Aluminum in the Brewing Industry*

Its Use for Fermenting and Storage Vessels

By C. Bleisch

ALUMINUM as a material for equipping the fermenting and storage cellars has for a long time excited great interest in technical circles. And this interest is justified, since, if this metal, distinguished by its great indifference to most chemical attacks, really fulfills the requirements of sufficient resistance to fermenting beer, it would be an ideal material, because, in contrast to the other substitutes for wood, it requires no isolating layer between the beer and metal. The practical world has become friendly to the new material within a relatively short time. A factory which is engaged in the manufacture of aluminum vessels for the fermenting and storage cellars has to date delivered 880,000 gallons of capacity.

The aluminum metal now on the market is a satisfactory article in its purely mechanical aspects, and in the course of years the quality has been considerably improved. Within recent times the commercial metal shows 99.5 per cent purity. The previous treatment of the metal is of great importance, and much has been learned in this regard within the last few years; for example, it is known that cold-rolled or cold-drawn aluminum does not satisfy the requirements of the brewing industry. It is known to-day that a subsequent warming of the aluminum up to 450 deg. Cent. alters the metal in a very favorable sense.

Although these facts have not remained unknown, the very thorough researches of the Royal Institute for Testing Materials, in Berlin, published a short time ago, have pointed out a possibility of a corrosion of aluminum and has caused much unrest in manufacturing circles which are interested in the production of aluminum vessels for breweries, and also in brewing circles.

We believe that this unrest is without foundation.

The experiments were carried out on cooking vessels and other utensils, which, as should be distinctly borne in mind, were not made of the same material, either chemically or mechanically, as the material used for fermenting vessels. Although such material when immersed in distilled water for from 48 to 210 days showed corrosion and loss of weight, this is no indication that carefully manufactured, high-grade aluminum will not answer for the purposes of our industry. Iron, which is quite subject to attack, finds the widest use in practical brewing operations, and it may be said that if small traces of aluminum pass into the fermented product these traces are much less to be feared in beer than traces of iron.

The question as to whether aluminum is suitable for brewery use can only be answered after a consideration of practical conditions; and since in the investigations of the Royal Institute for Testing Materials these conditions were not considered, it appears that an investigation as to how aluminum would behave under the conditions of practice is in order.

The material experimented upon, for which we have to thank a certain factory, was used in pieces having a total surface of 60 square centimeters, being about 2 millimeters and weighing about 24 grammes. The analysis of this material gave the following results:

Aluminum.....	99.52 per cent
Iron.....	0.261
Silicon.....	0.21
Zinc.....	Trace
Copper.....	Small trace
Carbon.....	Trace

The following experiments deal with the behavior of aluminum toward water, and above all, toward fermenting worts and cleaning and disinfecting agents, which in practice are the most important substances which come in contact with the interior surface of aluminum vessels:

I. BEHAVIOR OF ALUMINUM TOWARD WATER.

Aluminum plates of the above-mentioned dimensions were kept for five weeks in contact with distilled water and ordinary water contained in breakers. The plates of aluminum were allowed to project above the surface of the water in order to ascertain whether the double action of water and air upon the metal was in any way pronounced. The well-dried pieces of metal were weighed before and after the experiment. The greatest decrease in weight was observed in the case of distilled water, but this was only 0.0005 gramme. This, however, practically lies within the limits of error of weighing. If, however, we assume that this decrease represents a natural loss we may make the following calculations:

The total surface of aluminum amounted to 60 square centimeters. This would mean a loss of 0.0835 gramme, or $\frac{0.0835}{60} = 0.00139$ gramme decrease per day per square meter of surface. No corrosion could be observed. Good Thüringer glass yields to water 0.1 gramme per day per one square meter surface. This

is 40 times as much as was lost by the aluminum used in these experiments. The ordinary water caused a slight increase of weight after 3½ weeks. This was found to be due to the fact that some carbonate of lime had been deposited from the hard water, and this was the cause of the relatively small increase of weight. It might be objected that the experiments should have been carried out for a longer time, in which the decrease of weight would probably have been somewhat greater. However, we do not concur in this view, since in the brewing industry pure water remains in contact with the aluminum only during the process of washing, and it soon gives place to the fermenting beer.

Pieces of aluminum were also moistened with water and kept in the fermenting cellar for several weeks, after which they were carefully dried and weighed. No corrosion such as might be detected by loss of weight was observed. No spots or flakiness on the surface of the metal appeared. From the results of this investigation we may conclude that aluminum of the quality used by us in our tests will not be exposed to any danger when washed for years with hard or soft water under the conditions of practice.

II. BEHAVIOR TOWARD FERMENTING WORT.

(a) *In the Fermenting Cellar.*—For this purpose pieces of aluminum of the same size as before were left for 45 days in the fermenting beer in the fermenting vat. On the average, the following changes were detected by weighing:

After 16 days, weight increased 31.8 milligrammes from beerstone.

After 22 days, weight increased 55.6 milligrammes from beerstone.

After 30 days, weight increased 85.2 milligrammes from beerstone.

After 45 days, weight increased 129.0 milligrammes from beerstone.

Recalculating these figures to one square meter of surface, we find the following amounts of beerstone deposited upon one square meter of aluminum:

After 16 days..... 5.31 grammes.
After 45 days..... 21.54 grammes.

The deposit of beerstone is, therefore, extraordinarily great. Although this result would probably not be the same in all breweries, we must take account of the possibility of a stronger deposit of beerstone, which will be much greater than in the case of wooden vats.

In order to ascertain the time at which the deposits of beerstone began during the first fermentation in the aluminum vats different pieces of aluminum were brought into a fermenter (eight-day fermentation) and observed daily. The following gives the average of several experiments:

After 1 day, decrease 1 milligramme.
After 3 days, decrease 1.4 milligrammes.
After 4 days, decrease 1.4 milligrammes.
After 4 days, decrease 0.8 milligramme.
After 5 days, increase 1 milligramme.
After 6 days, increase 4 milligrammes.
After 8 days, increase 8.5 milligrammes.

From this we see that the greatest decrease in the first four days was 0.234 gramme per one square meter of aluminum surface as compared with the daily decrease of 0.1 gramme per one square meter on good Thüringer glass exposed to the action of water. It is therefore clear that only in the first days of the main fermentation occurs a loss of aluminum, which, however, is practically without significance. This is less than the loss caused by the influence of water on good glass and is followed by a rapid and extensive deposit of beerstone. This beerstone on examination was found to be completely aluminum-free, and to consist of its ordinary constituents, namely, oxalate and phosphate of lime, albumen, etc. The beerstone which adhered to the aluminum has a peculiar property, which is essentially different from the ordinary beerstone found in wooden vats. It deposits in a short time and in relatively large amount as a glassy coating on the aluminum and forms a natural and excellent insulation for the metal against the fermenting beer. It is resistant to not too strong mechanical influences, and in consequence of its very smooth surface and other peculiar properties it is surely not so dangerous as a source of infection as the beerstone of wooden vats. For this reason it is not necessary to remove it as often as usual. When removal becomes necessary this is not so easily done with mechanical means. Possibly dilute nitric acid is of value in this connection, since according to our observations a short action of this substance loosens the beerstone so that it can be easily removed without attacking the aluminum. This is naturally merely a suggestion, and only to be considered on the rare occasions when the removal of the beerstone from aluminum vats offers diffi-

culties. Hot soda solutions or caustic alkalies, as is pointed out below, cannot be used for this purpose without careful consideration.

It is said that aluminum is attacked at the points where the kräusen comes in contact with it, namely, at the point where moisture, carbonic acid and air, and possibly also hop resins, are to be found. Such corrosion cannot be easily explained on a chemical basis, especially in the case of high-grade aluminum. Long experimenting with pieces of aluminum in this direction showed neither change in the weight of the aluminum pieces nor a corrosion. These objections, therefore, we regard as without foundation when the material is really of high grade.

For the rest we know of vats which have been in use for nearly four years, and which in all respects corroborated our conclusions.

(b) *In the Storage Cellar.*—Aluminum pieces of the same dimensions as above were placed in beer four to six weeks old and kept therein for five weeks. The following changes were noted:

After 16 days, decrease of 2.6 milligrammes.
After 24 days, decrease of 1.2 milligrammes.
After 32 days, increase of 5.0 milligrammes.

The corresponding decrease therefore occurs within 16 days and amounted to 0.434 gramme per one square meter of aluminum surface, or a daily loss of 0.027 gramme, as against a daily loss of 0.01 gramme from one square meter of good Thüringia glass kept in water. Between the sixteenth and twenty-fourth day an increase in weight due to the deposition of beerstone was observed, which gradually became greater.

Next the aluminum pieces were placed in beer which had been drawn into barrels and observed for a period of 21 days. The increase—average of several experiments—was as follows:

After 15 days..... 29 milligrammes of beerstone
After 20 days..... 37 milligrammes of beerstone

This indicates 6.18 grammes of beerstone for one square meter of aluminum surface.

In the case of old beer in the storage cellar the beerstone deposits slowly. Young barrel beer, however, deposits beerstone rapidly, but even in the storage cellar the young beer soon deposits a layer of beerstone with all the desirable properties of that deposited in the vats in the fermenting cellars. However, the layer of beerstone in the storage cellar will not reach the thickness obtained in the fermenting cellar, because old beer deposits less beerstone than young. This, however, is not an important matter.

III. BEHAVIOR TOWARD DISINFECTANTS.

At the present time we use in our cellars a number of disinfectants for disinfecting the wooden vats, and of these we are able to say that considering the very smooth surface of the aluminum beerstone, these disinfectants will not be so necessary. Those, however, who intend to use them must clearly understand that many substances permissible for use in wooden vessels are not permissible in aluminum vessels. Before we begin a discussion of disinfectants in relation to aluminum we may consider caustic lime, caustic soda and ordinary soda, which are used for disinfecting purposes in wooden vats, the last chiefly for removing beerstone. These substances may be at once excluded, especially the caustic alkalies, because aluminum is very sensitive to the action of these substances. Even ordinary soda in lukewarm solutions of 8 to 10 per cent is unpermissible, because even within 15 minutes, at a temperature of 35 to 40 deg. R., this solution, when in contact with aluminum, will cause a considerable loss of weight and other indications of corrosion. Whenever it is desired to remove beerstone it will probably be best to use pure, dilute nitric acid of about 10 per cent to 15 per cent. It was shown by experiment that after treating with dilute nitric acid the metal was not more subject to attack by beer. A practical test would be desirable to test the practicability of this suggestion.

Among the direct disinfectants the following were investigated, both in the solid form and in 5 per cent solutions:

1. Antiformin (solution of hypochlorite of soda, reacting strongly alkaline). Strong action on the aluminum within 15 minutes; therefore not suitable.
 2. Ammonium florid (acid ammonium salt of hydrofluoric acid). Corrosion within 15 minutes; not suitable.
 3. A disinfectant "M" (very similar to Montanin; active principle hydrofluosilicic acid). After 15 minutes strong action; absolutely unsuitable for disinfecting aluminum vessels.
 4. Formol (formaldehyde). No corrosion and no loss of weight could be observed after 21 days.
- From these experiments it is clear that formaldehyde

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is a suitable material for disinfecting aluminum. For dissolving beerstone, alkali is out of the question unless used with great care. Doubtless these cleansing agents can be replaced by pure dilute nitric acid.

If now we draw conclusions from all the above observations, which are based upon tests under practical conditions, it may be said that the uneasiness caused by the report of the Royal Institution for Testing Materials, in so far as it relates to the use of aluminum for fermenting vessels in the brewing industry, is not justified. The material demanded for the purposes of our industry must be high-grade aluminum, which requires great care in its preliminary treatment, and on which higher requirements must be placed than aluminum used in ordinary

cheap utensils. If the manufacturers deliver such a material for fermenting vessels in the brewing industry, and in consequence of its other properties it deserves our best attention.

It requires no insulation against the fermenting liquid, because in the main fermentation, and also in the early after-fermentation, the thick layer of beerstone provides an excellent protection. This beerstone has peculiarly advantageous properties, for example, its smoothness and peculiar hardness, which sharply distinguishes it from ordinary beerstone. Consequently its periodical removal is not so necessary as in the case of wooden vessels. Since both theory and practice have come to the conclusion that aluminum can be brought into contact

with fermenting beer without disadvantage to the product or detriment to the metal, as appears from our experiments, the problem of installing such vessels, so as to protect the outer walls and outer influences of temperature, is not so difficult a matter and can be regarded as already solved. In our opinion aluminum is a first-class competitor with other substitutes for wood, such as iron and cement, and we should consider that it has a certain value which attaches only in part to the other materials. The chief point to consider is the price and cost of installation in comparison with these other materials, and this will decide the future of aluminum in the brewing industry. But the outlook for aluminum as a material for use in the brewing industry seems most favorable.

Vegetable Tissue Viewed by Transmitted Light.

Microphotography in the Service of Applied Science

By Our Paris Correspondent

The Wear of Steel Rails Submitted to Investigation Under the Microscope

The Same Viewed by Reflected Light.

ONE of the leading French authorities upon the microscopic structure of metals is F. Robin, of Paris. It is well worth while to take note of the special microphotographic apparatus designed by him, and his investigations by microscopic methods into the wearing qualities of steel rails are of special interest. It is necessary to examine the polished surface of the steel by reflected light, a procedure which presents some difficulty in its execution. Mr. Robin arranges the sample for examination underneath the microscope objective and illuminates it by means of an arc lamp placed on the right-hand side. The light passes through the box seen at the top of the apparatus (see figure) and thence down through the objective onto the surface of the metal viewed. The light is then reflected back through the objective, but is deflected to the left, so as to throw an enlarged image of the object on the ground glass screen of the camera. The operator thus sees a very brilliant image of the metal surface on the ground glass, and this is found much less fatiguing to the eye than viewing the object directly through the microscope. The apparatus is also thoroughly well adapted for the preparation of photographs.

For oblique illumination of metal surfaces the arc is lowered, so that the beam of light falls on a small circular mirror shown to the left of the metal block in our illustration, and is then reflected obliquely onto the specimen. Such oblique lighting is found to be very helpful in disclosing the structure of the metal, as it clearly brings out little pits and elevations on the surface of the metal. Oblique illumination is also found very useful in examining other objects, such as animal tissues, the appearance presented being very different from that seen by transmitted light.

In Mr. Robin's apparatus the piece of metal under examination is attached with wax to a table which is free to move with universal motion, being joined to the base by a ball and socket joint. A system of gears and levers is carried from this table to the observer's station, so that he can adjust the specimen while viewing it in the ground glass, and without leaving his post. The microscope is arranged to give also illumination by transmitted light when desired.

Some of the results which Mr. Robin obtained by

means of this apparatus in his investigation of the wear of steel rails are well worth quoting. According to a statement made by Mr. Dufaux, with ordinary French steel the wear averages 1 millimeter (0.04 of an inch) for the passage of 100,000 trains over the rail. The surface of a rail in service becomes gradually hardened as the rail is flattened. The slowing down and stopping of trains have a special effect, apart from the flattening of the rail, causing a certain alteration

of the surface of the metal. Parts which have been thus acted upon are very hard and show great resistance to wear, though they also become rather brittle. As the result of this influence the rail tends to crack in a direction perpendicular to the axis of the rail, and the latter is apt to become ruptured.

From the tests performed it appears that silicon and manganese exerts very different influences upon the properties of steel rails. According to some authorities, manganese has very little influence, while, on the contrary, the French metallurgist, Derihon, as the result of some experiments on the friction of steel against hardened steel with oil lubrication, concluded that the presence of silicon and manganese improved the wearing qualities by 100 per cent. Other tests bear out this conclusion. The matter, however, is as yet undecided.

One of our illustrations is a reproduction of a microphotograph showing the alteration in the structure of the rail near the surface. Note the approximately transverse cracks. The direction of the trains is from right to left. At the top is the altered zone, which has a structure different from that of the natural metal lying underneath, and the cracks in this part are plainly visible.

The mode of illumination here discussed will find useful application not only in metallurgy but also in other branches of science. Something may be gathered of the possibilities thus opened up by reference to those of our illustrations which represent sections from animal and vegetable tissues as seen by the ordinary transmitted light and also by reflected light. It will be readily understood that in this way one can obtain a very much better idea of the three dimensional properties of the material under examination than by the ordinary method.

Microphotographic work of this kind is likely to shed much light on many disputed questions, for as yet there is a good deal of mystery and conflict of opinions surrounding some of the effects under consideration. At the same time, it must be said that the method is decidedly calculated for the use of the specialist, so that the number of competent observers working in the field is comparatively small.

The Robin Microphotographic Camera.

Longitudinal Section of Steel Rail.

Cellular Animal Tissue Viewed by Transmitted Light.

Cellular Animal Tissue, Oblique Illumination.