materials usually used in building, and the roofs already erected, appear to have tested its durability. This roof has stood perfectly firm, and is not in the slightest degree altered in form, although of a large span.

Many corrugated roofs have been erected. There is one of 40 feet span and 225 feet in length in the entrance basin at the London Docks; one in the St. Katherine's Docks, and others on the Birmingham, Great Western, and Blackwall railways; they are, it is understood, generally approved.

Mr. Palmer has lately taken out a patent for corrugated cast-iron, which is now being used for erecting a bridge near Swansea in South Wales. It consists of three arches; two of them of 48 feet span, and one of 50 feet span. This corrugation requires no riveting, as the joint is cast on the plate, and the construction of the bridge is stated to be much simplified by the use of iron in that form.

The paper is illustrated by seven elaborate drawings (Nos. 3632 to 3638), showing the general plans, and giving the details of every part of the construction.

June 11, 1844.

The PRESIDENT in the Chair.

No. 687. "On the purification of Coal Gas, and the application of the products, thereby obtained, to Agricultural and other purposes."

By Archibald Angus Croll, Assoc. Inst. C.E.

Purifica-
tion of Coal
Gas.

The production of coal gas is now become of such importance, from the amount of capital employed in it, and the high degree of public utility resulting from the introduction of gas light, that the author conceives it to be his duty to lay before the Institution, an account of his improvements in the process of purifying and preparing gas for combustion.

In London alone, the annual rental paid to the different Gas Companies, for the supply of coal gas, amounts to about £600,000, and 250,000 tons of coal are annually consumed in its manufacture. As nearly every town of two or three thousand inhabitants, is now lighted with gas, vast as is the consumption of London, it forms but a small portion of the quantity of coal gas produced in the United Kingdom. The use of gas seems, however, to be capable of much greater extension than it has yet attained, for though almost universally adopted in the lighting of streets, workshops, ware-

houses, and places of business, it has been only partially introduced into domestic use. The causes of this limitation in the use of gas, are sufficiently obvious; they consist mainly in the unpleasant odours and unhealthy effluvia, supposed to be exhaled in its combustion; nor have the objections made, on that account, been without foundation; for it is well known to chemists, that notwithstanding all that modern science and invention have hitherto done, to purify gas, a considerable portion of ammonia, and its compounds, the origin of the offensive and injurious vapour complained of, still exist in combination with the gas, and compounds of a deleterious character are given off during combustion.

The author's attention has long been directed towards the manufacture and purifying of gas, and in the progress of numerous experiments, which were continued through several years, he has been fortunate in the discovery of a very simple process, of entirely freeing coal gas from ammonia, and its various combinations.

The gas used for illumination, is carburetted hydrogen, and the object of all gas manufacturers, is to obtain that gas, in the greatest possible state of purity, and at the least comparative expense. The method of making coal gas is this: coal being placed in retorts, and subjected to a high degree of heat, the carburetted hydrogen gas is generated, from whence it passes, by well-known contrivances, into the condensing apparatus; but the carburetted hydrogen thus generated, contains several gaseous impurities, the most prominent of which are,—1°, sulphuretted hydrogen; 2°, hydro-sulphuret of ammonia; 3°, cyanuret of ammonia; 4°, carbonic acid, &c.; all these impurities have, to a great extent, been got rid of in all well-conducted gas works. The sulphuretted hydrogen and the carbonic acid, are most effectively removed, by means of dry lime; but to its use (until the application of this process), insuperable objections existed, and it has therefore been usually abstracted from carburetted hydrogen, by wet lime purifiers. A large portion of the hydro-sulphuret of ammonia, the cyanuret of ammonia, and the carbonic acid, have been thus expelled, with much trouble and inconvenience. Still a very great quantity of ammonia remains, unaffected by all the processes used for purification, and passes, as before observed, into consumption with the gas itself.

The carburetted hydrogen, thus generated, passes, with all the impurities mentioned, into the condensers, where the hydro-sulphuret of ammonia is to some extent removed, by a reduction of the temperature of the gas, and in this way the ordinary ammoniacal liquor of the gas-works is obtained. That liquor is generally sold to manufacturing chemists, and from it, after saturation with either sulphuric

or muriatic acid, the ordinary ammoniacal salts are produced. From each gallon of this liquor about 14 ounces of sulphate of ammonia are produced.

The author's new process of purification is generally employed, immediately after the gas passes out of the condensers ; or it may be applied, when the gas has undergone the usual wet or dry lime purification.

The gas is conducted into a circular vessel (Figs. 1 and 2), constructed like those in use for the purpose of washing gas, and lined

Fig. 1.

Vertical section.

Fig. 2.

Horizontal section.

with lead, that metal not being acted upon by sulphuric acid; it is divided at the bottom into a number of sections (Fig. 2,) 8 inches or 10 inches in height, which support a lead plate, covering the whole surface of the vessel, except about 5 inches round the edge. The vessel is charged, up to the height of the plate, with water, to which oil of vitrol, at the rate of about $2\frac{1}{2}$ lbs., or thereabouts, of acid, to 100 gallons of water, has been added; the gas is then passed under the leaden plate, where the divisions, by which it is supported, completely separate the gas, and bring each portion of it into contact with the acid solution. The ammonia contained in the gas, combines chemically with the sulphuric acid, and forms sulphate of ammonia. But the acid being thus constantly in process of neutralization, the solution would soon lose its power of separating the ammonia from the gas, but for a small reservoir of sulphuric acid, which being carried into the vessel by means of a pipe furnished with a stop cock, insures a regular supply of acid. The gas thus freed from ammonia, is carried to the dry lime purifiers, which with this process can always be used. In large works, two vessels of this kind are preferable for passing the gas twice over the weak solution of sulphuric acid, which secures a more absolute certainty of the extraction of all the ammonia, should there have been any accidental or temporary deficiency of acid in one of the vessels.

Two vessels of 10 feet diameter and 3 feet deep will purify 500,000 feet of gas every 24 hours, and making that quantity, will require to be charged with the acid solution about every two days.

In order to prevent too great a strength of free acid in the vessel, which would precipitate the carbon of the gas, and diminish its illuminating power, the liquor may be tested with the common ammoniacal liquor of the gas-works.

When the solution in the vessel has become of the specific gravity of 1170, or thereabouts, as ascertained by the hydrometer, the supply of acid is to be shut off, and the gas is passed through the vessel, until that solution will restore the colour to reddened litmus paper.

The liquor thus obtained is evaporated, and produces sulphate of ammonia of remarkable purity, and of such strength, that one gallon produces 80 ounces of sulphate of ammonia, instead of the 14 ounces only, which are produced from the ordinary ammoniacal liquor of the gas-works. And this last-mentioned liquor, must first undergo the process of saturation with sulphuric acid before evaporation.

The same degree of purification of gas from ammonia, may be obtained, by means of chloride and sulphate of manganese, or chloride and sulphate of zinc, which salts are afterwards reproduced, to be used again and again in the same process.

In the ordinary mode of purification, the gas was conveyed directly from the condensers, to the wet lime purifiers; a considerable pressure on the retorts, was requisite to force the gas through the fluid lime, and thus a loss of gas ensued, with a larger incrustation of carbon in the retorts, and extra labour was necessary for agitating the liquid lime and for conveying the refuse liquor to be evaporated. This being effected in pans, placed under the retort furnaces, the sulphur given off tended to destroy very rapidly the iron retorts, which were exposed to the action of the flame. The wet lime purified the gas from the sulphuretted hydrogen, a great portion of the hydro-sulphuret of ammonia, the sulpho-cyanuret of ammonia, and the carbonic acid; but it still allowed a considerable quantity of ammonia and its compounds, to pass into consumption with the gas.

The dry lime purifiers used without this process, presented some advantages to the gas companies, over the plan of purifying with wet lime; but it was only in open places in the country that the dry lime could be used, without the works becoming a public nuisance. The objection to dry lime purifiers arose from this cause: the hydro-sulphuret of ammonia, which is generated with carburetted hydrogen gas, is highly volatile, and that portion which is extracted by the lime, having no chemical affinity for lime, but being merely held in mechanical combination, had a strong tendency to fly off.

The hydro-sulphuret of lime, is formed in the dry lime purifier, from the sulphuretted hydrogen of the gas; on the opening of the vessel, it rapidly combines with the oxygen of the atmosphere, and becomes converted into sulphate of lime. During that conversion, heat is rapidly evolved, which renders the hydro-sulphuret of ammonia, extracted from the gas by the lime purification, more volatile than ever, and the most offensive stench is the consequence. Besides, so noxious is this gas, that a comparatively small portion of it, in a given volume of atmospheric air, would render it destructive to animal life.

These obstacles would warrant the almost universal abandonment of dry lime purifiers; now, however, in connexion with this process of purifying gas from ammonia, the dry lime purifier will, it is anticipated, become the only system used for the abstraction of the sulphuretted hydrogen. The gas purified from all ammonia, by passing over the solution of sulphuric acid, has only to be freed by the dry lime purifier, from the sulphuretted hydrogen, the sulpho-cyanuret, and the carbonic acid, which form in chemical combination with the lime, the hydro-sulphuret of lime, cyanuret of lime, and carbonate of lime, neither of which are volatile, but are highly valuable for agricultural purposes.

In those instances, in which the localities have permitted gas companies to continue the use of dry lime purifiers, the value of the products as manure, has been so well understood, that the refuse lime has been bought up as fast as it was produced; and an impression having prevailed, that this refuse lime owed its value to the presence of ammonia, some of the contractors of such gas-works have expressed an apprehension that the adoption of this process, by previously abstracting the ammonia, would destroy the valuable properties of this lime.

It is evident, that this is entirely a misapprehension. The chemical causes before detailed will have shown, that the hydro-sulphuret of ammonia, which had been extracted from the gas, in the dry lime purifiers, having been volatilized and lost, long before the refuse lime (then become sulphate of lime), could have been taken from the works; the value of the lime really consisted in the fertilizing power of the sulphate of lime and of the cyanuret of lime. This power will still exist in the same products, concurrently with the use of this process, while the noxious exhalations, which formerly occurred on the opening of dry lime purifiers, will be absent.

In manual labour alone, the Chartered Gas Company have effected a saving, at their Brick-lane station, of between £400 and £500 a-year, by the use of dry lime instead of wet lime purifiers.

Against these many advantages, however, it is proper to mention, that there will be a slightly increased quantity of lime required, in purifying with dry instead of wet lime; for a bushel of lime in the wet process purified from 18,000 to 20,000 feet of gas, while in the dry lime process the same quantity will only purify 14,000 feet; but this trifling drawback on the dry lime process, does not render the comparative merits of the two processes in any degree doubtful.

Various plans have been tried, at different times, to separate the ammonia from the coal gas by means of acids, but either from their expense, or their complication and practical difficulty, or from their effect in diminishing the illuminating power of the gas, all of them have been successively given up as useless. But by this process, all those difficulties are avoided, whilst numerous positive benefits have resulted. The process has been adopted by the Chartered Gas Company, the Imperial, and Phoenix Gas Companies in London, and by several gas companies in the country; and several of the other metropolitan companies have the subject of its adoption under their consideration.

In addition to the advantages arising from the use of the dry lime in place of the wet lime purifiers, which this process renders everywhere possible, the saving which will accrue upon the meters and

fittings of the Chartered Gas Company, by the abstraction of the ammonia from the gas, will amount to a considerable sum annually.

At the Brick-lane station the number of meters requiring repair, has already been reduced by one-half, and those annually condemned have been two-thirds less, since this process has been adopted, although an increase of meters has taken place. The public lamp fittings requiring repair, since its adoption, have also been two-thirds less in number than previously. A large saving in wear and tear has thus been effected by the plan. In addition to the above, the illuminating power of the gas has been increased upwards of 5 per cent., by its freedom from ammonia, and it may now be consumed in the drawing-room or bed-chamber, with as little inconvenience or effluvia as a wax candle.

In addition to the advantages already enumerated, this process comprises another, fully equal if not superior to all the rest. This consists in fixing and neutralizing the ammonia in combination with sulphuric acid, and making it available, in the form of the valuable product of sulphate of ammonia.

Already many tons are produced weekly from the works which have adopted this process, and the purity of the product has been sufficiently attested. It is unnecessary to enumerate the various manufactures and arts, in which sulphate of ammonia is useful or necessary; but the author draws attention to its value for agricultural purposes, a subject upon which many men of science, education, and capital, have for several years past bestowed so much attention.

Next to the mechanical operations upon land, such as complete drainage and the more perfect disintegration of the soil, which are conditions necessary for improved culture and a high degree of fertility, there is nothing so important to successful farming, as the selection and right application of manures. This, chemistry alone can teach; and accordingly we find that chemistry is now universally studied with reference to agriculture, by all agricultural improvers, and the knowledge which a Liebig, a Johnston, or a Henslow have attained and tested by experiment, is being diffused throughout our rural districts.

The object of the skilful husbandman is not merely to produce quantity, but he must have quality also; he must be certain that he is growing the peculiar productions he desires, in their most complete state, and at the least comparative expense. It is known, that plants cannot attain maturity, in the richest vegetable mould, without the presence of nitrogen. Liebig says—"Every part of the organism of a plant contains nitrogen, the roots and seeds being particularly rich in that element; and as there cannot be a doubt but a soil must gra-

dually lose those of its elements which are removed by the plants raised upon it, but which, if the land is to be kept in a permanent state of fertility, must be supplied in the form of manures possessing the elements which have been so abstracted."

This fully and scientifically explains, that which has long been matter of daily observation, namely, that the so frequent repetition of grain crops, speedily exhausts most land. The nitrogen taken away in the form of corn has become deficient, and must be supplied by the extraneous aid of manure, or less perfectly, through the slow operation of the atmosphere.

The first inquiry for the farmer, therefore, is that asked by Liebig, "How and in what form does nature furnish nitrogen to vegetable albumen, and gluten to fruits and seeds?" The question is susceptible of a very simple solution.

"Plants,* as we know, grow perfectly well in pure charcoal, if supplied at the same time with rain-water. Rain-water can contain nitrogen only in two forms, either as dissolved atmospheric air, or as ammonia, which consists of this element and hydrogen. Now the nitrogen of the air cannot be made to enter into combination with any element except oxygen, even by the employment of the most powerful chemical means. We have not the slightest reason for believing, that the nitrogen of the atmosphere takes part in the processes of assimilation of plants and animals; on the contrary, we know that many plants emit the nitrogen which is absorbed by their roots, either in the gaseous form, or in solution in water. But there are, on the other hand, numerous facts, showing that the formation in plants of substances containing nitrogen, such as gluten, takes place in proportion to the quantity of this element which is conveyed to their roots in the state of ammonia, derived from the putrefaction of animal matter."

"Ammonia too, is capable of undergoing such a multitude of transformations, when in contact with other bodies, that in this respect it is not inferior to water, which possesses the same property in an eminent degree. It possesses properties which we do not find in any other compound of nitrogen: when pure, it is extremely soluble in water; it forms soluble compounds with all the acids; and when in contact with certain other substances, it completely resigns its character as an alkali, and is capable of assuming the most various and opposite forms. Formate of ammonia changes, under the influence

* Vide "Chemistry, in its application to Agriculture and Physiology." By Justus Liebig, edited by Lyon Playfair. 8vo., London, 1842. Taylor and Walton.

of a high temperature, into hydrocyanic acid and water, without the separation of any of its elements. Ammonia forms urea with cyanic acid."

The same eminent chemist, subsequently shows, most conclusively, that the ammonia, from which alone vegetables derive their nitrogen, is supplied by means of rain-water from the atmosphere, or by the use of manures containing that gaseous fertilizer. That ammonia, which, from its volatile character, is constantly escaping into the atmosphere, from its great solubility in water, quickly descends with the rain to reproduce abundant vegetation; and that all manures owe their degrees of fertilizing power, in a great measure, to the amount of ammonia they contain.

But when we remember to what an extent the loss of nitrogen takes place; that the liquid and solid excrements of each individual, amounting, on an average, to 1½ lb. daily, and containing 3 per cent. of nitrogen, or about 16 lbs. per annum, are almost entirely lost; and that each man carries to the grave with him nearly 3 lbs. of nitrogen, it will be obvious that the soil from whence man's food is drawn, cannot be supplied with sufficient nitrogen from the atmosphere alone. Hence in practice we see, that each farm is always in the course of improvement or deterioration; there is no neutral condition for the farmer, he must go on or fall back. The good farmer purchases artificial manures, maintains large flocks and herds, often fed on corn, oil-cake, and other food rich in nitrogen; constructs tanks, for the reception and preservation of liquid manure, which contains far more ammonia than the solid excrements of animals; and under such treatment he finds his fields year by year increasing in fertility, and himself growing in wealth; while the bad farmer sows, reaps, and sells, with grasping eagerness, all the grain he can obtain, without cattle, without sheep, or with such as he may have in a half-fed state; he tries no foreign manure, he uses no artificial food, and after a few years of struggle with what he designates "bad times," he finds that his land will scarcely return seed for seed, and he is a ruined man.

The agricultural chemist would describe this contrast, which involves much of human happiness and misery, by the simple statement that the one man is constantly adding ammonia to his land, and the other is as constantly abstracting it.

Such and similar considerations, which will naturally occur to the reflecting mind, show the important influence of a process in the advancement of husbandry, which can furnish a vast supply of ammonia in a form and at a cost which brings it within the reach of the humblest agriculturist, from a source previously unfruitful. It forms

literally a new mine of wealth, drawn from the exhaustless coal formation of the earth's former vegetable productions.

A chemical analysis of the sulphate of ammonia, produced by the evaporation of the saturate-sulphate liquor, before described, as drawn off from the purifying vessels, shows it to be of great purity, as it affords in 100 parts, nearly 30 parts of ammonia, after deducting water and sulphuric acid, equivalent to about 24 parts of nitrogen. This shows a fertilizing power two or threefold greater than any other manure.

Actual experiments have corroborated the conclusions of the analytical chemist, and some of the most accurate of these are recorded by Mr. W. M. F. Chatterley, at the Manor Farm, Havering-atte-Bower, in Essex, occupied by Collinson Hall, Esq. These were made in 1842, a season which, like the present, (1844,) was, from its dryness, by no means favourable to top dressings.

A field of wheat, which at the latter end of April, had presented a very thin plant, was dressed on the 12th May, with sulphate of ammonia, nitrate of soda, and nitrate of potash. In August, four equal portions of the field were measured.

No. 1, which had received no manure, produced per acre $23\frac{1}{2}$ bushels of wheat, weighing 1413 lbs. = $59\frac{1}{2}$ lbs. per bushel; and $63\frac{1}{2}$ trusses of straw, weighing 2287 lbs.

No. 2, had been dressed with $1\frac{1}{4}$ cwt. of sulphate of ammonia, at a cost of £1. 1s. 9d. per acre. The produce of the acre was $32\frac{1}{2}$ bushels of wheat, weighing 1999 lbs. = $61\frac{1}{2}$ lbs. per bushel, and $71\frac{1}{2}$ trusses of straw, weighing 2571 lbs.; showing an increase of 9 bushels of wheat and in money profit of £1. 16s. 9d. per acre.

No. 3, had been dressed with 1 cwt. of nitrate of soda, costing £1. 4s. 6d.; it produced $31\frac{1}{2}$ bushels of wheat per acre.

No. 4, had been dressed with 1 cwt. of nitrate of potash, costing £1. 7s. 6d.; the latter also produced $31\frac{1}{2}$ bushels to the acre.

The experiments show a considerable advantage from using the sulphate of ammonia, and mark still more distinctly, the benefits derived from supplying the wheat plant with the nitrogen it requires, in the form of ammonia. It will be remarked, that the weight of the wheat, the grand test of its quality, was increased by the use of sulphate of ammonia, and this alone would add at least 1d. or 2d. per bushel to the selling price. Other experiments might be detailed, but they have all shown very similar results. 200 lbs. of sulphate of ammonia applied in 1843 to poor grass land, by Mr. Bower, of West Dean House, produced an increase of 10 cwt. of hay per acre.

The result of all the experiments, however, seems to show, that 1 cwt. of sulphate of ammonia per acre, whether applied to grain or to grass crops, gives a maximum of profit for the outlay.

There is still another form in which ammonia may be used for supplying nitrogen to plants, which has been attended with so much success, that it must be mentioned. It is by steeping the seeds in a solution of sulphate of ammonia. An account of an actual experiment is given in the *Mark Lane Express*, of the 27th of May, 1843. The results there stated, accord very closely with experiments made under the author's own observation. The writer says—"I steeped the seeds in sulphate, nitrate, and muriate of ammonia, in nitrate of soda and potash, and in combinations of these, and in all cases the results were highly favourable. For example, seeds of wheat steeped in sulphate of ammonia on the 5th of July, had, by the 10th of August, tillered into nine, ten, and eleven stems, of nearly equal vigour; while seeds of the same sample, unprepared, but sown at the same time in the same soil, had not tillered into more than two, three, and four stems."*

These facts are decisive as to the value of the process, with reference to agriculture. It must be recollected also, that by the application of this process, one ton of sulphate of ammonia may be produced from every million cubic feet of coal gas generated, and that the quantity so obtained will dress 20 acres of wheat; producing thereby, a clear profit of £1. 15s. per acre, or £35.

The total yearly quantity of coal gas made in London, has been estimated at 2400,000,000 of cubic feet; whence some idea may be formed of the amount of sulphate of ammonia, which this process may render available for the purposes of agriculture.

It should be observed also, that this quantity is over and above that ammonia which was, and still is, obtained from the common ammoniacal liquors of the gas-works, and that the process which enables such agricultural benefits to be secured, effects at the same time, a considerable saving in the manufacture of gas by the companies which have adopted it, while the use of coal-gas for the purpose of illumination, from its being rendered more agreeable and healthy, will be greatly extended in all private families.

The paper is illustrated by two drawings (Nos. 3675 and 3676) by Alfred Upward, Assoc. Inst. C. E. The former represents the section and plan of two acid purifying vats, 10 feet in diameter, by 3 feet deep; with the leaden plate, the pipes for respectively supplying acid and water, and discharging the sulphate liquor, and the inlet

* The proportions of the solution used for steeping wheat are 1lb. of sulphate of ammonia to 1 gallon of water; and the seed should remain in the solution for 24 hours. If the sulphate of ammonia is used for the land when the crop is growing, the proportion is from 1 cwt. to 1½ cwt. per acre, according to the state of the crop.

and outlet pipes for the gas ; as well as showing the mode of dividing the bottoms of the vats into sections. The latter shows in detail the dimensions and construction of the dry lime purifiers used at the Brick-lane Gas Station.

Mr. Lowe confirmed the statements in the paper, relative to the Mr. Lowe. advantages of the new system. Formerly, when the dry lime purifiers were used at the Brick-lane Gas Station, the health of the men suffered, and the complaints by the neighbourhood, of the nuisance when the lime was changed, were so constant, that the system was abandoned ; at present, although ten times the quantity of gas was purified, there was not any nuisance, either in the works, or in the neighbourhood.*

It had been stated, that the system had been used in other places, and that the credit of the invention was not due to Mr. Croll. Although it was not the province of the Institution to enter into such an inquiry, he might perhaps be allowed to state, that a similar plan had been tried at Bristol, at the suggestion of Mr. Herapath ; the idea had originated in the same chemical facts, which had induced Mr. Croll's attention to the subject, but the *modus operandi* was essentially different. In Mr. Herapath's plan there was not any continuous supply of acid ; no valuable product was obtained ; it was troublesome and expensive, hence it was not successful, and the plan was abandoned. Mr. Croll had entered upon the subject, with perhaps more practical skill, which, joined to his chemical knowledge, had enabled him to attain the success which attended the present system.

The economy of the process, the diminution of the destructive effects of the purified gas upon the apparatus and the fittings, its increased illuminating power, and its greater fitness for combustion in dwelling-houses, with other advantages, had been fully and fairly stated in the paper.

The chemical products obtained from the process, deserved very

* In a report to the Directors of the Chartered Gas Company, dated November 19th, 1841, Professor Brande says,—“ I think it probable that much of that anomalous fetor and penetrating effluvia which infects the gas mains and the soil in which they lie, and which is generally, but, I think, erroneously, merely ascribed to tar and naphtha, is in great part attributable to ammonia and its compounds, and that this nuisance will be found greatly diminished, if not altogether prevented, by passing the gas through dilute acid liquors before it enters the main. Ammonia, and some of its compounds, exhibit penetrating and peculiar reactions upon certain metals, and are also probably concerned in some of those curious phenomena of exosmose and endosmose, which now constitute an important element of the philosophy of gaseous chemistry.”