JOINT MEETING OF THE LONDON SECTION WITH THE LONDON SECTION OF THE INCORPORATED BREWERS' GUILD, HELD AT THE BRITISH INDUSTRIES HOUSE, MARBLE ARCH, LONDON, ON MONDAY, 7TH DECEMBER, 1935

Mr. JAMES GRANT in the Chair

The following paper was read and discussed:—

CHEMICAL ENGINEERING IN THE BREWING INDUSTRY

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THE profession of chemical engineering may be said to have been founded by a former alkali inspector, Mr. G. E. Davis, who was the first secretary of the Society of Chemical Industry in 1880 and who wrote the first book on the subject in 1900. Some six years later the American Institute of Chemical Engineers was founded but it was not until 1922 that a similar qualifying body was formed in England, its initiation being largely due to the scarcity of men capable of operating and maintaining munition plants during the war.

The Institution of Chemical Engineers define a chemical engineer as "a professional man experienced in the design, construction and operation of plant and works in which matter is undergoing change of state or composition." It will be seen that this definition embraces the art and practice of brewing and can perhaps be best amplified by considering firstly, the education necessary for a chemical engineer, and secondly, how his training will fit him to deal with problems that arise in a brewery.

Some universities provide a course leading to a batchelor's degree in chemical engineering, whereas others, including London, provide a graduate course with a diploma which can be taken by students who have already taken their degree in either chemistry or engineering. Alternatively the Institution of Chemical Engineers holds a qualifying examination every year so that students who cannot attend the recognised courses can still be admitted to Associate Membership on passing the examination and on having had two years' experience in works of a kind approved of by the Institution.

A pamphlet on "The Training of a Chemical Engineer" was issued by the Institution in 1925 and this gives an outline of the subjects which he is required to know. These are divided into four main groups, of which the first, "Chemical Engineering Processes," or, more commonly, "Unit Processes," is the most characteristic and important. These operations, which include leaching, heating, pumping, grinding, filtering, evaporating, distilling, etc., are operations which occur in practically every type of works in which chemical changes occur. Since the publication of the physical and physico-chemical theory underlying these operations by Walker, Lewis & McAdams, in 1923, in a book entitled *Principles of Chemical Engineering*, the literature on this subject has made vast strides. This book was based upon the course given at the Massachusetts Institute of Technology, and covered entirely different ground to the earlier book by Davis, who had confined his attention mainly to the practice of the profession.

The second group is "Chemical Plant Construction" and includes the properties of metals and their alloys and of non-metallic materials with regard to both their constructional and corrosion aspects. Students are expected to know the rules for the design of plant from the point of view of strength. The third group is headed "Factory Design and Construction" and includes plant lay-out and construction and the generation of heat, electricity and compressed air. The final group includes "Industrial Economics," or the general principles of factory organisation and management.

To apply the subject of chemical engineering to brewing it is necessary to be more specific. An item of expenditure in breweries in which economies can often be effected is that incurred in the boiler house and in the heating system in general. In many breweries the load on the boilers is very

variable so that with coal firing it is practically impossible to attain good combustion of the fuel and to avoid smoke. A large amount of heat often can be lost up the chimney owing to the necessity of using a large excess of air. The boiler load can be smoothed out by maintaining an unfired but carefully lagged Lancashire boiler, containing water at the temperature of the steam, on the main steam line. This acts as an accumulator, but, for more careful control, it is better to have a steam accumulator which is specially designed to maintain the steam pressure constant. Much heat is often lost in the steam lines owing to inefficient or incorrect lagging and the chemical engineer is trained to be able to calculate the optimum thickness of lagging for any particular case. Other subsidiary factors, such as water softening, are important and call for expert technical supervision, especially now that so many unproven electrical methods are being put on the market more by good salesmanship than by properly substantiated results.

The grinding of malt and its relation to the efficiency of extraction in the malt tun would assume an importance if it were not for the fact that ample water is available for leaching owing to the weak extract required. Economic grinding can only be obtained if the crushed material is removed as fast as possible after its initial crushing, otherwise much of the power is consumed in converting the product into small unstable briquettes. The normal size reduction for most materials should be not more than three to one. The speed of revolution of the rolls therefore should be about three times that of the rolls of the previous stage. In determining the speed of revolution, it is generally found necessary with semi-plastic materials to apply the crushing force as suddenly as possible because they are then more liable to crack than to squeeze. Too high a speed however will bring increased friction on the bearings and increase the power consumption.

The correct design of a copper is an interesting problem although difficult in practice because it is not easy to obtain a clear conception of what happens when a wort is boiled. It is impossible to make a good design until the optimum time and temperature for each of the factors is known. In most food industries to-day, demands are made on the ingenuity of the chemical engineer to carry out some heating operation with the least damage to the food and vitamin content of the product and in this connection the use of a coal-fired copper seems rather like using a sledgehammer to drive in a tintack. Only recently it was stated by the Chief Sanitary Inspector of Edinburgh that the city air was being polluted by coal fired coppers owing to the fact that they are cooled down between successive boilings. Because of the low temperature of the furnace, smoke emission is unavoidable even by the most careful stoking. The relative advantages of coal and steam heating of coppers is a subject of perennial discussion and the suggestion made that fire heating imparted a flavour of caramelisation, could easily be arranged by less drastic means. In any case it would appear that copper is an unsuitable metal to use for this purpose because, owing to its high conductivity, it spreads the heat. For this reason copper is preferred to stainless steel in jam making, which has the opposite tendency of localising the heat and giving hot spots.

The chief objects of boiling in the copper appear to be:—

(1) To sterilise the wort. This is said to occur after 15 minutes.

(2) To coagulate certain proteins by heat. This apparently requires a temperature of 180° F.

(3) To extract the tannin and aroma from the hops.

(4) To remove or modify the malty smell and flavour of the wort.

None of these reasons accounts for the extensive boiling usually given to the wort, so that either reasons are incomplete or alternatively the boiling is carried on too long. Colour is given to the latter reason by the statement that "beer made in an iron square back with a steam coil, which only succeeded in keeping up a semblance of a boil, for often not more than 80 minutes, was not inferior to that made in a fire heated copper, and equal to that made in steam heated coppers." It would appear rather as if the brewer was trying to do too many things at the same time. The removal of the smell from the wort requires an open vessel with efficient agitation to expose plenty of surface, whereas the extraction of the full aroma of the hops requires the reverse process.

The correct filtration of the hopped wort in the hop back is another point which calls

for comment. The proper removal of the solids at this stage is necessary because of the resulting coating of the yeast cells and also of the possibility of a harsh flavour being transmitted to the beer. Hop backs do not appear to be designed as very efficient filters; possibly a Monel metal screen with a precoat of filter aid might produce a clearer wort.

In the fermenting vessel, the correct design of the attemperator coils is a small but interesting problem. Weighton (*Trans. Inst. Naval Architects*, 1906), showed that the most suitable surface section ratio for pipes was about 2,900, which means that, for a circular pipe, the ratio of the length to the diameter should be about 700. The length of a pipe can be decreased by making a pipe of the same cross section but oval in form. The total area of the tube is determined by the heat transmission from the cooling water to the wort and in this the metal of which the tube is made plays but a small part. The chief resistance to the transfer of heat resides in the very thin film of almost stationary fluid which adheres firmly to any solid-liquid interface and whose thickness decreases as the velocity of the fluid past the surface increases. Since most fluids are bad conductors of heat a high velocity is found to have a marked effect on the heat transference and consequently the area of cooling surface necessary to remove a given amount of heat. Since the wort cannot be stirred and is moving very slowly, it would probably be found that the addition of a fin running along the tube (instead of around it as in ordinary finned tube heaters) would be advantageous in that it would increase the area of heat transference on the side where it was least, and it would also be capable of easy cleaning.

The problem of the design of collectors for the carbon dioxide evolved during fermentation consists of having a gas governor which will draw off the gas at the same rate at which it is being produced, and to compress this gas without excessive generation of heat so as to avoid altering the flavour of the beer after carbonation. The handling and treatment of solid carbon dioxide has recently been discussed by Cosbie (this *Journ.*, 1932, 427). The view was expressed some years ago that it was difficult to see how copper could be taken up by the yeast from the bottom of the fermenting vessel, and in this connection it is interesting to note that recent research has shown that the copper content and vitamin B content of foods run parallel to each other. Brewer's yeast is one of the chief sources of vitamin B.

Great improvements have been made in recent years in the design of plant for cooling of the wort before fermentation by substituting enclosed plate heat exhangers for the older type of falling film coolers with exposed surfaces. The newer type takes up less space, although this point is not always of importance in a brewery. These plate heat exchangers require pumps to force the liquids through them at a high velocity, but the cost can be offset to some extent by that of the fan required for forcing sterilised air into the rooms containing the falling film cooler. Possibly the best method of judging their performance is to balance the freedom from bacterial contamination resulting from their use against the loss of prestige consequent on, and the actual cost of dealing with, "returns."

The filtration of beer is generally carried out in pulp filters, and the use of filter presses using filter aids does not appear to have been in much favour. This appears to be due to two main causes. In the first place, ordinary unpurified kieselguhr has been used and this has given an unpleasant flavour to the beer. In the second place, the filters have not always been designed to give good cleaning facilities. Neither of these problems is insoluble and in fact this method is used widely in the United States for Lager beers. An advantage of using a filter aid is that it enables the capacity of a filter press to be increased, sometimes as much as fivefold, and that is of course of great importance when the plant is required to meet a sudden demand. This very rigorous filtration of the beer to obtain a crystal clear product is not beneficial to the consumer as it may remove any traces of vitamins. Examination of such beers have shown them to be practically free of vitamin B. Patents have been taken out for rupturing the yeast cells and liberating the vitamin, which can then be put back into the beer. Probably this will give rise to unwanted flavours unless care is taken that the vitamin containing solution is treated to remove such flavours.

The chemical engineer should have an important part to play in a brewery, especially when due consideration is given to the other aspects of his training such as economics, plant design and layout. The intensive

analytical training which a chemist receives may result in a rather introspective and reserved character, which is not well suited for the handling of the human side of a works and is apt to make him overlook some of the broader issues. On the other hand the engineer who is liable to be engaged mainly on maintenance and repair work often develops the opposite characteristics and does not stop sufficiently to pause and consider the why and wherefore of the work which he is doing. His reference book becomes more and more thumbed and his brain gets less and less of that exercise which is so necessary for proper development. In the training of a chemical engineer it is necessary to apply a corrective in each case before a student finishes his course. The chemists are encouraged to widen their horizon by workshop training, and by the habit of making suitable approximations, to arrive at the decisions that are necessary for the proper economic management of men and plant. The engineers are required to extend their chemical laboratory experience so as to instil into it a spirit of adventure and not drudgery. Naturally it is not always possible to obtain a true balance in the short space of one academic year, and the ideal would be to have the students for the whole of their academic career instead of a post-graduate course.

Discussion

Mr. W. J. Watkins said that he had had no experience of steam accumulators, and he would like to ask the author if there was any use for them in a brewery in view of the fact that most of the steam was used for heating and not for power. Was not an accumulator a means of obtaining an extra supply of what must be saturated steam at a low pressure? He had been able to effect considerable coal economies by installing steam flow meters. He required information as to what the boilers were doing, and it was difficult to calculate from water meters, because water was derived from several points including the loop system from steam coppers. Results with steam flow meters taught him how to ration steam in such a manner that he was now able to get a more even load upon the boilers throughout the day. In these times brewers were not allowed to waste fuel, and he was inclined to question the author's theoretical considerations about boiling. The allocation of certain periods for sterilising and coagulation of proteins would, if adopted, result in unstable beer, for under such conditions he doubted if the spores carried forward from the mash tun would be destroyed. The reference to the breaking up of yeast cells was of interest for possibly some other means of preparing yeast as a saleable by-product would be more remunerative than the present price of waste yeast.

Dr. R. Seligman said he wished to draw attention to one respect in which the British chemical engineer differed from his colleague in America. In America the man who operated the plant was a chemical engineer, as stated in the description given by the Institute of Chemical Engineers, but here the chemical engineer did not as a rule operate the plant, otherwise brewers would all be chemical engineers, since they all operated their plants. He thought the author had overlooked the physical effects of boiling in the copper, and in that connection he suggested that the proposal to use mechanical means to do what at present was done by intensive boiling should be borne in mind. Most brewers he believed, would agree that in the cooling of wort there were other things to be considered than a mere exchange of heat. He did not think that the application of the knowledge of heat exchange to attemperating would be very fruitful.

In connection with the corrosion of copper by yeast, reference had been been made to the relation between copper and vitamin B. A. C. Chapman, in his researches on the effect of copper on yeast drew attention to the fact that minute quantities of copper were often stimulating, whereas subsequent doses were toxic. Was it not probable that the first small quantities were necessary for the development of the vitamins, whereas further quantities were toxic?

He believed that the steam accumulator had little value unless in connection with the generation of power by steam. The accumulator was most useful where pass-out turbines were used and the exhaust steam could be accumulated until required.

Mr. A. J. C. Cosbie said in view of the author's remarks about boiler-house control, it would be of interest to hear his opinion on the subject of mechanical stoking. Further, with regard to the question of water softening, had the author any experience of a system of water treatment involving the use of very small currents at low voltage? It was

claimed for that process that unlimited quantities of water could be treated at a negligible cost per annum. It was supposed that the carbonate crystals were caused to change from one crystal system to another under the influence of the electric current.

Mr. J. H. JEACOCK said he had been interested in the remarks about water softening as he had heard that the electrical method was supposed to be effective in keeping the scale formation under control.

Dr. OLIVER said he thought that, taking into consideration all the various factors involved, the brewer nowadays conducted such parts of his process, as grinding, and extracting the mash, with a high degree of efficiency, and, of the various subjects that the author had discussed, the greatest criticism could be made on the matter of layout. To some extent that was understandable because many breweries developed on a site that was limited, and expediency had to take precedence over technical efficiency.

Mr. H. HERON said the author had raised many points that had been agitating the minds of brewers and brewers' engineers for years past, and he had made some useful suggestions, especially as regards boiling. He believed the controversy between steam and fire boiling had been more or less settled by the introduction of up-to-date steam heating plant. When fire heating was preferred to steam heating, it was because with the latter a brewer thought he had got a boil, but it was really getting nothing of the sort. He had in fact seen coppers heated by steam coils, which never reached a temperature of more than 200° F. He would like to enlighten the author, as to the reason why a brewer boiled his copper for so long a time. Firstly, brewers wort could not be sterilised in half an hour, or even under an hour, owing to the presence of spores. Secondly, as had been shown by Dr. Walker, resins could not be extracted from a hop under 45 minutes. Then again, brewers got an excellent agitation if they had a fountain in their copper, but he was afraid that if they carried out the suggestion of the author, the hops would be broken up to such an extent that they would fail to obtain efficient hop back filtration, and would have difficulty in separating the hops from the wort. Most brewers had come to the conclusion that the hop bed was the most efficient filter they had. A brewer had to get his wort up from the hop back on to the cooler in a short time, and over his coolers in an hour, or in 1½ hours at the most.

Many suggestions had been made, but he had not come across one which would effect a sufficiently speedy filtration to enable a brewer to carry out his work in the limited time available.

With most CO_2 plants it was difficult to prevent oil being transmitted to the gas from the compressor, and if the CO_2 was used for carbonating beers the matter became serious. The minutest trace of oil in gas would destroy the head of a beer, and he had come across many instances where head retention trouble had been caused by oil.

Mr. M. B. DONALD said in reply that his paper was designed to submit the views of an onlooker and he was grateful to those speakers who had appreciated the spirit in which he had had to address them.

Accumulators had been installed in a number of breweries on the continent and it was only one of their functions to maintain better operating conditions for prime movers generating power. Most modern works now produced steam at a slightly higher pressure and, by passing it through a back pressure steam engine, supplied themselves with what electricity they required and then used the low pressure steam for heating purposes. A certain amount of balancing could be accomplished by the use of a steam meter to ration steam requirements during the day but it was not generally possible to ensure a constant load on the boilers by those means. An accumulator automatically ensured smoothing of the load and would thus secure more economical operation of the boilers and enable them to take higher loads. It also contributed to more continuous working in the brewery.

The process for extracting vitamin B from yeast involved the use of a colloid mill. A rotor, whose speed was from 1,000 to 20,000 revs. per minute, was separated from the stator by a gap of some two to ten thousandths of an in. through which the material was passed. The shearing action thus produced ruptured the cell walls and released the aqueous extract of the vitamin B complex. The extract ought to command a good price for medicinal purposes although it should have a greater ultimate value to the brewers if it were added at least in part to the beer.

In reply to Dr. Seligman, the majority of chemical engineering students operated plants in various industries and he believed that a chemical engineering training would be a valuable asset to a brewer. The question of the application of knowledge of heat transmission to attemperating might not produce very marked results but it provided an excellent opportunity to introduce the general effect of streamline surface films, the study of which was so important in many branches of chemical engineering.

Mechanical stoking was advantageous because it converted firing into a continuous operation and thereby gave increased efficiency. The volatile products from the coal were gradually distilled into an oxidising atmosphere and that diminished the smoke trouble. With hand firing the volatile products were evolved immediately after firing, and, if the air supply was increased to cope with them, then it meant that too much air was being introduced during the remainder of the period with consequent lack of efficiency.

With regard to electrical water softeners, a large amount of recent research had so far failed to confirm the claims made for those methods and it would be very dangerous to install them in a high pressure boiler plant. Assuming that the crystals of calcium carbonate did change their structure, then the solution of the problem of water softening was no nearer its goal because it was the calcium sulphate which gave rise to the troublesome scale. Also a change in crystal structure would not affect the soap requirements of water for washing purposes.

The reason he did not touch on the question of layout of breweries was because few breweries were now being built and it was very difficult to alter an old arrangement except in minor details.

Mr. Heron had raised a number of pertinent points, amongst which were that it took 45 minutes to extract all the resins from the hops and that excessive agitation would give bad hop-back filtration. The answer would appear to be that a compromise was necessary and to employ such agitation as would reduce the time of resin extraction comparable with a reasonable time of filtration. Alternatively the time of filtration could be reduced by the use of suitable filter aids. The speed of filtration was determined not only by the resistance of the cake but also by the surface area employed, and whether pressure or vacuum was used to assist the pressure head due to the liquor.

It should not be difficult to prevent oil being carried forward from a CO_2 compressor providing that a correct grade of lubricating oil was employed and a simple catch-all of the silencer type, with a trap to remove liquids, was placed after the compressor. For this purpose the compressor usually worked at a very slow speed.

Filter aids, similar to highly purified kieselguhr, could now be obtained with various pore sizes and it would seem merely a matter of selecting the right type to avoid removing the valuable colloids from the beer.