portunity was found in a libel suit, instituted by Mr. Francis Todd, a domestic slave trader, whom Garrison had denunciated. He was found guilty, and, being unable to pay his fine, was sent to jail abandoned by his half-hearted adherents.

In the South exultation was open, and in the North he was considered a fanatic. But during his imprisonment, and because of it, he gained the friendship of John G. Whittier and other men who afterwards became noted abolitionists. On his release from prison the partnership between himself and Mr. Lundy was dissolved by mutual consent, and with the warmest admiration on both sides that strengthened into a lifelong friendship. After a course of lectures throughout northern cities, in all of which he was coldly received except by the free colored people and a few individuals, mostly quakers, he decided to begin the publication of a new paper, to be called "The Liberator," in Boston. This threatened the cotton traffic, and arrayed the commercial interests and consequently the press, and, in most instances, the pulpit against him.

That "The Liberator" was feared by the slaveholder is proved by the efforts made to suppress it. In Georgetown, D. C., it was made a penal offense to receive a copy of the seditious paper from the post office, and vigilance committees were formed in various localities to detect and prosecute people who distributed it. In the North public sentiment was apathetic, though the converts made were men who were capable of carrying on the crusade in case Garrison's voice were hushed.

In 1831 Mr. Garrison was instrumental in forming the New England Anti-slavery Society, composed of twelve members. After an unsuccessful attempt to establish a college for colored people in New Haven, Conn., Mr. Garrison, in the spring of 1833, went to England to secure the co-operation of English abolitionists, of which Wilberforce was the most distinguished member. When he returned he organized the National Anti-slavery Society, the movement having grown sufficiently strong to warrant such a proceeding. This society convened in Philadelphia in December, 1833, and had delegates from eleven different States. John G. Whittier, Garrison and the Rev. Samuel J. May were the most distinguished men present, or rather the ones who afterwards became so. A constitution drafted by Garrison was adopted by unamimous vote and signed by all the delegates, sixty-two in number. It was a document filled with strong conviction and high and definite purpose fully stated, and was one calculated to make all thoughtful people consider the subject without predjudice; yet such was the violence of opposition to the abolition movement that it was received with abuse and ridicule. But the next year, 1834, was made memorable by the freeing of 800,000 slaves in the British West Indies. The American press and pulpit predicted the direst results from this proceeding, but the joy of the abolitionists was unbounded when the great event was accomplished without bloodshed, and nearly a million blacks made the equals in rights with white men. Necessarily this occurrence brought new recruits to the ranks of the anti-slavery party, notably from among the students of Lane University, Cincinnati, of which Dr. Lyman Beecher was the head. But the eminent preacher, although practically converted to abolition, failed to sustain his pupils in their open espousal of such an unpopular cause.

The history of William Lloyd Garrison is the history of the struggle to free the slaves, and from the time he published "The Genius of Universal Emancipation" until the Emancipation Proclamation was signed, the events of his life followed the progress of public sentiment and were inextricably bound up in it.

With 1835 began the pro-slavery mobs. In the same year the Southern press grew aggressive and threatening. The lives of Abolitionists were in danger, and Garrison was attacked in Boston, and was confined in prison over night to save him from the violence of a "respectable mob." This event and the outrages that followed culminating in the Alton tragedy, made many powerful friends for the Abolitionists.

The division in the American Anti-slavery Society was occasioned by the appointment of a woman on the business committee. This was led by Mr. Lewis Tappan. Its effect was to cripple the society by having the forces divided. The press, too, took advantage of it to heap obloquy on the head of Mr. Garrison. The worst effect on Mr. Garrison personally was the alienation from him of men with whom he had worked for years in harmony, particularly Mr. Arthur Tappan, who had secured his release from prison in Baltimore. Another friend, Mr. Rogers, editor of the "Herald of Freedom," fell away from him about the same time for a personal difference; but these troubles and obstacles only drove him on more relentlessly, for abolition had clarified his soul for the one purpose for which he existed. He refused to affiliate with the Liberty party, a political body which grew out of the discussions that were current. His policy was non-resistance and aimed at converting the great body of existing parties on a moral ground. He fought strenuously against the Anti-slavery Society's using their growing strength for political preferment. For this also he alienated many who were at one with him on every other point. It seemed as if he were almost as much alone as in the beginning, and was destined to remain to the end the single voice lifted up against the individual sin of owning slaves, untrammeled by any other consideration. It was by the moral sentiment of the country that he hoped to eliminate slavery, and to this idea, he and the small band who clung to him remained faithful throughout the conflicting agitations which followed. They allied themselves to no political party, yet out of them grew first the Liberty party, then the Free Soil and lastly the Republican, which absorbed all these ideas into a triumphant culmination of the common cause. Garrison and those who remained with him in this moral agitation were always at the head and front—the color bearers of the movement, and the target for scorn and vituperation. But moral sentiment was growing rapidly.

In 1844 Garrison took a stride forward in attacking the Constitution of the United States for its authorizing the slave traffic. This created great consternation at the time, but the North was growing accustomed to bombardments of all sorts from Garrison, directed against the institution of slavery, and was being gradually prepared for the struggle of '61.

The secession of the Southern States and formation of the Confederacy changed his views on the subject of freedom by violence. He saw that the purpose of disunion was the perpetuity of slavery, and that only by war could such a calamity be averted. To him and his teachings is due the fact that the North realized this and that the moral sentiment was ready, in the emergency, to rise and meet the occasion.

With the agitations of the fifties, which culminated in the Civil War, Mr. Garrison had but little actively to do. His voice had ever been lifted against violence, and he preached at the individual sinner, awakening approval of the system at a time when the war with Mexico, the admission of California, the free-soil movement in Kansas and the operations of the Fugitive Slave law were stirring animosities to the point of bloodshed. The moral sentiment had been roused to resistance against the encroachments of slave territory. He saw the effects of "Uncle Tom's Cabin" and the Dred Scott Decision, and John Brown's Raid, the compromises to avert war and one year before the beginning of the struggle, saw Abraham Lincoln inaugurated by a party pledged to protect the owners of slaves in the rights of property. But he never deviated one iota from his precepts and practices. He was still hoping for the extermination of slavery by creating such a moral sentiment that it could not exist longer.

After the war began by the attack on Fort Sumter, he changed his views and saw that bloodshed had been forced by the South and urged the North to fight, though he himself never took up arms. He could not do so consistently, and forever deplored the necessity for our terrible internecine strife.

William Lloyd Garrison seemed to have been born for a public life. His work for the good of mankind overshadows his private character. But that he fulfilled his domestic duties with equal faithfulness is well known. In his early manhood he married Miss Helen Benson, daughter of George Benson, of Brooklyn, Connecticut. She was a noble woman and sacrificed ease and comfort to help her husband in a cause with which she thoroughly sympathized. He lived in Boston until 1864, and then removed to a more retired life in Roxbury, Massachusetts. After a stormy life he enjoyed the fruits of peace with his wife and children, surrounded by loving friends and solaced for all his hardships by the approval of a nation which delighted to honor him.

There were seven children in this household, five reaching maturity. The eldest was named George Thompson, in honor

of the great English emancipator, who was mobbed with Mr. Garrison while trying to lecture in Boston on the unpopular cause. The charge that Mr. Garrison was an infidel was never thought of in his early years, but was brought out as a last resort by the enemies of abolition, who sought to throw discredit upon his teachings. He never made any distinct statement of his religious views. He had one thing to do, which was so simple and direct, and so in accord with divine light, that he had no time for self-analysis or for troubling about splitting the hairs of creeds. He was condemned for doing what every minister in the North did during the war—pleading the cause of the slaves on the Sabbath day. In this he affiliated more nearly with the Quakers, with whom he was closely associated during many years of his life, than with other religionists. It is not to be denied that as a body the Quakers at this time were far in advance of the orthodox churches in the recognition of the sin of slavery, and most of Mr. Garrison's active followers were from this sect. It is not strange, then, that he came to be more and more closely allied to these people in belief and practice, though he always contended that it was not the word of God which was at fault, but the preachers' interpretation of it, and that any sanction of slavery came not from the Bible but from the Devil. He had to come at last to the opinion that the churches were falling away from their true position and he dared not betray his own mission for a perverted church. As he got farther from church organizations he claimed that he grew nearer to God. He felt in spite of all church opposition that truth and justice would eventually triumph. Still his pure and lofty purpose did not save him from the charge of infidelity and further persecutions on that account. But in spite of this, his teachings crept finally into the churches and influenced the utterings from the pulpits. He thus spurred up the lagging orthodoxy of the day and brought the Christian churches into unity with the purposes of God.

For his views on other questions Mr. Garrison believed in the freedom of speech and the press and in the fearless inquiry into all ethical and intellectual problems. He admitted that many men might be sincere and right in their beliefs though differing widely from each other. Necessarily many new ideas found welcome in his heart and brain which were formulated into a sort of eclectic creed of his own that embraced even some of the tenets of spiritualism. He was an "infidel" because he refused to be labelled or claimed by any denomination. Before his death an eminent preacher said of him: "It would be a serious charge against Christianity to say that it is so narrow as to exclude such men as Mr. Garrison."

After the close of the war Mr. Garrison was the recipient of the greatest honors which could be bestowed upon him, but perhaps the occasion of his visit to Charleston, where he met the freedmen for whom he had labored so long, was the crowning joy of his life. "The Liberator" which had existed since 1831 was discontinued in 1865, having served its purpose and having no further excuse for existence. He refused to belong to any anti-slavery society after the war, saying that slavery was ended, agitation was ended, and urged that the energies of sympathizers should be turned to the new question that had sprung up—education, enfranchisement and employment of the freedmen. In the last number of "The Liberator" he published the ratification of the Thirteenth Amendment forever prohibiting slavery.

Mr. Garrison was never an orator in the rhetorical sense of the term, but he was so much in earnest and his words were so accurately chosen because of his integrity of character that he always impressed his hearers as being an eloquent man. His writings have a same convincing quality. In person he inspired profoundest respect and admiration in those who met him, even if they differed radically from the views he held. They always thought: "Here is a man who is terribly in earnest, whose intellect compels attention." His benevolence was so large that all his life up to sixty years of age had been spent in unremunerative toil, so that at the close of the war for the Union, he was a poor man. The sum of $30,000 was raised and presented to him in 1868 as a testimonial of the valne of his services to the cause of abolition, thus making him secure of a modest competence in his old age. His heart was very tender for the helpless, especially for children and animals, and his respect for women profound.

After the close of the war Mr. Garrison lived a quiet life, going to England for his health in 1867, and to visit two of his children who were in Paris. The attentions of people of note were showered abundantly upon him. A breakfast was given in his honor in St. James' Hall in London, at which the most distinguished men in England were present.

The great emancipator died May 24, 1879, aged 74 years, at Roxbury, Massachusetts, surviving his wife three years and leaving four children living. He was buried in the cemetery at Forest Hills.

Of his writings a book of sonnets and other poems, some of which were written while in prison in Baltimore, appeared, and a volume of lectures and papers on Emancipation was issued in 1852. Several histories of his life have been written, one by a lifelong friend and co-laborer and another by his children.

AUTHORITIES.—*Wm. Lloyd Garrison*, Story of His Life Told by His Children; *Men of Our Day*, by L. P. Brockett; *Garrison and the Anti-Slavery Movement*, by Oliver Johnson.

GARTER, ORDER OF THE. See KNIGHTHOOD.

GARTH, SIR SAMUEL (1670?–1719), a physician and poet of the age of Anne, was born of a good Yorkshire family, in 1670, it is said, but more probably at an earlier date. He was a student of Peterhouse, Cambridge, where he resided until he was received into the College of Physicians in 1691. In 1696 he became a prominent supporter of the new scheme of providing dispensaries for the relief of the sick poor, as a protection against the greed of the apothecaries. This labor having exposed him to the animosity of many of his own profession, and especially of the last named body, he published in 1699 a mock heroic poem, *The Dispensary*, in six cantos, which had an instant success, passing through three editions within the year. Garth became the leading physician of the Whigs, as Radcliffe was of the Tories. In 1714 he was knighted by George I., and he died on the 18th of January 1718–1719. Garth was a wealthy man, leaving estates in Warwickshire, Oxfordshire, and Buckinghamshire. He wrote little besides his best known work *The Dispensary*, and *Claremont*, a moral epistle in verse. In 1717 he edited a translation of Ovid's *Metamorphoses*, himself supplying the fourteenth and part of the fifteenth book. The subject of his mock heroic epic is treated in a cumbrous style; and even in his own day Garth was accused of flatness and poverty of thought.

GAS AND GAS-LIGHTING

ALL artificial light is obtained as a result either of combustion or of incandescence; or it might be more accurate to classify illuminating agents as those which emit light as a result of chemical action, and those which glow, from the presence of a large amount of heat, without thereby giving rise to any chemical change. The materials whence artificial light of the nature of flame has been derived are principally bodies rich in carbon and hydrogen. Wax, fats, and oils, on exposure to a certain amount of heat, undergo destructive distillation, evolving inflammable gases; and it is really such gases that are consumed in the burning of lamps and candles, the wicks bringing small proportions of the substances into a sufficient heat. Wood and coal also, when distilled, give off combustible gases; and ordinary gas-lighting only differs from illumination by candles and lamps in the gas being stored up and consumed at a distance from the point where it is generated.

Inflammable gas is formed in great abundance within the earth in connexion with carbonaceous deposits, such as coal and petroleum; and similar accumulations not unfrequently occur in connexion with deposits of rock-salt; the gases from any of these sources, escaping by means of fissures or seams to the open air, may be collected and burned in suitable arrangements. Thus the "eternal fires" of Baku, on the shores of the Caspian Sea, which have been known as burning from remote ages, are due to gaseous hydrocarbons issuing from and through petroleum deposits. In the province of Szechuen in China, gas is obtained from beds of rock-salt at a depth of 1500 or 1600 feet: being brought to the surface, it is conveyed in bamboo tubes and used for lighting as well as for evaporating brine; and it is asserted that the Chinese used this naturally evolved gas as an illuminant long before gas-lighting was introduced among European nations. At a salt mine in the comitat of Marmaro in Hungary, gas is obtained at a depth of about 120 feet, and is used for illuminating the works of the mine. Again at Fredonia (New York State) a natural emission of gas was discovered in a bituminous limestone, over the orifice of which a gasholder has been erected, and thus about 1000 cubic feet of a gas composed of marsh gas and hydride of ethyl has been made available for illumination. In the city of Erie (Pa.) there are 13 gas-wells, each yielding from 10,000 to 30,000 feet per day, the gas escaping from one of them at a pressure of 200 ℔ per square inch. At Bloomfield, Ontario co., New York, there is a spring which yields daily no less than 800,000 feet of gas of an illuminating power equal to 14½ candles. The city of East Liverpool (Ohio) is entirely illuminated, and to a large extent heated, by gas-wells which exist in and around the town. The light is of extraordinary brilliancy, and is so abundant and free that the street lamps are never extinguished, and much of the manufacturing steam-power of the town, which embraces 22 potteries, giving employment to 2000 hands, is derived from the gas. The first "well," 450 feet deep, was opened in 1859, and up to the present year (1879) neither it nor any of those tapped at later dates show any sign of failing. In many other parts of America similar gas-wells exist; and several such natural jets of gas have been observed in England.

By general consent the merit of the discovery and application of artificial gas belongs to Great Britain, and the name most honourably connected with the beginning and early stages of gas-lighting is that of a Scotchman—Robert Murdoch. But previous to Murdoch's time there occur numerous suggestive observations and experiments as to inflammable air and its sources. In the *Philosophical Transactions* of the Royal Society for 1667 the existence of a "burning spring" in the coal district of Wigan is noticed by Thomas Shirley, who traced its origin to the underlying coal. In the same *Transactions* for 1739 is printed a letter addressed to the Hon. Robert Boyle, who died in 1691, in which the Rev. John Clayton details a series of experiments he made in distilling coal in a retort, showing, not only that he had observed the inflammable gases evolved, but that he collected and stored them for some time in bladders. In Dr Stephen Hales's work on *Vegetable Staticks*, published in 1726, more precise statements are made as to the distillation of coal, he having obtained from 158 grains of Newcastle coal 180 inches of inflammable air. In 1787 Lord Dundonald, in working a patented process for obtaining coal-tar, experimented with the gas evolved in the process, and occasionally used it for lighting up the hall of Culross Abbey. None of these observations, however, led to distinct practical results; and it was not till the year 1792 that Robert Murdoch, then residing at Redruth in Cornwall, began the investigations into the properties of gases given off by various substances which eventuated in the establishment of coal-gas as an illuminating agent. In 1797 he publicly showed the system he had matured, and in 1798, being then employed in the famous Soho (Birmingham) workshop of Boulton & Watt, he fitted up an apparatus for the manufacture of gas in that establishment, with which it was partly lighted. Thereafter the apparatus was extended, and the gas manufactured by it was introduced to other neighbouring workshops and factories. Among others who helped most materially to develop the infant art in England were Dr Henry of Manchester, and Mr Clegg, who, succeeding Mr Murdoch at Boulton & Watt's, introduced many improvements in gas manufacture, and ultimately became the most skilful and famous gas engineer in the United Kingdom.

In 1801 M. Lebon introduced gas distilled from wood into his own house in Paris, and the success of his experiment attracted so much notice and comment as to give rise to an impression that he is entitled to the credit of the invention. Lebon's experiment came under the notice of Mr F. A. Winsor, who took up the subject with a zeal and unwearying patience which led to a recognition of the advantages of the system, and the breaking down of the powerful prejudice which existed in England against the innovation. In 1803, through Winsor's efforts, the Lyceum Theatre was lighted with gas; but it was not till 1810 that he succeeded in forming a public company for manufacturing gas, and in obtaining an Act of Parliament for the Gas-Light and Coke Company. In 1813 Westminster Bridge was first lighted with gas, and in the following year the streets of Westminster were thus illuminated, and in 1816 gas became common in London. So rapid was the progress of this new mode of illumination that in the course of a few years after its introduction it was adopted by all the principal towns in the kingdom, for lighting streets as well as shops and public edifices. In private houses it found its way more slowly, partly from an apprehension of danger attending its use, and partly from the annoyance which was experienced in many cases through the careless and imperfect manner in which the service pipes were at first fitted up.

SOURCES OF GAS.

Artificial gas is now distilled from a variety of substances, among which are coal, shale, lignite, petroleum, turf, wood, resins, oils, and fats; and it is also prepared by carburetting or impregnating with volatile hydrocarbons other non-luminiferous gases. Of the very numerous systems of gas-making which have been proposed since the early part of the century, none can compete for general purposes with the ordinary coal-gas process, when a supply of the raw material can be obtained at a moderate expense.

Coal-Gas.—Coals, varying greatly as they do in chemical constitution, differ also, as might be expected, as widely in their value and applicability for the manufacture of gas. Taking the leading varieties of coal to be included under anthracite, bituminous coal, and lignite or brown coal, we find that it is the class bituminous coal alone that yields varieties really serviceable for gas-making. Anthracite may be regarded as a natural coke from which the volatile constituents have been already driven off, and the more anthracitic any coal is, the less is it capable of yielding gas. Lignite also is rarely used for distillation, owing to the large proportion of oxygen and the amount of water in its composition. Of the bituminous coals again, it is only the caking or pitch coals, and the cannel or parrot coals, that are in practice used in gas-works. These also vary within very wide limits in their gas-making value, not only from the great difference among them in yield of gas, but also in the illuminating value of the gas they evolve. As a rule the coals which yield the largest percentage produce also the most highly illuminating qualities of gas. The cannel coals, which are specially recognized as "gas-coal," are most abundantly developed in Scotland and in Lancashire, and the fact of the unequalled qualities of Scotch cannel and of the allied substance, bituminous shale, for gas-making, has had the effect of rendering illumination by gas much more general and satisfactory in Scotland than in any other country It is only a very imperfect valuation of any

gas-coal that can be made from chemical analysis, the really satisfactory test being actual experiment. According to H. Fleck, the coal most available for gas-making should contain to every 100 parts of carbon 6 parts of hydrogen, of which 4 parts are available for forming hydrocarbon compounds. It is desirable that coal used for distillation in gas retorts should be as far as possible free from sulphur, that in the case of coking coal the amount of ash should be small, and the proportion of oxygen should also be low, since that element abstracts hydrogen to form injurious watery vapour. The amount of ash present, however, in the best forms of Scotch cannel is large; and consequently the resulting coke, if the residue can be so called, is of comparatively little value. Unless coal can be stored in sheds which protect it from the weather, it ought to be used as soon as possible after being raised, rain and sunshine being detrimental to its gas-making qualities. The following table exhibits the chemical analysis and gas-yielding properties of a few of the principal and typical examples of coal for gas-making:—

Composition of Coals used in Gas-Making.

Variety of Coal.	Disposable Hydrogen.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.
Newcastle Peareth Gas-Coal	...	82·42	4·82	...	0·86	11·11	0·79
Blaydon Main, Tyneside	6·88	78·06	5·80	1·85	2·22	3·12	8·94
Dukinfield, Ashton-under-Lyne	6·19	83·25	5·75	...	0·86	5·06	3·48
Wigan Cannel	5·65	84·07	5·71	...	...	7·82	2·40
Mold-Leeswood Green Cannel	...	77·81	8·47	...	0·71	6·32	...
Boghead Cannel (Scotland)	12·68	63·10	8·91	...	0·96	7·25	19·78
Methil Brown Shale (Scotland)	9·33	66·44	7·54	1·36	0·84	10·84	12·98
Kelty Gin Seam (Scotland)	...	76·50	5·03	...	0·94	11·68	2·25

Products of the Distillation of 1 ton of Coal.

	Cub. feet of Gas.	Lbs. of Coke.	Lbs. of Tar.	Lbs. of Ammonia Liquor.	Illuminating power of Gas in Candles.
Newcastle Cannel	9,883	1,426	98·3	60·0	25·2
Wigan Cannel	10,850	1,332	218·3	161·6	19·4
Boghead Cannel	13,334	715	733·3	nil.	46·2

When the bowl of an ordinary clay pipe is filled with small fragments of bituminous coal, luted over with clay and placed in a bright fire, immediately smoke is seen to issue from the stalk which projects beyond the fire. The smoke soon ceases, and if a light is then applied to the orifice of the stalk, the issuing gas burns with a bright, steady flame, while a proportion of a black, thin, tarry liquid oozes out from the stalk. After the combustion ceases there is left in the bowl of the pipe a quantity of char or coke. This simple operation is, on a small scale, an exact counterpart of the process by which the destructive distillation of coal is accomplished in the manufacture of gas. The products of the distillatory process classed in the gas-works as gas, tar, and ammoniacal liquor, with a solid residue of coke, are in themselves mixtures of various definite chemical compounds; and as may be evident from the following list, these substances are very numerous and complex:—

Products of the Distillation of Coal at high-red heat.

I. *Illuminating Gases.*

Acetylene, C_2H_2; Ethylene, C_2H_4; Propylene, C_3H_6; Butylene, C_4H_8	Gases.
Benzol, C_6H_6; Naphthalin, $C_{10}H_8$	Vapours.
Hydrogen, H; Light carburetted hydrogen, CH_4; Carbonic oxide, CO	Dilunets.
Carbonic acid, CO_2; Ammonia, NH_3; Cyanogen, C_2N_2; Bisulphide of carbon, CS_2; Sulphuretted hydrogen, H_2S; Oxygen, O; Nitrogen, N; Aqueous vapour, H_2O	Impurities.

II. *Components of Tar.*

Benzol, C_6H_6; Toluol, C_7H_8; Cumol, C_9H_{12}; Cymol, $C_{10}H_{14}$	Liquid hydrocarbons.
Naphthalin, $C_{10}H_8$; Anthracene, $C_{14}H_{10}$; Pyrene, $C_{16}H_{10}$; Crysene, $C_{18}H_{12}$	Solid hydrocarbons.
Carbolic acid, C_6H_6O.	
Cresylic acid, C_7H_8O	
Rosolic acid, $C_{20}H_{16}O_3$.	
Pyridine, C_5H_5N.	
Aniline, C_6H_7N.	
Picoline, C_6H_7N.	
Lutidine, C_7H_9N.	
Collidine, $C_8H_{11}N$.	
Leucoline, C_9H_7N.	

III. *Ammoniacal Liquor.*

Ammonium carbonate, $2NH_4.CO_3$.
" sulphydrate, $NH_4.HS$.
Ammonium sulphocyanate, $NH_4.NCS$.
" cyanide, $NH_4.NC$.
" chloride, $NH_4.Cl$.

IV. *Coke and Ash in Retort.*

The proportions in which coal yields these products may be indicated by the case of a cannel giving off 11,000 feet per ton of gas of a density of 0·600. From 100 parts of such a coal there would be yielded—

Gas	22·25
Tar	8·50
Ammonia water	9·50
Coke	59·75

The proportions, however, and even the nature of these products of distillation are greatly modified by the temperature at which the distillation is effected, a low red heat yielding a small proportion of non-condensible gas but a large amount of heavy hydrocarbon oils, whence the distillation of shales and coal in the paraffin manufacture is conducted at a low red heat. By excessive heat, on the other hand, the compounds evolved become simpler in their chemical constitution, carbon is deposited, pure hydrogen is given off, and the gain in amount of gas produced is more than counterbalanced by its poverty in illuminating properties.

Of the gases and vapours which pass out of the retorts in a highly heated condition, some portion, consisting of tarry matter and ammoniacal liquor, precipitates almost immediately by simple cooling, and other injurious constituents must be removed by a system of purification to which the gaseous products are submitted. What thereafter passes on as ordinary gas for consumption still contains some percentage of incombustible matters—aqueous vapour, oxygen, nitrogen, and carbonic acid. The combustible portion also is separable into two classes, viz., non-luminous supporters of combustion, and the luminiferous constituents,—the former embracing hydrogen, marsh gas (light carburetted hydrogen), and carbonic oxide, while the latter includes the hydrocarbon gases acetylene, ethylene (olefiant gas or heavy carburetted hydrogen), propylene, butylene, and vapours of the benzol and naphthalin series.

Formerly it was the habit to regard the proportion of heavy carburetted hydrogen (ethylene and its homologues) as the measure of the illuminating power of a gas. It has, however, been pointed out by Berthelot that the proportion of such compounds in some gas of good luminous qualities is exceedingly small; and in particular he cites the case of Paris gas, which, according to his analysis, contains only a mere trace of acetylene, ethylene, and other hydrocarbons, with 3 to 3·5 per cent. of benzol vapours. Subsequent experiments of Dittmar have proved that a mixture of pure ethylene and hydrogen burnt in the proportion of 3 volumes of hydrogen to 1 of ethylene yields little more light than ordinary marsh gas, while benzol vapour to the extent of only 3 per cent. in hydrogen, gives a brilliantly luminous flame. Frankland and Thorne have more recently determined the illuminating power of a cubic foot of benzol vapour burnt for 1 hour in various combinations, with the following results:—

With hydrogen it gave the light of	69·71	candles.
" carbonic oxide "	73·38	"
" marsh gas "	92·45	"
" " (second series) "	93·94	"

Thus it is highly probable that the illuminating value of coal-gas depends much more on the presence of benzol vapour than on the proportion of the heavy gaseous hydrocarbons, and the estimation of benzol in the gas is a point which has hitherto been comparatively neglected. In view of the inference that the presence of benzol vapour is so intimately related to illuminating power, the fact observed by Dittmar that water readily and largely dissolves it out of any gas mixture is of great consequence. When benzolated hydrogen containing 6 per cent. of benzol vapour was shaken up with water, the percentage of the vapour was found on analysis to be reduced to less than 2.

The average composition of the gas supplied to London is, on the authority of the late Dr Letheby, thus stated :—

	Ordinary Gas, 12 Candles.	Cannel Gas, 20 Candles.
Hydrogen	46·0	27·7
Light carburetted hydrogen	39·5	50·0
Condensible hydrocarbons	3·8	13·0
Carbonic oxide	7·5	6·8
Carbonic acid	0·6	0·1
Aqueous vapour	2·0	2·0
Oxygen	0·1	0·0
Nitrogen	0·5	0·4

Cannel gas is now, however, supplied only to the Houses of Parliament and to certain of the Government offices.

Manufacture of Coal-Gas.

The series of operations connected with the preparation and distribution of coal-gas embrace the processes of distillation, condensation, exhaustion, scrubbing or washing, purification, measuring, storing, and distribution by the governor to the mains, whence the consumers' supply is drawn. In connexion with consumption, pressure of the gas, measurement of the amount consumed, and the burners and other arrangements for lighting are the most important considerations.

Site and Arrangement of Works.—The choice of a site for a gas establishment is necessarily conditioned by local circumstances; but the facts that a considerable area is required, and that, at best, the works do not improve the amenity of any neighbourhood, are important considerations. A central position with respect to the area to be supplied is certainly desirable, but in the circumstances it is seldom to be obtained. Of even greater consequence for a large work is ready access to a railway or other means of transport; and most of the great establishments are now connected by sidings with lines of railway, whereby coals, &c., are delivered direct from the waggons to the store or retort-house, and in the same way the coke and residual products are removed. Where the arrangement is practicable, it is also desirable that the works should be erected at the lowest level of the area to be supplied, since coal-gas, being specifically lighter than atmospheric air, acquires a certain amount of pressure as it rises in pipes, which pressure facilitates its distribution, and it is much easier to control than to beget pressure. In the planning of works, regard must be given to economy of space and to labour-saving arrangements, so that the cost of manual labour may be minimized, and operations proceed in an orderly, methodical, and easily-controlled manner. The accompanying ground plan of gas-works (fig. 1) has been kindly furnished by Mr James Hislop of Glasgow, a gas engineer of known skill

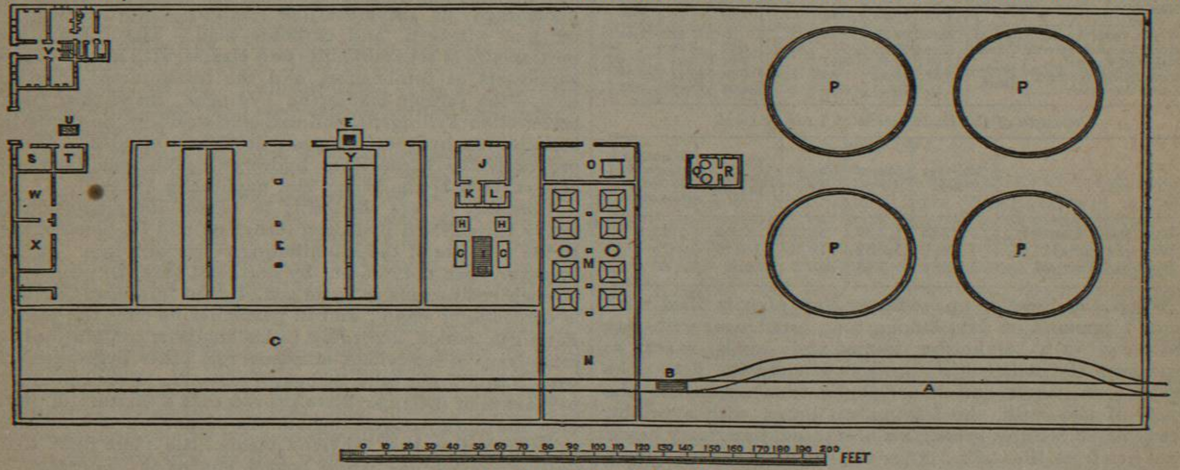

Fig. 1.—Ground-Plan of Gas-Works.

A, a line of rails leading into the works; B, waggon weighing machine; C, the coal store; D, retort house; E, chimney; F, coke yard; G, condensers; H, scrubbers; I, tar tank; J, exhauster house; K, pump room; L, store room (water tank is placed above K L); M, purifier house; N, lime store; O, meter house; P, gas-holders; Q, governor house; R, photometer room; S, board room; T, office; U. weighing machine; V, superintendent's house; W, joiner's shop; X, smith's shop; Y, engine boiler.

and experience; and while it shows arrangements of the most approved character, it will also enable the reader to recognize the position of the various erections and apparatus as they follow each other, and as they will now be described.

Retorts.—Retorts for destructive distillation of coal are formed of cast iron, clay, brick, or wrought iron. Various shapes have been adopted in the construction of these vessels; nor have their forms been more varied than the modes in which they have been disposed in the furnaces. In many instances they have been constructed of a cylindrical shape varying in length and diameter. Those first employed were of iron, with the axis vertical, but experience soon showed that this position was extremely inconvenient, on account of the difficulty which it occasioned in removing the coke.

The retorts were therefore next placed in a horizontal position, as being not only more favourable to the most economical distribution of the heat, but better adapted to the introduction of the coal and the subsequent removal of the coke. At first the heat was applied directly to the lower part of the retort; but it was soon observed that the high temperature to which it was necessary to expose it, for the perfect decomposition of the coal, proved destructive to the lower side, and rendered it useless long before the upper part had sustained much injury. The next improvement was, accordingly, to interpose an arch of brickwork between it and the furnace, and to compensate for the diminished intensity of the heat by a more equally diffused distribution of it over the surface of the retort. This was effected by causing the flue of the furnace to return towards the mouth of the retort, and again conducting it in an opposite direction, till the heated air finally escaped into the chimney. This arrangement was continued so long as iron retorts were in use, but on the general adoption of clay retorts the furnaces were constructed to allow the fire to play freely around them.

The cylindrical form of retort *a* (fig. 2) was long in favour on account of its great durability, but it is not so well fitted for rapid decomposition of the coal as the elliptical *b*, or

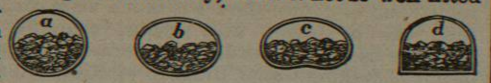

Fig. 2.

the flat-bottomed or D-shaped retorts *d*, which are now principally in use. Retorts are also made of a rectangular section with the corners rounded and the roof arched. Elliptical retorts are varied into what are called ear-shaped or kidney-shaped *c*, and it is not unusual to set retorts of different forms in the same bench, for the convenience of filling up the haunches of the arch which encloses them.

The length of single retorts varies from 6 to 9 feet, but they are now in some cases made 19½ feet in length and 12½ inches in internal diameter, these being charged from both ends.

Every retort is furnished with a separate mouthpiece, usually of cast iron, with a socket *b* (fig. 3) for receiving the stand-pipe or ascension-pipe, and there is a movable lid attached to the mouth, together with an ear-box cast on each side of the retort for receiving the ears which support the lid. Fig. 3 shows a form of mouthpiece attached to the retort *a*, and also the method of

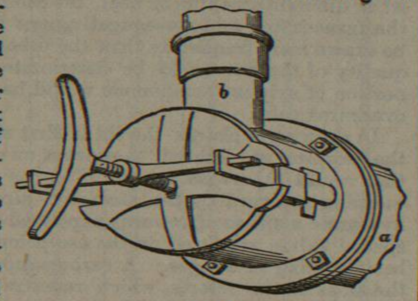

Fig. 3.

screwing the lid to the mouthpiece. That part of the lid which comes in contact with the edge of the mouthpiece has applied to it a lute of lime mortar and fire clay, and when the lid is screwed up, a portion of this lute oozes out round the edges and forms a gas-tight joint.

Except for small works, where the manufacture is intermittent, and where, consequently, the retort heat has to be got up frequently, iron retorts are now little used. Clay retorts, which at present are in most general use, wear out quickly; they very frequently crack so seriously on the first application of heat that they must be removed from the bench before being used at all, and in scarcely any case are they in action perfectly free from cracks. Numerous attempts have been made to introduce retorts built of brick; but the difficulty of making and keeping the joints airtight has proved a serious obstacle to their use. In the

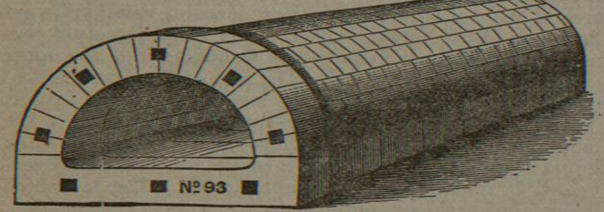

Fig. 4.—Hislop's Brick Retort.

brick retort made of Glenboig Star fire-clay, according to the plan of Mr James Hislop, it is claimed that the difficulty is surmounted, and that both the retort and its setting present great advantage and economy. These brick retorts (fig. 4) are D-shaped, 9 feet long and with diameters of 22 and 13½ inches, set four in an oven to one unarched furnace, as in fig. 7. Each retort will, it is affirmed, carbonize 500 tons cannel coal, or 2000 tons per oven of four, without any repairs whatever. Decayed bricks may be removed from these retorts and new ones inserted, and when thoroughly repaired they are again equal to new. Thus the durability of each retort is so great that they are calculated to cost about ⅛th of a penny per 1000 cubic feet of gas generated, as against 1d. in the case of moulded retorts, and 7d. with iron retorts, for the same production of gas. In the Hislop retort the arched bricks are made plain, without groove or rebate joints—being thus stronger, more readily put together, and also cheaper. Carbon does not collect so rapidly on brick retorts as on those of clay, the bricks being harder pressed and better burned. On first lighting brick retorts, a charge of coke, breeze, and tar mixed makes them perfectly gas-tight.

Retort Setting.—A furnace or bed of retorts is composed of a group or setting, heated by a separate fire. The furnace is lined with the most refractory fire-bricks, and while the whole brickwork is made of such strength and solidity as ensures the safety of the retorts, the internal construction is so planned that the heat has the utmost possible amount of direct play on the retorts. The number of retorts to one furnace varies from 1 to 15, from 4 to 7 being the number most commonly adopted; and these are variously arranged to bring them all as close to the furnace heat as practicable. In some retort-houses the furnaces are built in two stages or stories, from the upper of which the retorts are charged and drawn, while at the lower level the glowing coke is removed and quenched. The whole range of furnaces constitutes the retort bench, having a common flue which leads to the chimney shaft by which the products of combustion are carried away. The gas-coal for charging the retorts is broken into fragments about 1 lb in weight or thereby. Figs. 5 (elevation) and 6 (section) illustrate the

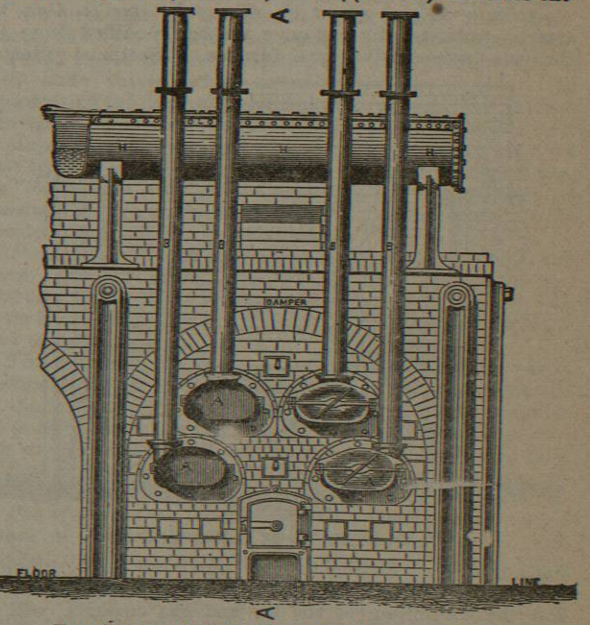

Fig. 5.—Elevation of Hislop's Gas Retort Furnace.

retort setting and arrangement of furnace and flues adopted by Mr Hislop for his brick retorts, in which, by the use of centre blocks, as seen in the open front illustration (fig. 7), the necessity for internal arching is avoided.

Retort furnaces are commonly fired or heated with a portion of the coke which forms one of the bye-products of