MEMORANDUM

ON THE

CORROSION OF THE LEAD LININGS

OF

INDIAN TEA CHESTS.

BY

ALEXANDER PEDLER, Esq., F. C. S.,

PROFESSOR OF CHEMISTRY IN THE PRESIDENCY COLLEGE.

[*Reprinted from the Journal of the Asiatic Society of Bengal, Vol. LIV, Part II, No. 3, 1885.*]

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Memorandum on the Corrosion of the Lead Linings of Indian Tea Chests.—*By* ALEX. PEDLER, F. C. S., *Professor of Chemistry in the Presidency College, Calcutta.*

During the last few years rather numerous instances have happened of chests of tea, apparently prepared and packed in the usual way in the tea districts of India, reaching Calcutta or England in a damaged condition; the damage consisting in the partial corrosion, and sometimes almost total destruction of the lead linings of the chests, and in the deterioration of the quality of the tea itself.

At the request of the Indian Tea Association I undertook some time since to make some experiments in order to ascertain the cause of this corrosion, and though my experiments have not yet been completed so far as I could wish, they are sufficiently far advancd to enable me, at the urgent request of the Indian Tea Association and of the the Bengal Government, to write a preliminary memorandum.

The previously published literature on this subject is remarkably meagre, and it may be summed up in a few words. On the other hand, there is reason to believe that there is a large accumulation of unpublished evidence on this subject, and it is desirable that some steps should be taken to collect and collate the mass of evidence which must have accumulated in the hands of the various agents of tea gardens, and in the hands perhaps of the more experienced planters.

The first experimental enquiry as to the corrosion of the lead linings of Indian tea chests and its cause which I can find published in scientific periodicals appears to have been carried out some time previous to 1883 by Dr. Wigner, who was then President of the Society of Public Analysts in England. He published, in Vol. II of the Journal of the Society of Chemical Industry, a paper entitled "The packing of substances of delicate odour such as Tea, &c."*, in which he describes his experiments, made during the previous five or six years, in certain cases of corrosion of tea-leads in boxes made of Indian woods, the consignments of tea coming principally from Assam. The conclusions at which he arrived were that the corrosion was due to the wood used in the boxes, and his theory, though he did not adduce any specific facts as to the cause of the corrosion, was that the wood must have in some way generated acetic or other volatile acid, which, in the presence of carbonic acid and moist air, would account for the corrosion of the lead. My experiments have in almost all respects confirmed this theory.

The next contribution to our knowledge of this subject which I can

* Journal of the Society of Chemical Industry, Vol. II, p. 256.

find is in a memorandum published by Dr. G. Watt, on special duty with the Revenue and Agricultural Department, Government of India, and dated Simla, June 21st, 1884. Dr. Watt makes the following statement:—"My views on the subject of woods suitable for tea boxes are at variance with the popular outcry against our Indian timbers as injuring the Indian Teas." He also states he has observed the following curious facts:—"The tea may be completely destroyed, and yet upon the most careful scrutiny not a single opening can be detected in the lead. It is obvious that until the lead is corroded any injurious influence which the timber might exert upon the tea could not take place." Again, "I have on several occasions had the pleasure of inspecting lead said to have been corroded by the action of the wood. But it is a curious fact that the action seems to commence on the inside of the lead instead of on the outside or on the surface in contact with the wood, (the supposed acid influence which decomposes the metal) has not been apparently observed." He also suggests "it may be the tea itself which corrodes the metal and not the wood."

Dr. Watt also during the Calcutta International Exhibition had an opportunity of working with 200 tea-box woods from all parts of India, and performed a large series of experiments on the action of these woods on tea-lead. He says both unseasoned and seasoned woods were used in these experiments, which were repeated once or twice, with moistened woods and under conditions intended to simulate those of the hold of a ship, and "in no instance has the lead been found to be in ever so slight a degree chemically acted on;" and finally Dr. Watt states "he failed utterly to discover any wood which seemed to possess the least chemical action upon lead."

In reply to this memorandum, Mr. Playfair, in the Indian Daily News of July 29th, 1884, gave the results of certain investigations on this subject, which had been made for him in London in 1883 by the late Dr. A. Voelcker, F. R. S. Dr. Voelcker's conclusions were that "the corrosion of the lead (in the Indian tea-chests) unquestionably is due to the attack of acetic or other volatile acids, and the subsequent formation of white lead (carbonate of lead) by the action of the air. Considering the fact that the surfaces of the leads which were in contact with the tea were quite bright and sound, whilst the under surfaces in contact with the wood were more or less corroded; it appears to me that in all probability green or unripe wood has been employed in making the tea-chests. Such wood is known to generate in a somewhat warm locality acetic and analogous organic acids which act upon lead."

Dr. Watt, in a long letter, dated August 13th, 1884, also to the Indian Daily News, discusses Dr. Voelcker's conclusions, and to a great extent reiterates the position he had previously taken up. His conclusions may be fairly well summed up in the following statement: "The chest is full of tea which has been fermented, its fermentation arrested rapidly, and the tea is rapidly enclosed in a case and shipped to Europe. Is it improbable that the acetification of the fermented tea may not be the primary agent in the decomposition of the wood and the consequent corrosion of the lead? Having arrived at this conclusion I had little difficulty in producing from tea an acetous organic acid which rapidly corroded lead; so I have no doubt this volatile acid on escaping through the lead lining would soon establish in certain timbers, especially green and unseasoned ones, corresponding acetification, but I am convinced that we have to look to the tea itself and to some imperfection in its manufacture, as the primary exciting agent in the corrosion of the lead and the damage of the commercial article."

In view, then, of these contradictory statements as to the cause of the corrosion of the tea-leads, Dr. Wigner and Dr. Voelcker being of opinion that the cause was the wood, though of course their proof was incomplete, and Dr. Watt holding that the cause was to be found in the tea, I commenced the following experiments.

From a practical point of view the first thing which it was desirable to settle was whether the tea or the wood of the chests was the active agent in inducing the corrosion of the lead. To test this view, certain boxes of tea were specially prepared, and they were then handed over to me by the Indian Tea Association.

Three boxes represent the matter typically.

No. 1 was a half chest containing 40 lbs. of pekoe souchong tea of ordinary manufacture. The half box was made entirely of wild mango wood (*Mangifera indica*), damp and unseasoned.

After being kept in the ordinary way for several weeks this box was examined. On being opened the upper surface of the lead next the wood was found to be almost entirely covered with a white powder, which on examination was found to be principally "white lead." The lead was largely corroded over the whole surface, and in fact eaten through in certain places. There were several clear cases of perforation, and, examined under a magnifying glass, the perforations were surrounded on the upper surface with very extensive corrosion. The lead was then cut off from the chest, and the surface next the tea examined; over the greater part it was quite bright and free from corrosion, though in certain parts it was slightly tarnished. The perforations were also examined from the under surface, and there was no trace of corrosion round the edges. Even in this, which should be the most favourable position for corrosion if the corrosion is caused by the tea, no corrosion was seen.

The lead of the bottom of the box and of the four sides was examined, and the results were similar to those above described. On all the external surfaces the lead was largely corroded, and in some parts to a most excessive extent. On the inner side of the lead next to the tea, except on those parts where the lead had been entirely eaten through, the lead was perfectly bright and clean.

The surface of the wood of this chest next to the lead was also found to be distinctly acid to test paper.

The lead having been perforated in this case the corrosion was still open to the possibility of explanation in the manner suggested by Dr. Watt, though, as described above, every appearance was against it. To test this point the following experiments were made :

Pieces of the slightly moistened wood were placed with tea-lead in a large bottle with air charged with moist carbonic acid, but, after standing for some time, practically no corrosion of the lead appeared.

Some of the tea was taken under similar circumstances to the above and placed with tea lead; the lead remained perfectly bright and uncorroded.

Some of the wood of the box was distilled in a current of steam, and the distillate tested by placing some of it at the bottom of a bottle; a piece of tea-lead was then hung in the bottle, so that it did not touch the liquid, and the bottle was repeatedly filled with air charged with moist carbonic acid.* The tea-lead was very distinctly corroded on standing.

Some of the tea was also distilled in a current of steam and the distillate treated as in the last experiment, but it had no corrosive action whatever on the tea-lead. Some pieces of the wood of this box were placed with water and tea-lead hung over it, but not so as to touch it, and exposed to the air. The lead was corroded very rapidly. Some of the tea was taken also placed in water and tea-lead hung over it, but not so as to touch it. For a long period there was no corrosion of the tea-lead, but after the tea had become mouldy and had decomposed for some time, then corrosion set in, but very much later than in the previous experiment with the wood.

It was highly probable, then, from these experiments that the wood was the source of the corrosion and certainly not the tea.

Examination of Case No. 2. This was a half chest containing 40lbs. of pekoe souchong tea, and made entirely of wild mango wood, which was thoroughly dry and well-seasoned, but after the tea was pack-

* The presence of the carbonic acid and moist air is a necessary condition to produce rapid action on lead in the presence of certain exciting agents. It is also the condition which a chest of tea would probably be subjected to in the hold of a ship.

ed in the box, one side, marked "B," was well damped with fresh water and the other sides left untouched.

This chest was again kept for several weeks under ordinary circumstances, and was then examined. Five of the outer sides of the lead lining were quite free from corrosion, but the sixth surface, opposite to the plank marked B, showed very evident corrosion, and considerable amounts of lead carbonate or "white lead" were present over almost the whole surface. This side of the lead lining was examined minutely, and there was no perforation of any kind visible.

The inner side of the lead lining was also examined and the whole of the interior was perfectly bright and free from all tarnishing and corrosion. The inner side of the corroded part was examined most carefully, but not the slightest evidence of any action could be detected, nor were there any perforations on this side of the lead.

The wood (seasoned) of this box and also the tea were allowed to remain in contact with moist air containing carbonic acid for many weeks, but no corrosion took place.

In this case, as there was no perforation of the lead on the side on which the lead was corroded on the external surface, Dr. Watt's explanation cannot possibly apply, and the only logical conclusion is that the corrosion was due to the wood. This time also it will be seen the corrosion was brought about not by unseasoned wood, but by seasoned wood which had been subsequently intentionally thoroughly saturated with water.

Examination of Case No. 3. This was a half chest containing 40lbs. of pekoe souchong tea manufactured in the ordinary way, and the box was made entirely of wild mango wood, but partly seasoned and partly damp and unseasoned. The pieces of wood marked A were the damp and unseasoned wood of the box. The unmarked planks were of seasoned wood.

For examination, the tea in its lead lining was removed from the wooden box, and the lead lining presented a very curious appearance. The following is a description of it.

Side No. 1. The lead lining under the upper or broad plank showed no corrosion: this plank was not marked. The lead lining under the narrow plank, which was the lower piece and was marked A, showed much corrosion. Side No. 2. Under broad unmarked plank practically no corrosion, under narrow plank (marked A) much corrosion. Side No. 3. Under large unmarked plank no corrosion and under small or narrow plank (marked A) much corrosion. Side No. 4. Under broad unmarked plank no corrosion. Top of box under broad unmarked plank no corrosion, and under narrow plank (marked A) much corrosion. Bottom of box. The greater part of the bottom lead was practically free from corrosion, but at its edges it showed marked evidence of corrosion, particularly near two sides of box where there were pieces of wood marked A.

The lead lining was very carefully examined, and, though the lead was much corroded in parts, it showed no sign of perforation by the corrosive action.

The interior of the lead lining was examined and it showed no signs of tarnishing or corrosion or any action whatever.

This tea was again allowed to remain in contact with tea-lead for many weeks in a moist atmosphere containing carbonic acid, and absolutely no corrosion took place.

Here, again, as there was no perforation of the lead lining, Dr. Watt's explanation is untenable, and the corrosion was solely due to the use of unseasoned wood.

Two other cases of lead corrosion were drawn to my attention, and though I regret I was unable to obtain the name of the wood of which the tea boxes were made, the results of the examination are interesting.

A case of tea marked S. (No. 1.) on being opened was found to have its lead lining corroded, but not to a very great extent. The corrosion in this case was of totally different nature from that in the above cases, and thus while in ordinary cases the corrosion was white and to a certain extent pulverulent, in the case in question the incrustation was greenish-yellow in colour, and firmly adherent to the lead. The wood of the box judged externally seemed well-seasoned, but on being splintered emitted a "cheesy" odour, which flavour, I was told, had communicated itself to the tea. The wood was examined and the odour appeared to be due principally to a minute quantity of butyric acid which was present.

This wood was subjected to distillation in a current of steam, the distillate placed in a bottle with tea lead hanging over it, and the bottle was filled with moist carbonic acid; on standing one side of the lead became dull and tarnished, showing faint action of corrosion.

Another chest of tea marked S. 2. showed presently similar damage, and the wood again though apparently good and seasoned on the outside, when splintered gave off a very rank and offensive smell. This apparently was also due to a great extent to the presence of butyric acid.

The wood of S. 2. was distilled in a current of steam, and the distillate placed in a bottle with tea lead hanging over it, though not touching it, and treated with air containing moist carbonic acid, and after a short time the lead showed distinct, though not a large amount of corrosion.

These two cases are principally interesting because they show that more than one agent may sometimes be at work in this corroding action, for the results of the action in this case are markedly different from the general corroding action found in the other cases.

Six other small boxes of tea made of different kinds of wood were also examined. These boxes were made I believe of wood after seasoning in the ordinary way. They were also handed over to me by the Indian Tea Association.

No. 1. Box made of simal* wood and kept in a damp atmosphere for many weeks. The lead lining was free from corrosion both on the surface next to the wood and also on that next to the tea.

No. 2. Box made of jokee† wood and kept in a damp atmosphere for many weeks. The lead lining was free from corrosion both on the surface next to the wood and also on that next to the tea.

No. 3. Box made of kudum‡ wood and kept in a damp atmosphere for many weeks. The lead lining was free from corrosion both on the surface next to the wood and also on that next to the tea.

No. 4. Box made of ahm § wood and kept in a damp atmosphere for many weeks. The lead lining was free from corrosion both on the surface next to the wood and also on that next to the tea.

No. 5. Box made of jowah|| wood and kept in a damp atmosphere for many weeks. The lead lining was free from corrosion both on the surface next to the wood and also on that next to the tea.

No. 6. Box made of seeta¶ wood and kept in a damp atmosphere for many weeks. The lead lining was free from corrosion except on one side where there was a faint trace of a white powder on the surface next to the wood, but next to the tea, the surface of the lead lining was absolutely bright. There was again no perforation.

The woods of boxes Nos. 1 to 4, and also the tea which was contained in them, were exposed in contact with some tea lead in the damp atmosphere of a chemical laboratory for many weeks, and in this atmosphere there would be large quantities of carbonic acid and also vapours of various other acids, but no corrosion of the lead was set up, by the action either of the wood or of the tea in the boxes.

Taking then the general results of the foregoing work, it may be said the experiments prove conclusively that the active agent in the corrosion of the lead linings of these tea chests was certainly not produced from the tea which was contained in the chests, but from the wood of which they were formed.

It will also have been noticed that the corrosion was never produced

* Probably wood of *Bombax malabaricum.*

† Probably wood of *Bischoffia javanica.*

‡ Probably wood of *Anthocephalus cadamba.*

§ *Mangifera indica.*

|| Probably wood of *Helicia robusta.*

¶ Probably wood of *Anona squamosa.*

when the wood of the box was in a *thoroughly seasoned and dry* condition, but that in every case where unseasoned wood was used corrosion of the lead was the invariable result. Again, in one instance it is shown that even where seasoned wood was used, if it be afterwards thoroughly saturated with water, it again becomes capable of producing corrosion of tea-lead, though perhaps not so violently as wood in the unseasonsd state.

It therefore became desirable to determine whether this power of corrosion of tea leads was a property common to unseasoned woods in general, or whether it was only an isolated action due to the use of the wild mango wood, and for this purpose the following ten (10) samples of wood were experimented with. These samples were also prepared and handed over to me by the Indian Tea Association, and I believe they represent wood which may be commonly used for tea boxes.

The following was the method of procedure. Pairs of planks of the various kinds of wood were prepared about 3 feet long by 8 inches wide. Between each pair a sheet of tea lead was placed and the planks well screwed together. The planks with the tea lead were then exposed to a moist atmosphere for many weeks. The following are the names of the woods and their condition.

1st Pair. Wild mango wood, damp and unseasoned, the wood of the *Mangifera indica.*

2nd Pair. Wild mango wood, dry and well-seasoned. Wood of the *Mangifera indica.*

3rd Pair. Wild mango wood, dry and well-seasoned, but after these pieces were screwed together, one of them (marked C) was well damped with fresh water and the other left untouched. Wood of the *Mangifera indica.*

4th Pair. Dumboil wood, damp and unseasoned, perhaps the *Calophyllum inophyllum.*

5th Pair. Jalna wood, damp and unseasoned (ahm-jalna).

6th Pair. Tulla wood, damp and unseasoned, perhaps wood of the *Sterculia alata.*

7th Pair. Sita wood, damp and unseasoned, probably wood of *Anona squamosa.*

8th Pair. Satrang wood, damp and unseasoned.

9th Pair. Bolos wood, damp and unseasoned, probably wood of *Juglans plerococea.*

10th Pair. Alodsake wood, damp and unseasoned.

The following is the description of the condition of the leads on examination.

No. 1. Both surfaces of lead very largely corroded, and a very considerable part of the lead entirely converted into white lead.

No. 2. One side of the lead quite bright and free from corrosion, and the other side covered with a fungus growth, which on removal showed the lead surface bright and uncorroded.

No. 3. The upper plank marked C was discoloured. (This was the plank which had been saturated with fresh water.) The lead surface next to this plank was partly covered with vegetable growth, and there was also a moderate amount of corrosion, "white lead" being present in considerable quantity.

The lower plank (seasoned wood *not* moistened with water) was clean, and the surface of the lead in contact with it was quite clean and free from all trace of corrosion.

No. 4. Both surfaces of lead were covered with vegetable or fungoid growth. The amount of corrosion seen on removing the vegetable growth did not appear to be large, but considerable quantities of white lead were found with the fungoid growth.

No. 5. The greater part of the lead was corroded and eaten entirely through, and almost the whole of the lead was converted into white lead or carbonate of lead.

No. 6. Both sides of lead were covered with vegetable growth. In certain parts of the lead there had been considerable corrosion, and a moderate amount of white lead was present.

No. 7. On both sides of the lead there was a large amount of fungoid growth and also of corrosion of the lead, much carbonate of lead was present, and in two places the lead was entirely eaten through.

No. 8. Parts of the wood had almost entirely decayed away or rotted, and the wood was an extremely soft one. Under the surface of the wood which had decayed, the lead was covered with vegetable growth and much corroded, but on the other surface of the lead, next to the wood which had not decayed, the greater part was quite clean and bright, and only a small amount of corrosion was detected.

No. 9. Both sides of the lead were much corroded.

No. 10. On the upper surface of the lead there was a moderate amount of vegetable growth, and a small amount of corrosion, and on the lower side of the lead there was a large amount of vegetable growth and a moderate amount of corrosion.

The results of the first three experiments in the above sets of wood strikingly confirm the results of the previous experiments with the tea chests, and it will be seen that unseasoned mango wood attacks lead in a moist atmosphere rather violently, also that seasoned mango wood kept dry has no action on it, but that seasoned mango wood, if it is subsequently saturated with water, becomes again in a condition in which it is able to attack lead in the presence of a moist atmosphere, though not so violently as is the case with the unseasoned wood. Of the other seven varieties of wood, all of them in a damp and unseasoned condition, every sample corroded the lead in a moist atmosphere, some woods corroding the lead very largely and others to a smaller extent.

In order to test further the action of these woods on tea-lead each of them was distilled in a current of steam to get off any volatile substance present or produced by the action of water. The distillates were then taken, a portion of each placed in large bottles with tea lead hanging over the liquid, and the bottles filled repeatedly with moist air containing carbonic acid.

No. 1 distillate had a very musty and unpleasant odour, and had only an excessively faint acid re-action. It was treated as above when the lead was somewhat corroded at the bottom of the slip, and lead carbonate was found to be present in small quantity.

No. 2 distillate also had a very musty unpleasant odour, and the watery layer was very faintly acid. The lead surface was slightly dulled, but no actual corrosion was perceptible.

No. 3 distillate had also a musty unpleasant odour, the liquid was almost neutral in re-action. The surface of the lead was very distinctly corroded, and a small amount of lead carbonate was found.

No. 4 distillate had a musty unpleasant odour,. and the liquid was faintly acid. The surface of the lead was slightly dull, and very faint traces of corrosion were found.

No. 5 distillate had a musty unpleasant odour, and the watery solution was faintly acid. The surface of the lead was slightly dull, and there was slight corrosion at a few points. Lead carbonate was present.

No. 6 distillate had a musty unpleasant odour, and the solution was faintly acid. The surface of the lead was decidedly dull and whitish, though there was only slight corrosion.

No. 7 distillate had a musty unpleasant odour, and the liquid was certainly not acid, but distinctly alkaline. The surface of the lead was practically unacted upon.

No. 8 distillate had a slight ethereal smell but also a musty unpleasant odour; the liquid was alkaline. The lead surface was almost bright and there was practically no corrosion.

No. 9 distillate had a musty unpleasant odour, and the liquid was distinctly alkaline. The lead surface was almost bright, and there was practically no corrosion.

No. 10 distillate had a musty unpleasant odour and the liquid was almost neutral. The surface of the lead was distinctly tarnished, and a small amount of corrosion was visible; small amounts of lead carbonate were present.

The action of these woods on lead was tested in another way by macerating samples of the splintered wood in water, evaporating till a fairly concentrated extract of the soluble principles of the wood was obtained, and then painting the surface of some tea-lead with the extract, and exposing the lead so prepared to the action of moist carbonic acid and air.

No. 1	sample.	The lead scarcely acted on.
No. 2	,,	,, ,, ,, ,, ,,
No. 3	,,	,, ,, ,, ,, ,,
No. 4	,,	A small amount of lead carbonate formed.
No. 5	,,	Slight amount of lead carbonate formed.
No. 6	,,	,, ,, ,, ,, ,, ,,
No. 7	,,	Practically no action on the lead.
No. 8	,,	,, ,, ,, ,, ,, ,,
No. 9	,,	Slight amount of lead carbonate formed.
No. 10	,,	,, ,, ,, ,, ,, ,,

The amount of action in this set of ten experiments, and also in the previous set of ten experiments with the distillates in steam of these woods, was in all cases comparatively slight, and it was not to be compared in extent or in nature, to the action which the same woods had produced originally on the tea-leads which had been packed between them; and the conclusion which naturally suggests itself from this is, that the cause of corrosion does not pre-exist in the wood in the condition of a volatile substance, and that it is not present to any large extent in the solution obtained by extracting the wood with water.

Taking these results then in connection with those previously detailed, it is clear that the corroding substance, whatever it may be, must be formed gradually in the wood, and that the formation is connected with the continued presence of moisture, or with the wood being in a damp and unseasoned state, and also that the active agent in the corrosion is a volatile body.

The next step in the investigation of the subject is clearly to trace out the active agents which induce the corrosion of the tea-lead, and, in order to do this, I thought it desirable to observe the action of tea-lead when placed in contact with vapours of various classes of substances which might induce corrosion, or which under certain circumstances might be produced from wood, and in the presence of moist air and carbonic acid also induce corrosion. My reason of course for working only with the vapours of these substances was that in all the cases of corrosion I had examined there were always parts of the corroded lead which were not in actual contact with the wood, and which therefore could only have been corroded by the agency of some vapourous body, and also that the active agent of the corrosion was volatile in a current of steam in almost all cases.

Lead is a metal which, it is well known, is easily corroded by certain substances, and the most important case is the action which is employed on an enormous scale in the manufacture of white lead or carbonate of lead by the Dutch process. In this process sheets of lead rolled up in spiral form are exposed in earthenware vessels, which contain a very small quantity of acetic acid or vinegar; these vessels are then stacked together and surrounded by decomposing tan or other organic material, which on standing under the influence of moisture, heats and evolves carbonic acid. The quantity of acetic acid used in such operations is very small, less, I believe, than one per cent. of the lead operated upon, and yet the lead under the influence of this minute quantity of acetic acid, and in the presence of moist air and carbonic acid at a slightly elevated temperature, is very rapidly corroded, and finally becomes almost entirely converted into white lead, which, as is well known, consists of carbonate mixed with hydrate of lead, and which, as produced in the first instance, contains minute quantities of lead acetate adhering to it, the acetate being afterwards removed by washing with water before the article is sent into commerce.

The first series of bodies the action of which I tried on tea lead, was the group of organic substances to which acetic acid belongs. In organic chemistry there is a large group of fatty acids as they are called, of which acetic acid stands next to the lowest, and which acids possess a precisely similar constitution, and act usually in precisely similar ways. These acids are homologous, only differing in composition by a well known increment of carbon and hydrogen. The lowest members only of this series are volatile, and I experimented with the five lowest with the following results. The mode of experiment was simple: a drop or two of the acid was placed at the bottom of a large bottle, a strip of tea lead was then hung in it, but not so as to touch the acid and the bottle filled with moist carbonic acid and air, the carbonic acid being renewed from day to day, or at frequent intervals as seemed necessary. The action then could only take place between the lead and the vapour of the acid, and the carbonic acid and moist air.

The first or lowest member of this series is Formic acid, and under its action the lead surface became dull and corroded to a small extent. There was a grey coherent film adhering to the lead and little or no white incrustation. The film on examination appeared to be Lead formate, and it is therefore evident that formic acid does not act on lead in the same way that acetic acid does.

Acetic acid in very small quantity was tested in the same way; the lead in a few hours was entirely covered with a film of white lead; in twenty-four hours the greater part of the lead had been corroded and destroyed, and in thirty-six hours the lead had been entirely eaten through, and converted into white lead with a small quantity of lead acetate present in it as usual.

Propionic acid, the third member of the series, after a few days had corroded the lead rather rapidly, and the greater part of the lead was entirely eaten through. The greater part of the lead was converted into the carbonate, though some soluble propionate was found.

Propionic acid then acts on lead in a manner analogous to acetic acid.

Butyric acid was tried in a similar manner, and after standing some days the lead was more than half eaten through, and the surface was covered with a moist yellowish green deposit. The lead was to a considerable extent converted into lead butyrate, but lead carbonate was also present in small quantity. Butyric acid therefore acts on lead in a manner analogous to acetic and propionic acid, but far more feebly.

Valeric acid, the fifth and last member of this series tried, caused a large amount of action on the lead, the surface of which became covered with a greenish yellow incrustation, and on some parts of which considerable amounts of crystalline scales were present. A large part of the corrosion was due to the formation of lead valerate, but a small amount of carbonate was also present.

Valeric acid therefore acts on lead in the same way as acetic, propionic, and butyric acid, but the production of the carbonate is much more feeble.

A most interesting point in the case of the last two bodies, butyric and valeric acids, is that the incrustation on the lead was strikingly analogous to that found in the rarer form of corrosion in tea chests as described under the cases S. 1. and S. 2.

Other but less volatile organic acids, such as Benzoic acid etc., were tried, but they produced no appreciable action on lead.

Hydrochloric acid in the same way was tried and the lead surface became covered with chloride of lead with which a minute trace of carbonate was mixed.

Nitric acid tested in the same way caused very rapid corrosion, the product of the action appearing to be either a basic nitrate or a mixture of nitrate and hydrate.

Ammonia acted on the surface of the lead to a small extent, and converted it partly into oxide.

A series of alcohols, consisting of methylated ethyl alcohol, ethyl alcohol, propyl alcohol, butyl alcohol and amyl alcohol, was tried, but beyond a slight superficial action no corrosion was found to take place.

A series of essential oils was then tried, including oils of anise, bergamot, cinnamon, cloves, eucalyptus, lemon, peppermint, and turpentine, and also camphor, menthol, and thymol. In almost all the cases of the oils, slight corrosion of the lead into oxide and carbonate was found. It was therefore clear that these oils facilitate the action of moist carbonic acid and air on lead. In no case however had the corrosion proceeded to any large extent, and it consisted only of a kind of white film or bloom on the surface of the lead, such as is frequently seen in tea chests when there appears to have been a tendency to action, though no actual corrosion. In the case of camphor, menthol and thymol the lead was perfectly unacted upon.

Other tests have been made, but they need not be here described, and so far as my experiments have gone they indicate that the only class of organic substances which is capable of producing rapid chemical action on tea-lead in the presence of moist air and carbonic acid is the class of fatty acids or the acetic series of acids. Of these formic acid does not produce any carbonate of lead; the action of acetic acid, as is well known, is violent; that of propionic acid is of similar nature but less violent: the principal products of the action being in these two cases white lead; and finally butyric and valeric acids produce yellowish green incrustations on lead which contain only small quantities of carbonate.

The next point which I have endeavoured to work out is to trace the actual active agent which induced the corrosion in some of the cases described in the first part of the paper, and for this purpose a more minute investigation was made into the products of the corrosion of the leads. Four of the leads which had been much corroded in the ten samples which had been placed between boards were taken. The numbers selected were No. 1. Wild mango wood, No. 4. Dumboil wood, No. 5. Julna wood, and No. 8. Sita wood.

In the corroded lead of No. 1, the material was principally lead carbonate and lead hydrate; acetic acid was also distinctly detected by several tests, so that the active agent in the corrosion of this lead was clearly acetic acid. In the corroded lead of No. 4., the material was again principally lead carbonate and hydrate; acetic acid was also clearly detected, but the quantity present was very minute. In the corroded lead of No. 5, again, the corroded material was mainly lead carbonate and lead hydrate; acetic acid was tested for and detected with great ease, and the quantity was comparatively large, sufficiently large to convert the acid into barium acetate, which presented the usual properties but the quantity was not large enough for a quantitative analysis. In the corroded lead of No. 8, the principal material was lead carbonate and hydrate, but the presence of acetic acid was also clearly detected.

Evidently then the action which has taken place in the case of these woods in contact with the tea-lead has been identical with that previously described as the Dutch method of making white lead. Acetic acid was present in minute quantity, moist air and carbonic acid have also been present at a comparatively high temperature, and thus all the conditions were favourable for the production of white lead.

The conclusion, then, at which I arrived was that the corrosion was produced by the unseasoned, or moistened wood, and that acetic acid was the active agent in the corrosion. In order to further test the point, I made extracts from the various samples of wood numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, and distilled these extracts with dilute sulphuric acid. In all cases a distillate of distinctly acid and acetous smell was obtained, evidently showing the presence of small quantities of acetic or some analogous acid in combination in these woods.

The final point which then remains to be cleared up is the origin of the acetic acid from the wood, for, as previously pointed out, it evidently does not exist in the first instance ready formed in the wood, but is produced by some secondary action. Dr. Wigner in the publication previously referred to put forward a very probable theory. He remarks "The sap of wood invariably contains sugar. The quantity is small, but still measurable. This sugar is in every case, which has come under my knowledge, a fermentable sugar, and the first result of the fermentation is in most cases alcohol. Fermentation being carried a step further free acetic acid is the natural result. With the formation of acetic acid carbonic acid is also formed ... Transferring this from a theoretical to a practical case: A wood containing sap which was more than usually saturated with sugar, and exposed to a moist heat, would ferment more readily, would produce a larger quantity of alcohol, would consequently produce a larger quantity of acetic acid, and would therefore, by inference, derived from practical work, produce a larger amount of carbonic acid, and thence of white lead. These effects would be produced mainly, if not entirely, upon the surface of the wood, and one of these surfaces would be in contact with the metallic lead which forms the lining of the case. Now let us see what would take place. The lead lining would be exactly in the same condition as the lead in a leadstack which was being worked by the Dutch process. Acetic acid, carbonic acid, and moisture would all be present. There would be a reasonable and probably, in accordance with practice, a very proper degree of heat, and the lead and wood would be in contact; and it seems the most natural thing in the world to assume that, as the result, acetate of lead would be formed by the direct action of the acetic acid. Carbonate and hydrate of lead would be formed from this by the action of the carbonic acid and the moisture in the air, and although the two chemical changes would run on almost concurrently, yet the result would be the direct formation of a film of white lead.

The samples of wood Nos. 1 to 10 were therefore tested to see whether any fermentable sugar could be detected in them. It must, however, be remembered that these woods had already produced their corrosion, and according to the above theory a part, if not the whole, of the fermentable sugar contained in the wood would have disappeared in the process. Of the ten samples No. 1 Wild mango wood was tested most carefully, and very distinct indications of a fermentable sugar were obtained. No. 5 jalna wood and No. 9 bolos wood also gave clear indications of fermentable sugar, and in the case of Nos. 2, 3, and 8 as well, there appeared to be traces of this substance, but in Nos. 4, 6, 7, and 10, I could not detect any indications of fermentable sugar at all.

The presence of fermentable sugar in small quantity in the wood is certainly a probable cause of the formation of acetic acid, but wood contains other ingredients besides. Thus, for instance, some kind of starchy matter is a nearly constant ingredient of the stems of trees, and forms the chief bulk of the reserve matter out of which leaves and shoots are produced in spring. The presence of starch is also in some way connected with the presence of sugar, for experiments have proved clearly the existence of varying amounts of sugar in fruit trees, and also that the sugar reaches its maximum in the spring when the starch is undergoing solution. Starch also in the condition in which it is found in unseasoned wood under the continued influence of heat and moisture will undoubtedly suffer decomposition, and the products of decomposing starch, as is well known, are of a decidedly acid character, and of the acids formed, some are of the acetic series, and of these butyric acid may be recognized.

The sap of woods has also been investigated and one of the principal constituents is sugar. Of the presence of carbo-hydrates other than sugar no definite evidence exists, but in the cases which have yet been investigated malic acid was also present in the sap. Now malic acid is a substance on which the action of putrefactive ferments has been tried, and the products of the fermentation are carbonic acid, acetic acid, succinic acid, and butyric acid.

I regret that up to the present time I have not been able to investigate the sap of any Indian trees, nor have I found malic acid in the woods experimented on, but given the probable, if not the almost certain presence of small quantities of malic acid in the sap, and given the conditions of heat, moisture, etc. to set up putrifactive fermentation in the moist and unseasoned wood, the presence of all the substances necessary to corrode tea-lead will at once follow.

In the case of an unseasoned wood, the sap will still be present in small quantity, and thus the presence of acetic acid, butyric acid, etc., may be readily accounted for, if the wood is placed under circumstances of heat and moisture favourable to the production of fermentation.

The conclusions that my experiments have led me to form are as follows:—

1. That tea properly manufactured in the ordinary way has no power to corrode lead.

2. That if unseasoned and damp wood is used for the manufacture of the tea boxes, corrosion of the tea lead is, under favourable circumstances, almost certain, but that some varieties of wood act more violently than others.

3. That even if seasoned wood be used to make the tea boxes, and if it be allowed to become saturated with water, and then placed in favourable circumstances of heat and moisture, corrosion of the tea lead may occur, though not to so great an extent as if unseasoned wood had been used.

4. That the active agent does not exist ready formed in unseasoned wood, but is produced by a secondary action from the constituents of the wood.

5. That the corrosion is not usually due to contact action between the lead and the wood, but that a volatile substance is gradually produced from the unseasoned wood.

6. That the corroding agent is usually acetic acid in the presence of moist air and carbonic acid, but that other acids of the same series are sometimes produced, and also act on the lead, and in the case of butyric and valeric acids a greenish yellow incrustation is formed differing entirely from the whitish or yellowish incrustation produced from acetic acid.

7. That the acetic and other acids are produced by the decomposition (probably by a kind of fermentation under the influence of heat and moisture, and perhaps started by decomposing nitrogenous matters) of certain substances which are known to be present in woods. Such bodies are fermentable sugars, starchy matters, malic acid, etc.

8. That the lead linings of the tea chests having been corroded and perforated by the corroding action of these acids in the presence of moist air and carbonic acid, the tea can easily take up the disagreeable odour which the wood itself will possess, after it has undergone the change in which acetic and butyric acid, etc., are formed, and thus the quality of the tea will be deteriorated.