rapidly filtered through flannel, to remove suspended coagulated matters, and finally intermingled with the weighed-up portion of pitching yeast two or three hours before main bulk of brewing, for which this yeast is intended, passes to the collecting vessel.

Concentrated wort.

The principle of yeast feeding, therefore, according to this view, depends upon taking, day by day, not merely an ordinary strong cooler wort as collected for pitching purposes, but a special type of wort secured from perfect material at a low infusion heat, concentrating this so as to have a large quantity of yeast nutriment in a small bulk of fluid. This method of yeast coaxing is thoroughly successful wherever it is practised, while a bushel of malt manipulated in the way described should yield a sufficiency of wort for 100 lbs. of yeast.

Preparation and mode of using special wort for yeast feeding.

Many brewers have, without due thought, attempted a makeshift plan, taking some of the first wort as running from an ordinary mash, but such proceeding is worse than useless in cases of extreme yeast weakness, since a great deal of trouble is taken without any advantage resulting. I can definitely specify, indeed, that the yeast feeding wort must be from malt of the best quality, the extract must be obtained on true Continental lines, while the reader, once gaining confidence in the proceeding, can naturally increase, according to requirements, the quantity of such feeding wort employed, since such fluid extract actually costs nothing but the trouble of preparation. The surplus portion of weak wort from the miniature mash, or the goods and wort together, may be transferred to the ordinary mash tun as soon as the limited proportion of strong wort has been obtained.

I may suggest, in reference to the practical preparation of this wort, that the mash should be made with liquor at a temperature of 110°, while about twenty minutes afterwards the initial heat should be raised either by intermixture of boiling liquor or definite hot circulation of wort, till a final initial of 150° is reached, when the strong wort may at once be run off for concentration. I may as well state here, to prevent all misunderstanding, that the Inland Revenue

Excise regulations.

authorities have no objection either to the erection or use of a small plant for this particular purpose, and readily grant permits for the process itself being carried out, so long as the wort is collected with main portion of brewing, while if gathered otherwise this must be in a specially entered vessel, so that duty charge may be made upon produce.

I am powerfully impressed with the idea that if the large number of brewers at present battling with physical defects of yeast, would only give this one matter their careful attention, they would be able to rectify the physical defects in question, and at the same time restore their barm to a state of purity, since there is nothing, perhaps, that determines more persistent impurity of yeast, and final disaster, than imperfections of original wort, facilitating, as these do, the weakness of the store barm first of all, the final results, as my readers are aware, being acidity of beer of persistent cloudiness, ropiness, and other forms of disease which only become apparent too soon.

The microscope.

If I now refer to the subject of the microscope, it is simply because I am perfectly certain that, in the vast majority of instances, it is used without the necessary knowledge. To begin with, the microscopical instrument makers are far too prone to advise clients to adopt

High powers.

high powers; they are naturally more expensive, while the young brewer is, of course, very pleased to see alcoholic yeast enlarged to such an extent as "to look well," as he terms it, forgetting altogether that when such yeast is so magnified as to be seen with great readiness, the probability is that the yeast is not only

Distortion.

distorted in itself, but its interior physical development is more or less out of focus, the impurities also, and for a similar reason, often not being seen at all. In my opinion, therefore, the brewery pupil or young brewer should attempt to secure an instrument with the following qualifications:—first, great weight and stability (*i.e.*, one that will remain free from vibratory movement); secondly, low powers, *i.e.*, a low combination of one-fifth or one-sixth, with deep eye-piece; and thirdly, a very powerful illuminating agency, since a strong and perfectly pure reflected light will pass direct through yeast to the retina of the eye, and enable the observer to determine not only general form but true interior development of yeast, while if the light is not sufficiently strong it does not penetrate in the same manner, nor carry to the retina the same impressions. There is little doubt, indeed, that the large bulk of yeast which looks fairly well on the sub-stage of a microscope inefficiently illuminated, would examine out as being weakly and physically imperfect if viewed under the agency of a powerful clear white light properly reflected, or more strictly speaking, properly concentrated and reflected; while the benefit of relying upon a combination of low powers is to be noted chiefly in the fact that you can focus yeast, its interior structural formation, and disease in the shape of foreign ferments, at one and the same time—a highly desirable result, not usually obtainable when any of these necessary conditions of examination are wanting.

Suitable lenses.

Illumination of object.

In other words, we do not require to see merely a number of circular organisms, since we all know that yeast is either oval or round in shape; nor do we require to deceive ourselves by arriving at what I may term a pretty picture of yeast. It is necessary, indeed, that we should know something about the interior physical structure, and it is only a good combination of powers

Interior physical structure of yeast.

and a perfect light that shows this to us; while, in the great majority of instances, if the interior structure is perfect, we may save ourselves the trouble of looking for impurities, since there will be none, or at any rate very few, present.

It is in this direction that grave mistakes have no doubt been made in reference to yeast examination, the observer merely looking for impurities, and talking of intermixed sticks and bacilli generally, while giving but scant attention to regularity in size of cells, interior structure, and type of alcoholic yeast present. I am not very far wrong in expressing the opinion, therefore, that brewers, or a large majority of them, got on very much better, when determining fitness of yeast for use, by observing simply its colour, clinging capacity, vinosity, rapid alcoholic development, and satisfactory reproduction, than by relying, as many do at present, solely upon the use of a microscope, which they employ, not for the specified purposes that I have named, but merely for seeing whether the yeast sample presents an intermixture of round or oval cells, contenting themselves with this delusive view, and frequently employing yeast, on the basis of such examination, that, both physically and in point of purity, is perfectly unsuited for their requirements.

Physical characteristics of good yeast.

This statement should, indeed, constitute a definite warning, and I would advise my readers either to carefully study the working of the microscope, and the bearing of the enlarged views of yeast, as regards structure and degree of purity, that can only be determined by its aid so long as they rely upon a suitable combination of definite powers and a sub-stage properly illuminated, or to go back to the old-fashioned plan of selecting yeast on the basis of totally different signs, a ready capacity of separating from its fluid portion being perhaps one of the most important.

Résumé.

The Appendix remarks, therefore, on the subject of fermentation, have so far turned upon a lengthy reference to the true connection existing between limited supply of air to alcoholic yeast, the necessity for purity of atmosphere, and the influence of a definite cold atmosphere in determining purity of yeast and its stability during periods of maturing.

I have also tried to detail the causes of yeast weakness and the methods of overcoming such defect, while I have concluded by an explanation of microscopical working, in which I have tried to show that the microscope as a brewery instrument is worse than useless, unless so used that we can determine through its agency the real quality of yeast as distinct from a deceptive appearance, determining, indeed, when using it properly, the true value of barm in far more perfect manner than when examining it in the old-fashioned casual way, by taste and eye judgment, depending, as we then did, upon the peculiar characteristics already specified.

CHAPTER V.

THE STORAGE OF BEER—RACKING CONDITION—FINING OPERATION—TREATMENT DURING STORAGE—TREATMENT OF "RETURNS"—THE STERILISATION PROCESS.

Clean racking condition.

THE contents of the present chapter refer to subjects of the most extreme importance, and I cannot do better, perhaps, than commence by saying that brewers' troubles have been more prevalent since the time that plant arrangements facilitated clean racking condition of beer, and export necessities determined the consignment of such beer to distant outlets.

It will not be difficult to make this statement perfectly clear, since, some twenty years back, trade was, practically speaking, very local, while before this time the method of cleansing and racking carried on turned almost entirely upon purging the beer in the identical casks in which it was shipped to the consumer, so that what we may call condition of beer at time of shipment ran in connection with the existence in the fluid of a considerable quantity of yeast, young in nature, which exercised a most characteristic preservative influence, far more so, perhaps, than the influence of modern antiseptics, such as sulphites, salicylic acid, and so forth.

Now, as trade developed under the favouring influence of railway communication, agencies became established, and brewers gradually drifted into the system—in many cases a most costly and disastrous one—of consigning a very large proportion of their total output to agencies at some considerable distance from the brewery, while placing such beer in charge of men who, as a rule, had no previous training in reference to practical brewing operations, and who consequently were, and still are, apt to neglect beer, regarding it as a mere saleable article which should retain its condition and capacity of fining from day to day or week to week.

Brewers' agencies.

Now, how does the question of racking condition of beer bear upon this particular subject? In this way, and I would beg my readers to give careful attention to the statement:—The general tendency of beer drinkers during the last few years has certainly been in the direction of favouring the production of weaker beers, and these, naturally being less alcoholic than stronger brands, are changeable in themselves, not only by reason of their minimised alcoholic character, but because the class of extract making up the original gravity of such beers is entirely different to that existing in the case of heavier grades, while, as modern systems of brewing and the complex arrangements of plant have tended to determine absolute cleanliness of racked beer, I say, without fear of contradiction, that such clean thin fluid is unfortunately open to aëration and acidity changes if remaining quiescent in cask for any length of time during the warmer weather, while no extent of antiseptic matter can possibly prevent such change if the beer remains persistently flat.

Changeable character of weak beers racked clean.

Again, its clean condition means the absence of much gas that would otherwise be present, this facilitating the more rapid absorption of air either directly through the pores of the timber constituting the cask in which the beer is placed, or from the atmosphere existing above the level of the fluid in cask, so that, while we are perpetually struggling to obtain clean racking samples, we are perhaps exposing our weak beers to possible cask changes that they would not otherwise undergo. It may well be asked, then, why brewers have taken all the trouble in reference to improving brewing systems and plant arrangements to facilitate a state of things that at first sight may appear absolutely disadvantageous. Here again the reply is ready, since it would be impossible to submit a rough beer to the trying influences of lengthy transit in warm weather, and equally so to subject it to the suctional influence of the ordinary pump used by the publican when drawing beer from cask; while for these two reasons brewers have, intentionally or no, given up the idea, if it really ever held possession of their minds, of preserving beer from change by leaving it in rough condition, while they have adopted the general principle of determining greater and greater cleanliness as a necessary although somewhat deceptive safeguard, the beer losing at the very same time that peculiar home-brewed flavour characteristic of all beer purged from yeast and sent to the customer in the selfsame cask.

Relation of racking condition to lengthy transit.

Now the racking condition of beer depends in a great measure upon two simple influences, viz., the quantity of amorphous and precipitating matter that exists in the fermenting wort, and the assimilative and buoyant capacity of the yeast employed for causing fermentation. A Burton brewer, for instance, neither cares for nor obtains a very clean racking sample, his alcoholic yeast being too quick indeed for a wort somewhat rich in amorphous matter on account of the excessive quan-

Racking condition of Burton beer.

tity of hops used. The stone square brewer, on the other hand, working with a slow assimilative yeast, and carrying on fermentation during a great number of days, can purge a beer so thoroughly that at the racking gravity it exists in a condition of glass brightness.

Racking condition of stone square beer.

Between these two extremes we have any number of examples, cleanliness of beer being facilitated by the use of sugar, thin malt, medium action of yeast, while turbidity, on the other hand, is determined by the employment of soft water, heavy material, and quick yeast. Readers will not overlook, of course, the immense influence also of thorough boiling, lengthy cooler process, and the employment of complex fermenting plant, embracing the use of intermediate skimming vessels and subsidiary racking tanks.

Storage.

This brings me to the subject of storage, and no one, I think, will dispute the statement that beer should be stored at a temperature not favouring any rapid change in such a fluid, such temperature being about 55°. Any higher range of heat is forcing in its influence, while variations are, generally speaking, far more detrimental than the influence of temperatures abnormally high, if only such heats remain more or less constant.

Prevention of change in clean racked beers.

Now, if we succeed by our brewing process in determining actual clean condition of beer racked, what steps should be taken to prevent the changeability that always results if it is left quiescent in cask during warm weather? We should, of course, determine a fermentability not naturally brought about by the pleasing racking condition of the beer itself (since I am speaking of one essentially bright and clean), but through the agency of means that are within the control of every brewer, but which few brewers or their agents ever think of practising.

Rolling.

The mere rolling of beer is, of course, a very old-fashioned and natural method of determining condition, since it stirs up any sedimentary yeast that may exist, while inducing also the absorption of air through intermingling the fluid with that existing above the level of beer in cask. The movement, or rolling, of an absolutely clean beer, however, is of very little use, since the fluid contains no sedimentary matter to act in the way described, while mere aëration would be detrimental to quality, and such beers consequently require heading with "kreising," or the semi-fermenting fluid which has proved so successful in use abroad. The "kreising" referred to merely consists of beer, preferably of identical gravity to that of the fluid about to be treated, as existing in fermenting round on completion of actual fermentation, and withdrawn just as the fluid is throwing up its last films of yeast, which are essentially pure and young in physical development, while the fluid holding such yeast in suspension is, if judiciously employed, perfectly incapable of determining turbidity or fretful action of any kind.

"Kreising."

I can assure readers, indeed, that this "kreising" can be used with perfect safety for the purpose specified, since it never determines sickness, tumultuous fermentation, or acidity, experience being only required in the direction of securing the fluid mentioned in the exact condition in which it is capable of exercising its forcing influence, while incapable of determining any excessive fermentative power.

Test for kreising.

Perhaps the most ready practical test for deciding the condition or fitness of the kreising beer in question is by trying whether it will filter perfectly brilliant, since in this case, although yeast may be in suspension, the clear filtration proves that fermentation has entirely ended, and that the kreising fluid is perfectly ready for use. Now, the quantity of such fluid required varies enormously, many American brewers employing as much as 15 per cent., while in English beers, added as it would be for merely determining slight fermentative action in the cask, the proportion would never exceed, as a maximum, some 3 per cent., while the average, I think, would be as low as 1 per cent.

Quantity employed.

The importance of this matter is extreme, since, if the general idea of the suggested treatment is once grasped, it will be noticed that it may still be recommendable to bring infusion beers into very clean condition for racking, while, when doing so, it is essential, during the summer months at least, that we should see that such clean fluids do not remain persistently quiet in cask, but are brought, by one means or another, into reasonable cask condition, so as to prevent the entry of air and resulting oxidation changes.

It is for this reason that tank fining is frequently so dangerous a process, although successful enough if the beer so fined is immediately shipped to the consumer and rapidly drawn; while many readers, no doubt, have experienced the disastrous influence of the process in question, without quite understanding why beers racked so bright should exhibit such a tendency to immediately become turbid again. It is, indeed, for two reasons, since the tank-fined beer is destitute of carbonic acid, and therefore absorbs air with the greater readiness, while, being free also from sedimentary deposit, there is no possibility of gradual cask condition developing, and thus the absorbed air, in place of being

Danger of tank fining.

assimilated by yeast in suspension, is free to exercise its oxidising capacity and throw nitrogenous matters out of solution.

Purging in cask.

The purging process with finings, on the other hand, is far more successful. This is carried on in the usual trade casks, the beer being racked direct from unions or skimming vessels in rough condition into clean casks, at a temperature of 60°, dilute finings being then stirred in, the mixture soon purging itself completely, careful topping over with bright beer being constantly carried on. On completion of purging, all excess of sedimentary deposit is withdrawn by means of valinch tubes, the beer being left perfectly clean, but (and this is the important point) neither denuded of the natural gas nor freed from the whole of the sedimentary yeast deposit, so that in both directions its condition is totally different to that of the tank-fined beer previously commented upon. This particular purging process was first carried out by Australian brewers, but is now practised by many large English firms, who, for the most part, are very successful in their working, while the nicety of the *modus operandi* is, perhaps, to be seen in the fact, that while tank fining is very frequently disastrous in its influence, cask purging, under certain circumstances, is exceedingly recommendable.

The action of finings.

Fresh light, perhaps, has been thrown upon the artificial fining action by the statement that, when employing modified gelatine for the purpose, clarification of beer does not depend upon filtration, *i.e.*, the filtration of the fluid through the rising flocculent cloud of modified gelatine, but hinges upon the fact that in adding such material to turbid beer, a kind of attractive influence comes into play between the nitrogenous substance (gelatine) added and the albuminous bodies that are causing turbidity of beer, while the astringent constituents of the fluid at once exercise a semi-coagulating influence, so that the combination spoken of actually separates from the fluid, and on account of natural buoyancy rises to the surface. If this is a correct explanation of the fining action, readers will understand readily the new method of fining suggested by Messrs. Ewens, of Bristol, since, in this case, two albuminous fluids are employed, the one having an attractive influence for the suspended matters in turbid beer (the degree of solubility enabling it to pass more or less into a condition of semi-solution), while the second possesses a powerful affinity for the first, although insoluble in the fluid, so that on adding this second nitrogenous fluid to the beer it decides the separation of the first addition at once through its own attractive capacity, while the matters previously causing turbidity separate, of course, at the same time in combination with the first nitrogenous matter spoken of, the result being rapid clarification of the fluid so treated.

"Magic finings."

There is every reason to suppose, that in both cases of practical fining the exact influence of the fining agent is the same, since in tank-fining operations we notice that the gelatine never separates in flocculent form, and could not possibly, therefore, act as a filter, but that clarification of the fluid seems to depend upon the added fining agent directly entering into combination with matters causing turbidity, separation of the blend being determined under the influence of astringent matters present in the fluid.

We can easily see from this argument why beer has to be in a certain definite condition in order to take finings rapidly or with success, since we may presume that the gelatine exercises a certain discriminating assimilative tendency, failing to exhibit its combining capacity for nitrogenous matters in all conditions of physical change, while entering into the necessary state of combination when the condition of nitrogenous matters causing turbidity is normal, or as a brewer might term healthy. In other words, the healthy finished beer readily taking finings is one that contains the nitrogenous matters causing turbidity in a condition enabling them to combine more or less readily with gelatine, when modified to the necessary extent under the influence of acid; while stubborn beer, on the other hand, is one either undergoing fermentation, so that solid matter is actually passing out of solution as a result of attenuation, or a fluid which holds nitrogenous matter in suspension in thoroughly abnormal or unhealthy condition, *i.e.*, in a state that does not admit of its readily combining with the gelatine added.

Influence of acidity on fining capacity.

It sometimes happens, again, that persistent turbidity is caused by an excess of acidity, this being specially the case, perhaps, with vatted beers, while under such circumstance ready fining may possibly be brought about by reduction of acidity to normal limit, although I must observe that such modification of acid reaction facilitates after-change in fluid, unless this is rendered impossible by some definite antiseptic treatment of the clarified beer.

There is no subject, perhaps, of greater interest than that of the practical fining operation carried out by the brewer, and although it may appear very easy to fine beer artificially, its capacity of fining depends upon a vast number of conditions that few brewers ever think of. The wonder, indeed, is that English beer comports itself so readily in this particular direction; or, on the other hand, fortunate is it for brewers that the large bulk of beer produced is fined and consumed long before it has ever had the chance of changing in a direction that would render artificial clarification more or less impossible. It is for this reason that I have more than once called attention to the unworthy boasting of certain brewers, who cannot find excuse for the troubles of others, forgetting that, in their own case, the beers they produce are never submitted to the slightest forcing test, the class of trade done by English brewers, as a whole, varying immensely in this respect, while in all cases it is totally different to the trading system existing abroad.

The subject of "returns" and their treatment is likewise becoming of more importance year by year, this naturally turning upon the consignment of beer to distant agencies, greater discrimination on the part of the beer-drinking public, and the principle of allowing publicans to return waste. I cannot do better, perhaps, than deal with the question of "returns" in some definite order, while I may preferably describe them under such headings as—(1) Flat Beer; (2) Turbid Beer; (3) Casky Beer; (4) Acid Beer; (5) Ropy Beer. "Returns."

If beer is returned on account of flatness, it is sufficiently easy to determine reasonable condition by the heading process referred to in this chapter when dealing with the subject of kreising, although, in certain cases, it may be necessary to add also a little dilute invert sugar syrup to facilitate the fermentative action necessary. Flat beer

The question of turbid beer is not so easily settled, since persistent dulness or persistent thickness may be due either to extreme cask fermentation and condi- Turbid beer.

tion, or to the subsidence of a copious deposit of albuminous matter under circumstances of acidity that prevent the precipitation taking place with any degree of rapidity. Now, it is never recommendable, of course, to re-ship such beer to the consumer; for although it may possibly be brought into quiescent and bright condition by definite treatment, the quantity of sedimentary deposit is sure to be so extreme that, on rolling the cask over, it again determines a more or less prolonged turbidity or persistent dulness that is certain to occasion dissatisfaction to the customer if such beer is sent out on the chance of passing muster.

"Returns" of such nature are, therefore, more recommendably dealt with either on the principle of forcing through the cask fermentation that is in progress, bringing beer into perfectly bright condition by the aid of finings, and finally either mixing off in fresh brewings, or drawing the beer off bright from its sedimentary deposit; while, in this latter case, if the palate flavour of fluid is recommendable and fulness sufficient, the drawn-off beer may be re-hopped, treated with kreising, and again sent out with impunity.

Sickness.

If, however, the turbidity is due to abnormal cask change, such as sickness, a much more sweeping form of treatment is required, since, if attempting to blend beer that has at any time been sick or exceedingly fretful during cask changes, it is certain to determine a like state of change in the blend eventually made with it. The only plan, therefore, that can be adopted with advantage in dealing with such descriptions of beer is to force through the definite cask change by constant rolling, taking the precaution to treat the beer, first of all, with a dose of salicylic acid, boracic acid, or calcic bi-sulphite, so that, in forcing change, we may still be more or less confident of the eventual soundness of the beer treated, while, when falling practically bright, the beer should, before mixing, be carefully "sterilised" so as to cripple or destroy all active ferments contained in it. Sterilisation.

Musty or casky beer.

Musty or so-called casky beer is unfit for any purpose, since the cask flavour is, in this case, so intense, so capable of development, that, when mixing even the smallest proportion of an ill-flavoured beer, the persistent "tack" or defective taste will show through the blend.

Ropy or viscous beer.

Ropy or viscous beer is undoubtedly becoming far more common than formerly, while there is every reason to believe that such ropiness is not caused in all cases by the mucous ferment, since I have repeatedly examined samples and failed to distinguish its presence. I am not prepared, at the moment, to say why this peculiar oily or viscous appearance of beer should be so prevalent at the present time, but probably we shall find an explanation of the matter in the modified character of English-grown grain, and the tendency that brewers have exhibited to rack their weak beers in very clean condition, although, comparatively speaking, at high gravity, so that absorbed air frequently seems to determine first of all the sick fret, and eventually the appearance in the fretting fluid of viscous matter that puts an end to all chance of fining until the mucous or gummy substance is either taken again into solution, or thrown down as a precipitate under the influence of some powerful coagulating or astringent agent.

Brewers have been advised to employ mustard seed for this particular coagulating purpose, but I am afraid that such treatment, although possibly preventing mucous change, is of no great service in actually curing a viscid beer; nor do I think that the alternative curing process is in any way perfectly successful, since it depends upon submitting the fluid to extreme heat in order to determine the re-solution of the matter causing the viscid appearance in question. If such viscosity of beer is really due, on the other hand, to subsiding dextrine (and this, of course, is just possible, since attention has more than once been drawn to the fact that many beers are persistently cloudy on account of the extreme percentage of dextrine existing in them), a cure might possibly be found in the employment of some active diastatic substance which, on being added to the viscid beer, might lead to rapid hydration of gummy matter. As this subject of ropy beer is becoming of great importance to brewers in all parts of the country, they are sure to find constant reference to it, as time advances, in the columns of the *Brewers' Journal*, since, at the moment, our knowledge respecting this matter does not go beyond the points already referred to.

Acid beer.

I may, perhaps, presume that acid beer constitutes the greatest proportion of "returns," since I may class bottoms and waste with the turbid beer already noticed. Aged or acid beer has to be dealt with in a very distinct way, since the probability is that while excessively acid it will not spontaneously brighten, while in being extremely sour it would, if mixed off in natural condition, introduce into the mild beer the very ferments that had previously determined its own changeability. The treatment, therefore, of acid beer, turns firstly upon the

Neutralisation.

point of neutralising excess acid, so favouring a ready spontaneous or artificial clarification of the fluid; secondly, upon the definite sterilisation of the fluid at a high temperature under pressure in a vessel properly fitted, so that pressure may be applied, while no escape of alcohol can result; and finally, upon the restoration of original palate by the employment of the registered "Glyco-saccharine," now largely used by brewers in all parts of the country.

The sterilisation process dates, of course, from the time when M. Pasteur first explained the fact that the ferments concerned in determining change in beer were all more or less easily destroyed or rendered absolutely inert (when in developed condition) by very moderate temperatures, the more readily if the fluid in which they existed was more or less acid.

It unfortunately happens that an English infusion beer, rich as it is in changeable forms of nitrogenous matter, will not submit itself to the Pasteurisation process very successfully; and, notwithstanding that endless experiments have been made, and, several patents taken out, the fact remains that every English beer within my knowledge, however carefully sterilised, still possesses the unfortunate capacity of becoming dull some few weeks after Pasteurisation has been accomplished. Pasteurisation.

I have said "unfortunately," since Continental beer is widely different in this respect, the character of lager beer extract being entirely different; and thus, as the Continental lager can be bottled in perfectly bright condition while saturated with gas, the producer scores an immense advantage when sterilising such beer under pressure, still leaving in it the gas which gives it the appearance of condition, while in Pasteurising the fluid under pressure it is rendered more or less unchangeable, and does not in any way become dull, throw a precipitate, or carry the slightest trace of shade. So prominent is the defect of English beers in this particular direction, that when sterilising a beer of extreme age, even after the fluid has passed through a series of cask changes, it will still show a strong tendency to throw down a deposit after the Pasteurisation process has been carried out.

Catalytic action of depositing albuminous matter.

It is for this reason, and this alone, that sterilised "returns" cannot be dealt with successfully during the summer months, since this subsiding deposit of albuminous matter appears to act as a distinct catalytic agency, leading to changeability, of blended fluid, although, of course, the sterilising temperature must have completely destroyed all the acid ferments existing in the beer treated. I am led to say this, since many writers have contended that if there is any basis of truth in M. Pasteur's idea respecting sterilisation of fluids, the brewer should be able to mix off "returns" when sterilisation has been accomplished, just as easily in the summer as during the winter months. This, however, is not the case, since although we may destroy by our sterilisation process the whole of the acid ferments, we do not put an end by Pasteurisation to the changeable nature of albuminous substances which exist even in the oldest beer, and which become modified, no doubt, in the direction of insolubility, while in eventually subsiding from solution during the storage of the treated beer after blending has been accomplished, they unfortunately decide a catalytic influence ending in the pronounced acidity of the fluid as a whole, an influence not coming into play, however, during the colder months of the year, when the condition of beer generally is more stable. I do not claim, therefore, for the process of sterilisation an influence that it does not really possess, but merely assert that in submitting beer to the influence of combined heat and pressure, we determine the destruction of acid ferments, and a greater stability of nitrogenous extract, than would otherwise be characteristic of it, although may be, at the same time, a semi-soluble character that leads to its eventual precipitation.

Conditions of successful sterilisation.

I take it for granted that it is not necessary for me to argue, firstly, that pressure must have, *per se*, an enormous influence when carrying out such a process; secondly, that it is advisable to sterilise the fluid in a closed vessel to prevent escape of alcohol; thirdly, that the vessel should be constructed of metal not capable of undergoing ready oxidation; fourthly, that the fluid should be sterilised in bright condition, and with its excess acidity present; fifthly, that any excess acidity should be carefully neutralised with a perfectly pure solution of bicarbonate of potash or pearlash before attempting to blend off the sterilised fluid with mild beers; or, lastly, that after all that I have said on the subject of sterilisation, it seems needless for me to urge upon readers due discretion as to when such sterilised beer should be mixed off, since, as a general rule, we may consider that all beer between April and September is open to a degree of changeability not evidenced during the other months of the year, and that during the period stated it is not advisable to intermix even carefully treated forms of "returns," although these may have been submitted to the most extreme antiseptic influence known. I could name many examples, indeed, proving the vast importance of this matter, while I have personally seen beers in a state of sick fermentation that, after being treated with excessive quantities of very powerful antiseptics, and brought by such treatment into a perfectly bright condition, would still exercise a capacity of determining a similar state of change in the case of mild beers when mixed off at the rate of 5 or 6 per cent. I am firm, therefore, in my belief, that although it is possible, through the influence of heat, to render diseased ferments inert, it is not possible to denude certain types of nitrogenous matter of their catalytic agency when once subsiding from solution under the influence of either air or heat.

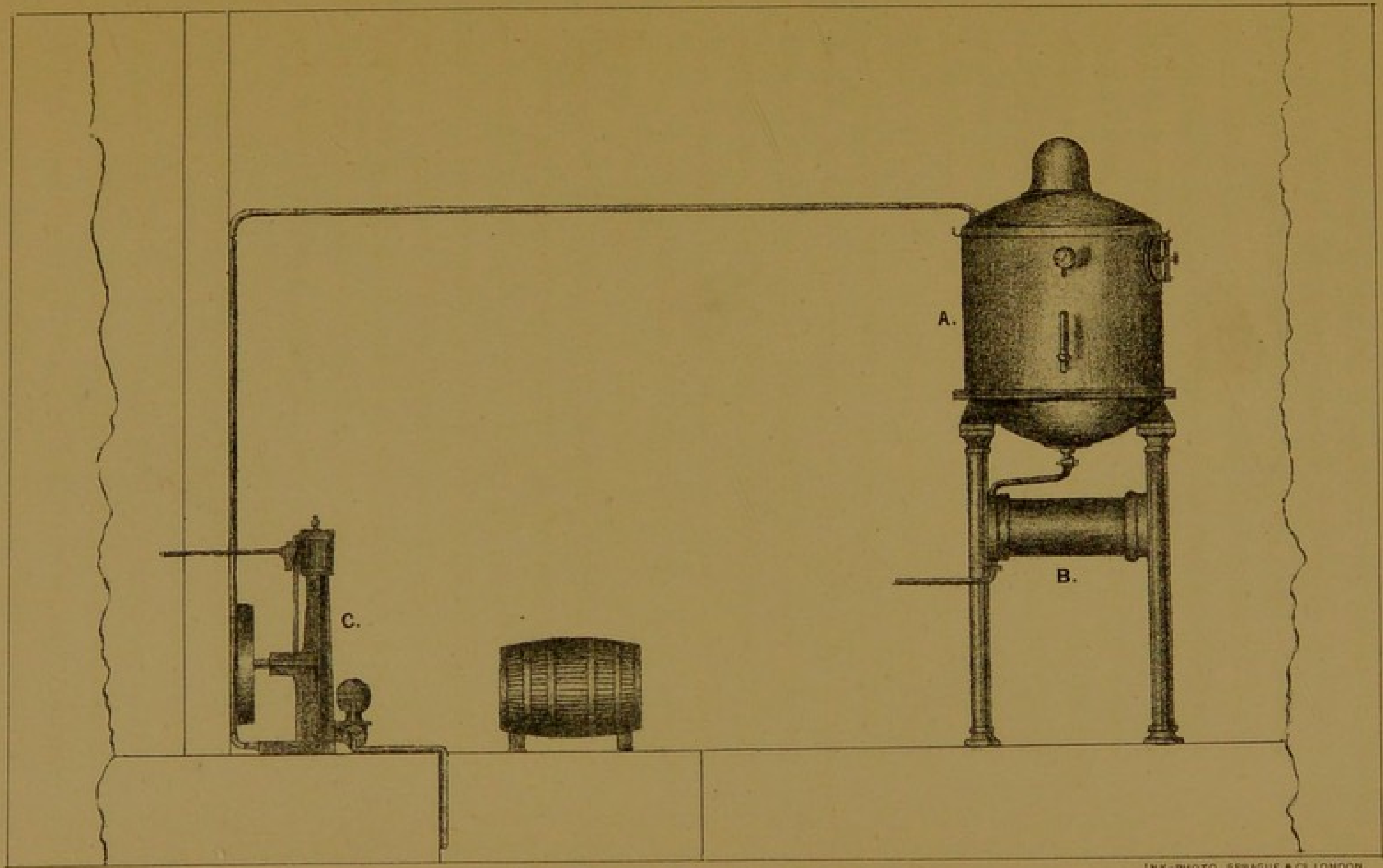
Sterilisation plant.

Readers will easily understand the illustration of closed sterilisation vessel appended. This plant is constructed of copper, with interior attemperators that enable the fluid to be rapidly reduced to a mixing temperature, with condensing coils also that prevent the escape of alcohol, and with all necessary fittings for allowing beer to be sterilised under pressure, but I beg of them once more to remember that no pressure and no heat will determine the absolute stability of English beer so long as it possesses the eventual capacity of throwing down a nitrogenous precipitate after the process. So far I have never seen an infusion beer that had not this fatal capacity, while I cannot possibly admit the perfection of the English infusion process in view of this unfortunate tendency that all English beer exhibits to change, either under the influence of air absorbed, or under that of heat in the Pasteurisation process.

Storage.

It has frequently been supposed that success in brewing depended upon mashing and fermentation, but I am certain myself that the storage question is of equal importance, and that conditions of storage and the general treatment of beer prior to shipment should receive an amount of attention previously thought unne-

Fig. 5.



STERILIZATION PLANT.

A Sterilization Vessel. B. Refrigerator, C. Pump.

cessary. At the present day the percentage of "returns" in the case of breweries doing a large export or rail business is continually increasing, and the subject of beer sterilisation should invariably form part, I think, of the education of every young brewer, since if such returns be carefully dealt with, if suitably brightened and sterilised, there is no reason why the great bulk of so-called waste beer should not again be mixed off with advantage to the brewer, and no sort or kind of disadvantage to the consumer of the blend itself. Increasing importance of "returns" question.

CHAPTER VI.

LABORATORY TEACHING—SKETCH OF THE NECESSARY ANALYTICAL KNOWLEDGE AND THE DIRECTION THAT INVESTIGATIONS SHOULD TAKE — FORCING TRAY WORK—EXAMINATION OF WATERS, MALTS, AND BEERS BIOLOGICALLY.

The importance of chemical knowledge.

THE contents of this chapter deal with a subject of the most extreme importance to every practical brewer in the kingdom, since, although the chemistry of brewing may not be clearly understood, or recognised by the majority of practical men as thoroughly essential knowledge, we are forced to the conclusion, in view of what is happening abroad, that sooner or later each brewer will have to gain a clear insight into the theory of the process that he is attempting to conduct, while, as it is more or less chemical in its nature from beginning to end, it naturally follows that no weighty argument can be raised in opposition to the statement just made.

There is, indeed, not the slightest doubt that English beers are losing their hold upon the foreign market, for year by year we notice diminishing exports, while the competition that is driving English beer out of foreign markets is already commencing to make its appearance nearer home. The reason for this centres upon the fact that Continental workers have universally, and for many years past, paid far more attention than English brewers both to the principles of their process, and to the theory underlying every single operation that they carry out in practice.

It is not difficult, on the other hand, to explain why English brewers have hitherto been so exceedingly sceptical as to the benefits to be derived from thorough chemical knowledge. To begin with, the brewing trade in England is almost entirely based upon the principle of monopoly, while the owners of this monopoly know little or nothing about the absolute details of the manufacture they are engaged in, and have a supreme scorn, therefore, for scientific teaching, so long as they can note a favourable return upon invested capital. In the next place, a very strong but hardly justifiable antipathy exists to the employment of chemicals in brewing, and each brewer, or brewing firm, knows perfectly well that if he or they attach a laboratory to their brewing department, the public voice will say that this laboratory is utilised for enabling the proprietors to doctor their beer to the best advantage.

Monopoly.

The public antipathy to chemicals.

Then, again, chemical analysis has often proved somewhat conflicting in result, the consequence of this being seen in the very distinct scepticism which exists in the mind of many brewers as to the accuracy of any figures submitted to them by the analyst. I have myself, on many occasions, heard that a certain brewing water has been sent for analysis to several different chemists, while the reports received as to its suitability for brewing purposes varied in the most extraordinary manner; and although it would be sufficiently easy to reconcile these discrepancies from the mere chemical point of view, the sceptical brewer

Conflicting analytical results.

refers to them exultingly, as proving that no reliance can be placed upon the figures of such analytical reports. Now, of course, it is well known that discrepancies of the kind named may be mainly attributed to the fact that different chemists follow distinct lines of teaching in reference to the subject of affinity when combining the acids and bases actually determined by analysis, this accounting for the apparent variation in saline character of water.

Then, again, the main view of the ordinary analyst is, or at any rate has been, that a water should be extremely hard in order to be well fitted for brewing purposes, so that many have indicated a tendency to condemn a water when finding it deficient in the special saline matters held to be so influential in a practical brewing sense. I might enumerate many other instances to prove that brewers as a body have never looked upon the chemistry of brewing as of any real value, while, if seeking the aid of scientific knowledge at all, they have done so in a kind of half-hearted manner that has left its mark upon the whole course of English brewing operations during the last few years. We are, indeed, confessedly behind the times, and may well note with dismay the keen competition that is driving English beer out of the market.

I am therefore hopeful that in this chapter I shall succeed in impressing upon my readers not only the fact that chemical knowledge is of extreme service, but possibly show them the direction in which such knowledge should tend, since the mere determination of quantity of organic matters is of comparatively little service to the brewer, while investigation as to their quality is of the most extreme importance.

Every brewer his own analyst.

There is no doubt whatever that every brewer, whether managing an extensive business or carrying on simpler operations on a limited scale, should know how to analyse a brewery water, and, besides this, be able to determine with equal accuracy its true organic or biological character; while, on completing such determinations, he should be able to say whether the saline character of the water is recommendable or no, and work out for himself the needful or desirable saline additions, and prove, finally, that the organic character natural to the water is innocent in nature and incapable of determining change in resulting beer.

Then again with malt, is it not of importance to all to know its possible available yield, and determine the normal acidity, and arrive at some knowledge as to the proportions of nitrogenous matter present both in soluble and insoluble form, and thus ascertain whether the malting process has been carefully carried out or no? Then again, the moisture percentage as indicating careful storage, and percentages of idle grain and sinkers that enable us to judge as to the character of barley steeped, are surely worthy of determination also. This, however, is not all, since a malt analysis gives us merely percentage composition, and tells us little or nothing of the quality of the soluble constituents that we shall have to deal with as constituting the extract of our beer, excepting in the sense that analytical figures indicate indirectly the general tendency of the extract that we may expect to secure, but prove very little conclusively. It is in this particular direction, indeed, that scientific teaching has made great strides within the last few years, since when M. Pasteur once showed, in his distinct works on Wine and Beer, that the quality of extract in each might be determined by a simple forcing test, scientific workers soon evidenced an inclination to apply some kind of biological test not only to water used in the production of beer, but also to the material employed as the basis of the dry extract and the transformation products of such extract.

Biological examination of water and malt

Now, it is not my purpose in this chapter to go into any great detail respecting the biological examination of either water or malt, although a brief outline of each process may prove of interest to readers. I believe I am correct in asserting that great difference of opinion exists among scientists as to the value of the biological test as applied to water in connection with the problem as to whether a certain supply is suitable or not for domestic purposes; but surely there will be no diversity of opinion among brewers concerning the statement that if water shows a strong tendency to facilitate putrefaction, it cannot be in itself of recommendable organic purity. Generally speaking, I have never failed to see this statement confirmed in practice, and am therefore a strong advocate of the method usually carried out when the brewer is desirous of determining the true biological character of the water supply at his command.

Apparatus and *modus operandi.*

The apparatus required is exceedingly simple, the test itself easily made, the principle turning upon the addition of a measured quantity of the water undergoing examination to a measured bulk of prepared gelatine, pouring the semi-fluid mixture upon a sterilised glass plate, solidification being redetermined by placing the glass plate, with its gelatinous film, upon a block of ice. By this process we not only mix the measured quantity of water with the sterilised gelatine nutriment, but by solidifying the gelatine after intermixture, we fix the position of any organisms that the water may contain, and give them, therefore, the chance of developing as so-called "colonies," while these may be counted without any difficulty after certain intervals of time, the plate spoken of, with its gelatine film, being placed on a forcing tray, duly protected by a cover, at a temperature of 65°, under conditions that prevent any contamination from aërial matter that might otherwise subside on to the field of growth.

Results of examination.

Now, it will be perfectly evident to readers that if, in a few hours, mould spores commence to develop upon the surface of the gelatinous film, if these rapidly propagate, spread, and become exceedingly numerous, and if their defective character is indicated by the rapid liquefaction of the film spoken of, surely we may assume that the single cubic centimetre of water, intermixed with something like 10 cubic centimetres of the gelatinous nutriment, must have been of very defective organic character; and although such water would be submitted, in the practical operations of brewing, to repeated ebullition, the fact still remains that its defective organic nature would cling to it in spite of this, and would, no doubt, exercise an influence not only upon fermentation itself, but upon the stability of the resulting beer.

Influence of boiling.

It would be easy for me to show that all good brewing waters are wonderfully pure in a biological sense, and that all surface waters are just the reverse; while, of course, these vary in biological character at different times of the year, obviously according to variation in amount of rainfall, or quantity of suspended aërial matter in the different districts where such surface water is obtained. Although a water, biologically imperfect, may perhaps safely be used for domestic purposes, and though the human or animal system may be sufficiently

Surface waters.

vital to prevent the organisms of an underground water supply exercising any detrimental influence on the animal economy, it is, nevertheless, absolutely certain that such organisms can and do develop during the brewing process, when existing to any extent in the water used, more rapidly, of course, when the class of organism is putrefactive in its tendency owing to the inferiority of the contaminating organic matter present.

Influence of impure water.

The influence of such a water, in a practical brewing sense, can only be disastrous in its nature, and brewers, therefore, who are interested in their subject would certainly do well to master the *modus operandi* of accurately determining organic purity of water as a very necessary step when estimating its general fitness for brewing purposes. The advice given by a celebrated Dutch brewer, to the effect that, if desiring to know whether water is suitable for brewing purposes, it should be employed in practical operations and its fitness judged by results, is advice surely by no means absurd, although this gentleman suggested a very erroneous course of proceeding, since the brewer would obviously be risking too much, and might just as well carry out the principle of the suggestion on a small scale, first of all, before attempting to use any new supply in the production of an entire gyle.

Biological examination of malt.

If what I have been saying is important in reference to water supply, ten times the importance attaches to a similar biological examination of malt, since this is the source of the main portion of extract in our beers; while, according to the quality of this extract, so will be the character of our yeast, the flavour and eventual soundness of our beer.

I have taken a good deal of trouble lately, in conjunction with my energetic and exceedingly clever assistant, Mr. W. Virtue, to perfect a method of examining malts biologically, while in the July, 1887, number of the *Brewers' Journal*, readers will find a full description of the method in question, with comments upon the various points that have influence upon results, since, if carried out in any clumsy or imperfect manner, the indications arrived at are so conflicting and dubious as to lead us, perhaps, to condemn malts that are sound, or pass specimens of material as good that are in reality very defective.

Faults of present-day malts.

Now, the chief faults of malt at the present day are mainly to be attributed to one or two very simple causes, although it is strange that maltsters should have forgotten so readily the teaching of bygone years. Latterly they have been carrying on, for instance, methods of vegetation less and less in accordance with natural growth ; and by this I mean that as in bygone years we kept grain cool during its growth and forced vegetation less by excessive moisture supply, at the present day, on the other hand, every maltster seems eager to attain the evidences of perfect vegetation, while caring little for the eventual results of it, so that endless samples of malt indicating complete growth are utterly incapable of yielding a wort of desirable character.

Forced growth.

Inefficient curing.

Another common defect of modern malting is due to the imperfect knowledge of many maltsters as to the absolute necessity of careful curing as distinct from mere drying of the green corn, a large number of samples tasting exceedingly raw upon the palate ; while a third point is the careless storage of material, so that the absorbed moisture soon facilitates degradation in the general character or condition of the nitrogenous matter present. It is easy to discover, no doubt, some

Careless storage.

of these faults by laboratory methods, while the biological test that I refer to will prove conclusively, in a very few hours, whether malt has been efficiently cured in the first instance, or whether the storage of it has been in any sense successful.

In the notes just referred to as having appeared in the *Brewers' Journal* I carefully explained the influence exercised by presence of rootlet, the intermixture of damaged and mouldy grain, while calling attention at the same time to the enormous preservative influence of caramelisation by curing, as well as excessive acidity, this latter being frequently due to imperfections in malthouse plant, *i.e.* to the existence of cavities and interstices in flooring, so that moisture, exuding from material working on the floors in question, soon facilitates putrefaction and acidity of the solid matters existing in the escaping moisture, which accumulates, of course, in the spaces spoken of.

I need not enter into any great detail upon this particular point of biological working, since full reference has been made to it in the number of the *Brewers' Journal* quoted, while it is sufficient for me to say, at the moment, that the stability of a malt or its extract in the presence of an extreme amount of acid must of necessity be very defective, since brewers, either accidentally or by design, take steps in many cases leading to minimised proportion of acid as naturally present in mash wort. Besides this, it is noticeable that putrefaction or changeability of mash wort sometimes appears to start from material or draff itself, while in other cases the supernatant wort seems to cloud and enter into a state of preliminary putrefaction prior to any evolution of gas from the sedimentary draff, and for this reason Mr. Virtue devised means of separating mash

Influence of acidity upon stability of wort.

from its wort without allowing either to come in contact with unfiltered air while doing so.

We have thus been able to prove that sometimes the cause of putrefaction may be attributed to the type of insoluble material dealt with, as evidenced by the instability or changeability of the mash goods, while in other cases the wort itself seems to have a prominent capacity of changing, although the material yielding it after its separation may entirely lack this. I have recently, too, been able to show, as briefly explained in Chapter I., that it is possible, by miniature laboratory or brewery experiments, to prove beyond doubt a most important point in reference to malt, viz., that many varieties are rich in peptonised forms of nitrogenous matter, while others are poverty-stricken in this respect, these latter, indeed, corresponding to the varieties of material that have been excessively forced during artificial growth. The evidences of perfect vegetation—and I cannot repeat the statement too frequently—are, indeed, more or less delusive, for while spire and root, in point of quantity, may lead us to suppose that vegetation has been perfect, the forcing of this fully-grown malt, under the influence of warmth and moisture, has been so extreme that they cannot fairly be taken to represent in any sense the success of the vegetation process, in so far as the first modification of interior constituents of grain is concerned.

Peptonised matter of malt

We have been able to prove this all-important point, as I have said, by showing that if badly vegetated malt be infused at a low heat, and stewed at the temperature of blood, viz., 97° Fahr., the proportion of soluble albuminous matter yielded by it eventually is about double as compared with that yielded by the same material when infused at the high temperature common in

Influence of infusion heats

English breweries; while the results, when dealing with malt of high-class character, prove that such material is already rich in peptonised forms of nitrogenous matter, since we do not, under these circumstances, determine a much greater percentage of soluble albuminoids when infusing the material in question in liquor at a low heat to commence with. In other words, when dealing with malt of this kind, we may rest satisfied that the grain contains fully-digested forms of nitrogenous matter as influenced by the slow artificial growth practised in the malthouse, so that no mere variation of infusion heat determines the formation of bodies that already exist; while in the case of defective material we are, by the adoption of preliminary extremely low heats, enabled, as it were, to complete in the mash tun the very defective operations of the maltster.

Value of malt analysis.

It is not too much to say, therefore, that the mere analysis of a malt is of no particular value as a proof of its entire fitness for brewing purposes; and, personally, I should almost prefer to determine its real quality by its taste when chewed, since by the action of our teeth we can determine whether it is friable and dry, while we can discover also by our palate taste whether complete curing has been determined. On the other hand, if the material under examination is steely, if the taste of the malt is raw, we may conclude that the maltster has failed in his working; while such conclusion may be confirmed in the most absolutely correct manner by determining in the laboratory whether the yield of soluble albuminous matter varies widely according to temperature of infusion, and whether the extract yielded is unstable (as indeed it would be), by submitting the malt to the very distinctive biological examination described.

What could possibly be of more importance at the present day than the question of determining purity of water supply and quality of malt extract through the agency of biological examination? I have myself equal and well-justified confidence in the results of both processes, and can definitely assert that I have never known a malt, incapable of comporting itself satisfactorily when exposed to forcing influences, that yielded beers during the trying months of the year otherwise than exceptionally changeable from date of racking to final day of storage, while a test that enables us to judge accurately of character of malt extract before mashing it, should indeed be looked upon by brewers as one of the greatest possible value.

Unstable malt yields unstable beer.

These, then, are points in connection with the necessity for determining quality or type of extract as distinct from mere quantity yielded; and in this particular direction great advances have of late been made, enabling the skilful brewer, without any loss of time, to determine whether a certain sample of malt offered to him is recommendable or otherwise in actual quality.

If it is of importance to determine the biological character of waters and malt used in the production of beer, it is equally necessary that we should be able to determine whether the produce of our manufacture is also recommendable in stability, and the forcing test, therefore, for beer described in the body of this work, is one that is never likely to lose its hold upon the fancy of English brewers, because, if carefully conducted, it enables us to foretell the general tendency of the beer experimented upon, and to decide as to whether it would be advisable to ship certain brewings to distant countries, or, on the other hand, whether they are endowed

Forcing test for beer.

only with the capacity of resisting trying summer influences during a reasonable length of time.

Importance of biological examinations.

I cannot impress upon readers too seriously the necessity for giving careful attention to the statements that I have just made, since every one connected with the manufacturing department of a brewery should, in my opinion, study well the influence which the quality of extract has upon the general character of beer produced, and be also in a position to accept material as of standard quality, or to condemn that which is only likely to yield defective results; while if we thoroughly master the secrets of biological working, we shall soon be able to determine whether the malt or other material employed in the production of our beer can be looked upon without suspicion, whether the resulting beer itself is likely to prove stable, or, on account of defects in character, should be disposed of at once, even at a loss on trade price.

In saying all this I am anxious that brewers should no longer rest content with mere analytical reports that are fallacious, deceptive, and valueless in every way unless they are confirmed or refuted by careful biological examination of material reported upon. So convinced am I that the biological test corresponds exactly with a similar operation on the larger scale that each brewer carries out unknowingly on his own premises, that I assert, without fear of contradiction, that if brewers would only take the necessary care in determining the true biological character of material offered to them, they would be able to keep comparatively clear of returns, since they would invariably discover whether the material suggested for use in the production of a certain beer warranted the good opinion held of it by the buyer, who, as a general rule, accepts merely the eye appearance of malt as determining its good quality.

If such biological examination is of importance in one direction, it must be allowed that chemical knowledge is more or less recommendable in another, since every tyro in brewing should know how to determine the true value of a sugar, its percentage composition, the acidity of a malt or that of sugar extract, the moisture percentage in sugars and the means of calculating it out. All brewers, too, should be able to determine the original gravity of beers and the essential features of their composition, although this knowledge would be of little value unless we kept in mind the fact that analysis shows us only the quantity of extract obtainable, and very indirectly, if, indeed, at all, the quality that we shall be securing.

Chemical laboratory work.

In all these forcing experiments, *i.e.* in biological working, where temperature has such an enormous influence in reference to results, it is requisite that our forcing trays should be of two descriptions, these being kept perfectly distinct—forcing trays for beer generally being steady at a temperature of 75° to 80°; while a forcing tray for malt extract should not be higher than 75°, the forcing cupboard employed when determining the biological character of water being retained, as a rule, at a temperature of about 65°. Readers will please remember that it matters little what the temperature of forcing tray is, so long as we always steadily adhere to a fixed limit, and determine for ourselves the relative connection between results, or otherwise fix our own standards of quality when carrying out the manipulation in a certain way, and see afterwards that future manipulation, in reference to material of different kinds, is in strict accordance with that

Temperature of forcing trays.

practised when experimenting with the standard material.

We have undoubtedly much to learn in connection with the subject of biology, but, in dealing with this matter as one of practical importance, I have endeavoured to show that laboratory teaching of the present day should be a little more in advance of what was common a few years back, and that the mere determination of percentage composition of material is of very little importance unless we are able to prove conclusively something in connection with quality. Fortunate it is for brewers that means have been determined for arriving with accuracy at the general biological tendency of a water, the malt which yields the extract of our beer, and of the beer itself when exposed to an ordinary forcing test. I have never known biological results, when carefully arrived at, to prove in any way deceptive, although, of course, great accuracy of manipulation is required so as to prevent the dubious results that I have referred to as likely to arise if manipulation is carelessly carried out, through want of knowledge or skill on the part of the operator. Every young brewer should also know how to determine the true peptonised character of malt, *i.e.*, whether it is already rich in nutritive yeast-forming matter, or whether this will have to be brought into existence through the influence of low infusion heats, although he would do well to remember that, when attempting to determine easy fermentation by low infusion temperatures, he will be driven by necessity (*i.e.*, if he wishes to produce a beer of stable character) to call into play in the after-processes of brewing, corrective means to determine a stability of wort that has not, in the first instance, been secured under or through the agency of any high striking heats

Determination of peptonised character of malt.

of the liquor dealt with. I have learnt by experience that repetition and reiteration of certain important statements is the only way of engrafting them successfully on the minds of ordinary readers, and am not ashamed, therefore, in this particular chapter, to confess that I have adopted this principle, in referring to the subject of biological examination, as a means of enabling the brewer to determine for himself the true value of material, while writing of it from several distinct points of view, and I sincerely trust that readers will see for themselves the immense importance of the whole subject.

The microscope for biological work.

Of course, in determining biological results, we have to depend upon microscopical observation, and I must again impress upon readers the necessity of avoiding any combination of very high magnifying powers, which invariably over-enlarge yeast, both healthy and diseased, giving to the former, at any rate, a distorted appearance, while it is seldom that the varying types of diseased ferment-life present come into focus at the same time. It is absolutely essential, also, that great care should be taken in selecting the objective glass, since few evidence that true definition-capacity that is altogether different, of course, in meaning, to simple magnifying power. From long experience I may safely assert that the majority of microscopes employed in breweries are very defective in this particular sense, and that, in viewing yeast by their aid, it is almost impossible to successfully determine the true physical formation of each individual cell that may come into focus. This is, indeed, a great pity, since, when examining pitching yeast, it is very necessary that we should know and recognise not only the type or family to which our yeast belongs, but also the physical appearance of the interior plasma, while if we merely look for shape, size and pretty appearances of yeast itself, we shall be wofully deceiving ourselves in accepting the microscope as a guide in its selection.

In dealing, therefore, with the subject of this chapter, I have tried to show the direction in which laboratory teaching should extend; while urging that mere chemical knowledge, or the elementary rudiments of it, are of little or no service, unless we adapt them to requirements and extend our knowledge in the way of ascertaining not only mere quantity of matter, but its tendency in biological direction. Let readers apply their knowledge, therefore, not only to the mere examination of chemical substances which are now largely used in practical brewing operations, but, if wishing to be uniformly successful, let them also grasp the meaning of true biological knowledge, and apply it to the examination of the principal materials that they employ, and the resulting beer they produce.

CHAPTER VII.

DETAILS OF ILLUSTRATED PLANT ARRANGEMENTS.

In concluding the present Appendix, it is necessary, I think, to give a description of the new illustrations inserted, a little more fully than in the foot-notes appended to each Plate, although not attempting to go into any great detail while so doing. I may divide the subject under the following headings:—(1) Howatson's Water-softening Plant; (2) Limited Decoction Plant; (3) Multitubular Mash-tun Circulating Plant; (4) Hot and Cold Aëration Plant; (5) Cold Air Plant; (6) Sterilisation Plant; (7) Miniature Mashing Plant.

Howatson's Water-softening Plant.

The Water-softening Plant in the illustration is self-explanatory, the water being softened by chemical treatment; while the subsidence filter, shown in section, is simply an arrangement that facilitates the rapid subsidence of saline matter from water while passing slowly between diaphragms constructed of a material that possesses an attractive influence for suspended particles of any kind. The whole arrangement is more or less automatic (*i.e.*, requires no particular attention), the water after passing through the softening and filter vessel being admirably pure and soft. I may commend this arrangement not only to large users of boiler power, but to brewers who are anxious to secure a pure supply of steam for various purposes in the brewhouse.

Limited Decoction Plant.

The Limited Decoction Plant is illustrated from three different points of view, so that readers may the more readily understand the general arrangement, as it would be in the case of their own individual plants. The decoction vessel itself is fitted with under-gearing, and internally the motive power is the simplest form of screw propeller, while, as before stated, such vessel may be readily fitted with a slotted bottom and sparge arrangement, so that it may be used for infusion mashes if required. A steam shoot is provided to carry off excess of vapour, and, as will be noticed, the decoction vessel is fed by a revolving disc mixing machine, this being commanded by a small grist case, which receives the 20 or 30 per cent. of grist that we intend submitting to decoction influences, the run-off pipe being connected to Steel's mixing machine in connection with the larger mash-tun below. This decoction vessel is also admirably adapted for sugar inversion, or the preparation of hot liquor for blending purposes, these diverse processes possibly carried out in it rendering necessary a point previously specified, viz., that all fittings should consist of either copper or gun-metal. The foot-notes appended to the illustrations are, I think, sufficiently explanatory of details.

Multitubular Mash-tun Circulating Plant.

The Multitubular Circulating Plant is simply plant giving the brewer the means not only of carrying out extended wort circulation at any temperature that may be desired, but also enabling the operator to first raise the temperature of wort to a very high point, and then lower it again before re-sparging on to goods, while, as the pump obtains its supply from the run-off mains from mash-tun, the circulating wort never comes in contact with the atmosphere. This would not be very objectionable in itself, but the heating capacity of the multitubular plant specified would be minimised to a considerable extent if the wort had any large proportion of air intermixed with it, since this would act as a kind of cushion, and prevent the wort actually touching the heated tubing itself. This multitubular plant, of course, requires constant cleaning, for not only does the wort passing through leave a deposit on the interior piping, but the steam used frequently throws a saline deposit (steam generally carrying some portion of water mechanically suspended) on the outer surface of the same pipes, so that, if these two deposits be allowed to accumulate, the heating capacity of the arrangement is seriously minimised. Cleaning is best carried out either by means of friction, or by allowing strong caustic potash solution to stand in the multitubular plant when out of use; the tubes themselves, too, can readily be removed when necessary, while, as the ends of each cylinder are closed by screw caps, these can be easily removed, so as to render cleaning of the interior and removal of tubes a very simple matter.

In the main portion of the Appendix a tabular statement appears, showing the revolution in dextrine proportions that can be determined by the employment of this plant, so further reference to this particular matter is, I think, unnecessary.

The pump employed for wort circulation need not, of course, be of any particular pattern, while the one shown is termed a "combination pump," being used not only for wort circulation, but also for the purpose of aëration, pumping, and throwing either a supply of hot or cold air as required.

Hot and Cold Aëration Plant.

The illustration showing the Hot and Cold Aëration Plant is also sufficiently detailed.

The combination pump, just spoken of, sucks the air supply through cotton-wool, this removing all suspended aërial matter, while, after passing through the pump, it is again filtered through cotton-wool, to remove any trace of oil, since a lubricant is, of course, necessary for the proper working of the pump, and, as pressure is employed also in the pumping operation, the temperature of air passing through the cylinder is raised very considerably, and takes up in result a certain amount of volatile oily matter which is quite as well removed, this being accomplished, as I have said, by passing the filtered air under pressure through a cotton-wool filter as before. When the air is required hot for oxidation purposes (*i.e.*, in connection with circulating mash-tun wort, copper wort as collected, or cooler worts as passing from hop back to cooler,—each brewer having his own particular views upon this question),—the necessary rise in temperature is determined by passing the air pipes carrying the air under pressure through cylindrical heaters, the pipe carrying the air being small in diameter and spiral in form, so as to determine the greatest heating area possible in a limited vertical length of cylinder, while under such circumstances, and as depending upon pressure and heating area of cylinder, the temperature of the air pumped can be raised to 260° or 270°, this being indeed a matter of importance as deciding more ready oxidation and the greater possibility of air remaining in the fluid into which it is forced. In other words, cold air would accomplish just the same oxidation change, although the larger proportion of cold air introduced into the fluid would escape by expansion. Readers will understand, no doubt, that as hot air forced through a confined space owes a considerable portion of its apparent heat to the existing pressure, such portion disappears on the re-expansion of the air when liberated from the carrying pipe at the moment of introduction into the wort undergoing aëration, so that no actual rise in temperature of fluid results, and it is for this reason that hot air is not destructive to either diastase or peptase; nor can it be used as a forcing power like steam, its diffusive tendency being too great.

When air, on the other hand, is required for cold aëration purposes, *i.e.*, for accelerating speed of attenuation, or reviving yeast that is in any sense weak through inefficient air supply (this being extremely common in breweries where fermenting tuns are deep, and when the system of brewing carried on does not embrace preparatory pitching, or indirect aëration through the removal of fermenting beer from one vessel to another) the air passing through the pump is cooled merely by carrying the conveying pipe in spiral form through a corresponding cooling cylinder, the water being supplied, if necessary, from a small tank containing ice and salt also.

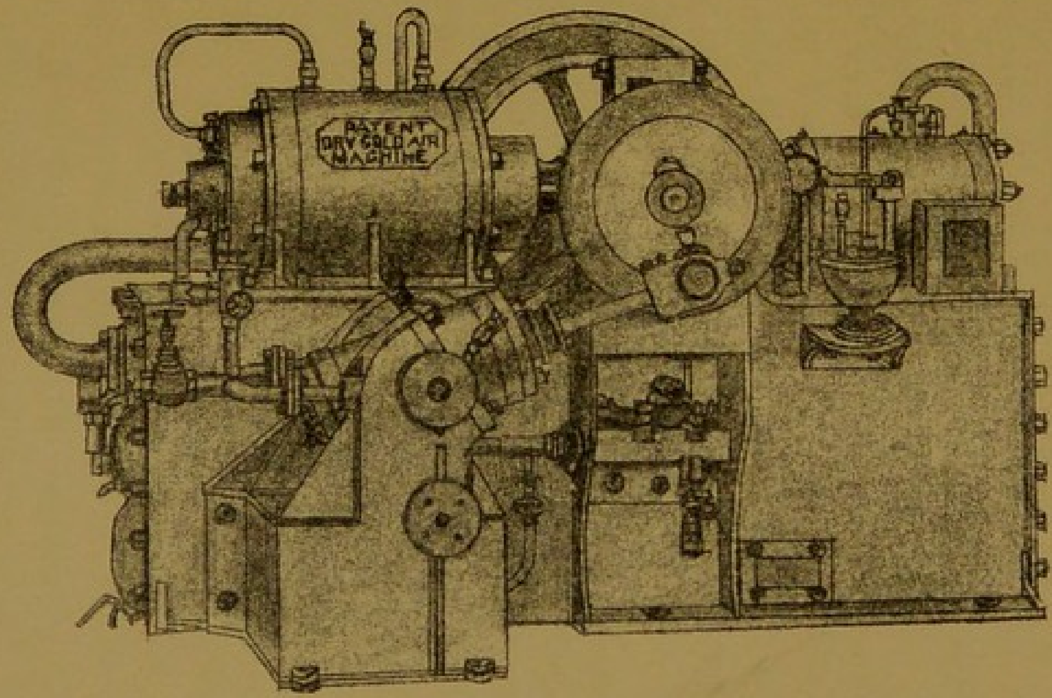
Now, cooling under pressure means, that when the air so cooled is allowed to expand and again escape from the delivery pipe, it becomes much colder by rendering heat latent, and thus, if we cool air in one of these cylindrical arrangements to a temperature of 50°, it will drop quite 3° or 4° when passing from the delivery pipe into wort that we are aërating. This air supply, consequently, may be employed with great advantage as a cold blast above the surface of fermenting wort, as it not only keeps up a definite current, but determines naturally a purity of atmosphere above the surface of wort that would not otherwise exist, this being an influence quite out of connection with the mere aërating office which it is called upon to perform. The illustration shows the air plant in detail; the combination pump supply pipe in connection with circulating cylinders, the air supply passing also through a multitubular heating cylinder to underback and copper, and through a corresponding cooler to fermenting tuns, the cold blast pipe, duly perforated, being shown above level of wort, the aërating pipe, in this case, being carried to bottom of fermenting vessel. The whole of the piping is, of course, connected by means of unions, so that it may be readily taken down for cleaning, although, perhaps, the most simple and commendable plan would be to blow steam through the whole arrangement once or twice a week, while, as the air passing through is always double filtered, it is easy to understand that the amount of dirt accumulating is very minute.

Cold Air Plant.

The Cold Air Plant illustrated is quite out of connection with the subject of aëration, being used in breweries for the purpose of deciding a cold atmosphere in the fermenting rooms, yeast stores, or beer cellars.

The particular arrangement illustrated is used very

Fig. 6.



INK-PHOTO, SPRAGUE & Co LONDON.

WINDHAUSEN'S DRY COLD AIR MACHINE.

extensively on the Continent, under the name of the Windhausen Cooling Machine, and is, I think, generally preferred by Continental brewers, since it does not involve the employment of chemicals in any shape or form, the principle of the machine depending upon the compression of air that is cooled under pressure, and the liberation of the cooled air to accomplish refrigerating power while undergoing expansion.

I have referred to this matter above when dealing with the point of cylindrical coolers, stating that when air under pressure is cooled, and again allowed to expand, it renders latent the same identical amount of heat as that liberated on compression, and since it is possible to cool hot compressed air by the aid of water at a comparatively useless temperature for actual refrigerating purposes, it is easy to see that we can gain an enormous advantage when determining refrigeration by allowing the cool compressed air to again expand to its original volume.

The working of this machine is in every way exceedingly simple, air being continually compressed, the liberated heat being removed by refrigeration—that is, by the aid of water that need not in any sense be very cold—while the cooled compressed air is allowed to expand and pass continuously into fermenting rooms or other parts of the brewery that are best kept, if possible, at a low temperature; while, as the air pumped by one of these machines can, if required, be carefully filtered, it is easy to see how we can not only determine low temperature of atmosphere, but also a greater purity than would otherwise exist.

The general idea of cold pure air as a necessary factor in successful brewing has been recognised for years past on the Continent and in America, yet

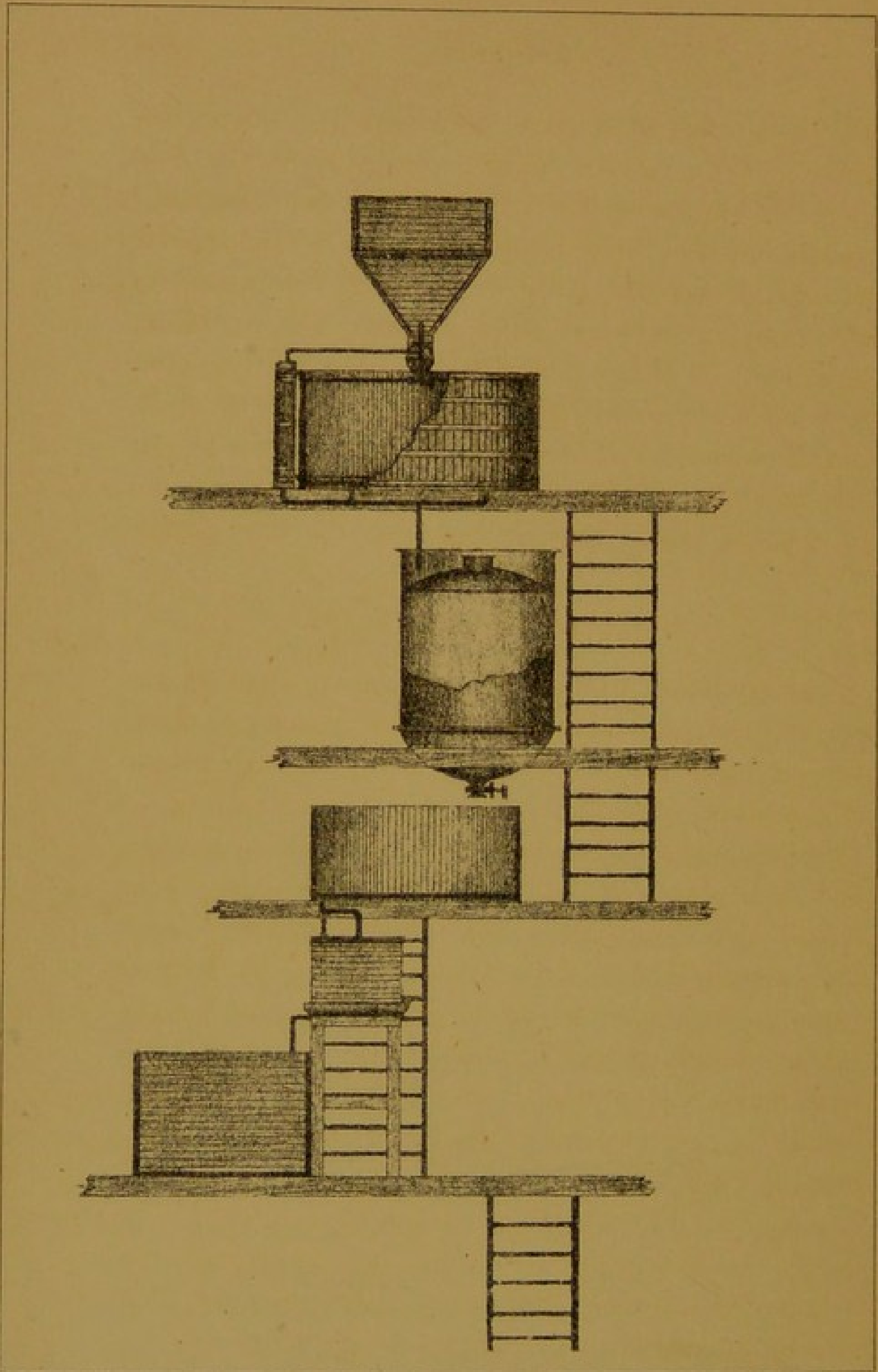
English brewers, for reasons in connection with the monopoly that exists, have hitherto paid but slight attention to it. Messrs. Guinness & Co., of Dublin, however, have shown during recent years, in a very perfect way, the benefit that can be secured by adopting the principle of cold as determining direct and indirect success in fermentation through improved quality of yeast; and I am sure, therefore, that the general principle of modifying the normal condition of atmosphere existing in fermenting rooms, yeast stores, and beer cellars, during unfavourable seasons, will meet with far more attention in the future on the part of English brewers than it has done in the past, while I am equally certain that the adoption of the principle in question will invariably lead to improvement in practical results.

The Sterilisation Plant.

The Sterilisation Plant is a very simple arrangement, the following explanation being sufficiently detailed.

The Pasteurisation vessel itself is a cylindrical steam-jacketed copper fitted with the necessary safety-valves, and placed at a sufficient altitude so that, after refrigeration of contents, the treated fluid may pass either to casks or tanks, as most convenient. As it is not exactly advisable to allow a sterilised fluid to come in contact with air after the treatment has been carried out, it is usual to pass it by preference through a closed refrigerator, which is shown in a sketch immediately below the cylindrical vessel itself, while the combination pump previously spoken of may obviously be used for the purpose of supplying the vessel. The beer undergoing sterilisation is raised in temperature through the agency of the steam jacket, while

Fig. 7.



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MINIATURE BREWING PLANT.

For determining Color and Value of Malt, and preparation of Concentrated Wort for Yeast-feeding purposes.

the evaporation of spirit is prevented by fitting to the interior of the vessel a spiral condenser above the fluid line, the beer, as readers will remember, being sterilised under pressure, this being regulated by safety-valve fittings, the pressure itself being mainly determined by the escaping carbonic acid; in order also to secure large pressure at the limited sterilisation heat adopted, it is necessary to fill the vessel completely with fluid, or otherwise the vacant space renders it impossible for any pressure to be determined by the limited amount of gas and vapour that escapes from the fluid itself.

Miniature Mashing Plant.

The Miniature Mashing Plant is, in my opinion, one of the most important portions of a modern brewery, since in using it the reader may easily determine some of those very important points that I have referred to when dealing with the biological examination of malt, and each parcel of malt bought can be readily submitted to a preparatory test on a sufficiently large scale that will enable the brewer to judge of its real value in reference to colour and character of the extract that it is likely to yield, such data forming a basis for judgment as to the probable results when employing the material in the larger operations of the brewery itself. This plant is also of extreme importance in enabling brewers to prepare some eighteen gallons or so of highly concentrated wort, this being used for definite yeast-feeding purposes, *i.e.*, the pitching yeast is intermingled with concentrated wort containing no hop extract, and allowed to feed in this, or, in other words, to revive, mature, and gain alcoholic capacity, under the influence of the strong aërated wort, some thirty or forty minutes before being introduced into the main portion of brewing collecting.

The illustration shows a miniature mashing plant of one or two bushel capacity, fitted with bin, miniature Steel's mixing machine, naked steam wort circulating arrangement, jacketed copper fitted also with naked steam supply, and dome, circular hop back fitted with sparge and slotted bottom, and, finally, vertical refrigerator and collecting vessel,—the whole being in strict unison, and constructed with the idea of favouring the usefulness of the arrangement for the special purposes named.

The Excise authorities invariably grant a permit for the employment of such plant under very simple control, no duty being chargeable on the limited quantity of beer produced if this wort be run to waste before or after fermentation, while if it be carried forward for yeast feeding purposes it constitutes, of course, a portion of the entire wort collected.

It is needless to refer to these illustrations in greater detail, since, in the text of the various chapters, the special purpose for which the several portions of all plant illustrated are used has been fully described.

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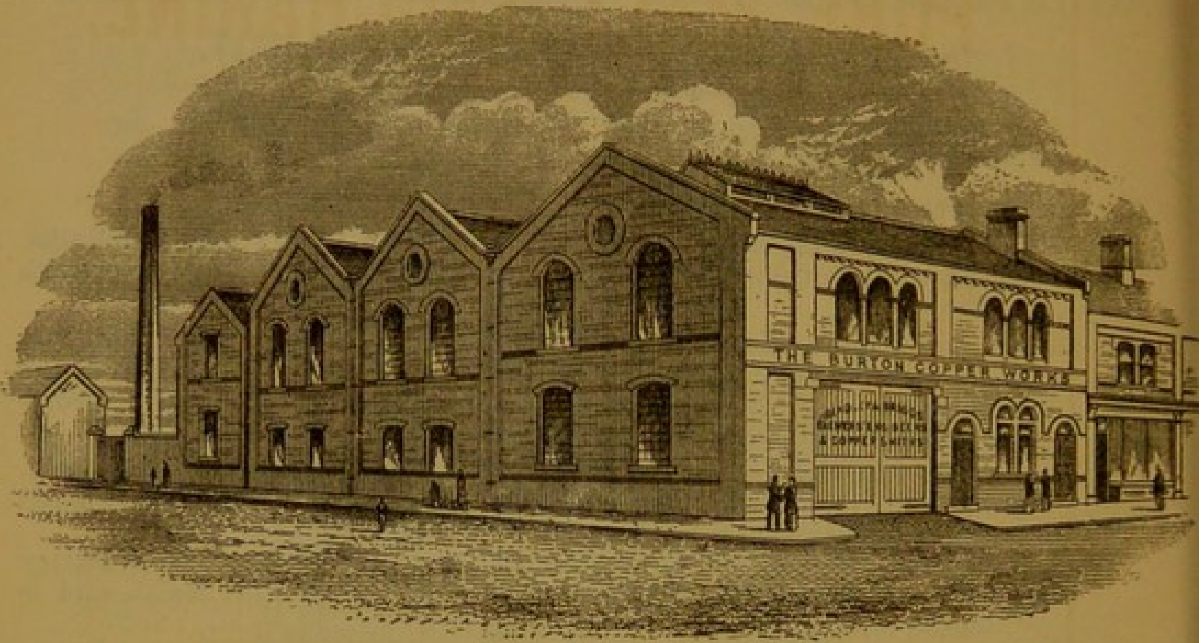

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