No. 14.	Grains.
Carbonate of lime and carbonate of magnesia	18·5
Organic matter	3·5
Sulphate of soda	17·0
Carbonate of soda	3·0
Total .	42·0

"These three are all of inferior quality, and if better can be obtained, the saving in the engines will probably pay for some cost in bringing better water."

No. 15. (B.)	Grains.
Carbonate of lime	4
Sulphate of lime	20
Sulphate of soda	16
Total .	40

"This water is far from good, though worse has been used. The quantity of carbonate and sulphate of lime deposited in an actual experiment was 10 grains per gallon, or nearly 1½ lb. per 100 gallons."

No. 16.	Grains.
Carbonate of lime	2·45
Sulphate of lime	5·9
Sulphate of magnesia	5·17
Chloride of sodium	1·53
Carbonate of soda	2·15
Total .	17·2

"This may be considered a good water, though not the very best."

The above are selected from many others, to show the character attached by the writer to water of various kinds.

Nos. 8 and 9, the water supplied by public waterworks to two large towns, at a distance from each other, may show what can be obtained in some situations when carefully sought.

Mr. J. V. Gooch said, that the subject of incrustation in steam boilers generally, and more especially in those of locomotive engines, had for some time occupied his attention. Every means had been used upon the London and South-Western railway, to obtain water containing as small a proportion as possible of carbonate of lime, which was the basis of all incrustation. To effect this, at the Nine Elms station, the supply was taken from a public water-works company, and at Southampton, a well was bored down to the low springs. This had been done at a great expense, and still a considerable amount of incrustation was formed in the locomotive boilers. He had tried many methods for preventing incrustation, but had never met with anything that was successful, until about nine months since, when he heard, that by the simple introduction of a portion of muriate of ammonia into the boiler, Dr. Ritterbandt had succeeded in preventing the deposition of lime. After being satisfied that no injury could arise from an experiment, Mr. Gooch permitted a trial to be made, on a locomotive engine belonging to the London and South-Western Railway Company. The 'Reindeer' engine, which had been partially fitted with new tubes, was selected for the purpose; the upper rows were old tubes, and had on them an incrustation of about $\frac{1}{16}$th inch thick; the fire-box, and the sides of the boiler, were also coated to about $\frac{1}{8}$th inch thick. A space of about 6 inches square on the top of the copper box was cleaned quite bright, and the engine was placed in the hands of the man who had worked it almost exclusively for two years previously; it continued running in the usual manner, being washed out every fourth day for about five weeks, Dr. Ritterbandt attending and applying the muriate of ammonia, as he thought necessary. At first, on washing it out, large pieces of incrustation appeared; this increased for about a fortnight, after which time, the quantity gradually diminished, until nothing but loose sand, &c. was found, and during this time the supply of steam generated, was so much increased, as to enable the blast-pipe to be enlarged $\frac{3}{16}$ths inch in diameter. At the end of five weeks when the boiler was opened, it was found to be perfectly free from incrustation, and the part which had been cleaned, remained quite bright.

Mr. Gooch was then anxious to ascertain whether any injurious action had taken place upon the metal plates; he therefore drew off a bottle of water from the boiler, at the conclusion of the experiment, and had it severely tested by a practical chemist of considerable experience, but no trace either of copper or iron was found. During the last six months the muriate of ammonia had been constantly used in every boiler under his charge, whether locomotive or stationary, with the same beneficial effects. An increased supply of steam had in every case followed, and it was found, that the boilers would carry at least 2 inches more water than before, and in many instances the blast-pipes had been enlarged.

He had also carefully watched the application of the muriate of ammonia in sea-going boilers, and the effect had been very extraordinary. It was well known, that to work such boilers at all, it was necessary, either to use brine pumps, as applied by Messrs. Maudslay and Field, or to blow out, by cocks provided for that purpose, a very large quantity of heated water so as not to allow of a greater density than 20° upon the hydrometer, or equal to 215½° Fahrenheit; and even then a thick incrustation was formed. To remove that incrustation after every voyage, a great expense was incurred, and serious injury to the boilers frequently occurred, either from the use of large hammers, in chipping it off, &c., or, as was more frequently the case, from suddenly expanding the plates by heating them with shavings, for the purpose of breaking the incrustation, and causing it to leave the plates more easily.

The first experiment with muriate of ammonia, was tried in a marine boiler on board the 'George the Fourth' steam boat, plying between Southampton and Portsmouth. It had been working for some time, without cleaning the boilers, and the engineer used to blow out every two hours. During the first few days, after the muriate of ammonia was applied, the boilers were blown out about once a day, after which the blowing out was gradually discontinued. At the end of six weeks the boilers were opened, and it was found, that nearly all the scale or incrustation which had been formed, before the application commenced, was then removed. From that time, not a drop of water was blown out for about twelve days, and yet no deposit took place, although the density of the water had increased to 80° on the hydrometer.

In another sea boat, the muriate of ammonia was applied to the boilers, where there was a considerable thickness of incrustation, and the whole of the blow-off cocks were soldered up, so that no water should be removed; this vessel was under steam only for a few hours each day, but the experiment lasted until she had been 58 hours altogether under steam, when the water was found to have increased in density to 82° per hydrometer, after which it was allowed to stand for three days, and was then pumped out through the man-hole, so that the deposit (if any existed) should not be disturbed. At that time Mr. Gooch saw the boilers; and he found the sides perfectly clean, but on the bottom and top of the flues there was a deposit which, on examination, was found to be nothing but fine sand, perfectly free from lime, or salt. All the incrustation previously formed was also entirely removed. A further experiment was tried with the same boilers, when no water was blown out during 48 hours' steaming, at which time the density was equal to about 52° per hydrometer, at which it was kept by occasional blowing out, until the total time under steam was 100 hours, when, on examination, they were found to be perfectly free from incrustation.

The cost of the application of the muriate of ammonia to a locomotive engine did not exceed $3\frac{1}{2}d.$ for every 1500 gallons of water evaporated—or for every 100 miles travelled.

Dr. RITTERBANDT agreed with Mr. West, that the greatest portion of incrustation consisted of carbonate of lime, with smaller portions of sulphate of lime, and of other inorganic matters which had been mechanically suspended in the water, and were precipitated with the former substance. His experience, however, did not allow him to confirm Mr. West's observations, as to the greater hardness of those incrustations, which contained the calcareous sulphate in the largest proportion; on the contrary, he had always found those deposits most coherent, which consisted of pure carbonate only. However this might be, carbonate of lime was undoubtedly the cause of the peculiar structure,—of that coherence of the particles of the deposited mass of salts, which merited for it the term incrustation. Engineers had been too long accustomed to consider the substances deposited in boilers under vague terms. They had spoken of them under the terms deposit, or sediment, and incrustation. Now, there was a great difference between a mere deposit, or sediment, and an incrustation, and they should learn clearly to distinguish between them, not so much for scientific accuracy, as for practical purposes.

A deposit or sediment, could be readily collected and removed by mechanical means, without arresting the operation of the boiler; but an incrustation could not be so removed.

A deposit was but slightly prejudicial to the working of a boiler, (unless it existed in a large quantity) if the consideration of it as a source of priming, was omitted. An incrustation was, on the contrary, highly prejudicial. It was the chief cause of explosion, and was incompatible with the economical use of fuel.

A deposit, or sediment, arose from earthy matters and other impurities mechanically mixed with, and suspended in, the water.

An incrustation, as had been shown by Mr. West, arose from a chemical change in the mineral constituents of the water.

An incrustation, if formed from water which had been filtered, or from which the mechanical impurities had been removed, consisted, in the greater number of cases, and for the most part, of pure carbonate of lime, and under these circumstances, it would be deposited in the densest form of incrustation. These views accorded with Mr. Armstrong's opinions, as given in his work on steam-engine boilers.

The other substances, such as argillaceous and silicious matters, which were usually found in incrustation, associated with the calcareous carbonate, had been carried down with, and cemented together by it; but by preventing the particles of this substance from approximating as closely as they otherwise would have done, they rendered the incrustation less dense and coherent than in the former case.

In examining, therefore, the mode in which incrustation was formed, the consideration of the suspended substances might be omitted, and it would be only necessary to observe the process, by which bicarbonate of lime passed from the state of solution, to become the indurated, dense mass, called incrustation. In watching its formation in a glass vessel, it would be found, that it was first deposited, and then incrusted, or crystallized; for that was really the nature of the indurating process.

On heating a solution of the bicarbonate of lime, before the temperature arrived at the boiling point, the gaseous acid began to escape, and the insoluble carbonate to be precipitated.

The carbonate thus precipitated, possessed properties not appertaining to the incrusted carbonate. It was amorphous, and was capable of being re-dissolved, while cold, on the addition of a further quantity of carbonic acid, to replace that which was expelled. On allowing the precipitated carbonate to stand and to collect, a change of structure was observed: the amorphous particles agglomerated and formed crystals, and then, on the additon of carbonic acid, no solution took place. This process of agglomeration, or formation of crystals, constituted petrifactions, stalactites, stalagmites, and the so called "alabaster" casts of Italy. Such was the cause of incrustation.

The basis of all attempts to prevent incrustation, previous to the system alluded to by Mr. Gooch, consisted in adding to the water of the boiler, vegetable or animal matter, such as potatoes, starch, leather shavings, logwood, sugar, turmeric, &c. The manner in which these acted, was long since pointed out, in a paper by Mr. West, published in the 'Journal of the Royal Institution.'* He there said:—"The adhesion of the earthy matter to the iron is lessened, and the interval between the cleanings consequently protracted, by the use of potatoes; the pulp of which, by enveloping the crystals, lessens their tendency to adhere, and preserves them for a while suspended in the water of the boiler."

These abortive efforts might be characterized as partially preventing incrustation, by greatly increasing the amount of sediment. The inconveniences of such processes were equal to those arising from the evil itself, and had caused them to be generally discontinued.

If it was considered, that carbonic acid was one of the constituent

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* *Vide* 'Journal of the Royal Institution of Great Britain,' 1830, p. 38.

elements of the atmosphere, and that carbonate of lime was one of the most abundant of mineral substances, it would be seen, that there were ever present the conditions necessary for the formation of mineral water capable of producing incrustation. In addition to this, there were large districts, situated like London, in the centre of chalk basins, through which its water must percolate, before reaching the surface; under such circumstances, a supply of non-calcareous water was not to be expected.

Mr. Gooch had shown, that, however the water might be loaded with chalk, by the simple addition of minute portions of muriate of ammonia in the boiler, no more incrustation was formed, than if distilled water had been employed. Dr. Ritterbandt felt satisfied, that the practical proofs adduced by Mr. Gooch must induce conviction of the efficacy of the process. It only, therefore, remained for him to explain its mode of action.

When his attention was first called to the subject, after investigating the nature of incrustation, and arriving at the conclusions he had just endeavoured to explain, he felt convinced that the question was entirely chemical, and must be so treated. To dissolve the carbonate, by an acid, at once suggested itself. But acids had a tendency to destroy the iron, and more particularly the oxide, by which alone, in many cases, the joints were rendered tight. The question then was, how to form a soluble salt of lime, without the inconvenience of acting upon the metal. The salts of ammonia then occurred to him. It was known, that if to a soluble salt of lime, a solution of carbonate of ammonia was added, precipitation took place. The acid which held the lime in solution, united with the ammonia, while the carbonic acid of the carbonate of ammonia, combined and fell down with the lime. It was necessary for the success of this re-action, that the operation should be carried on at a low temperature; for on heating the precipitated carbonate of lime with the salt of ammonia, the converse of what he had just described, took place. The precipitated carbonate of lime was re-dissolved, and carbonate of ammonia was formed, which escaped with the vapour of the boiling water. This experiment had often been discussed among the French chemists, in connexion with the peculiar views of Berthollet on the nature of affinity, and was one of those which gave weight to his opinions. On satisfying himself, that this peculiar re-action took place, viz., that carbonate of lime, just precipitated from a salt of lime by carbonate of ammonia, would be again dissolved by the mere application of heat, it only remained for him to try, how far this principle was applicable, to decompose the carbonate of lime already existing in calcareous water. The result exceeded his most sanguine expectations. The process answered completely, however highly charged with lime the water might be, and the solution was in all cases perfect.

He then explained the rationale of the process, by referring to the following diagram:—

Muriate of Ammonia.	Mur. Acid + Ammonia	Mur. Acid + Lime	Muriate of Lime (soluble).
Carbonate of Lime (insoluble).	Lime + Carb. Acid	Carb. Acid + Ammonia	Carbonate of Ammonia (volatile).

Muriate of ammonia was composed of muriatic acid and ammonia. On being brought into contact, at a high temperature, with carbonate of lime in solution, or just precipitated, mutual decomposition ensued. The muriatic acid seized the lime, forming the soluble muriate of lime, while the carbonic acid took the ammonia, and the volatile carbonate of ammonia, so formed, escaped with the vapour.

This account of the mutual decomposition of two salts was not strictly in accordance with the views of modern chemists, nor were the names of the salts, those assigned to them by the present nomenclature, muriate of ammonia being called chloride of ammonium, &c.; but the result was in both cases the same, and the old view was, in his opinion, most likely to be understood by practical men.

Dr. Ritterbandt then exhibited the action of heat upon a strong solution of bicarbonate of lime, with and without the addition of muriate of ammonia. The solution, in the former case, remained perfectly transparent, carbonate of ammonia escaping; while, in the latter, a strong deposit of carbonate of lime was found, which partially incrusted the sides of the glass vessel in which the experiment was made.

He subsequently referred to the quantity of muriate of ammonia necessary to produce the beneficial effects described, and stated, that if the chemical equivalents of carbonate of lime and muriate of ammonia were considered, it would be found that they were nearly equal:—

Muriate of ammonia = 54
Carbonate of lime . = 50

So that for each grain of the latter, contained in the water, about a grain of the former must be used, for perfect solution. It was necessary, therefore, to ascertain the per centage of lime present, before directions could be given as to the actual quantity to be used in each particular case, to ensure perfect success; and for this purpose, a correct analysis of the water was required.

Mr. Gooch had found, that for the water used on the South-Western Railway, 1½ lb. of common muriate of ammonia was sufficient for a locomotive during a journey of 160 miles, during which, he estimated the quantity of water evaporated to be about 2400 gallons.

This, however, was not a true criterion, as water differed in composition in each locality; analysis, or a series of experiments, could therefore alone be depended on.

Mr. Cooper said, he had paid considerable attention to the subject, and had made many experiments, with the view of diminishing the injurious effects of incrustation; but he had never attained the success of Dr. Ritterbandt's process, which, he was of opinion, must be considered by engineers as an essential service rendered to them. The basis of the system was as sound as it was simple, for by preventing the cementation together of the deposited carbonate of lime, the crystallization of the mass was rendered impossible, and with water, like that in the neighbourhood of London, containing from 120 grains to 130 grains of solid matter in a gallon, the amount of incrustation would, no doubt, be very great, and the rapid destruction of the boilers could be easily accounted for.

Mr. Cooper had analysed water from a very large number of wells on the south side of the Thames, between Wandsworth and Deptford, and in all he had found considerable traces of oxide of manganese, for which he could scarcely account, as there was no geological indication of a deposit of that mineral.

Professor Brande agreed with the soundness of Dr. Ritterbandt's process, which, with ordinary attention in proportioning the dose of muriate of ammonia to the contents of the water, as shown by analysis, must, he imagined, be unfailing. It was intinitely superior to the clumsy process of cleansing by means of acids, which had hitherto been practised. Much of the injurious incrustation in boilers, in London, arose from the use of the mixed waters of the upper and lower springs. The water from the deep wells, when the top water was excluded, contained but little carbonate of lime; but there was much carbonate and sulphate of soda. An instance of the bad effects of the mixed waters, occurred a short time since, in a boiler which he was requested to examine. The workmen found in the boiler considerable quantities of what they supposed to be chalk. It was a light pulverulent substance, formed like froth or scum. It proved to be stearite of lime, or a combination of carbonate of lime with the fatty matters brought from the engine by the feed pump. This substance was never observed to be formed, when the water of the deep springs alone was used, but was always produced by the mixture of the two kinds of water.

In all the analyses he had made of London water, or that he had seen made by other chemists, carbonate of lime appeared, and it was evident, that any system of preventing incrustation, must attack that substance as the most noxious. In many samples of water, he had found twice as much saline matter as in the Thames water; this would be termed, twice as hard as Thames water, hardness being occasioned by the presence of salts of lime.

Mr. F. Braithwaite said, that from few of the deep wells in and about London, was it practicable to procure separate samples of water, from the different strata passed through; for instance, in an analysis made by Professor Graham, of three samples of water, stated to be from the same source, the results varied, although carbonate of lime predominated in all.

The analysis referred to, was made by the direction of the Commissioners of Greenwich Hospital, on the water of three wells.

The first, was from the well of the Royal Hospital, Greenwich; the second, from Page's brewery, at Greenwich; the third, from Lambert's brewery, at Deptford. The Greenwich Hospital well was sunk 123 feet down to the chalk, then dug 30 feet in the chalk, and bored 100 feet in the chalk, making a total depth of 253 feet; the land-spring water, the sand-spring water, and the chalk-spring water, in this well, were all separated by means of iron cylinders.

The well at Page's brewery, at Greenwich, was bored down to the chalk, 124 feet, and then bored in the chalk, 152 feet, giving a total depth of 276 feet. No means existed in that well of separating the waters.

The well at Lambert's brewery was bored down to the chalk, 55 feet, and in the chalk, 123 feet, making a total depth of 178 feet; there was no evidence there, also, of the waters from the different sources being separated.

Professor Graham's analysis showed the following results:—

Well at Greenwich Hospital:—

	Grains.
Carbonate of lime . . .	19·08
Carbonate of iron . . .	0·52
Sulphate of magnesia . .	2·04
Sulphate of soda	3·62
Chloride of sodium . . .	0·37
Loss	1·67
Solid matter .	27·30

In one imperial gallon, weighing 70,000 grains.

Well at Page's brewery:—

	Grains.
Carbonate of lime	21·23
Sulphate of magnesia . .	2·88
Sulphate of soda	0·60
Chloride of sodium . . .	3·12
Solid matter .	27·83

In one imperial gallon.

Well at Lambert's brewery:—

	Grains.
Carbonate of lime	16·74
Carbonate of magnesia . .	0·80
Sulphate of magnesia . .	2·75
Sulphate of soda	2·67
Chloride of sodium . . .	1·91
Loss	1·33
Solid matter .	26·24

In one imperial gallon.

Only one of the three samples (that of the Greenwich Hospital well) could be stated, with certainty, to have been obtained from the chalk; hence the discrepancy in the analyses, and this discrepancy arose from the difficulty of separating the sand-spring water from that of the chalk, by the present mode of forming wells by boring only.

The different results of all analyses of water, stated to be from the same source, must not be attributed to the want of professional skill in the chemist, but to the carelessness of those who selected the samples of water.

At the desire of Mr. Walker, a sample of the Greenwich Hospital water was analysed by Mr. Phillips; that gentleman declared the water to be softer than that of the Thames, while Professor Graham declared it to be one-half as hard again. This difference of opinion arose, probably, from the samples of water not being identical.

Referring to the paper under discussion, Mr. F. Braithwaite considered Dr. Ritterbandt's process as of the greatest importance to engineers, particularly when applied either to the boilers of locomotive, or of marine engines; it was valuable, not only as preventing the destruction of the tubes, but as enabling the diameter of the blast-pipes of the former to be increased, their usually contracted dimensions being the cause of much loss of power, as was well known to persons practically acquainted with locomotive engines.

He however considered Dr. Clarke's mode of purifying water, to be very simple and economical where it could be applied.

Dr. Clarke had stated, that 16 ozs. of carbonate of lime (common chalk) was composed of 9 ozs. of lime, and 7 ozs. of carbonic acid :—

$$\left.\begin{array}{ll} \text{Lime} \quad . \quad . \quad . & 9 \text{ ozs.} \\ \quad + & \\ \text{Carbonic acid} \quad . & 7 \text{ ozs.} \end{array}\right\} = 16 \text{ ozs. carbonate of lime (insoluble).}$$

To render these 16 ozs. of carbonate of lime soluble in water, it was necessary to add an additional quantity of 7 ozs. of carbonic acid, forming a bi-carbonate of lime, which was soluble.

$$\left.\begin{array}{ll} \text{Lime} \quad . \quad . \quad . & 9 \text{ ozs.} \\ \quad + & \\ \text{Carbonic acid} \quad . & 7 \text{ ozs.} \\ \quad + & \\ \text{Carbonic acid} \quad . & 7 \text{ ozs.} \end{array}\right\} = 23 \text{ ozs. bicarbonate of lime (soluble).}$$

This represented the quantity of bi-carbonate of lime in 560 gallons of filtered Thames water.

To precipitate these 23 ozs. of bi-carbonate of lime, from the 560 gallons of water, he added lime-water—say 9 ozs. of lime to 40 gallons of water; this gave the following combination :—

$$\left.\begin{array}{ll} \text{Lime} \quad . \quad . \quad . & 9 \text{ ozs.} \\ \text{Carbonic acid} \quad . & 7 \text{ ozs.} \end{array}\right\} \text{Carbonate of lime, 16 ozs. (insoluble).}$$

$$\left.\begin{array}{ll} \text{Carbonic acid} \quad . & 7 \text{ ozs.} \\ \text{Lime} \quad . \quad . \quad . & 9 \text{ ozs.} \end{array}\right\} \text{Carbonate of lime, 16 ozs. (insoluble).}$$

It would be seen, that the 9 ozs. of lime contained in the 40 gallons of lime-water, united with the 7 ozs. excess of carbonic acid in the bi-carbonate of lime, forming 16 ozs. of insoluble carbonate of lime, and the bi-carbonate of lime being deprived of its extra carbonic acid, became insoluble carbonate of lime; thus leaving the 600 gallons of water free from 32 ozs., or 2 lbs. of common chalk.

Mr. F. Braithwaite illustrated Dr. Clarke's method of purifying water by precipitating the carbonate of lime. To a glass of the ordinary London water, he added a solution of lime; in a very short time the water became clouded and milky, and, within half an hour, a considerable deposit was evident; showing that the lime attracted the excess of carbonic acid on the bicarbonate of lime, precipitating the carbonate of lime, as common chalk, in which state it was insoluble in water.

In many instances, where the water was required to be pure, and where the presence of the muriate of ammonia, used by Dr. Ritterbandt, might be prejudicial, for instance, for dyeing and other manufacturing purposes, Dr. Clarke's process was, in his opinion, preferable; although, for locomotive boilers only, the erection of tanks and settling reservoirs, might be found inconvenient in practice.

Mr. Peto said, the subject of incrustation was not only of great importance, when viewed as causing the destruction of the boiler; but he was convinced, that in many instances, the retardation of railway trains, and even accidents from collision, might have been traced to the fact of the surface of the tubes being so incrusted, as to render it impossible to keep up the supply of steam. He would instance, as an example of the expense caused by incrustation, that the locomotives employed on his contracts on railways, had cost, within the last nine months, upwards of £1500, for the repairs of the tubes alone. Every one who used steam power, must, he thought, feel indebted to Dr. Ritterbandt for bringing forward so valuable a discovery.

Mr. R. Stephenson said, that not having been present at the commencement of the discussion, he was scarcely in a position to draw a comparison between Dr. Ritterbandt's system and a process which had been tried on the Birmingham and Derby Railway, the object of which was also to prevent the hard deposit of carbonate of lime. This was accomplished by the exhibition of a given proportion of muriatic acid, by which muriate of lime was formed. He apprehended, that by the use of the free acid the same end was attained, as by employing the neutral salt, and he could not perceive the advantage of forming a carbonate of ammonia, which he imagined would act prejudicially upon the metal of the boiler.

The chief difficulty, in adapting any of these chemical compounds, arose from the variation in the quality of the water used for the locomotives;—in times of floods, the water was comparatively free from carbonate of lime, but was surcharged with other earthy substances in suspension; whereas during a drought, the quantity of carbonate of lime was greatly increased. Anything, therefore, which might act chemically upon the metal of the boiler, should be used only in proportion to the analytic contents of the water; this in practice would, he apprehended, be difficult of attainment.

Dr. Ritterbandt said, it was well known, that by the application of muriatic acid, the carbonate of lime would be converted into muriate of lime, and the same end would be thus attained as by his process; but the action was totally different, and he must be permitted to contend, that the one process must be injurious to the boiler, while the other was completely innocuous. Any excess of free acid would act upon the metals and form muriate of iron and muriate of copper, it would therefore require to be used with great caution, and to be introduced in small quantities into the boiler, which he imagined would hardly be compatible with practical convenience. Now, muriate of ammonia being composed of chlorine and ammonium, contained no more free acid than common salt, and when the quantity required by his process was introduced into the boiler, it remained perfectly inert, until ebullition commenced, when the muriate of ammnia seized upon the carbonate of lime, as it was set free from the carbonic acid, and the carbonate of ammonia that was formed, was enveloped in, and escaped with, the steam evolved. From the quantity of 1 lb. of muriate of ammonia, which was used to 1,500 gallons, or 2,000 gallons of water, so minute an amount of carbonate of ammonia would be given out, that he felt convinced no injury could ever accrue to the tubes of boilers or the faces of the safety valves. Polished pieces of copper had been inserted, with the view of testing the action of the muriate on the metal, and not the slightest corrosive action could be detected.

Mr. Smee thought, that whether the free acid, or the neutral salt was used, the result would be the same, as the muriate of ammonia would combine with metallic salts or oxydes, and therefore the boiler must be injuriously affected. If the pieces of polished brass or copper were only partly immersed in the saline mixture, that is, were in contact with the air as well as with the solution, they would be powerfully acted upon, and still more powerfully, when galvanic action took place. If the metal formed the poles of a galvanic circuit, while immersed in a solution of the muriate, then rapid corrosion would ensue.

Mr. Johnson was surprised to hear the opinions just expressed by Mr. Smee. Fortunately, the premises were stated whence such opinions were deduced, so that the meeting was enabled to judge how far they were correct. It appeared, that although muriate of ammonia did not act upon polished copper immersed, and boiled, in a solution of that salt, yet that if the copper was but partially immersed and air was in contact with the metal, as well as the muriate, that rapid action ensued.

It was essential to mark the necessary conditions. Air, that is, free oxygen, must be present. Now, how could free oxygen be present in the boiler, and in contact with metals immersed in the muriate of ammonia; if not, was there any necessary connexion between such an experiment and the strong opinion expressed, on the subject?

Another instance adduced was, that when a galvanic current was passed through a solution of muriate of ammonia, the metal forming one of the poles of the battery became rapidly dissolved.

Mr. Johnson was sure Mr. Smee would agree, that this action could only take place, when the current was of sufficient intensity to produce electrolysis, or decomposition of that solution. Under such circumstances, the base passed to one pole and the acid to the other, the latter being the solvent of the metal. But this surely could not be cited as the result of the solvent power of the muriate of ammonia. By the conditions assumed, the dissolution of the metal only took place, after the muriate had been resolved into its constituents, that is, had ceased to exist.

Or was it meant, that a galvanic current existed in the boiler, of sufficient intensity to decompose the muriate, and to liberate its acid? If so, Mr. Johnson must be allowed to offer his decided dissent to that proposition, and in doing so he would remind the meeting that the question was simply one of fact. The metal could not be dissolved to any extent, without its presence being indicated on the application of tests to the water of the boiler. Now, no proof had been brought forward, of the presence of the dissolved metal in the boiler, and assuredly more than mere conjecture or hypothesis was necessary in a case of this importance.

On the other hand, several specimens of water taken from boilers, in which the muriate had been used, had been submitted to Mr. Johnson, and in none had he been able to detect the presence of the metals, said to be so energetically acted upon by the neutral salt. These experiments accorded with those quoted by Mr. Gooch, and would, he doubted not, be confirmed by all who might make similar trials.

Mr. Johnson must state, that although he had never supposed, that any action, deleterious to the boiler, would ensue with so dilute a solution; yet he certainly had expected to find traces of iron dissolved. The action, however, proved to be so small, that the quantity dissolved was inappreciable. He had also looked for a slight corrosion of the bell-metal safety valves, by the action of the liberated carbonate of ammonia, but there again the result was negative. It must be remembered, that this salt was formed in very small proportion, that it was diluted with a large quantity of vapour, and passed rapidly over the surface of the metal: in addition to that, it was not caustic ammonia which escaped, a substance which was known to have a great affinity for copper, but carbonate of ammonia with excess of acid, which was comparatively inert in its action upon metals, even under the most favourable circumstances.

It should be borne in mind, that the objections raised were purely hypothetical, and their correctness, or incorrectness, could be easily determined by experiment, which he would suggest to engineers, as the easiest method of setting at rest any doubts arising in their minds from the observations which had been made.

Mr. STEPHENSON was of opinion, that the whole question hinged on the action of the carbonate of ammonia upon the copper or brass, and whether the quantity evolved was sufficient to be practically injurious. He was impressed with the idea, that the action of the neutral salt upon the metal must be active, and the question was, whether this chemical action amounted to a serious objection to the proposed process. It had been recently tried in the locomotives on the Norfolk Railway, and in a very short time all the incrustation fell off. Now, he would argue from that fact, that a chemical action did take place, and he thought it must end by attacking the metal. That, however, could be only satisfactorily tested by experiment, and there appeared to be so much merit in the process, that it ought to be carefully tried, and if found to be successful, it would be of the greatest importance to every one having a steam engine.

Mr. SMEE stated, in reply to Mr. Johnson, that he must contend for the presence of oxygen in the boiler, inasmuch as the water was composed of oxygen and hydrogen, and, therefore, the experiment he had brought forward did apply to the question before the meeting. He also would assert, that a voltaic circuit was formed by the two metals, iron and brass, composing the boiler and, though with pure water, the action would doubtless be very weak, yet, with a saline compound, it would be active.

He was of opinion, also, that the partial heating of the plates of a boiler might be another powerful source of action, and that what he would term thermo-voltaic circuits would be formed by the more or less heating of the metal. The hottest parts being in a positive state, and the colder parts in a negative state. The addition of a neutral salt must materially add to this voltaic action.

He agreed with Mr. Stephenson, that the fact of the incrustation being thrown off by the muriate of ammonia, did indicate a chemical action upon the metal.

Mr. HAWKSHAW was at a loss to conceive how there could be any chemical action upon the metal, when it was entirely covered with the hard incrustation of carbonate of lime, which was insoluble in water; but he could readily account for the fact of the removal of the incrustation, from Dr. Ritterbandt's description of the process of disintegration, which took place on the application of the muriate of ammonia, to the carbonate of lime. He was of opinion, that this sufficiently accounted for the falling off of the incrustation, and that the chemical action did not extend to the metal.

Dr. RITTERBANDT contended, that the falling off of the incrustation from the tubes of the boilers, did not at all indicate a chemical action upon the metal. It would be found, on boiling a quantity of hard incrustation in a solution of muriate of ammonia, that it would become soft and disintegrated; the muriate attacking the cementing carbonate, and thus destroying the coherence. The action of the muriate upon the carbonate in solution, was to prevent its forming an indurated crust, and if that crust had been formed previously, to soften or disintegrate it. This he had satisfactorily proved, by numerous experiments on a large scale, for more than twelve months past.

With respect to the presence of oxygen in the boiler, he could only admit the presence, in a free state, of one gas (hydrogen), and that only under circumstances of most rare occurrence. He alluded to the case, in which, from a thick incrustation having formed, the plates of the boiler had become red hot, and the water subsequently coming in contact with the heated metal, a decomposition of the fluid took place, the oxygen uniting with the metal to form oxide of iron, and hydrogen being evolved; but he did not see how this could, under the position put by Mr. Smee, be made applicable to the subject; for in that case free oxygen was required, whereas the decomposition of the water from the heating of the boiler to redness, only supplied hydrogen.

He must repeat, that with the most delicate tests, after the application of the muriate of ammonia to the same water for long periods, he had never been able to detect any traces of metallic decomposition.

Mr. J. V. GOOCH stated, that although theoretically the chemical action might be granted for the sake of argument, yet amongst engineers this must be considered practically, and he again contended that with so dilute a saline mixture, no deleterious action upon the metals did take place; that even upon polished copper, no apparent action occurred, and that on submitting specimens of the water to several chemists, who had used the most delicate tests, no traces of either iron or copper had been found. He was convinced, that the action was entirely upon the carbonate of lime, preventing its induration and adhesion to the metal; or in the case of its use in an old boiler already incrusted, the solution acted upon the cementing matter, and found its way beneath the incrustation, enabling the muriate to destroy its adhesion to the metal, and thus detaching the incrustation. As a further proof he stated, that the owner of a high pressure boiler which was worked with salt water, entertaining a similar opinion of the deleterious action of the muriate upon the metal, instead of adding 1 lb. of muriate of ammonia to the contents of his boiler, threw in 14 lbs. of that salt, and worked it for four days without blowing out. At the expiration of that period the water, on being carefully tested, gave no traces of metallic oxide, although the whole of the previous incrustation was separated. This only confirmed Mr. Gooch's own experience after using the system for nine months, with the most perfect success.

Dr. Ritterbandt then briefly explained his views of some of the inconveniences arising from incrustation in boilers.

1st. Incrustation was, in his opinion, the cause of the majority of steam boiler explosions.

This was also the opinion of many eminent practical engineers, and was confirmed by reasoning and experience.

In the first place, it was found by examining extensive explosions, that they were all, or with very few exceptions, the result of some sudden increase of pressure. If this were not the case, it would be found, that even when the safety-valve had been fixed, some other part of the boiler would yield, if the pressure were gradually increased, and the explosion would be partial, and not entire. But in the extensive explosions alluded to, every part seemed to have yielded at the same time. The strongest parts of the boiler were rent asunder equally with the weaker. Now this sudden increase of pressure, could only arise from an equally sudden formation of steam, or, as had been suggested, by the generation and explosion of gas. The latter he believed to be a fallacious hypothesis; but, admitting it to exist, it would not lessen the force of the argument which attributed to incrustation, the cause of the majority of boiler explosions; for the only gas which could be generated from water, in contact with iron, was hydrogen, and this production of the gas could alone take place, when the water was brought in contact with the iron, while the latter was at a bright red heat. Now, under what circumstances could the sudden evolution of steam, or production of gas take place? It was necessary to assume, that the following conditions existed:—

First, That a considerable portion of the boiler was strongly heated, without the contact of water.

Second, That the water was suddenly brought in contact with the heated surface.

If it were supposed, that the boiler was incrusted to the extent of half an inch, which was of common occurrence in many districts, it would at once be seen, that nothing was more easy, than to heat the boiler strongly, even to a red heat, without the immediate contact of water. For in all cases the incrustation was so firmly attached to the boiler, that no water could pass between the surfaces, and being an imperfect conductor of heat, the high temperature required by the gas hypothesis, was not difficult of attainment. But, under what other circumstances could the boiler be thus heated? An inferior conductor must be present, to prevent the contact of water, and of what other materials could this new conductor be formed, but of this incrustation?

The effect of this great increase of temperature on the iron, coated with incrustation, was to expand it, while the incrustation itself being imperfectly heated, and of less expansible material, retained its original dimensions or nearly so. Separation took place frequently with a slight report, and the second assumed condition at once was brought into existence; for the metal being no longer protected by the imperfectly conducting shield, came in contact with the water, and an explosion was the result. This separation of the incrustation by the application of heat, was not assumed: it was a plan constantly used by the boiler cleaners, and was nearly the only mode of effectually separating the scale.

These views of the cause of explosions received considerable confirmation from a fact, which had been constantly observed, and commented on, viz., that by far the greater number of explosions occurred after the boiler has been some time at rest; which was precisely the case, in which the lime and other earthy substances, having been allowed to deposit, were under the most favourable circumstances to crystallize or incrust, and in which the boiler being at a low temperature, and requiring the greatest amount of heat to be applied, in order to raise the steam, was most liable to be injuriously heated.

It had been objected, that it was nearly impossible to heat the bottom of a boiler to a red heat, even when protected by an imperfectly conducting crust. If it were necessary to establish that point, in order to defend these views, evidence, as to the actual heating of boilers to redness, would not be wanting; but, except for the gas hypothesis, which was, he contended, untenable on other grounds, no such supposition was required. In order to account for the most sudden generation of steam, the metal should be heated to the point of maximum evaporation, and this was far below a red heat, as had been shown by M. Boutigny.

2nd. Incrustation was incompatible with the economical use of fuel.

Fuel might be stated to be burnt most economically, when the temperature of the air leaving the boiler-flues, and entering the shaft, was reduced to a point nearly equal to the temperature of the water in the boiler. In a boiler coated with a bad conductor of heat, it was absolutely necessary, that the surface in contact with the flame and heated air, should be many degrees higher than that of the water contained in the boiler; the temperature of the air entering the shaft, would be that of the surfaces, and in proportion to the greater height of this temperature, so would be the loss of fuel.

Another source of loss of fuel from incrustation, always occurred in sea-going steamers. It was well known, that to prevent the boilers of such vessels becoming filled with incrustation, it was necessary, that the brine should be blown out frequently, or pumped out continuously. This was highly important, as the incrustation from sea water was, from its light, porous texture, a most imperfect conductor of heat. Much heat was lost in both plans, notwithstanding the admirable arrangement attached to the brine pumps, and incrustation was not entirely prevented, even by the adoption of these means.

3rd. Incrustation rapidly destroyed the boiler, the extra heat necessary to raise water to a given point greatly increasing oxidation or scaling.

This proposition required no argument; it was self-evident.

4th. Incrustation was a source of serious expense, by rendering labour necessary to remove it, and by the destruction of the boiler, in this mechanical removal of the fur.

Taking the Transatlantic, Oriental, or other long sea-going steam vessels, as instances, even after the use of the brine-pumps, or blowing out, a very large amount of incrustation was formed during each voyage, and an expense varying from £20 to £30 was incurred, to remove it; while the means employed for effecting the object were such, that no one could for a moment doubt the effect produced.

The usual plan was, for the workmen to remove the incrustation with large picks, or hammers and chisels; or by heating the flues with shavings, or other inflammable matter, which by expanding the plates, separated the scale in large flakes. The injury to the boiler from such operations need not be insisted upon.

These were a few of the most evident disadvantages arising from incrustation, and others must naturally suggest themselves to all practical men.

Mr. Farey had frequently seen muriatic acid used for throwing off the scale from boilers, and he believed the practice was first introduced by Gurney, for cleansing the small compartments of the tubular boilers, used for his steam carriages. At that time, the action was attributed to the disintegration of the carbonate of lime by the muriatic acid, and it was not found that there was any injurious effect upon the boiler.

The ordinary method of preventing incrustation, by the introduction of potatoes and other substances into the boilers, merely acted mechanically, and had the effect of preventing the carbonate of lime from aggregating into a solid mass. The French government had caused many experiments to be made on the subject, and at one time they introduced a quantity of clay into the boilers, that by mingling mechanically with the insoluble salts, it might prevent their coherence, and render their removal more easy.

Mr. Gordon said, he had used muriatic acid for cleansing boilers in small compartments: it accomplished the object effectually; but he believed the metal was also acted upon prejudicially. He thought, that the chemical action of the muriate of ammonia was confounded with mechanical action, in throwing off the incrustation. It appeared probable, that the chemical action induced an expansion of the incrustation, causing it to leave the metal; and that when broken up and precipitated, the chemical action proceeded more rapidly, and the substance was disintegrated.

Mr. R. Stephenson said, there could be no doubt, that if an excess of muriatic acid was used, there would be some action upon the metal of the boiler; but even in that case, not until all the lime had been neutralized. In order to test practically the comparative efficiency of the systems, he had given orders for half the engines, on the Norfolk Railway, to be worked with muriatic acid, added to the water in the tenders, and the other half with muriate of ammonia. He would lay the results of the trials before the Institution.

Mr. C. May said, it was important to bear in mind, that free muriatic acid was a volatile acid, and that, in using it, even at a moderately low temperature, there was every probability of its distilling over, and thus practically causing the boiler to prime; this could not occur with muriate of ammonia, even allowing that carbonate of ammonia was formed; but the quantity was so small, and it was enveloped in such volumes of steam, that its action upon the metal must be feeble, and practically it might be entirely disregarded.

In almost all waters, besides the deposit of carbonate of lime, there was generally found a considerable amount of other earthy matter, which was very prejudicial. He suggested the more general adoption, for stationary boilers, of the trays suspended in the water. He had found these trays of 4 inches in depth, not only filled, but heaped up with matter, which would otherwise have been distributed over the bottom of the boiler, and would have diminished the conducting powers of the metal.

Mr. Lowe regretted that Dr. Clarke's system of adding lime to take out lime, beautiful and simple as it was, was so little practised. The plan proposed by Dr. Ritterbandt was very ingenious, and must, he thought, be effective; and as the manufacture of ammoniacal salts was daily increasing, on account of gas companies adopting such means as were recommended by Mr. Croll,* and others, it would be inexpensive.

The action of muriate of ammonia would, he conceived, be very superior to the plan proposed by Mr. Stephenson; the free muriatic acid, he was afraid, could not be restricted to attacking merely the calcareous matter, but would act upon the metallic tubes.

The double play of affinities, brought into action by Dr. Ritterbandt's plan, would effectually prevent the carbonate of lime from forming an incrustation, by its being converted into muriate of lime, which was one of the most soluble salts. Whether the muriate of ammonia would dislodge also the sulphate of lime, which many waters contained, especially those from the red marl of the midland counties, was more problematical; but Mr. Lowe thought, that, under the circumstances of the high pressure, and temperature of locomotive boilers, it would, to some extent, be also found effective.

Brewers, in certain localities, had long been in the habit of adding a quantity of pearlash to the water in the cistern, in order to precipitate the lime, which was prejudicial to the process of brewing.

Mr. Gordon recalled to Mr. Thorold's recollection a communication made by him to the Institution, in the year 1830, in which the effects of deposit were somewhat remarkably shown.

Mr. Thorold replied, that the two boilers mentioned in the communication alluded to† were of very different forms. The first was of an arched section, with a semicircular top, and a deep concave bottom; this form left a space or pocket on each side, which was speedily filled with deposit, and the plates were burned through in three weeks. The other was of a cylindrical section, with hemispherical ends, and though it was worked nearly without interruption, night and day, for upwards of nine years, at the expiration of that time, the plates were but little injured.

* Vide Minutes of Proceedings, 1844. Vol. iii, p. 390.

† Original communication, M.S. No. 72. "On supplying high pressure steam boilers with water, and on their duration," by William Thorold, M. Inst. C. E., June 6, 1830.

He had under his charge several boilers which were known among engineers, by the name of "Hall's" boilers. They were of a cylindrical form, with two tubes extending beneath and connected with the bottom of the boiler. The ebullition and circulation in these boilers was so rapid, that he had rarely seen any deposit or incrustation in them, and by the simple precaution of blowing out at given periods, he thought they could be kept very clean with any kind of water.

February 24, 1846.

SIR JOHN RENNIE, President, in the Chair.

No. 723. "Description of the Dinting Vale Viaduct, on the line of the Sheffield and Manchester Railway." By Alfred Stanistreet Jee, M. Inst. C. E.

This viaduct consists of sixteen arches, five of which are of timber and eleven of brick, faced with stone quoins. The whole of the large piers, wings, outside spandrils and parapets, are of ashlar stone, of excellent quality, from the quarries in the neighbourhood.

The foundations of some of the piers are laid upon the hard shale, and of others upon a bed of wet sand of considerable depth; in the latter cases masses of concrete were formed to receive the masonry.

Several of the smaller piers are founded upon the marl; also with beds of concrete beneath them.

The piers for the large arches are built solid, up to the surface of the ground, and above that level they are hollow, nearly up to the impost; the hollow portion having an inverted arch at the bottom, and being also arched over at the top. The portion above the impost in the large piers is solid to the top.

The smaller piers are cased with ashlar on the outside, and are filled in solid with good flat-bedded rubble, well grouted, and with through stones at intervals of 6 feet horizontally in each course.

The smaller semicircular arches of brick, at each end of the viaduct, are 50 feet in the span and 3 feet in thickness, with stone quoins, and are built in a curve of 40 chains radius.

The face of each pier is parallel to that of the next, the piers themselves being wedge-shaped, on account of the curve.

The abutments between the large and the small arches are hollow, and are arched over in the interior, to carry the roadway.